STATISTICAL INVESTIGATION ON SOCIO-ECONOMIC STATUS OF KIWIFRUIT GROWERS AND FACTORS INFLUENCING KIWIFRUIT PRODUCTION IN HIMACHAL PRADESH

Thesis

by

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(F-2021-45-D)

submitted to

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in

partial fulfilment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY
AGRICULTURAL STATISTICS

DEPARTMENT OF BASIC SCIENCES
COLLEGE OF FORESTRY

2024

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CERTIFICATE - I

This is to certify that the thesis entitled **"Statistical Investigation on Socio-Economic Status of Kiwifruit Growers and Factors Influencing Kiwifruit Production in Himachal Pradesh"**, submitted in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY** in the discipline of **AGRICULTURAL STATISTICS** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) is a record of bonafide research work carried out by **Ms. Shilpa Sharma (F-2021-45-D)** daughter of Shri Satish Kumar under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations have been fully acknowledged.

Place: Nauni, Solan
Dated:

Dr. R.K. Gupta
Major Advisor

CERTIFICATE - II

This is to certify that the thesis entitled **"Statistical Investigation on Socio-Economic Status of Kiwifruit Growers and Factors Influencing Kiwifruit Production in Himachal Pradesh"** by **Ms. Shilpa Sharma (F-2021-45-D)** daughter of Shri Satish Kumar to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY** in the discipline of **AGRICULTURAL STATISTICS** has been approved by the student's Advisory Committee after an oral examination of the same in collaboration with an External Examiner.

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ACKNOWLEDGEMENTS

"Every great journey begins with a single step, and perseverance turns steps into milestones."

Finally, the time has come to delve into the deeper layers of my heart, brimming with feelings of togetherness, affection, unity, satisfaction, relief, and fulfillment. Some of these feelings are fleeting, while others are enduring. Regardless, they all involve the cherished individuals in my life. I take this moment to extend my heartfelt gratitude and formally express these emotions in writing.

First and foremost, I offer my deepest gratitude to Goddess Durga for bestowing upon me her fervent blessings, granting me the opportunity, strength, enthusiasm, and good health needed to accomplish my academic pursuits.

With heartfelt gratitude, I sincerely thank my Major Advisor, Professor & Head of the Department, Dr. Rakesh Kumar Gupta, Chairman of the Advisory Committee, for his exceptional and generous guidance, insightful suggestions, and unwavering encouragement throughout this research. His support has been instrumental in the successful completion of this work.

I express my sincere gratitude and humble thanks to members of my advisory committee Dr. Ashu Chandel (Professor Statistics, Dept. of Basic Sciences), Dr. Vishal S. Rana, (JDR, Directorate of Research), Dr. Subhash Sharma (Head, Dept. of Social Science), for their inspiring guidance, congenial discussion and encouragement during the preparation of this manuscript.

I cordially acknowledge Dr. Geeta Verma (Assistant Professor, Dept. of Basic Sciences), Dr Samriti (Assistant Professor, Dept. of Social Sciences), and Dr Neeraj Sankhyan (Assistant Professor, Dept. of Basic Sciences), for their insightful feedback and constructive criticism which enriched the content and scope of this thesis.

I would like to thank my parents, whose continuous efforts make my journey successful and accomplished. I owe this to my mother Smt. Swarn Lata, my father Sh. Satish Kumar, and my brother Sarthak Sharma for their constant support and belief in me. My maternal uncle Sh. K.S. Rana and maternal aunt Smt. Uma Rana, who rigoursly supported me with their blessings. Without their assistance and dedicated involvement in every step throughout the process, this thesis would have never been accomplished.

I would also like to express my deep appreciation to the Directorate of Horticulture, Shimla, for their generous provision of secondary data on the area and production of kiwifruit. Their comprehensive data has significantly contributed to the robustness and depth of this research.

I extend my sincere gratitude to Dr. Nitika Thakur (HDO Manali) for their invaluable assistance in providing the list of farmers essential for the data collection in this research. Her support and cooperation have been instrumental in the successful completion of this study.

It is my pleasure to acknowledge the help of my seniors, colleagues and juniors who gave me assistance and encouragement in every possible manner. I shall be failing in my duties if I do not keep on record my gratitude to them especially to Dr. Umesh Sharma, Dr. Neha Mishra, Dr. Sunny Sharma, Dr. Bharti, Dr. Pawan Singta, Tania, Anurita, Sukhdeep, Rakesh, Pratibha, Varnika, Vishani, Charu, Renika, Ankita and Sushmita.

I extent my sincere and warmest thanks to all teaching and non- teaching staff members of Department of Basic Sciences for their cooperation and help during the course of investigation.

I owe entire responsibility for all the errors and omissions.

Place: Nauni
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CONTENTS

LIST OF ABBREVIATIONS USED

Abbreviation		**Meaning**
$\bar{R}^2$	:	Adjusted R square
R^2	:	Coefficient of determination
%	:	Per cent
/	:	Per
<	:	Less than
>	:	Greater than
°C	:	Degree centigrade
µm	:	Micrometer
amsl	:	Above mean sea level
AOSB	:	Approximate Optimum Strata Boundaries
BIC	:	Bayesian information criterion
CD	:	Critical Difference
cm	:	Centimeter
cm^2	:	Square Centimeter
df	:	Degree of freedom
e.g.	:	For example
et al.	:	Co-Worker Et Alia (And Others)
Etc.	:	Et Cetera (And Rest)
Fig	:	Figure
FYM	:	Farm yard manure
ha	:	Hectare
i.e.	:	Id Est (That Is)
Kg	:	Kilogram
m	:	Meter
m^2	:	Meter Square
MAE	:	Mean Absolute Error
MAPE	:	Mean Absolute Percentage Error
MSS	:	Mean Sum of Square
MT	:	Metric Tones
PCA	:	Principal Component Analysis
RMSE	:	Root Mean Square Error
SPSS	:	Statistical Package for the Social Sciences
SS	:	Sum of Square
viz.	:	Vide Licet (Namely)
vs.	:	Versus
λ	:	Lambda

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Chapter-1

INTRODUCTION

Kiwifruit (*Actinidia deliciosa* A. Chev.) also known as Chinese gooseberry belonging to the family Actinidiaceae, is a worldwide commercially domesticated and cultivated fruit vine native to China (Lin et al., 2022). The genus Actinidia has 75 taxa, comprising 54 species and 21 variations, as of the most recent classification (Li et al., 2007; Yuan et al., 2023). The Actinidia species are deciduous, dioecious, woody perennials characterized by vigorous growth, climbing nature, and strangling attributes (Sharma et al., 2022). Out of more than 54 species in the Actinidia genus, only few have attained significant economic importance. Among these, the green-fleshed "Hayward" and "Allison" cultivars are widely cultivated across the globe (Ferguson, 1990).

Kiwifruit is renowned for its distinctive appearance, featuring a brown, fuzzy exterior and a vibrant green, juicy interior filled with tiny black seeds (Zehra et al., 2020). It occupies a significant position in the global fruit industry, due to its unique flavor, exceptional nutritional profile (notably high in vitamin C and dietary fiber), and numerous health benefits (Yang et al., 2020). These advantages include positive effects on cardiovascular health, lipid metabolism, inflammatory response, blood pressure regulation, and weight management, making it a preferred choice among vegetarians as well. The roots of kiwifruit contain triterpenoids and flavonoids, which exhibit pharmacological effects such as anti-tumor, anti-inflammatory, and anti-viral properties (Wang et al., 2019). Additionally, kiwifruit juice has been found to aid patients with type 2 diabetes due to its anti-inflammatory and antioxidant properties (Sun et al., 2017). Moreover, kiwifruit consumption can alleviate constipation by enhancing gastrointestinal motility and improving blood pressure (Zhuang et al., 2019; Eady et al., 2019). Due to its delicious taste and abundance of health-promoting nutrients, kiwifruit remains highly demanding in the fresh fruit market (Wang et al., 2021).

The world production of kiwifruit is 4.34 million MT (FAO, 2022) with China having the largest share followed by Italy, New Zealand, Iran, and Chile. These countries have favourable climate and growing conditions for the cultivation of kiwifruit, and they have developed robust production systems to meet the global demand for this fruit. In India, it is cultivated in 5000 ha with an annual production of 13,000 MT (MOSPI, 2022) in the mid hills of Himachal Pradesh, Uttarakhand, J&K, Sikkim, Meghalya and Arunachal Pradesh. At present, Arunachal Pradesh is the leading Kiwifruit producing state in the country. In Himachal Pradesh, it is grown in valleys of Solan, Sirmaur, Mandi, Kullu and Shimla districts. The area under kiwifruit cultivation in Himachal Pradesh is 220 ha with an annual production of 944 MT (Directorate of Horticulture, Shimla, 2023).

Himachal Pradesh is bestowed with suitable agro-climatic conditions for the development of Horticulture (Thakur et al*.,* 2014). For optimal kiwifruit production, specific climatic requirements are essential (Singh et al*.,* 2022). It grows in Himachal Pradesh, at elevations of 900–1800 m amsl, with 600–800 chilling hours to break dormancy. Frost and low temperatures during spring and autumn can be harmful, while high summer temperatures (>38°C) and low humidity can cause leaf scorch and fruit damage. Proper rainfall (120–150 cm) throughout the growing period is crucial. Protection from high winds, hail, and rainfall during flowering is necessary. Ideal soil is deep, well-drained sandy loam with pH between 5.5–6.5, providing sufficient moisture and organic matter. Heavy clay soil with poor drainage is unsuitable for kiwifruit cultivation.

Kiwifruit is dioecious, which means it produces staminate and pistillate flowers on separate plants (Ferguson, 1990). Both male and female vines are necessary for fruit production, and they must bloom simultaneously to ensure successful pollination. Typically, one male pollinator vine is required for every eight female vines. In Himachal Pradesh, commercially grown pistillate kiwifruit varieties include Hayward, Allison, Abbott, Monty, and Bruno. Additionally, there are staminate (male) kiwifruit varieties such as Allison, Tomuri, and Matua. To support the vines and their heavy fruit, sturdy structures like T-bars or hitching post trellises are commonly used. These structures also facilitate easy access during harvesting. Among the cultivated varieties, Hayward holds the highest commercial significance globally, representing the majority of kiwifruit production. The Allison variety, renowned for its high yield, excellent fruit quality, and resistance to diseases, is prominently grown across various regions of the state and is particularly favored in Himachal Pradesh.

Sample surveys play a crucial role in research, especially when aiming to draw precise inferences about population parameters while managing costs effectively. By selecting a representative sample from the population of interest, researchers can estimate population characteristics with maximum accuracy. The precision of these estimates relies not only on sample size and sampling fraction but also on the variability or heterogeneity within the population. Understanding the socio-economic status of kiwifruit growers are essential for evaluating their livelihoods and identifying areas for potential improvement. By examining factors such as cropping patterns, land utilization, the extent of active cultivation, income levels, education, access to resources, and participation in market activities, valuable knowledge can be gained into the challenges and opportunities faced by growers. This information is valuable for policymakers, researchers, and agricultural practitioners in making decisions and implementing effective interventions.

Marketing plays a pivotal role in the agricultural sector, encompassing various activities from product inception to consumer distribution. It involves creating utility in terms of time, place, form, and possession throughout the product's journey. Kiwifruit presents a unique case in agricultural marketing due to its distinctive patterns and channels, reflecting the complexity of the global agricultural market. An efficient marketing system for Kiwifruit is vital for farmers to maximize their net returns and expand market reach. This process involves several crucial stages, starting with careful picking to ensure fruits are harvested at the optimal ripeness for flavor and nutritional quality. Grading follows, where Kiwifruits are sorted based on size, color, and quality, ensuring consistency and meeting market standards. Packing is another critical aspect, where proper packaging materials are chosen to protect fruits during transportation while allowing for adequate ventilation to maintain freshness. Transportation plays a pivotal role, with factors like transportation mode, temperature control, and handling practices impacting product quality and market value significantly. Each stage is integral, as any oversight or carelessness can lead to lower prices, jeopardizing farmers' efforts to maximize returns. Therefore, meticulous attention to detail and adherence to best practices are essential throughout the marketing process to ensure success and achieve desired financial outcomes for Kiwifruit growers. By prioritizing these aspects, farmers can enhance market competitiveness and meet consumer demands effectively, ultimately bolstering their profitability and sustainability in the agricultural sector.

In recent years, kiwifruit cultivation has expanded beyond its native regions, with Himachal Pradesh in India emerging as a significant contributor to its production. It continues to play a significant role in driving socio-economic transformation in rural areas of the state. However, ensuring accurate assessment of kiwifruit area and production estimates remains a critical requirement for effective horticultural planning. Presently, disparities persist in the estimates provided by key state agencies, namely the Directorate of Land Records and the Department of Horticulture. The demand for precise and dependable data on kiwifruit area and production is escalating from various stakeholders, including state and district authorities, as well as those involved in horticultural planning at lower administrative levels for scheme evaluation. Despite the growing importance of kiwifruit in Himachal Pradesh, efficient estimation techniques for its area and production are lacking. The current stratification method, which is convenience-based, often results in either overestimation or underestimation, thereby impacting the horticultural planning process adversely. Consequently, there is a pressing need to enhance the efficacy of existing methods. The ongoing study seeks to address this gap by establishing optimal strata boundaries and refining related aspects of stratification to achieve more accurate estimates. By using advanced statistical techniques and updated data collection methodologies, the aim is to improve the precision and reliability of kiwifruit area and production estimates in Himachal Pradesh, thus facilitating informed decision-making and effective horticultural planning at all levels.

Morphological characteristics of kiwifruit vines significantly influence yield potential and overall productivity. Factors such as vine girth, fruit weight, number of flowers per bearing shoot, and flowering patterns play crucial roles in determining the quantity and quality of harvested fruits. This study aims to assess the relative contribution of these morphological characteristics towards kiwifruit yield, providing valuable insights for cultivar selection, orchard management practices, and breeding programs aimed at enhancing yield and profitability. However, yield, being a complex trait, is a combination of individual characters that often vary together. Identifying a single variable representative of the complex trait may not be possible, leading researchers to separately examine many related variables. These separate univariate statistical analyses, known as yield variable analyses (Fraser and Eaton, 1983), enable researchers to assess the most responsible yield contributors for increasing yield. Moreover, they overlook the multiple correlations present among yield-contributing characters. To address these limitations and understand the relationship between yield and its contributing characters more comprehensively, several statistical methods are employed.

Commonly used methods include multivariate analysis, path analysis, and multiple linear regressions. Multivariate analysis, as pioneered by Moore (1965) and discussed by Holland (1969), considered the interdependence and relative importance of various characters, providing more meaningful insights. Ramachander et al., (1979) utilized factor analysis in onions, revealing that factors such as plant vigor and flowering significantly influenced yield. Discriminant analysis, on the other hand, identifies a linear combination of variables that separates groups by maximizing the between-group variance related to within-group variance. This method aims to find a function of variables that maximizes discrimination amongst groups, offering valuable insights into factors influencing yield.

Forecasting kiwifruit yield holds significant importance for effective resource allocation, supply chain management, and market planning, providing growers, policymakers, and industry stakeholders to anticipate production levels and adapt strategies accordingly. However, the current methods for kiwifruit yield forecasting rely heavily on subjective eye estimates, lacking a probabilistic approach. To address this gap and introduce a more reliable forecasting method, the development of statistical models becomes imperative. Developing the best-suited model involves careful consideration of independent variables, estimation procedures, and validation techniques. While kiwifruit production primarily depends on the bearing area of the crop, yield is influenced by various factors such as morphological characteristics like vine girth, plant height, number of flowers per bearing shoot and number of fruits per bearing shoot, etc. Through systematic development and complete validation, these statistical models will serve as indispensable tools for enhancing efficiency and profitability in kiwifruit cultivation and marketing in the region.

Keeping in view the above considerations, this multi-approach aimed study offers to advance the sustainable growth and development of the kiwifruit production in Himachal Pradesh. The present study envisages following objectives:

i) To study the socio-economic status of kiwifruit growers with respect to production and marketing of kiwifruit

ii) To determine the approximate optimum strata boundaries for obtaining efficient estimates of kiwifruit production in Himachal Pradesh

iii) To assess the relative contribution and comparison of morphological characteristics of kiwifruit vine towards the yield

iv) To develop statistical models for forecasting kiwifruit yield

Chapter-2

REVIEW OF LITERATURE

This chapter is dedicated to discussion of the studies that significantly contributed to conceptual clarity and the improvement of statistical techniques used in this research, aligning with our objectives. The methodological approaches applied in previous studies have provided valuable insights and experience. In this chapter, summaries of research conducted by various researchers are presented, organized chronologically in respective sections. The existing literature on the subject has been thoroughly reviewed and categorized under the following headings:

2.1 To study the socio-economic status of kiwifruit growers with respect to production and marketing of kiwifruit

2.2 To determine the approximate optimum strata boundaries for obtaining efficient estimates of kiwifruit production in Himachal Pradesh

2.3 To assess the relative contribution and comparison of morphological characteristics of kiwifruit vine towards the yield

2.4 To develop statistical models for forecasting kiwifruit yield

2.1 To study the socio-economic status of kiwifruit growers with respect to production and marketing of kiwifruit

Waghmode et al. (2013) conducted a study to examine the socio-economic status and challenges faced by pomegranate growers in the Sangola and Malshiras tehsils of Solapur district. Their findings revealed approximately 60.83% of pomegranate growers were middle-aged, ranging between 33 to 56 years. The majority (77.50%) demonstrated a medium level of scientific orientation. About 63.33% of growers exhibited medium planning orientation. 47.50% of respondents showed a favorable attitude towards NHM. Around 66.67% growers cultivated a medium area of pomegranates (1 to 4 ha), while 37.50% had medium-sized land holdings (4.01 to 10 ha). All pomegranate growers faced constraints due to the lack of availability of disease-resistant varieties under supply constraints.

Kaur et al. (2014) examined guava production and marketing in Punjab, focusing on Amritsar and Patiala districts, where guava cultivation is prevalent. Through purposive selection, these districts were chosen, and a random sample of 60 farmers, including 28 from

Amritsar and 32 from Patiala, was selected for the study. The findings revealed that cultivated guava on 2.69 hectares of land per farmer, yielding an estimated 487.77 quintals per holding. The study identified a marketed surplus of 98.33 per cent. Notably, 79.95 per cent of the land was leased out to contractors, with farmers retaining the remaining 20.05 percent. Most pre-harvest contractors preferred selling their produce in the Delhi market, the largest in North India. When sold through these contractors, the producer's share in the consumer's rupee was 51.44 and 51.28 per cent in Amritsar and Patiala markets, respectively.

Bhat et al. (2015) analyzed the marketing channels of citrus fruit in Samba district, focusing on marketing costs and price spreads. Three primary marketing channels were observed: Producer → Forwarding/Commission agent → Retailer → Consumer, Producer → Retailer → Consumer, and Producer → Consumer. The study found that the average per quintal marketing cost at the producer level varied significantly across channels, with values of 438.65, 264.00, and 226.67 Rs./Quintal for channels I, II, and III, respectively. Retailers bore a per quintal marketing cost of 30.95 and 19.40 in channels I and II, respectively, while in channel III, the entire cost of 226.67 was borne by the producer due to direct marketing. Comparing different channels, channel III demonstrated the highest producer share in the consumers' rupee, indicating its efficiency. Additionally, consumers benefited from lower prices, paying 1300 per quintal in channel III compared to 2150 and 2020 per quintal in channels I and II, respectively. This suggested that direct sales from producer to consumer were advantageous for both parties. Channel III exhibited the highest marketing efficiency at 4.74, followed by Channel II (1.05) and channel I (0.79).

Kashyap and Guleria (2015) conducted an assessment of the socio-economic status of apple growers and the factors influencing apple production in Mandi district of Himachal Pradesh. The study was based on primary data collected from a survey of 60 farm households, highlighted several significant findings. The regression analysis indicated that factors such as the area under apple cultivation, educational attainment, and marital status were positively related to apple yield, with regression coefficients of 7.33, 3.84, and 24.86, respectively. Furthermore, the study evaluated marketing efficiency across different channels, revealing that channel A exhibited the highest efficiency (4.90), followed by channels B, C, and D. Interestingly, despite channel A being the most efficient, the maximum quantity of apples was transacted through channel D (66%), followed by channels C, B, and A. Moreover, the producer's price varied between Rs. 3986 and Rs. 4700 across different channels.

Verma et al. (2015) conducted a study on 160 kinnow growers from Nurpur and Indora blocks in Kangra district, Himachal Pradesh, during 2013–14 period to assess the socio-economic status of kinnow orchardists and marketing system in the area. Data was collected through personal interviews using well-designed and pre-tested schedules. The average size of kinnow crop holdings for small, medium, and large orchardists was calculated, with Nurpur block averaging 1.46, 2.83, and 4.12 hectares, respectively, and Indora block averaging 1.79, 2.79, and 3.95 hectares, respectively. Net farm income was highest among large farms (87.09%) and lowest among small ones, indicating that larger holdings were more focused on horticultural crops, particularly kinnow. The study revealed that kinnow production significantly contributed to the socio-economic upliftment of kinnow orchardists in the area. Among the three marketing channels, channel III demonstrated the highest efficiency (2.18), followed by channel II (1.56), while channel I was the least efficient (0.76).

Naqash et al. (2017) executed an economic analysis of the marketing and price spread of apple fruit in the Kashmir Valley of Jammu and Kashmir state. The study revealed that the majority of the farmers were marginal farmers with up to 2 hectares of land under apple orchards. The cost of apple cultivation was calculated to be Rs. 206,730 per hectare, with net returns of Rs. 496,395 per hectare. The market study identified five marketing channels, with the channel (Producer → Commission agent → Retailer → Consumer) being the major route for apple trade, as more than 30 percent of the farmers' produce was marketed through this channel. It was observed that the producer received the maximum share of the consumer's rupee in the channel where the produce was directly marketed to the wholesaler.

Rede and Bhattacharyya (2018) examined different market channels for pomegranates in Solapur district of Maharashtra. They identified three main channels from producers to consumers: Channel-I: Farmer-Pre-harvest contractor-Commission agent cum wholesaler-Retailer-Consumer, Channel-II: Farmer-Distant Market wholesaler-Retailer-Consumer, and Channel-III: Farmer-Exporter. Channel-I emerged as the most popular choice due to higher net prices received by producers as compared to other channels. Additionally, the presence of pre-harvest contractors in Channel-I saved producers' time and transportation costs. Advance payments by pre-harvest contractors before taking delivery of the produce also contributed to the channel's popularity. However, many farmers expressed dissatisfaction with the lack of remunerative prices, instances of being cheated by middlemen, high transportation costs for sales outside the local area, excessive commission charges, limited market information, and low prices paid to farmers.

Bharti et al. (2019) examined the socio-economic status of apple orchardists in Shimla district, Himachal Pradesh. They employed multistage sampling to select respondents and collected primary data on demographic features (such as family size, age, education, and occupation) and economic parameters (including land inventory, livestock, cropping pattern, etc.) using well-designed, pre-tested schedules. Tabular analysis was then utilized to assess the socio-economic status of the apple orchardists.

Sampa et al. (2019) conducted a study involving 104 mango producers in four villages of the Northern region of Bangladesh to evaluate the profitability of mango production and assess the demographic and socio-economic conditions of farmers. The study compared the costs and profits of mango cultivation with other crops due to the unfavorable climate for field crop production but favorable conditions for mango cultivation in the Barind ecosystem. The researchers used the Problem Confrontation Index (PCI) to measure the challenges of mango production. Among the identified problems, insects and diseases infestation had the highest PCI of 429, followed by dropping of fruits and flowers with a PCI of 409. The study found that the average profit from mango cultivation (299,010 Tk/ha) exceeded that from onion cultivation (260,412 Tk/ha). Most farmers (about 87%) practiced intercropping with mango, although the cost incurred for harvesting, sorting, and grading mango cultivation was higher than for other crops.

Kumari and Chauhan (2020) evaluated the production and marketing channels of major cash crops in Sirmour district, Himachal Pradesh, based on a random sample of 60 farmers using proportional allocation. The findings showed varying vegetable production levels, ranging from 4.42 quintals for capsicum to 18.93 quintals of tomato per farm. Garlic, classified as a spice crop, exhibited the highest production of 22.37 quintals per farm. Consequently, garlic had the highest marketable surplus i.e. 99.12% of total production, with only 0.40% reserved for home consumption. Marketable surplus percentages for tomato, capsicum, beans, and peas were 97.99%, 97.29%, 96.15%, and 95.07%, respectively. The study identified two primary marketing channels: Channel I, involving local traders, wholesalers, and retailers outside the state, and Channel II, involving local traders, wholesalers, and retailers within the state. Garlic was predominantly sold in markets across

Tamil Nadu, Kerala, Gujarat, and Delhi, while tomatoes, capsicum, beans, and peas were marketed in Delhi, Karnal, Ambala, Chandigarh, and Ludhiana. Within the state, Shimla, Solan, and Rajgarh were the major markets utilized for selling selected crops. To enhance the producer's share in the consumer's rupee and create additional employment opportunities, the study suggested the establishment of agro-processing units near the study villages.

Sharma and Guleria (2020) investigated the marketing and price-spread patterns of the apple crop in Himachal Pradesh, aiming to propose policy interventions for promoting apple cultivation in the state. The study was conducted in the Banjar and Naggar blocks of Kullu District, Himachal Pradesh, with a representative sample of 70 farmers. The findings revealed that the apple produce was marketed through four channels, with the majority (about 59%) being disposed off through Channel B (Producer-primary wholesaler-secondary wholesaler-retailer-consumer). A comparison between different channels shown that Channel D (Producer-retailer-consumer) had the highest share in consumer rupees, accounting for 73.95%, and also exhibited the highest marketing efficiency at 2.84. This indicates that smaller channels are more profitable. Major challenges faced by apple growers in the study area included a lack of good infrastructure and skilled labour availability. These findings emphasised the importance of addressing infrastructure and labour issues to support the apple cultivation sector in Himachal Pradesh.

Giri et al. (2021) studied constraints faced by kiwi fruit farmers in Ilam municipality and Sandakpur rural municipality of Ilam district. The study employed a simple random sampling method to select 80 households, with 40 households each from Ilam municipality and Sandakpur rural municipality. The findings revealed a slight increase in production rates in both areas. Approximately 25 and 20 per cent of farmers in Sandakpur and Ilam, respectively, produced their own seedlings, while the remaining seedlings were obtained from other nurseries. The primary constraint identified was the presence of wild animals, particularly Kala, in both Ilam and Sandakpur areas. In Ilam municipality, technical factors were the predominant constraints, whereas disease and pest issues were more prevalent in Sandakpur rural municipality. Despite these challenges, the benefit-cost ratio was calculated to be 2.67 and 2.53 in Ilam and Sandakpur, respectively, indicating the profitability of kiwi cultivation in both regions.

Malla et al. (2022) investigated on improvement of household economy through kiwi farming in dolakha district, Nepal at three locations namely Boach, Jiri, and Bigu. The study aimed to assess the impact of kiwi farming on the local economy. Various methods, including questionnaires, discussions, direct observations, and literature reviews, were employed. A total of 60 households were randomly selected for the study, with both male and female respondents participating. Results indicated that 60% of respondents were male and 40% were female. Regarding education, 20% were illiterate, 38% had primary education, and 17% had secondary education or S.L.C. level. The Monty variety was widely cultivated in the study area, with agriculture being the primary occupation for 47% of respondents, followed by government jobs (30%), business (13%), and other occupations (10%). Half of the respondents cultivated kiwi on 1-5 ropani of land. Additionally, 47% of respondents received training in kiwi cultivation, mainly organized by DADO and other agricultural organizations. Most farmers sold kiwi in the local market themselves, contributing to the economic upliftment of households in the area. Overall, the study concluded that kiwi farming positively impacted household economy and livelihoods.

Gayathri and Sahana (2022) investigated the socio-economic characteristics of fruit and vegetable growers in Karnataka's Davangere district using an Expost facto research design. A total of 120 farmers, with 40 each from public, cooperative, and private market interventions, were surveyed using a pre-tested interview schedule through personal interviews. Results shown that 75.00% of farmers from public markets, 72.50% from cooperative markets, and 72.50% from private markets had a medium level of education. Majority of respondents in public (72.50%) and private (77.50%) markets exhibited medium decision-making abilities, while only 50.00% in cooperative markets had medium decision-making abilities. 87.50% of farmers in private markets had a medium level of market orientation. 77.50% of farmers in public markets had a medium level of information-seeking behavior. Additionally, the study found significant associations between education and information-seeking behavior with the knowledge level of farmers in public markets. Cosmopoliteness was significantly associated with the knowledge level of farmers in both cooperative and private markets.

Sehgal and Kumar (2022) studied the marketing channels and marketing efficiency of apple growers in Kashmir (J&K), India to understand how different intermediaries can impact producers' returns and consumers' prices. This study examined the marketing channels, efficiency, costs, and margins in Jammu and Kashmir for the movement of apples from producers to consumers. The findings showed that Channel-I in Baramulla and Channel-II in

Kupwara and Shopian were popular among farmers, with most apple growers selling their produce through these channels. It was observed that a higher number of intermediaries between producers and consumers resulted in increased marketing costs, and vice versa. Channel-II was found to have the highest marketing cost. The analysis further revealed that Channel-V in Jammu & Kashmir exhibited higher efficiency as compared to other channels due to the absence of middlemen between producers and consumers. This underscores the importance of understanding and optimizing marketing channels to improve efficiency and benefit both producers and consumers.

Sharma et al. (2022) reviewed on kiwifruit supply chain in Uttarakhand. This study analyzed the supply chain management of kiwi fruit, a major crop in Uttarakhand's Bageshwar area. Additionally, they proposed a business plan tailored for small-scale farmers to enhance employment opportunities, economic development, and overall benefits. This study addresses the specific challenges of the Himalayan fruit supply chain, focusing on kiwi fruit. It suggests that sustainable business models like horti-tourism can not only increase farmers' revenue but also improve the efficiency of the Himalayan produce supply chain.

Jalthariya et al. (2022) examined the marketing aspects of fruits in Punjab. The primary data was collected from both fruit growers and various market intermediaries. The findings of this study indicated that the marketed surplus of kinnow and malta constituted 98.20% and 96.06% of the total production, respectively. While comparing different marketing channels, it was observed that the pre-harvest contract system yielded the highest price spread, while the producer's share in the consumer price for average-quality fruits was lowest in this system. Conversely, selling produce directly to retailers resulted in the highest producer's share in the consumer rupee and was identified as the most efficient channel. Major challenges faced by fruit growers included the lack of nearby processing plants, cold supply chains, local marketing centers, export bottlenecks, and price fluctuations.

Magh and Ramchandra (2023) conducted a study on the marketing channels employed in pineapple farming, focusing on associated costs, the producer's share in consumer rupees, and marketing efficiency. This research analyzed various marketing channels involving wholesalers, retailers, and pre-harvest contractors. The findings revealed that in channel 1, the retailer incurred marketing costs amounting to 45.20%, while in channel 2, it was approximately 36.47%. Additionally, in channel 2, producers incurred a marketing cost of

13.27% due to the necessity of transporting the produce to the village trader. In this study the marketing efficiency was compared between the two channels, with channel 1 showing higher efficiency (171.43%) compared to channel 2 (155.56%). This difference can be attributed to the higher marketing cost (Rs. 1233.75) and marketing margin (Rs. 3266.25) per 100 fruits in channel 2, ultimately reducing the producer's share in consumer rupees.

Thakur et al. (2023) investigated the marketing channels of the persimmon crop in Kullu District, Himachal Pradesh, focusing on marketing costs, producer's share, and marketing efficiency across different channels. The study analyzed various marketing channels involving wholesalers, retailers, and pre-harvest contractors to understand their impact on producer returns and consumer prices. The findings revealed variations in marketing costs across channels, with producers incurring costs ranging from ₹187.40 to ₹245.86 per quintal. Additionally, wholesalers, pre-harvest contractors, and retailers faced significant expenses such as commissions, transportation, and taxes. An analysis of price spreads among channels highlighted the net prices received by producers, consumer prices, and marketing margins. Furthermore, the study evaluated the marketing efficiency of each channel, with Channel-1, Channel-2, and Channel-3 exhibiting efficiency values of 5.48, 3.10, and 2.44, respectively.

Bharti et al. (2023) conducted a marketing analysis of the apple crop in the high hills of Himachal Pradesh. The study aims to scrutinize the marketing aspects of apple crops in this region, considering the complex nature of its marketing patterns. The research underlines the importance of maintaining a cautious approach within the marketing channel, as any oversight can potentially lead to reduce prices and profits for farmers. The findings of the study indicated that the retail channel exhibits the highest marketing efficiency, followed by the commission agent's channel. This study suggests that reducing the number of intermediaries in the channel can contribute to enhanced marketing efficiency and better returns for apple growers.

2.2 To determine the approximate optimum strata boundaries for obtaining efficient estimates of kiwifruit production in Himachal Pradesh

Dalenius (1950) was the first in addressing the challenges of determining Optimum Strata Boundary (OSB) when the study variable itself serves as the stratification variable. He formulated a set of minimal equations aimed at identifying OSB, but these equations often proved difficult to solve due to their implicit nature. Consequently, various researchers have explored alternative methods to approximate strata boundaries using conventional techniques.

Dalenius and Gurney (1951) proposed the idea of establishing strata boundaries while keeping $W_h\sigma_h$ constant, where W_h represents the weight of h^{th} stratum.

Mahalanobis (1952) proposed dividing populations into an appropriate number of strata and suggested a practical method of stratification where the sum of strata were equal.

Hansen et al. (1953) illustrated that an effective stratification only yields valid conclusions for populations where the coefficient of variation across all possible strata were consistent. However, this condition was not typically met across all populations.

Aoyama (1954) proposed the creation of strata based on the equalization of strata ranges, denoted as (Y_h - Y_{h-1}) = constant, where Y_h and Y_{h-1} represent the upper and lower boundaries of the h^{th} stratum. This approach is supplemented by equal sample allocation to each stratum. However, this rule operates under the assumption that the distribution within each stratum is approximately rectangular, a condition that is more likely to hold true when the number of strata is large. Since this rule is not dependent on the density of y, it may not yield highly accurate results.

Dalenius and Hodges (1957) developed a more convenient method for constructing strata by utilizing equal intervals on the cumulative square root of f(y). This approach proved to be an excellent approximation to the Optimum Strata Boundary (OSB) for both equal and optimum allocations. Furthermore, it was noted that the OSB for equal and optimum allocations nearly coincide. Subsequent research by Dalenius and Hodges (1959) demonstrated that this rule functions satisfactorily even for small numbers of strata, such as 2 or 3.

Raj (1958) investigated the estimation of the mean value of a characteristic for a finite population, utilizing information on an auxiliary variable. A comparison was drawn among the probability proportional to size (pps) estimate, simple average, ratio, regression, and stratified sample estimates. The findings were derived under the assumption that the finite population is a random sample from an infinite population with certain properties.

Dalenius and Hodges (1959) examined the estimation of the mean value of a quantity (x) in a population divided into (L) strata based on the value of a closely correlated quantity. They emphasized the importance of selecting (L - 1) points of stratification. Optimal points were approximated by equalizing intervals across the strata based on the square root of the population density. They provided a straightforward method for iteratively refining these points, demonstrated through various examples.

Durbin (1959) suggested equalizing cumulative frequencies of a distribution, g(y), positioned between the original distribution f(y) of the study variable y, and a uniform distribution r(y across the range of y. The Approximately Optimum Strata Boundaries (AOSB) were determined by taking equal intervals on the cumulative of the function $g(y) = \frac{1}{2}[r(y) + g(y)]$.

Ekman (1959) conctructed the strata boundaries under the condition that $W_h(x_h - x_{h-1})$ = constant. Dalenius and Hodges (1959) suggested the construction of strata by taking equal intervals on the cumulative of $\sqrt{f}$.

Mickey (1959) examined a category of ratio and regression type estimators ensuring unbiasedness for random sampling, without replacement, from a finite population. They provided non-negative, unbiased estimates of variance for a subset of these estimators. Comparable results were offered for the generalized procedures of sampling without replacement. Efficiency was evaluated against comparable sample selection and estimation techniques for this scenario.

Cochran (1961) conducted a comparative analysis of four methods for determining AOSB, namely (i) Dalenius's cumulative square root of the frequency distribution (ii) Ekman's method, (iii) Durbin's approach, and (iv) the criterion of constant product of stratum weight and mean. These methods were evaluated for different numbers of strata (L = 2, 3, and 4) using eight skewed frequency distributions commonly encountered in practice. The study revealed that methods (i) and (iii) consistently performed well across various distributions, while method (iv) was generally satisfactory except for two highly skewed distributions. Method (ii) demonstrated satisfactory performance only for four out of the eight distributions.

Sethi (1963) approached the problem of optimum population stratification for estimating the population mean in a novel way. Instead of deriving AOSB through theoretical methods, he considered the approximation of population distributions by standard continuous distributions for large-sized populations. He proposed the development of precomputed tables providing OSB for such distributions, and examined normal and chi-square distributions for this purpose. His study revealed that the cumulative square root of the frequency distribution $\sqrt{f(y)}$ rule, as suggested by Dalenius and Hodges (1957), served as an excellent approximation to OSB for both equal and optimum allocations. Moreover, he observed that the OSB for equal and optimum allocations were nearly identical.

Rao and Graham (1964) conducted an investigation into a unified finite population theory, focusing on composite estimators for both the current level and changes in level between consecutive occasions in rotation sample designs. They provided explicit variance functions assuming exponential and arithmetic correlation patterns over time for the characteristics of interest. Through numerical analysis, they determined optimal values for weight coefficients in composite estimators, the ideal number of consecutive visits by a sampling unit, and the efficiency gains compared to using simple estimators. Their findings shown moderate improvements for level estimation and significant enhancements for change estimation, particularly in scenarios with high correlation.

Raj (1965) investigated the common use of auxiliary information based on a single variable to enhance the accuracy of estimators for population totals, means, and other parameters. In this study, a novel approach was proposed, using information from multiple variables to achieve greater precision. The method of difference estimation was utilized extensively. It was demonstrated that the variances of difference estimators were similar to those of ratio estimators. Additionally, the findings were extended to double sampling procedures and sampling over two occasions.

Kokan (1965) suggested two methods for construction of strata that do not require extensive computations. In the first method, equal intervals were taken across the range, while in the second method, the range was partitioned to form strata of equal size. Generally, Method I exhibits better performance as compared to Method II when the population was divided into more than three strata.

Herlekar (1967) attempted an investigation into a two-stage sampling procedure applied to a bivariate normal population for estimating the population mean of a variable y using stratified sampling, with the stratification based on the auxiliary variable x. In the first stage, a sample of size n_1 was selected, and the values of the auxiliary variable were measured. Subsequently, the Optimum Strata Boundaries (OSB) and the relative sizes of strata were estimated, particularly in the case of proportional allocation. Then, using these estimates, a second sample of size n_2 was selected, and the values of the study variable were measured through stratified sampling.

Singh and Sukhatme (1969) addressed the challenge of optimum stratification based on an auxiliary variable x in a more generalized form. They developed various methods to approximate solutions to minimal equations for Neyman and Proportional allocations.

Singh (1971) investigated the relative efficiency of the methods of obtaining AOSB on study variable (y). New method for obtaining AOSB in case of proportional allocation, known as cum.$\sqrt[3]{f(y)}$ rule was proposed by Singh and Prakash (1975). This method consists of taking equal intervals on the cum.$\sqrt[3]{f(y)}$. The proposed method is easy to apply in practice.

Deutler and Buhler (1975) provided the proof of the existence of optimal stratification and demonstrated that the Dalenius equations serve as necessary conditions for the optimality of a stratification, even in cases where the variance of the stratified sample mean was not differentiable everywhere.

Singh and Parkash (1975) investigated the optimization of stratification based on the auxiliary variable x for equal allocation. They introduced the cum $f\sqrt{\phi}$ rule as a method for determining the Approximately Optimum Strata Boundaries (AOSB) for allocation proportional to strata totals using simple random sampling.

Thomsen (1976) gave an approximately optimum method of construction o*f* strata boundaries for proportional allocation. The method is based on equi-partitioning of the cum.$\sqrt[3]{f(y)}$, where f(y) is the distribution of stratification variable.

Wang and Aggarwal (1984) derived Optimum Strata Boundaries (OSB) for a positively skewed stratification variable. Subsequently, they examined this issue further within the framework of the proportional allocation method.

Khan et al. (2002) approached the task of determining Optimum Strata Boundaries (OSB) by reframing it as a task of determining the optimal width of strata. They applied their method to compute OSB for populations exhibiting uniform and right triangular distributions.

Kozak et al. (2007) outlined a modern approach to stratify finite populations. They presented a comprehensive overview covering univariate and multivariate stratification, addressing various aspects including strata geometry, optimization functions along with their constraints, dimensionality of stratification, approximate univariate stratification, selection criteria for optimization methods in stratification, initial parameters for optimization-based stratification, and additional population and stratification attributes like subdivision of populations into domains, domain-oriented approaches, and the inclusion of a take-all stratum.

Park et al. (2007) suggested a compromise allocation method that combines Neyman allocation using an estimator of the pooled standard deviation of combined strata with proportional allocation. This approach aims to reduce the efficiency loss in Neyman allocation caused by using estimators instead of the unknown strata standard deviations of the population. Their study demonstrated that the compromise allocation method resulted in a more efficient estimator as compared to both proportional allocation and Neyman allocation using estimated strata standard deviations.

Verma and Rizvi (2007) examined the issue of optimal stratification for two study variables when units from different strata were selected using a probability proportional to size with replacement sampling scheme. They obtained solutions to minimal equations by minimizing the trace of the variance-covariance matrix to identify optimal stratification points. They proposed a cumulative cube root rule $\sqrt[3]{M_6(x)}$ to approximate solutions to the minimal equations. Furthermore, they derived limiting expressions for the generalized variance-covariance matrix, optimal numbers of strata, and expressions for approximate sample sizes.

Verma (2008) explored the problem of optimal stratification for two study variables when units from different strata were chosen using a simple random sampling with replacement scheme. Under the super population model, they proposed a cumulative square root rule to approximate optimal strata boundaries for compromise allocation, particularly when there is a high correlation between the auxiliary variable and study variables. Moreover, he suggested a limiting expression for the trace of the variance-covariance matrix.

Vishwakarma and Singh (2011) proposed an estimator for the population mean ($\bar{Y}$) of the study variable y utilizing an auxiliary variable x in stratified random sampling. They derived the bias and variance of the proposed estimator under the large sample approximation. Additionally, they identified the Asymptotic Optimum Estimator (AOE) along with its approximate variance formula. Furthermore, they investigated an estimator based on "estimated optimum values." An empirical study was conducted to demonstrate the performance of the suggested estimator compared to others.

Mehta and Mandowara (2012) addressed the challenge of determining strata boundaries to minimize the variance of the estimator of the population mean. They approached this problem by conducting sampling in each stratum independently using simple random sampling without replacement (SRSWOR). However, exact solutions to the resulting minimal equations were challenging to obtain. Therefore, they derived approximate solutions for these minimal equations under three allocation methods: proportional allocation, equal allocation, and Neyman allocation.

Ozel et al. (2012) proposed separate ratio estimators for estimating population variance in the context of stratified random sampling. They derived equations for mean square error and conducted a comparative analysis of the proposed estimators to assess their efficiency relative to each other. Through these comparisons, they identified the conditions under which the proposed estimators outperformed others in terms of efficiency. Their analysis demonstrated that the proposed classes of estimators exhibited greater efficiency as compared to conventional unbiased estimators. Additionally, they observed that separate ratio estimators showed superior efficiency when compared to combined ratio estimators. The theoretical findings were collaborated by numerical illustrations using original data. Furthermore, they conducted a simulation study to empirically evaluate the performance of the estimators.

Tsatiris (2012) implemented a stratified random sampling approach with optimum allocation for a research study focused on the rural population, which exhibited significant variations across three distinct strata. The rural population of Evros Prefecture in Greece was categorized into three strata based on the mean altitude of settlements: mountainous, semi-mountainous, and flat population. They aimed to estimate the mean consumption of forest fuelwood for heating and cooking purposes in households across these three strata. The methodology involved several steps: (i) Determining the total sample size for the entire rural population and allocating it to the various strata. (ii) Assessing the effectiveness of stratification using the analysis of variance (One-Way ANOVA) technique. (iii) Conducting sampling research through face-to-face interviews in selected households. (iv) Ensuring the questionnaire forms were correctly structured and analyzing the collected data using the Statistical Package for Social Sciences (SPSS) for Windows.

Verma et al. (2012) evaluated the issue of optimal stratification for two sensitive quantitative variables. The data were collected from various strata using the scrambled response technique and an auxiliary variable was employed as a stratification variable. In their study, they derived the limiting expression for the trace of the generalized variance-covariance matrix, as well as expressions for the number of strata and the approximate sample size.

Barnabas and Sunday (2014) employed various methodologies to examine the optimal design for sample allocation across strata. They utilized real-life stratified data from the education and meteorological sectors in Ondo state, Nigeria, subjecting it to thorough analysis to derive population characteristics through three distinct allocation procedures. After assessing and comparing the variance estimates obtained from these procedures, they made conclusions. While the performance of the three allocation methods—equal, proportional, and optimum—varied across different conditions, the optimum allocation procedure emerged as the most efficient.

Tailor and Lone (2014) investigated separate ratio-type estimators for population mean, their properties and possible uses. Using the known parameters of auxiliary variables, they presented many distinct ratio-type estimators of the population mean. The study analyzed the bias and mean squared error of these estimators up to the first degree of approximation. Their investigation revealed that the proposed estimators exhibited higher efficiency compared to unbiased estimators in context of stratified random sampling, as well as in comparison to conventional separate ratio estimators, under specific conditions. To further validate the efficacy of their proposed estimators, they conducted an empirical study, providing real-world context to their theoretical findings and offering practical insights into the performance of these estimators in real-world scenarios.

Danish et al. (2020) proposed a methodology for determining Approximately Optimum Strata Boundaries (AOSB) based on two closely related auxiliary variables (X and Z) in surveys involving a single study variable (Y). They developed this approach considering a regression model, where Y = C(X, Z) + e, with C(X, Z) representing a function of X and Z, and 'e' representing the error term. By minimizing the variance of the estimation variable under certain assumptions, they derived minimal equations. Due to the implicit nature of these equations, they propose a Cum$\sqrt[3]{D_1(x,y)}$ rule for determining AOSB. They empirically compared their method, utilizing certain density functions, with the cube root method proposed by Singh and Sukhatme (1969) for a single auxiliary variable. The results show a remarkable gain in efficiency when two auxiliary variables are used as the basis of stratification.

Rattan et al. (2022) studied optimum stratification for estimating mango production in Himachal Pradesh. The primary data was collected on mango area and production from 325 mango orchardists in Himachal Pradesh through a well-designed survey. The area under mango, considered as an auxiliary variable, was stratified to facilitate the stratification of mango production, as the study variable. Four stratification methods were employed, namely Equalization of Strata Total, Equalization of Cumulative, Equalization of Cumulative and Equalization of Cumulative. These methods stratified the area under mango production into different numbers of strata (L = 3, 4, 5, 6). The study revealed computed estimates of mean and variance for varying numbers of strata and sample sizes (n = 60, 90, and 120) allocated by proportional and Neyman allocation under the four stratification rules. Additionally, the study assessed the gain in precision achieved through these methods. Their findings indicated that for L = 6 and n = 120, the minimum variance was achieved, suggesting the optimal configuration for precision in mango production estimation.

Reddy and Khan (2023) constructed efficient strata boundaries in stratified sampling, focusing on optimizing survey cost. The study aims to achieve maximum precision in estimating population parameters by determining the optimum strata boundaries (OSB) based on continuous study variables rather than categorical ones. These OSBs lead to homogenous units within each stratum, resulting in optimal stratum sample sizes (OSS). The study highlighted that OSB and OSS may not remain optimal when considering a fixed total sample size, particularly in survey designs with a fixed budget. The proposed methodology involves computing OSB and OSS using known per unit stratum measurement costs or their probability density function. They also provide numerical examples for hypothetical study variables following exponential and right-triangular distributions. Moreover, they implemented this technique in the updated stratify R package.

2.3 To assess the relative contribution and comparison of morphological characteristics of kiwifruit vine towards the yield

Anderson (1958) provided a comprehensive recent exposition of principal component analysis (PCA), a technique also utilized by several authors to elucidate complex growth patterns using a minimal number of fundamental trends.

Moore (1965) was the first to employ PCA to quantify yield component interactions in horticultural crops, particularly in understanding the correlation between plant vigor, vegetative growth, and fruit yield in apple cultivation.

Davidson (1975) applied principal component analysis to investigate variation in twenty-four parameters measured on small wood samples of *Eucalyptus deglupta*. Additionally, factor analysis and varimax rotation were used to interpret these components and determine the relative significance of variables within each component.

Rathore (1981), based on regular physical and chemical analyses, recommended the optimal harvest times for Abbot, Allison, Bruno, and Hayward cultivars of Kiwifruit under the conditions of Shimla, Himachal Pradesh, as 211.2, 209.4, 215.6, and 223.0 days from full bloom (DFFB), respectively. It was suggested that the fruits were harvested after approximately thirty weeks from anthesis, which was about seven weeks longer than the period required in New Zealand. Among the cultivars, Allison was identified as an early cultivar, while Abbott and Bruno were categorized as midseason cultivars, and Hayward was classified as a late cultivar.

Lahav et al. (1989) found a negative correlation between fruit number and fruit weight in kiwifruit. Specifically, they observed that vines with 700 fruits produced 100g fruit weight, whereas vines with 4700 fruits yielded only 30g fruit weight when left unthinned.

Testolin (1990) observed that decrease in fruit weight by 0.08g for each increase of 1000 buds per hectare in Kiwifruit. Kiwifruit crop response to variations in plant density and bud number per surface unit of growing area was studied to determine optimum levels of these factors. Five bud numbers per surface unit (50,000, 100,000, 150,000; 200,000, and 250,000 mixed buds/ha) and four plant densities, obtained by varying the in-row spacing's (1.5, 3.0, 4.5, and 6.0m), were combined in a factorial design and tested in a Kiwifruit orchard during two growing seasons on the same vines. Kiwifruit yield increased from 7 to 24 times ha^{-1} with increasing bud number per hectare according to a 2nd-order polynomial function. Both the reduction in the mean fruit mass as well as the percentage bud break caused a decrease in orchard efficiency. No differences between 1.5m and 3.0m in-row spacing's were found; spacing's wider than 3.0m reduced crop efficiency principally by decreasing fruit mass.

Garriz et al. (1991) carried out a study in order to estimate apple tree yield (kg/tree). Samples were collected in a Red Delicious apple orchard at the experimental station of the Universidad Nacional del Comahue, in 1989. The main parameters evaluated were tree top area, fruit density and fruit weight. Results showed that the estimated tree yield was 144.10 kg/tree (equivalent to 60,041 kg/ha). The obtained value was compared with data derived from direct tree yield determination and no significant differences were found. It was concluded that the methodology used was efficient to estimate apple tree yield and it would provide useful information for management decisions.

Lezzoni and Pritts (1991) utilized principal component analysis (PCA) in their horticultural study. They employed PCA to quantify the response of groups of variables or compound traits to imposed treatments or evolutionary pressures. This approach allowed them to experience and analyze the data using a combination of principal component analysis and simple multivariate statistics.

Belie et al. (2000) used principal component analysis to chewing sounds to detect differences in apple crispness. The basic relationship between the crispness of Cox's Orange Pippin apples and recorded chewing sounds was investigated. Crispness groups were created by submitting apples to varying storage conditions after carrying out a fast Fourier transformation on the time signal of the generated sound. Principal component analysis was carried out on the power spectra of training set, and a calibration matrix for group prediction was created. The PC values were compared with mechanical parameters, maximum force and slope of the force deformation curve during a penetrometer measurements and tensile strength in the ring tensile test. Principal component analysis on Fourier transformed chewing sounds appeared to be promising technique and has potential as an objective measure for crispness evaluation. Mealy and crisp apples could be distinguished by Principal component analysis.

Currie et al. (2000) utilized principal component analysis (PCA) for the qualitative evaluation of apple fruit shape. They examined apples from 1233 genotypes representing 82 open-pollinated families planted at three sites in New Zealand. The fruit was cut along the stem calyx axis at the widest point, and an image analysis program was employed to extract caliper measurements of the fruit outline. Through PCA of the Fourier descriptors for each fruit outline, five independent shape traits were identified. Genetic and residual variance components were estimated using data from two sites, employing restricted maximum likelihood techniques to select genetically inherited apple shape traits. They also drew a chart based on the aspect, conicity, and sparseness principal component values to facilitate visual assessment of shape.

Momen et al. (2004) used multivariate statistic to identify and rank a set of seedlings characteristics that could predict the performance of mature trees in *Pinus ponderosa*. Results indicated that metabolic heat rate (q), a measure of total metabolism of one-year-old foliage during the peak growth in May was the most important seedling characteristic that predicted mature-tree performance. Increased metabolic heat rate in seedlings corresponded with greater vigour of mature trees. Additionally, seedling basal stem diameter, height and needle length measured in November were in order of importance, other variables that defined the vigour class of the mature clones. However, these seedling morphological characteristics correlated negatively with vigour classification of the mature clones, contradicting the notion that greater diameter and/or height during the seedling stage may indicate a greater vigor at maturity.

Aravanopoulus (2010) studied seven leaf parameters from four full-sib *Salix eriocephala* and three *Salix exigua* families. Principal component analysis of variance and discriminant analysis showed that most of the variation was resolved in low multidimensional space. Leaf and stipule shape parameters emerged as most important variables.

Felenji et al. (2011) evaluated and classified morphological traits of potato cultivars in fall cultivation of Jiroft area, 22 potato cultivars and experiment in randomized complete block design with three replications, was done in Jiroft Agricultural Research Center. Correlation coefficient showed that tuber weight and harvest index have positive and significant correlation with tuber yield. Factor analysis based on principal component analysis method and varimax rotation indicated that three important factors accounted for 80.05 per cent of the total variation among traits. The first factor assigned 33.29 per cent of total variation between traits and was significantly related with tuber yield. Therefore, this factor was regarded as tuber yield factor. Other factors accounted for 30.48 and 16.28 per cent of variation between traits and were entitled as stolon length factor and negative factor for diagonal height, respectively.

Rakonjac et al. (2014) studied thirty-three wild cherry (*Prunus avium* L.) accessions from Central Serbia. Tree, leaf, fruit, and stone morphological characters were evaluated during three consecutive years. The goal was to detect relationships between the genotypes and to identify the most useful traits for discrimination among them. The study revealed a high variability in the set of the evaluated wild cherry accessions and considerable differences were found among them in all studied attributes. The majority of important correlations were determined among variables representing fruit and leaf size, and variables related to colour. Cluster analysis distinguished wild cherry accessions into two distinct groups. In PCA, fruit and leaf traits such as leaf length and width, and fruit height, width, and weight, and skin flesh and juice colour were predominant in the first two components, indicating that they were useful for the assessment of wild cherry germplasm characterization. These results indicated that these accessions must be conserved as valuable genetic resources to enrich the cherry gene pool and can be used for improving breeding efficiency of important horticultural traits worldwide.

Salunkhe et al. (2014) estimated the tree density, basal area, biomass and carbon status with the help of non-destructive allometric biomass equations in tropical deciduous forests of state Madhya Pradesh, India. They concluded that relationship between basal area and above ground biomass showed positive correlation. The biomass ranged from 3.99 to 53.90 t/ha.

Verma et al. (2014) concluded that *Grewia optiva* Drummond is one of important agroforestry tree species grown by the farmers in the lower and mid-hills of western himalayas. Different models viz., monomolecular, logistic, gompertz, allometric, rechards, chapman and linear were fitted to find the relationship between total biomass and diameter at breast height (DBH) as independent variable. The adjusted $\overline{R}^2$ values were more than 0.924 for all the seven models implying that all models were apparently equally efficient. Out of the six non-linear models, allometric model fulfils the validation criterion to the best possible extent and was considered as best performing. Biomass in different tree components was fitted to allometric models using DBH as explanatory variable, the adjusted $\overline{R}^2$ for fitted functions varied from 0.872 to 0.965 for different biomass components. Using the developed model, the estimated total biomass varied from 6.62 Mg ha-1 in 4 year to 46.64 Mg ha-1 in 23 year old plantation. MAI in biomass varied from 1.66–2.05 Mg ha-1 yr-1. The total biomass carbon stocks varied from 1.99 Mg ha-1 in 4 years to 15.27 Mg ha-1 in 23 year old plantation.

Bhartiya et al. (2015) assessed the genetic variability using multivariate analysis among elite lentil lines derived through hybridization between macrosperma and microsperma types. As per principal component analysis, first four principal components (PCs) expressed 83.50 per cent of total variation in which PC_I, PC_{II}, PC_{III}& PC_{IV} accounted for 34.73, 27.14, 11.94 and 9.69 per cent of total variation, respectively.

Kumari et al. (2016) worked out correlation coefficients and regression models for different biomass components of *Ulmus villosa* in mid-hills of Himachal Pradesh. They concluded that green and dry biomass was positively and highly correlated with all the growth characteristics. However, highest correlation was observed with diameter at breast height. Exponential function was best fitted for the prediction of green and dry biomass and diameter at breast height remained the best predictor of green and dry biomass.

Wani et al. (2017) studied 40 Kashmiri apricot cultivars/genotypes that were assessed for 28 morphological traits. The results displayed a high level of variability among all the cultivars/genotypes. The fruit characteristics such as fruit size, shape, fruit volume, flesh and skin colour which determines the quality and marketability of apricot exhibited huge variation. Two groups were identified based on fruit size; small fruit (<30 g) and large fruit (>30 g). PCA revealed that 84.28% of the total variation among cultivars/genotypes was explained by the first ten components. UPGMA cluster analysis divided apricot cultivars into two groups. Cluster I contain the 33 cultivars/genotypes and cluster II contains six cultivars/genotypes. The present study highlighted that the characters related to fruit morphology such as, dimensions, shape, fruit flesh colour and leaf dimensions and shape were valuable traits for fast and easy discrimination of apricot cultivars. This was the first report on genetic diversity analysis of apricot cultivars/genotypes from the region. This study provided a sound and authentic basis for effective management and sustainable utilization of apricot germplasm in future breeding programmes in the region.

Djuric et al. (2018) did the investigation of three wheat varieties (PKB Talas, BG Merkur and PKB Lepoklasa) carried out at experimental field and laboratory of Institute PKB Agroekonomik, during two years 2009 and 2010. Correlations between morphological and production traits of plants number of shoots, number of spikelets per spike, number of grains per spike, 1000 grain weight and grain weight per spike, were studied. Correlations were observed separately for three Institute PKB Agroekonomik varieties. The manner of preparing data for calculating correlations influences obtained correlation values, and these values can differ substantially. Correlations calculated based on aggregated data were higher than those based on all data. Correlations differ for different varieties, which is logical, because each variety has a different genotype and specific genes forming various interactions. Taking into account all three varieties, high and positive correlations were found between: number of grains per spike and grain weight per spike (>0.78), number of spikelets per spike and number of grains per spike (>0.79), and number of spikelets per spike and grain weight per spike (>0.73).

Sharifi et al. (2018) conducted an experiment to estimate the extent of genetic diversity among 25 chickpea genotypes. The study was carried out based on a randomized complete block design with four replications at Brojerd Agricultural Research Station over two seasons, 2012–2013 and 2013–2014. The first three principal components (PCs) explained 69.69% of the variation. Four groups of characters were distinguished based on the first (PC1) and second (PC2) principal components. Factor analysis revealed three main factors, which accounted for 69.69% of the total variability. These factors were labeled as 'phenological traits', 'morphological traits', and 'yield components'. Communalities indicated that the studied traits were reliable, ranging from 0.537 (canopy height) to 0.881 (seed yield). A two-dimensional ordination biplot showed a positive correlation between seed yield, pods per plant, canopy width, harvest index, and biological yield. Cluster analysis grouped the 25 genotypes into two main groups and four clusters. At a distance of 5, the 11 examined traits formed two clusters. These findings can be utilized in breeding strategies for future hybridization programs aimed at yield improvement and are suitable for classifying diversity among chickpea germplasm.

Igbari et al. (2019) conducted a study on the morphological characteristics of seven mango cultivars collected from the National Horticultural Research Institute (NIHORT) in Ibadan, Nigeria. The morphological traits assessed included leaf length and width, leaf apex, petiole length, fruit length and width, fruit color, and shape. Principal component analysis based on a similarity matrix revealed correlations between leaf length and petiole length, fruit length, width, and shape. However, fruit color showed no correlation with any of the other parameters. Cluster and dendrogram analysis, employing farthest neighbor, mean character difference, and constrained clustering strategies, revealed two distinct groups of mango cultivars based on their fruit features. Cluster A comprised Julie, Edward, Palmer, and Kent, while cluster B comprised Saigon, Madoe, and Lipen. This study provided valuable insights into the characterization of different mango cultivars in Nigeria, serving as a foundation for germplasm management and crop breeding endeavors.

Wang et al. (2021) conducted multivariate statistical analyses on fruit characteristics of wild kiwifruit germplasm resources across various ecological regions in Yunnan, China. The study aimed to identify genetic differences and diversity among these kiwifruit resources, offering insights for future genetic breeding and germplasm utilization. A survey was conducted from 2019 to 2021, collecting wild kiwifruit germplasm resources from five regions in northeastern, southeastern, southern, northwestern, and eastern Yunnan. Multivariate statistical analyses, including variation analysis, factor analysis, correlation analysis, and cluster analysis, were performed on 12 fruit traits of 76 Yunnan kiwifruit germplasm resources. The coefficients of variation for the 12 traits ranged from 23.96% to 117.01%, with hair type and hair density showing the largest coefficients. The study demonstrated significant genetic differences and diversity among wild kiwifruit germplasm resources in different ecological regions of Yunnan. These findings can inform future genetic breeding efforts, guide germplasm screening, and accelerate research and utilization of kiwifruit germplasm resources in the region.

Peng et al. (2023) conducted an evaluation of preharvest melatonin's impact on soft rot and quality of kiwifruit using Principal Component Analysis. Results revealed that melatonin significantly inhibited the mycelial growth of *B. dothidea*, with 1.0 mmol/L concentration inhibiting growth by up to 50%. Principal component analysis indicated that 0.3 mmol/L melatonin concentration enhanced kiwifruit's resistance to soft rot while preserving postharvest fruit quality. These findings suggest a positive impact of melatonin application on maintaining the nutritional composition and quality of kiwifruit.

Kumar et al. (2023) conducted a study on the usefulness of multivariate analysis in forestry research, focusing on wild pomegranate (*Punica granatum* L). The study employed contrast, cluster, discriminant, and principal component analysis. Data on various morphological and seedling characters were collected from five different districts, each comprising ten seed sources. The evaluated characteristics included tree height (m), tree diameter (cm), crown spread E-W (m), crown spread N-S (m), fruit weight (g), leaf length (cm), internodal length (cm), collar diameter (mm), number of branches per plant, and leaf petiole (cm). Contrast analysis revealed significant variations among the different districts and within the districts. Cluster analysis grouped the seed sources into three clusters, while discriminant analysis categorized them into high and low yielders. Six seed sources from Mandi, Kullu, and Shimla districts were classified as high yielders, while the remaining four were categorized as low yielders. Principal component analysis extracted three principal components, explaining 34.675%, 23.002%, and 11.587% of the total variation, respectively, accounting for a cumulative variation of 69.26%.

2.4 To develop statistical models for forecasting kiwifruit yield

Yaseen et al. (2005) performed research to anticipate the production of sugarcane in Pakistan. The results of the investigation centred on sugarcane production data collected during 1947 to 2002. The best acceptable model for the investigation was ARIMA (2, 1, 2). Prediction was carried out as well during the period 2008-2009. To make comparisons, the initial three predicted values from 1999-2000 to 2001-2002 were compared with the actual values. The values that were forecasted were quite comparable to the actual ones.

Yusuf et al. (2007) assessed the expected production of fruits such as citrus and mango. They utilised secondary data from 1961 to 2003, a duration of 43 years. The study employed descriptive statistics as well as growth models to build the framework for the prediction over the medium-term of 2004 to 2010. The regression models were utilised for forecasting. The value of the coefficient of determination for every model ranged from 0.792 to 0.970, demonstrated a significant goodness of fit. According to this, the temporal trend accounted for a minimum of 79 per cent and up to 97 per cent of the variations in the yield of mango and citrus fruits, respectively. The model likewise performed effectively, as demonstrated by the observed F-values. The forecast was computed on the basis of expectations that the previous patterns (area planted and yield) and the presence of a consistent weather trend will hold. The study indicated three distinct time periods: 1961–2003, 1986–2003, and 1991–2003. These periods were employed to simulate the various policy regimes of regulation, structural adjustment, and liberalization. Overall, citrus and mango yield has increased over time. But for the period that included structural adjustment, the growth rate was greatest. As a result, the study by employing the Structural Adjustment period had the greatest medium-term output forecasts.

Aparna et al. (2008) applied compound growth rates to examine trend in the growth rates for important vegetable crops in the Visakhapatnam district. The exponential growth function has been employed to determine compound growth rates. The research findings identified a significant and negative compound growth rate for region, while productivity and output increased positively but non-significantly.

Rajarathinam et al. (2010) conducted an investigation utilising data from time series on tobacco area, production, and productivity spanning 1949-1950 to 2007–2008. Parametric models used various linear, nonlinear, and ARIMA time-series models. In statistical terms best appropriate parametric models had been adopted based on adjusted R^2, substantial regression coefficients, coefficient of determination (R^2), Root Mean Square Error (RMSE), Mean Absolute Error (MAE) values, and residual normal and random distribution assumptions. Following a visual examination, auto-correlation and partial auto-correlation function assessment of the time-series data for stationarity, adequate ARIMA models were fitted. The auto-correlations up to fifteen lags were worked out. The statistically best-suited time-series model has been chosen on the basis of several goodness of fit standards, which includes Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), RMSE, MAE, and residual assumptions (Shapiro-Wilks test for normality and Ljung and Box test for randomness). In nonparametric regression, the initial step was to estimate the optimal bandwidth, which was done through the cross-validation approach. Nonparametric estimations of the underlying growth function have been calculated for each time point. To ensure randomization, residual analysis was performed. Relative growth rate was computed using the best fit model.

Priya and Bajpai (2011) analysed time series data for sugarcane output, productivity, and area in India from 1930 to 2006. Production, productivity, and area all showed an upward trend. The analysis discovered that the growth rate in area and output has decreased. The consistent productivity throughout the years was most likely attributable to agronomical methods and market variables. They also determined compound growth rates for India's sugarcane area, production, and productivity. The growth rate was estimated using the Logistic, Gompertz, and Monomolecular models. The variables of the aforementioned models were evaluated and computed for goodness of fit. The logistic model has the best fit based on values of R^2, MAE, MSE, and RMSE.

Bagri (2012) investigated the trend and growth rates of tomato production in Madhya Pradesh's Satna area, as well as costs, returns, and constraints. Secondary data on tomato area, production, and productivity, were obtained from 2000-2001 and 2010-2011. A linear equation has been employed to estimate the trend and growth rate of area, production, and productivity of the tomato crop. The investigation found that the trend values of area and production were in increasing order, whereas the trend value of tomato crop productivity was positively non-significant during the course of the investigation.

Chepuru (2012) studied the growth rates of chilies, paddy, cotton, and tobacco in Guntur district of Andhra Pradesh. She tested linear, logarithmic, power, s-curve,quadratic, cubic, compound, growth, and exponential models to determine the best trend equation for future forecasts. The study was conducted employing time series data between 1970 to 2011. The linear and compound growth rates were determined. The most suitable model has been selected considering the lowest RMSE and significant R^2. It became apparent that paddy production and productivity increased significantly, but paddy area revealed a stationary trend. The forecasts for paddy production and productivity indicated a downward trend. Over the investigation period, there was a considerable increase in the area, production, and productivity of chillies. In the instance of cotton, the results demonstrated an increasing trend accompanied by a moderately decreasing trend in area over the course of the research, as well as an increasing trend in production throughout the investigation period, while the forecasts of area revealed a decreasing trend. From 1970 to 2020, productivity increased significantly. It was found that the area and production of tobacco decreased during the research period while increased from 2012 to 2020. Tobacco productivity was observed to increase between 1970 to 2020.

Kumar et al. (2012) applied nonlinear statistical models to analyse the trend in area covered coffee production in India. They employed six nonlinear statistical growth models. Parameters of each model were calculated. Two most appropriate models were chosen on the basis of goodness of fit criteria including MAE, MSE, RMSE, MAPE, AIC, and BIC. Logistic and MMF models have been demonstrated fairly effective in specifying the area under coffee production. The investigation concluded that the series exhibited an increasing trend in the area under coffee production. Prediction values were also calculated utilising two best fit models, indicated the findings that the Logistic model produced somewhat bigger values compared to the MMF model.

Prasad et al. (2012) analyzed 41 years of data from 1969 to 2009 to study the growth rates in area, production, and productivity of maize in Telangana. The forecasts have been provided up to 2014 applying various growth models. The model exhibited the least RMS and notable adjusted R^2 was best fitted model for forecasting. The study found that the compound model provided the best trend values for maize area and production, while the s-curve function turned out to be the best fit model for future forecasts.

Dastagiri et al. (2013) utilized the exponential model to forecast vegetables area and production trends. They estimated the compound growth rate of India's vegetable production and area. The research project was carried out by National Centre for Agricultural Economics and Policy Research, New Delhi, India and included 20 crops from 8 states: Andhra Pradesh, Karnataka, Tamil Nadu, Punjab, Rajasthan, West Bengal, Manipur, and Mizoram. 4.12 per cent growth rate was observed in the total area under vegetable cultivation. Onion exhibited the greatest area growth rate. All vegetable areas had positive growth rates, with the exception of the sweet potato, which had negative growth rates. The overall average vegetable production growth rate was 6.48 per cent. Except for the sweet potato, all vegetable production growth rates exceeded 4 per cent. The findings demonstrated a rich past and an optimistic future for Indian vegetables production.

Debnath et al. (2013) predicted cotton cultivation area and production in India applying ARIMA models. The research was conducted by using secondary data on cotton area, production, and yield from 1950-1951 to 2010-2011. Cotton area, production, and yield time series data was generated adopting the Box Jenkins stochastic ARIMA method. The ARIMA model has been implemented in four phases: model specification, estimations, diagnostic checking, and prediction. Data on cotton area, yield, and production over the previous 55 years were applied for modelling, and data from the last 5 years was taken to validate the model. ARIMA (0,1,0), ARIMA (1,1,4), and ARIMA (0,1,1) were identified as the best fit models for area, production, and productivity, respectively. The best fit models were applied to predict ten-year forecasts for cotton area, production, and yield.

Mishra et al. (2013) employed ARIMA and the autoregressive model to determine instability and forecast onion area, production, and productivity in India. The study examined time series data spanning the years 1978 to 2008. It became evident that the cubic trend model, out of all the parametric trend models, had the capacity to accurately explain trends in onion area, production, and productivity. Onion exhibited large variations in area, production, and productivity. The research further concentrated on projecting onion cultivated area and production in India using the ARIMA model. They forecasted onion production for the year 2020.

Shah et al. (2014) examined growth and trends in area, production, and yield of primary crops in Khyber Pakhtunkhwa employing time series data from 1980-1981 to 2011-2012. The compound growth rates and trend evaluation demonstrated that the area under wheat crop reduced over the years as a result of shifting of agricultural land to various rabi crops. Wheat production increased from 1981-1985 to 2011-2012 because of a boost in per hectare wheat crop yield. The outcomes demonstrated that the area, production, and yield of maize maximized over the years as more agricultural area was planted with hybrid and improved open pollinated maize varieties. The area for rice cultivation decreased while production increased as the per hectare yield of rice crop boosted. The data gathered indicated that the area, production, and yield of the sugarcane crop increased at an average of 0.24 per cent, 0.85 per cent, and 0.60 per cent every year, respectively.

Debnath et al. (2015) applied an exponential model to investigate sesame growth and instability in north-eastern hills of India. The investigation includes the states of Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura. They examined time series data spanning 20 years, from 1991-1992 to 2010-2011. The area and production growth rate have been maximum for Nagaland, whereas productivity was maximum in Manipur. The data has been split into two phases: Period I (1991-1992 to 2000-2001) and Period II (2001-2002 to 2010-2011). The overall period under consideration was referred as period III (1991-1992 to 2010-2011). The Log Linear model was used to estimate the compound annual growth rate of area, production, and productivity separately for each crop throughout the two periods.

Dinesha and Sriramappa (2015) conducted a study to determine the trend of area, production, and productivity of fruits and vegetables in India, with a particular emphasis on Karnataka. Secondary data were obtained for a period of 22-years, from 1991-92 to 2012-13. It has been split into two sub-periods: 1991-92 to 2000-01 and 2001-02 to 2010-11. From 1991-1992 to 2012-2013, there was a positive growth rate of 4.3 per cent in both area and fruit production. The productivity of the fruit crop exhibited a non-significantly positive growth rate. During the investigated period of 1991–1992 to 2012–2013, the area, production and productivity of vegetables showed positive growth rate likewise, the area and fruit production in Karnataka have exhibited positive growth rates of 1.80 and 0.90 per cent, respectively. However, productivity was reduced by 0.90 per cent between 1991-1992 to 2012-2013. Positive growth rates of 1.90, 2.50, and 0.70 per cent were observed in the areas, production, and productivity of vegetables, respectively.

Kumar (2015) projected mango and potato production in Himachal Pradesh applying a variety of statistical models. The investigation included secondary data from the last 18 years on mango area and production, in addition to 40 years of potato area and production in Himachal Pradesh. Autoregressive, straight line, second-degree parabola, exponential, modified exponential, and Gompertz models had been adopted and assessed. All of the prediction models shown high adjusted R^2, low RMSE, and low Theil's inequality coefficients, indicated that they were all well-fit to the area under mango crop. Straight line, second degree parabola, Gompertz curve, and 1st order autoregressive models appeared to be best fit for mango production. The 1st order autoregressive model was the best fit for the potato crop area under cultivation. All models used for forecasting were well fit for potato production in Himachal Pradesh.

Velayutham and Kuppusamy (2015) evaluated chilli crop area, production, and productivity trends in Guntur district of Andhra Pradesh. Data spanning 2002-2003 to 2011-2012 were used for assessment. Employing the regression analysis approach, the compound growth function was fitted to the data, and the compound growth rates, t-statistic, regression coefficient, and standard error were calculated. Area, production, and productivity all increased at rates of 2.59, 5.55, and 2.87 per cent, respectively. The findings revealed that farmers became more aware of the crop's profitability, which was most likely because of strong extension initiatives and the implementation of suggested package of practices.

Borkar and Tayade (2016) evaluated cotton time series data to develop a model for predicting production and reported that ARIMA (2, 1, 1) was the best fit. Cotton production data spanning 1950-1951 to 2014-2015 were utilised for modelling studies. The analysis consisted a class of linear time series models developed by Box and Jenkins (1976). The time series plot of production revealed an upward trend. Cotton production in India reached during 2013-2014 with 398 lakh bales and dropped to an all-time low of 30.4 lakh bales in 1950-1951. The ARIMA model was executed in four phases: model specification, estimation, diagnostic checking, and prediction. ARIMA (2,1,1) was selected. Cotton production was projected to be about 29.73 lakh bales for 2015-2016, with lower and upper limits of 19.40 and 40.06, respectively. Cotton production was predicted to be about 28.99 lakh bales for 2020-2021, had lower and upper ranges of 16.02 and 41.95 lakh bales, respectively.

Dhekale et al. (2017) applied parametric, nonparametric, and semi-parametric regression approaches to identify prior trends in tea production in the most important states in India. They assessed the effectiveness of all of the methods utilising higher R^2 values and lower values of residual criteria and observed that nonparametric/semi-parametric regression performed better than parametric regression for fitting trends in tea production. Furthermore, semi-parametric spline regression was identified as the model that fitted best for studying trends. It came to light that, with the notable exception of Kerala, the area under tea had increased in all of India's primary states from 1951 and 2011, and that productivity had been reported downward trend.

Poyyamozhi and Mohideen (2017) predicted cotton area under cultivation and production in India applying the ARIMA model. The investigation was conducted by employing secondary data on cotton area, production, and yield from 1955 to 2015. Cotton area, production, and yield time series data were simulated using Box-Jenkins Stochastic ARIMA models. A total of 60 years data were utilized for modelling purposes, while the last 5 years of data was applied for model validation. ARIMA (0, 1, 1) and ARIMA (0, 1, 0) were the best fits for production and area prediction, respectively. The best model was used to predict cotton area, production, and yield over a ten-year period. The findings of this research demonstrated that the area, production and yield of cotton in the year 2016 amounted 10.71 million ha, 37.90 million bales averaging 170 kg of each, and 520 kg/hectare, respectively. The study has revealed that the cotton area, production, and yield in the year 2025 will amount to 11.70 million ha, 42.53 million bales of 170 kg of each, and 532 kg/hectare, respectively.

Sahu (2017) performed research to determine the costs, returns, trends, growth rate, and production constraints for brinjal. Secondary data were obtained all over the past 10 years (2006-2007 to 2015-2016). The obtained data had been analysed applying both compound and simple growth rates. The area, production, and productivity of brinjal in the Indian state of Chhattisgarh were all boosting at a rapid rate, while in Dhamtari district, it was reported that only the area of brinjal was rising at a rapid rate.

Sathish et al. (2017) investigated the trends and growth rate in the area, production, and productivity of the chilli crop in Telangana. This investigation used the years 1971–2010 as its reference period. To assess the trend, 10 growth models were fitted to the area, production, and productivity of the chilli crop, and the most suitable model for the trend was selected depending primarily on the least RMSE and significant R^2. The randomness of residuals has been confirmed employing a one-sample run test. The polynomial trend was determined to be the best fit for the data. The chilli production prediction for 2018 has also been performed. This was accomplished by computing both linear and compound growth rates. The findings revealed that the linear and compound growth rates of area, production, and productivity of chilli were significantly increasing all through the course of the investigation. The polynomial trend model was determined to be the best fit for every aspect of the Telangana state. The prediction for chilli production in 2018 was 308.66 thousand tonnes.

Abid et al. (2018) forecasted the area and production of potato in Pakistan. Time series data of potato area and production in Pakistan from 1980-1981 to 2012-2013 (33 years) were used. Linear, quadratic, exponential, s-curve, double exponential models were tried. Forecasting errors namely mean absolute percentage error (MAPE), mean absolute deviation (MAD) and mean squared deviation (MSD) were used as model selection criteria. Lowest values of these errors indicated a best fit model. The study shown that exponential growth model was appropriate for forecasting potato area and production in Pakistan due to lowest values of the forecasting errors. The forecasted values of both area and production of potato crop depicted increasing trend.

Devi and Parasher (2018) conducted a study in Himachal Pradesh in order to examine the trends in area, production and productivity of different crops. The compound growth rates were estimated separately for the districts and the state as a whole for the period 1995-1996 to 2015-2016 by using exponential production function $Y=ab^t$. Student’s t test was used to test the significance of growth rate. It was found that fairly large number of districts had positive growth regarding area and production of pea, tomato, cabbage and cauliflower. While in case of productivity, tomato, capsicum/chilies and peas were the vegetables for which large number of districts had positive growth rate. Yet, few districts had negative growth rates. Area under different vegetable crops was increasing at varying rates in almost all the districts except Lahaul-Spiti. Lahaul-Spiti had negative growth rates or statistically non-significant change for most of the vegetables during the study period. Similarly due to area expansion, production of these vegetables was increasing at different rates in these districts. At the same time an undesirable trend of decline in yield growth for more vegetable crops in large number of districts had emerged. Though, the decrease in yield growth had been marginal and statistically non-significant.

Pandey et al. (2018) analysed the growth and instability in area, production and productivity of potato in Eastern Uttar Pradesh. The study related to 1980-1981 to 2014-2015 which was further divided into four sub periods. Linear and exponential models were used for this purpose. Growth was examined by compound growth rate and simple growth rate. The area under potato registered positive growth rate throughout the period in Vindhyan Zone. The productivity of potato was found to be highest in North Eastern Plain Zone whereas lowest in Eastern Plain Zones.

Rajan and Palanivel (2018) conducted a study on area, production and productivity of cotton crop in India during the period 1951 to 2013. The cotton crop secondary data were collected from Cotton Corporation of India (CCI). They compared different models viz., linear, quadratic, cubic, exponential, compound, logarithmic, inverse, power, S-curve, and growth model for estimating the growth of cotton on area, production, and productivity to find the best fit. Appropriateness of a model was judged by the magnitude and sign of the parameter estimates and goodness of fit viz. adjusted R^2 for best fit model. The developed regression model for cotton was found to be best fit in cubic regression model and cotton crop area, production and productivity of India during the study period showed increasing trends. Finally, the selected model for cotton area, production and productivity was used for eight years forecast.

Karn et al. (2019) studied the trend in area, production and productivity of coffee in Nepal. The investigation was based on secondary data collected for a period of 1994-1995 to 2015-2016 in Nepal. The study period was divided into two sub-periods 1994-1995 to 2004-2005 and 2005-2006 to 2015-2016 i.e. in decades. Compound Annual Growth Rate was calculated. The growth trend analysis for area under coffee was increasing with a compound growth rate of 4.3 per cent per annum during overall period of study. The sub- period wise analysis showed increasing area under coffee cultivation in the country during sub- period of study. The growth trend analysis for coffee production of Nepal was found positive and it was rising with a compound growth rate of 16.8 per cent per annum during over all study period (1994- 1995 to 2015- 2016). Sub- period wise growth trend analysis found that it was positive during both periods of study. Growth of coffee yield was expanding with a compound growth rate of 2.3 per cent per annum during 1994- 1995 to 2015- 2016. The subperiod wise growth trend analysis for coffee yield suggested positive growth for first period of study, whereas it was negative growth trend during 2^{nd} period of study.

Ismail et al. (2019) attempted to find past trends of cherry in Jammu and Kashmir using parametric, nonparametric and semi-parametric regression methods. The performance of each method was compared using higher values of R^2 and lower values of residual criteria. It was found that the nonparametric/semi-parametric regression was good fit for trends in cherry production in comparison to the parametric regression. Even semi parametric spline regression was selected as the best fit model for trend analysis. It was inferred that the area under cherry cultivation in Jammu and Kashmir was increasing from 1974-2017 and the productivity had also shown an increasing trend except for some recent years where the trend was found declining.

Gocmen and Kuvvetli (2020) conducted a study on the prediction of citrus fruits production utilizing artificial neural networks (ANN) and linear regression analysis. The study aimed to predict the production amounts of various citrus fruits in the city of Adana, Turkey, including oranges, mandarins, and bigarades, utilizing data spanning ten years. The results indicated that the proposed method achieved high accuracy, with R^2 values exceeding 0.98 for all datasets. This suggested that the model accurately predicted production amounts based on the provided input parameters, demonstrating the effectiveness of the approach in forecasting citrus fruit production.

Ajiono and Hariguna (2023) conducted a study comparing three time series forecasting methods: Linear Regression, Exponential Smoothing, and Weighted Moving Average. Their aim was to identify the method with the smallest error value or closest to zero. The results revealed that Linear Regression as the most accurate method, predicting 502 students with a Mean Absolute Deviation (MAD) of 27.83, Mean Squared Error (MSE) of 1152.1, and Mean Absolute Percentage Error (MAPE) of 8.1%. The Tracking Signal value remained within control limits (-1 to 1), indicating the method's accuracy. Similarly, the Moving Range value fell within control limits (-117.83 to 117.83), affirming the method's reliability. These findings suggest that Linear Regression was suitable for future decision-making, demonstrating a significant increase in data movement over seven periods.

JL and Maryani (2023) forecasted on Cacao (*Theobroma cacao*) Production in Lampung Province using the Double Exponential Smoothing Method. The research findings indicated a consistent increase in cacao production over a 10-year forecasting period, meeting the criteria for good Mean Absolute Percentage Error (MAPE) at 10.81484. The discussion emphasized the suitability of employing the Double Exponential Smoothing method, aided by R software, for accurate and reliable cacao production forecasts, thus providing valuable information for stakeholders.

Sharma et al. (2023) predicted the papaya area and production in India utilizing the Autoregressive Integrated Moving Average (ARIMA) method. The research aimed to analyze the sustainable production trends of papaya in India using yearly data spanning from 1950 to 2020 for stochastic trend estimation. In this study, forecasting was done for the period of 10 years from 2021 to 2030, projecting the values for the area under cultivation and production of papaya to reach 1538 hectares and 6,384,220 metric tons, respectively, by 2030. This study holds significance in identifying the potential demand gap between the area and production for papaya in the future, providing valuable insights for stakeholders in the papaya industry in India.

Chapter-3

MATERIALS AND METHODS

A systematic methodology forms the foundation of any scientific study, as the precision, reliability, and validity of scientific study relies on an appropriate methodology used. The present study on **"Statistical Investigation on Socio-Economic Status of Kiwifruit Growers and Factors Influencing Kiwifruit Production in Himachal Pradesh"** was carried out in three districts viz. Sirmaur, Solan and Kullu of Himachal Pradesh. This chapter comprises of the methodology employed for selection of the study area and sampling procedure, collection of data and analytical framework used for the study.

3.1 To study the socio-economic status of kiwifruit growers with respect to production and marketing of kiwifruit

- 3.1.1 Selection of study area and sampling procedure
- 3.1.2 Analytical techniques

3.2 To determine the approximate optimum strata boundaries for obtaining efficient estimates of kiwifruit production in Himachal Pradesh

- 3.2.1 Construction of optimum strata boundaries
- 3.2.2 Allocation of sample size
- 3.2.3 Method and procedure of estimation
- 3.2.4 Gain in efficiency due to stratification

3.3 To assess the relative contribution and comparison of morphological characteristics of kiwifruit vine towards the yield

- 3.3.1 Variability Analysis
- 3.3.2 Correlation Analysis
- 3.3.3 Path coefficient Analysis
- 3.3.4 Multivariate Analysis
    - 3.3.4.1 Discriminant Analysis
    - 3.3.4.2 Principal Component Analysis

3.4 To develop statistical models for forecasting kiwifruit yield

- 3.4.1 Prediction of area and production

3.5 Software used for analysis

3.1 To study the socio-economic status of kiwifruit growers with respect to production and marketing of kiwifruit

3.1.1 Selection of study area and sampling procedure

Sirmaur, Solan and Kullu districts of Himachal Pradesh were purposively selected for survey due to its high concentration of kiwifruit growers. Sirmaur district is located at latitude 30.5758° N and longitude 77.7800° E, Solan district at latitude 30.9075° N and longitude 77.0966° E and Kullu district at latitude 31.9560° N and longitude 77.1097° E.

Simple random sampling technique was used for the selection of units. The primary data was collected from 300 respondents across three major kiwifruit-producing districts of Himachal Pradesh: Sirmaur, Solan, and Kullu. In each district, different blocks were randomly selected based on preliminary information collected, as they are prominent kiwifruit-producing areas of the state. From Sirmaur district, Rajgarh and Pachhad blocks were chosen; from Solan district, Kandaghat and Solan blocks were selected; and from Kullu district, Kullu and Naggar blocks depending on the availability of kiwifruit cultivation in the households were included (Plate 3.1). The data consists of demographic features, economic parameters, cost of production, yield, marketable or marketed surplus, marketing costs, mode of transportation and problems faced by the growers in various aspects of production and marketing were gathered using designed pre-tested schedules through personal interviews conducted with the selected households. Secondary data, including the list of village households, cropped area, and kiwifruit production from Himachal Pradesh, were obtained from the Directorate of Horticulture in Shimla and the Horticulture Development offices of the respective blocks.

3.1.2 Analytical techniques

To address the specific objectives of the study and considering the nature and extent of data variability, the following analytical tools and techniques were utilized for data analysis.

3.1.2 (a): Tabular analysis

3.1.2 (b): Marketing analysis

3.1.2 (a): Tabular analysis

To fulfill the study objectives, tabular analysis, calculation of averages, and percentages were performed. Simple tabular analysis was used to assess the socio-economic

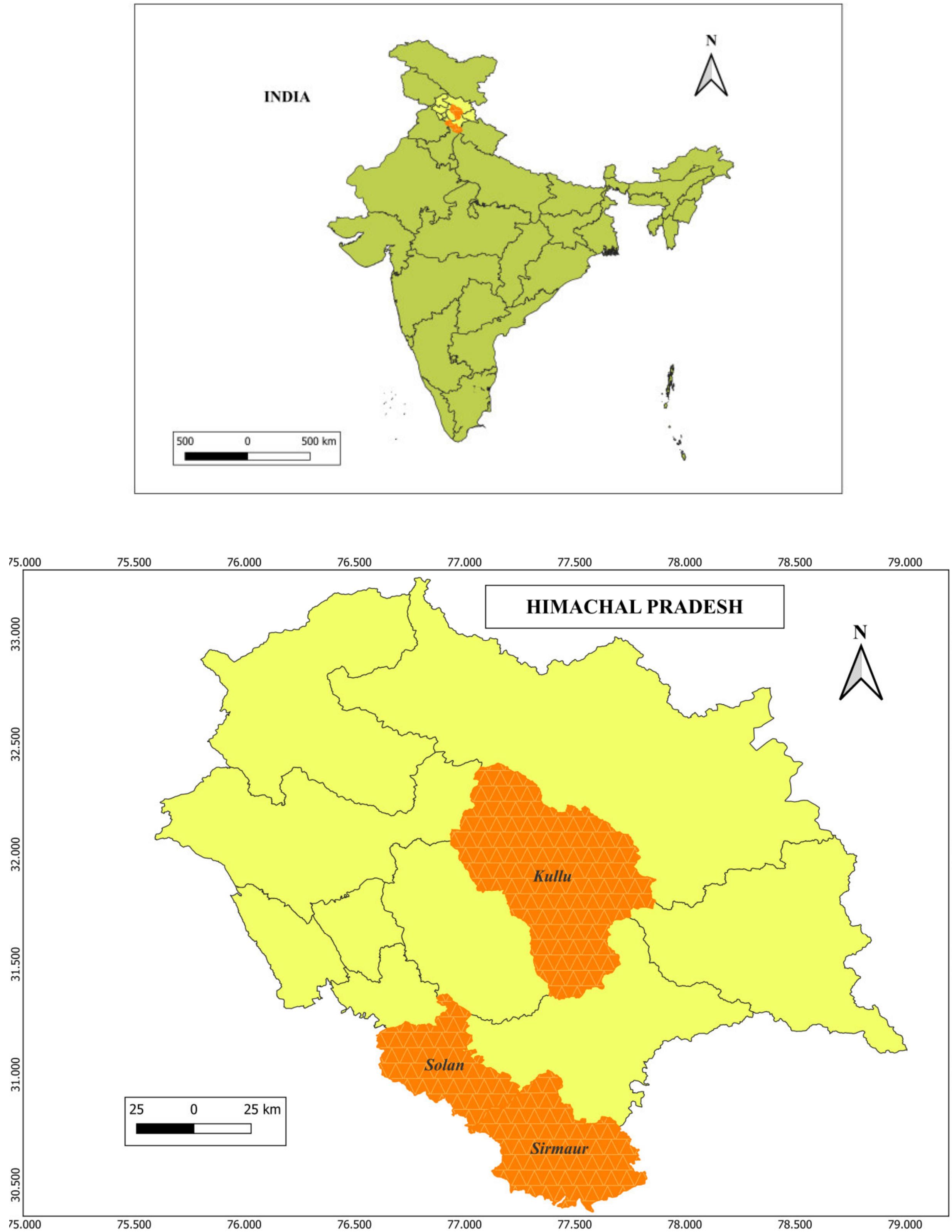

Plate 3.1 Selection of study srea

status of growers, analyze marketing channels, evaluate price spreads, and gather kiwifruit growers' opinions on production and marketing challenges.

The analysis of data involved categorizing 300 selected farmers into three groups based on the size of their land holdings, namely marginal (< 1.00 ha), small (1.00 - 2.00 ha), and medium farmers (> 2.00 ha). The distribution of sampled kiwifruit growers according to their holding size is presented in Table 3.1.

Table 3.1: Categorization of sampled kiwifruit growers based on their land holding size

Category	Size of land holding (ha)	Sample size
Marginal	< 1.00	116
Small	1.00 – 2.00	92
Medium	> 2.00	92
Total		300

The sex ratio was computed using the following formulas:

$$\text{Sex Ratio} = \frac{\text{Number of females in a family}}{\text{Number of males in a family}} \times 1000$$

3.1.2 (b) Marketing analysis

i) Marketable surplus

The marketable surplus refers to the remainder left with the producer farmer after fulfilling their needs for family consumption, payments to labor, and social and religious obligations made in kind.

$$M_s = T_p - C_h - C_g$$

Where,

M_s = marketable surplus,

T_P = total production,

C_h = home consumption,

C_g = gifts

i) Marketed surplus

The marketed surplus represents the quantity of produce that the producer sells in the market, irrespective of their requirements for family consumption, farm needs, and other payments. Hence, it can be more, less, or equal to the marketable surplus.

ii) Marketing efficiency (Operational efficiency)

Marketing efficiency is measured in terms of marketing costs, marketing margins, and price spread.

c.1) Marketing Costs

The total costs incurred on marketing by the farmers and by the various intermediaries involved have been calculated as follows:

$$C = C_F + C_{mi}$$

Where,

C	=	Total cost of marketing,
C_F	=	Cost paid by the farmers,
C_{mi}	=	Cost incurred by middlemen

c.2) Marketing Margin

The marketing margin of the middleman was calculated as the difference between the total payments (marketing cost + purchase price) and receipts (sale price) of the middlemen, and it was calculated as follows:

$$A_{mi} = P_{Ri} - (P_{pi} + C_{mi})$$

Where,

A_{mi}	=	Absolute margin of middlemen,
P_{Ri}	=	Total value of receipts per unit (sale price),
P_{pi}	=	Purchase value of goods per unit,
C_{mi}	=	Cost incurred on marketing per unit

c.3) Price spread

The economic efficiency of the marketing system is measured in terms of price spread. A smaller price spread indicates a higher efficiency of the marketing system. Price spread refers to the difference between the price paid by the consumer and the price received by the producer.

c.4) Producer’s price

The net price received by the kiwifruit grower was calculated by subtracting the marketing costs borne by the producers from the original price paid to the producers by the commission agent/wholesaler, and it is calculated as given below:

$$P_F = P_s - P_c$$

where,

P_F = Net price received by the producer,

P_s = Producer’s selling price,

P_c = Marketing cost incurred by the producers.

c.5) Efficiency Methods

In the context of marketing channels, marketing efficiency relates to the movement of goods from producers to consumers at the lowest possible cost while still providing the desired services to consumers. Therefore, the marketing efficiency of various marketing channels in the study area has been computed by employing the following formula:

$$\text{Acharya's method : } E = \frac{\text{Producer price}}{\text{Total marketing cost + Total marketing margins}}$$

c.6) Market intermediaries

Commission agents: A commission agent is an individual that purchases and sells goods in large quantities, assuming the risk associated with these transactions. They take ownership of the goods they purchase.

Retailers: The retailer functions as a licensed marketing intermediary responsible for retailing, which involves satisfying consumer needs. Typically operating from small establishments like shops equipped with weighing equipment, they serve as intermediaries between producers or wholesalers and consumers.

Consumers: The ultimate consumers in the market are either industries or households. They are the final users of goods and services produced by businesses or provided by service providers.

3.2 To determine the approximate optimum strata boundaries for obtaining efficient estimates of kiwifruit production in Himachal Pradesh

Primary Data from 300 respondents were collected from three major kiwifruit-producing districts in Himachal Pradesh: Sirmaur, Solan, and Kullu, through a meticulously designed survey. This data was stratified using four specific rules: i) Equalization of Strata Total ii) Equalization of cumulative $\sqrt{f(y)}$ iii) Equalization of cumulative $\sqrt[3]{f(y)}$ and iv) Equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$ and the sample was allocated using three different methods: equal allocation, proportional allocation, and Neyman allocation. These methods were employed to obtain precision-based estimators of kiwifruit yield.

3.2.1 Construction of Approximate Optimum Strata Boundaries

The primary consideration in forming strata is to ensure that each stratum is as internally homogeneous as possible. When dealing with a single study variable (y), the most effective characteristic for forming strata is the distribution of that study variable (y) itself. The L strata can then be formed by dividing this distribution at (L-1) appropriate points. However, sometimes the distribution of the study variable (y) is either unknown or should not be assumed in advance, preventing the researcher from generalizing the rule for all distributions. In such cases, the next best approach is to stratify based on an auxiliary variable (x) closely related to the study variable (y). Although constructing strata using such an auxiliary variable may not result in precisely optimal stratum boundaries, it can lead to approximately optimal stratum boundaries (AOSB).

In the present study, total production was considered as the study variable, and strata were constructed using this study variable itself. The following are the procedures for constructing approximate optimum stratum boundaries (AOSB) for different allocation methods:

i) **Equalization of strata total**: Mahalanobis (1952) introduced the concept of equalization of strata total ($N_h\mu_h$) with equal allocation. He proposed that when dealing with a large number of strata, denoted as L, a practical approach to stratification is to divide the entire population into a set of L strata in such a way that the total value of the characteristic remains consistent across each stratum. The key advantage of this approach lies in its simplicity. Hansen, Hurwitz, and Madow (1953) further demonstrated that this method leads to efficient stratification if the coefficient of variation within each stratum is consistent.

ii) **Equalization of cumulative $\sqrt{f(y)}$**: Dalenius and Hodges (1957) proposed a method for forming strata by equalizing the cumulative square root of the frequency function $\sqrt{f(y)}$, where f(y) represents the frequency of occurrence of the study variable y. This method assumes a bounded distribution and a large number of strata. Since the frequency function f(y) is typically unknown, an auxiliary variable x, highly and positively correlated with y, is used in its place [denoted as f(x)]. If the cumulative total is denoted as H, the approximate strata boundaries (x_i) are determined using $\frac{iH}{L}, i = 1, 2, \ldots, L-1$.

iii) **Equalization of cumulative $\frac{1}{2}\{r(y) + f(y)\}$**: Durbin (1959) introduced a method for equalizing the cumulative frequencies of a distribution, denoted as g(y), which lies between the original distribution f(y) and a rectangular distribution r(y) over the range (y_o, y_L) of the study variable y. In this method, the rectangular distribution r(y) is defined as $r(y) = \frac{F(y_L)}{y_L - y_0}$. The optimum stratification points are determined by equalizing the cumulative frequencies of the stratification to the cumulative frequencies of the function $g(y) = \frac{1}{2}\{r(y) + f(y)\}$.

iv) **Equalization of cumulative $\sqrt[3]{f(y)}$**: Singh and Sukhatme (1969) proposed a method for constructing strata, which is known as equal intervals on cumulative $\sqrt[3]{f(y)}$, where f(y) is the frequency function of the character under study. In this method, the value of $\sqrt[3]{f}$ are cumulative where y is the character under study. Since f(y) is unknown, f(x) is used in place of f(y), where x is an auxiliary variable positively correlated with y. If the cumulative cube root total is H, the approximately optimum strata boundaries are given by $\frac{iH}{L}, i = 1, 2, \ldots, L-1$.

3.2.2 Allocation of sample size:

The total sample size (n) for a survey is typically constrained by the available budget. However, the distribution of the total sample across strata is left to the discretion of the investigator. The precision of the estimator of the population mean, derived from stratified random sampling, depends on the allocation of the sample to different strata. Arbitrary allocation is not advisable; instead, several important factors should be considered for optimal allocation, including stratum size, variability within strata, and the cost of observations per sampling unit in each stratum. A good allocation maximizes precision while minimizing resource utilization.

Various sample allocation methods exist in the literature, and the allocation of the sample to different strata is commonly based on these methods. These methods are as follows:

i) **Equal allocation:** In case of equal allocation, number of sampling units from each stratum is equal. Thus, for h=1,2, …, L; $n_h = \frac{n}{L}$ units were selected from each stratum. Using this method of allocation, the estimate of variance of the $\bar{y}_{st}$ becomes

$$\hat{V}(\bar{y}_{st})_E = \frac{L}{n}\sum_{h=1}^{L} W_h{}^2 s_h^2 - \frac{1}{N}\sum_{h=1}^{L} W_h s_h^2$$

ii) **Proportional allocation:** In this method, allocation of a given sample size 'n' to different strata is done in proportion to stratum weight i.e., in the hth stratum $n_h = nW_h$ where, $W_h = \frac{N_h}{N}$. Using this method of allocation, the estimate of variance of the $\bar{y}_{st}$ reduces to

$$\hat{V}(\bar{y}_{st})_P = \left(\frac{1}{n_h} - \frac{1}{N_h}\right)\sum_{h=1}^{L} W_h s_h^2$$

iii) **Neyman allocation:** Most of the times, a survey statistician has to work within a fixed budget and therefore, the sampling variance has to be minimized for a given cost. In this case, the sample size in the hth stratum is given by $n_h = n\frac{W_h S_h}{\sum_{h=1}^{L} W_h S_h}$. Then, using this method of allocation, the estimate of the variance of the $\bar{y}_{st}$ becomes:

$$\hat{V}(\bar{y}_{st})_N = \frac{1}{n}\left(\sum_{h=1}^{L} W_h s_h\right)^2 - \frac{1}{N}\sum_{h=1}^{L} W_h s_h^2$$

3.2.3 **Method and procedure of estimation:** Let the population under consideration consisting of N units be divided into L strata such that hth stratum (h = 1, 2, 3, ..., L) contains N_h units of population. Let a stratified simple random sample of size n be drawn from it, the sample size in hth stratum being n_h so that $n = \sum_{h=1}^{L} n_h$. If y is the study variable and y_{hi} denote the value of study variable for ith unit in the hth stratum, i = 1, 2, . . . , N_h, then an unbiased estimate of the population mean $\bar{Y}$ is given by $\bar{y}_{st} = \sum_{h=1}^{L} W_h \bar{y}_h$ where, $W_h = \frac{N_h}{N}$ is the proportion of units in the hth stratum and $\bar{y}_h = \frac{1}{n_h}\sum_{i=1}^{n_h} y_{hi}$ is the sample mean of the study (estimation) variable based on n_h units drawn from the hth stratum. The variance of the estimate $\bar{y}_{st}$ is given as:

$$V(\bar{y}_{st}) = \sum_{h=1}^{L} W_h^2 \left(\frac{1}{n_h} - \frac{1}{N_h}\right) S_h^2, \text{ where, } S_h^2 = \frac{1}{N_h} \sum_{h=1}^{L} (Y_{hi} - \bar{Y}_h)^2$$

The estimator of variance is

$$\hat{V}(\bar{y}_{st}) = \sum_{h=1}^{L} W_h^2 \left(\frac{1}{n_h} - \frac{1}{N_h}\right) s_h^2, \text{ where, } s_h^2 = \frac{1}{N_h - 1} \sum_{h=1}^{n_h} (y_{hi} - \bar{y}_h)^2.$$

3.2.4 Percentage gain in efficiencies due to optimum stratification: The efficiency of i^{th} probability sampling over simple random sampling is defined as

$$E = \frac{1/V(\bar{y}_i)}{1/V(\bar{y}_n)_{SRS}} = \frac{V(\bar{y}_n)_{SRS}}{V(\bar{y}_i)}$$

And percentage gain in efficiency is given by:

$(E - 1)\times 100$

3.3 To assess the relative contribution and comparison of morphological characteristics of kiwifruit vine towards the yield

The primary data on randomly selected kiwifruit vines were collected from three districts of Himachal Pradesh: Sirmaur, Solan, and Kullu, in the year 2023. Five villages were randomly selected from each district, and from each selected village, two orchards were randomly chosen. This resulted in a sample of 10 orchards from each district. From each selected orchard, 7 kiwifruit vines were randomly sampled to collect data on various morphological characteristics.

For this purpose, primary data on 210 kiwifruit vines were collected in total, focusing on the following morphological characteristics:

Recorded characters	**Computed characters**
Vine girth	Leaf fruit ratio
Number of canes/vine	Fruit weight
Number of leaves/shoot	Fruit length
Duration of flowering	Fruit width
Number of flowers/shoot	Shape index (length/width)
Number of fruits/ shoot	TSS/TA ratio
	Total fruit yield
	Graded fruit yield
	Yield efficiency

3.3.1 Variability Analysis

The collected data on the aforementioned morphological characteristics from various locations underwent variability analysis to assess significant differences in variance across the parameters. Mean, standard error, coefficient of variation, and fudicial limits were computed for each morphological character and subjected to statistical significance testing. To compare variances across locations (Sirmaur, Solan, and Kullu), the Bartlett test was employed. The analysis aimed to provide results on the variability and significance of differences in morphological characteristics among different locations.

3.3.1.1 Bartlet test for testing the homogeneity of several variances

To test the hypothesis that all the sample have been drawn from the population having same variances

$H_0 : \sigma_1^2 = \sigma_2^2 = \sigma_3^2 = \ldots \sigma_k^2$

H_1 :Atleast two of the population variances are not same

Sample variance for the theith sample $S_i^2 = \frac{1}{n_j - 1} \sum_{j=1}^{n_i} (X_{ij} - \bar{X}_i)^2$

Where $\bar{X}_i = \frac{\sum_{j=1}^{n_i} x_{ij}}{n_j}$

χ'^2(uncorrected) = N $\log_e \bar{S}^2 - \sum_{i=1}^{k} v_i \log_e S_i^2$

Where $v_i = n_i - 1$, N = $\sum_{i=1}^{k} v_i$, $\bar{S}^2 = \frac{\sum_{i=1}^{k} v_i S_i^2}{N}$

Correction factor C = $1 + \frac{1}{3(k-1)} \left[\sum_{i=1}^{k} \frac{1}{v_i} - \frac{1}{N} \right]$

χ^2(corrected) = $\frac{\chi'^2}{C}$

If calculated value of χ^2 is less than χ^2 table value with k-1 df, H_0 is not rejected and it is concluded that population variances are same or the samples have been drawn from the population having same variances. If calculated value of χ^2 is greater than χ^2 table value with k-1 df, H_0 is rejected and atleast two of the population variances are different.

3.3.2 Correlation Analysis

Correlation between the two variables is the magnitude of the linear association between the two variables. The Karl Pearson's coefficient of correlation was worked out between the above mentioned plant characteristics and the significance was checked of the same. The Karl Pearson's statistic for the correlation coefficient (r) is given by $r = \frac{cov(X,Y)}{\sqrt{V(X)V(Y)}}$ and the significance of the same is tested by t-statistic $t = \frac{r(\sqrt{n-2})}{\sqrt{1-r^2}}$ with n-2 degrees of freedom.

3.3.3 Path Coefficient Analysis

Path coefficient analysis measures the direct and indirect effect of various morphological characters on kiwifruit yield and permits the partitioning of the correlation coefficient into two components i.e. direct and indirect effect and was employed in line with procedure described by Wright (1921) and modified by Dewey and Lu (1959). Let x_1, x_2, x_3 be three morphological characteristics, y be yield of kiwifruit, r_{ij} be simple correlation between i^{th} and j^{th} variable and P_{iy} be path coefficients. The path coefficients were obtained as:

$$\begin{bmatrix} r_{1y} \\ r_{2y} \\ r_{3y} \end{bmatrix} = \begin{bmatrix} 1 & r_{12} & r_{13} \\ r_{21} & 1 & r_{23} \\ r_{31} & r_{32} & 1 \end{bmatrix} \begin{bmatrix} P_{1y} \\ P_{2y} \\ P_{3y} \end{bmatrix}$$

$$\begin{bmatrix} P_{1y} \\ P_{2y} \\ P_{ny} \end{bmatrix} = \begin{bmatrix} 1 & r_{12} & r_{13} \\ r_{21} & 1 & r_{23} \\ r_{31} & r_{32} & 1 \end{bmatrix}^{-1} \begin{bmatrix} r_{1y} \\ r_{2y} \\ r_{3y} \end{bmatrix}$$

Further, residual effect is the variation in the dependent variable which remained undetermined by including all the variables was assumed to be due to the variables not included in the present investigation.

The degree of determination of such variable (s) on dependent variable was calculated as follows:

$$1 = P_R^2 + P_{1y}^2 + P_{2y}^2 + P_{3y}^2 + 2P_{1y}P_{2y}r_{12} + 2P_{1y}P_{3y}r_{13} + 2P_{2y}P_{3y}r_{23}$$

3.3.4 Multivariate Techniques

Multivariate techniques viz. Discriminant analysis and Principal Component analysis were used for the assessment of relative contribution of morphological characters contributing significantly toward the kiwifruit yield.

3.3.4.1 Discriminant analysis: Fisher (1936) introduced discriminant function analysis, which utilizes a set of multiple measurements to establish a discriminant function (linear) in the observations. This function have the property of being better to any other linear functions. Consequently, the problem is reduced to that of a single variable by selecting a linear component from the original variables and constructing a statistic suitable for the univariate case. The maximized value of this statistic, obtained through a suitable choice of coefficients, is considered as the appropriate test criteria. In such circumstances, discriminant analysis often yields more satisfactory results as compared to regression or correlation analysis.

Let $d_1, d_2, \ldots, d_p$ are the 'p' normal variate with same dispersion matrix (α_{ij}) but distributed independently of W_{ij}, where W_{ij} (i j =1,2,...,p) is the matrix giving the estimates on n degrees of freedom of the elements in the dispersion matrix (α_{ij}) of p-normally correlated variables. Considering only the first r variables, $d_1, d_2, \ldots, d_r$ the statistic T_r is defined by:

$$nT_r = \sum_{i=1}^{p} \sum_{j=1}^{p} W_r^{ij} d_i d_j$$

Where W_r^{ij} is the matrix reciprocal to W_{ij} (i, j =1,2,........,r)

such that, $$\frac{n-r+1}{r} T_r \sim F(r, n-r+1)$$

It can be easily shown that if $d_{r+1}, \ldots, d_p$ are distributed independently of $d_1, d_2, \ldots, d_r$ and $E(d_{r+i}) = \ldots E(d_p) = 0$, $E(d_i)$ being not necessarily zero when i = 1,2....r, the statistic is distributed as:

$$\frac{n-p+1}{p-r} U_{p-r,\, r} \sim F(p-r, n-p+1)$$

The average value of W for class I and II having number of cases a and b respectively was given by:

$$\overline{W}_I^a = \lambda_1 \overline{X}_1^a + \lambda_2 \overline{X}_2^a + \ldots + \lambda_p \overline{X}_p^a$$

$$\begin{matrix} \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \end{matrix}$$

$$\overline{W}_{II}^a = \lambda_1 \overline{X}_I^b + \lambda_2 \overline{X}_2^b + \ldots + \lambda_p \overline{X}_p^b$$

The cut-off point choosing between class I and II lies between $\overline{W}_I^a$ and $\overline{W}_{II}^a$. Its exact value could be dependent on the relative cost of miss-classifying the units, but frequently it is taken as the midpoint between W_I and W_{II}. A test of the hypothesis that the discriminant function has no discriminating provided by the F- test constructed as follows:

$$F = \left[\frac{\frac{n_I n_{II}/(n_I+n_{II})D^2}{p}}{\frac{D}{n-p-1}}\right] \text{with p and n-p-1 df}$$

Where $D = \bar{W}_I^a$ and $\bar{W}_{II}^a = \sum \lambda_j d_j$ and $n = n_I + n_{II}$

The real adequacy of the discriminant function, is determined by how well it discriminates between classes I and II on a fresh sample of data. Three districts were divided into high and low yielder groups in terms of kiwifruit production.

3.3.4.2 Principal Component Analysis: Principal Component Analysis (PCA) is a multivariate statistical technique used to reduce data with a large number of correlated variables into a substantially smaller set of new variables. PCA focuses on explaining the variance-covariance structure of a set of variables through a few linear combinations of these variables. Its general objectives include:

1. Data reduction
2. Interpretation

PCA does not necessitate the assumption of multivariate normality. Instead, it addresses the internal structure of the variables under consideration. Its primary goal is to reduce the dimensionality of the data by retaining as much variance as possible in a smaller set of variables. This reduction in dimensionality aims to preserve as much information from the original variables as possible, while still minimizing the loss of information.

The aim of principal component analysis is to ascertain new variables, called principal components, which carry most of the information present in original variables. Principal Components are generally estimated from either the correlation matrix (R) or sample variance-covariance matrix (S). When the variables are measured in different units, scale effect can influence the composition of the derived components. In order to overcome such situation, it is desirable to standardize the variable. Also, correlation matrix should be used.

The first few principal components usually account for most of the variation of the original variables and the variation described by following principal components is relatively little, it is often useful to retain only those first few principal components and drop all subsequent components from the analysis. It is so because the variable they express is largely random and is of no use in the analysis. Several thumb rules have been proposed for the number of principal components of the correlation matrix with eigen roots less than one. The principal components with the variance less than one contains less information.

Various steps involved in worked out of principal components is summarized as below:

i) First of all Keyser – meyer – olkin measure for sampling adequacy is computed. If the value of KMO comes out to be more than 0.5 only then we should go for principal component analysis.
ii) After that find the eigen value of variance-covariance matrix or correlation matrix.
iii) Arrange eigen values in decreasing order. Let these values in decreasing order be λ_1, λ_2,. . ., λ_p and corresponding variability be V_1, V_2 …. V_p, where V_p is variability for λ_p.
iv) Starting from first principal component, go on adding the variance of first few principal components whose value is more than unity. The variability described by them is of greater use. Discard the remaining principal components.
v) From the eigenvectors of the selected principal components, the variables that load onto the respective principal components are identified.

The output desired for interpretation and grouping include:

i. Eigen value and percentage of total variation explained by each principal component.
ii. The eigen vector for each principal component.
iii. The principal component scores.
iv. The correlation between original Standardized variable and the corresponding principal component scores (occasionally called loading).

Principal component analysis technique was used to identify the important characteristics contributing towards the yield of kiwifruit yield.

3.4 To develop statistical models for forecasting kiwifruit yield

3.4.1 Prediction of area and production

Regression analysis is a statistical technique for investigating and modelling the relationship between variables. The relationship is between the response variable (dependent variable) and the predictor variable (independent variable). It provides an approximation to the true functional relationship between the variables of interest. It is used to predict the value of the response variable in terms of the regressor variable. Generally, regression equations are valid over the region of the variables contained in the actual data. If these equations are used to predict the values of the response variable, it contains error term which indicates the presence of unknown variables not included in the model like climate and weather factors during the period of time.

Various linear and non-linear mathematical functions and statistical models (Exponential Smoothing) was tried for the development of model for estimation of kiwifruit area and production. Finally Adj. R^2 and RMSE were used to select best fitted regression function.

When we consider the time as an independent variable, various linear and nonlinear regression models can be represented by the following equations:

i) Linear $Y_t = a + bt + e_t$

ii) Quadratic $Y_t = a + bt + ct^2 + e_t$

iii) Cubic $Y_t = a + bt + ct^2 + dt^3 + e_t$

iv) Power $Y_t = a \times t^b + e_t$

v) Compound $Y_t = a \times b^t + e_t$

vi) Exponential $Y_t = a \times e^{bt} + e_t$

Where;

Y_t = time series values of dependent variable

t = independent variable, time element which takes the value 1,2,…,n for various years.

a = intercept

b & c = regression coefficients

e_t = error term

3.4.1.1 Linear model:

The straight-line trend between the time series values (y_t) and time t be given by the equation:

$$Yt = a + bt + e_t$$

Where,

Yt	=	time series values at time t.
t	=	independent variable, time element which takes the value 1,2,…,n for various years; a and b are constants.

Principle of least square technique consist in minimizing the sum of square of the deviation between the value of Y_t and their estimates by above equation. The values for a and b are computed such that for values of Y_t corresponding to n different values of t.

The normal equations used for estimating a and b are

$$\sum Yt = na + b \sum t$$

$$\sum tYt = a\sum t + b \sum t^2$$

The normal equations were solved to get a and b constant values. These values of a and b put in the equation of straight-line model to get the estimated and prediction values of area under kiwifruit cultivation and kiwifruit production.

3.4.1.2 Quadratic model:

The second degree parabola trend between the time series values (yt) and time t be given by the equation:

$$Yt = a + b\,t + c\,t^2 + e_t$$

Where,

Yt	=	time series values at time t.
t	=	independent variable, time element which takes the value 1,2,…,n for various years; a, b and c are constants.

Principle of least square technique consist in minimizing the sum of square of the deviation between the value of Y_t and their estimates by above equation. Computed a, b and c by solving the three normal equations.

The normal equations used for estimating a, b and c.

$$\sum Yt = na + b\sum t + c\sum t^2$$
$$\sum tYt = a\sum t + b\sum t^2 + c\sum t^3$$
$$\sum t^2Yt = a\sum t^2 + b\sum t^3 + c\sum t^4$$

The normal equations were solved to get a, b and c constant values. These values of a, b and c put in the equation of second degree parabola model to get the predication values of area under kiwifruit cultivation and kiwifruit production.

3.4.1.3 Cubic model:

The third degree parabolic trend between the time series values (yt) and time t be given by the equation:

$$Y_t = a + b\,t + c\,t^2 + d\,t^3 + e_t$$

Principle of least square technique consist in minimizing the sum of square of the deviation between the value of Y_t and their estimates by above equation.

3.4.1.4 Compound model:

The compound model is:

$Y_t = a\,t^b + et$

3.4.1.5 Exponential model:

The exponential model is:

$Y_t = ae^{bt} + et$

Where, t is the time period and Y is the observation at time t. This implies that series is changing by a constant ratio b per unit time.

3.4.1.6 Power Model:

The power model is $Y = ab^t$

3.4.2 Model performance Measures

Regression models were assessed for adequacy using various measures to evaluate their overall fit and the quality of the predictions. Some commonly used measures to assess the adequacy of a multiple regression model include:

1. Root Mean Square Error (RMSE)
2. Coefficient of determination (R^2)
3. Adjusted R Square ($\overline{R}^2$)
4. Standard Error
5. t-test

3.4.2.1 Root Mean Square Error (RMSE): The average prediction error of a regression model is frequently measured using the Root Mean Square Error (RMSE) formula. It quantifies the discrepancies of the dependent variable's projected values from its actual values. The square root of the mean of the squared discrepancies between the expected and actual values is used to calculate the RMSE.

$$RMSE = \sqrt{MSE}$$

Where,

y_i = Actual value.

$\hat{y}_i$ = Predicted value

MSE = Mean sum of square due to Error

3.4.2.2 Coefficient of determination (R^2):

It is one of the indices to measure the goodness of fit of the time series models. It is also known as coefficient of determination and is defined as the proportion of variation explained by the model. It depends upon the ratio of regression sum of square to the total sum of square. This statistic measure how successful the fit to the data and explained the variation of the given set of data.

$$R^2 = 1 - \frac{SSE}{SST}$$

Where,

$SSE = \sum(y_i - \hat{y}_i)^2$ and

$SST = \sum(y_i - \bar{y})^2$

or

$$R^2 = \frac{RSS}{TSS}$$

Where,

RSS = Regression sum of square

TSS = Total sum of square

3.4.2.3 Adjusted R Square ($\bar{R}^2$):

The coefficient of determination (R-squared) is a modified measure that takes into consideration the quantity of predictors in a regression model. It modifies the R-squared value by penalising the model's inclusion of extraneous variables and defined as the number of response values 'n' and number of fitted coefficients 'm' estimated from the response value.

Mathematically, V = n-m

V, indicates the number of independent piece of information involving the n data points that are required to calculate the SS. The $\bar{R}^2$ statistic is generally best indicator of the fit quality.

$$\bar{R}^2 = 1 - \frac{SSE(n-1)}{SST(v)}$$

Adjusted R^2 statistic can take all values ≤ 1 closer to 1 indicating better fit, negative values can occur when the model contains terms that do not help to predict the response.

or

In case of more than one regressor variables R^2 sometimes misleads results regarding the fitting of model, so instead of using R^2 we use $\bar{R}^2$.

$$\bar{R}^2 = 1 - \frac{\frac{ESS}{(n-k-1)}}{\frac{TSS}{(n-1)}}$$

Where, ESS = Error sum of square

TSS = Total sum of square

n = Total number of observation

k = number of independent variables

3.4.2.4 Standard Error:

Standard error of the regression coefficients is useful in testing the significance of regression coefficients. If the estimate of regression coefficient is non-significant then the regressor to which this estimate of regression coefficient relates does not in fact influence the response.

This method is also used for goodness of fit, also known as standard error fit of regression, it is an estimate of the SD of the random component of the data.

$SE = \frac{SD}{\sqrt{n}}$

Where,

SD $= \sqrt{MSE}$ and

n = Total number of observations

3.4.2.5 t-test:

t- statistic is a measure used for testing the significance of regression coefficients of a model.

$t = \frac{\hat{\beta}}{SE(\hat{\beta})}$

Where;

$\hat{\beta}$ = estimate of the regression coefficient

$SE(\hat{\beta}) = \sqrt{var.(\hat{\beta})}$ = standard error of estimate of the regression coefficient

t – statistic were computed for all the regression parameters for all the prediction models.

3.4.3 Model Validation:

A model that fits well to the data helps in final application, but we are not always sure the best fit model is also a good predictor. Some new factors negligible at the time of modelling may affect the response variable significantly in the future. In such situations the forecasting is almost useless. Validation is performed to determine if the model will function well in real situations or not. In the validation step, we investigate the stability of regression coefficients. The most effective method for model validation is to collect new data and then directly compare the predicted data with the newly collected data.

3.4.4 Exponential smoothing models

Exponential smoothing is a particular moving average technique applied to time series data and to produce smoothed data to make forecast. The exponential smoothing method, weights past observations by exponentially decreasing weights to forecast future values. In exponential smoothing, one or more smoothing parameters are to be determined explicitly and those choices determine the weights assigned to the observations. Brown model of exponential smoothing for forecasting time series data was used.

3.4.4.1 Brown model of exponential smoothing

The Brown model of exponential smoothing, also known as simple exponential smoothing, is a widely used method for forecasting time series data. Developed by Charles C. Holt in the 1950s and later extended by Robert G. Brown, this technique is particularly effective for forecasting time series data that exhibits a linear trend and non-stationary behavior. The formula is given as:

$$F_t = \alpha . Y_t + (1- \alpha)\, F_{t-1}$$

Where,

F_t is the forecast at time t

Y_t is the actual observation at time t

α is the smoothing constant

The Brown model assumes that the time series data can be represented by a linear trend and a random error component. It calculates forecasts by recursively updating estimates based on the most recent observation and the previous forecast. However, it may not perform well for time series data with complex patterns such as seasonality or abrupt changes in trend. Overall, it provides a straight forward approach to forecast time series data with a linear trend to make short-term predictions.

3.5 Software used for analysis

The data analysis for socio-economic parameters, construction of strata boundaries, multivariate analysis, forecasting model, and map making was performed using a combination of software tools including MS Excel, OPSTAT, SPSS, R (version 4.3.1), and QGIS.

Chapter-4

RESULTS AND DISCUSSION

The present investigation entitled "**Statistical Investigation on Socio-Economic Status of Kiwifruit Growers and Factors Influencing Kiwifruit Production in Himachal Pradesh**" was carried out in the Department of Basic Sciences, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.). The outcomes of the current study related to the various objectives are presented in this chapter and have been discussed with suitable and reasonable explanations under the following headings:

4.1 To study the socio-economic status of kiwifruit growers with respect to production and marketing of kiwifruit

4.2 To determine the approximate optimum strata boundaries for obtaining efficient estimates of kiwifruit production in Himachal Pradesh

4.3 To assess the relative contribution and comparison of morphological characteristics of kiwifruit vine towards the yield

4.4 To develop statistical models for forecasting kiwifruit yield

4.1 To study the socio-economic status of kiwifruit growers with respect to production and marketing of kiwifruit

Studying socio-economic status is essential for identifying the adaptive capacity of individuals or communities based on factors such as education, economic status, gender, experience, training, and access to information. This study also helps to examine the social standing of individuals or groups, often revealing inequities in access to resources and issues related to privilege, power, and control. In this section, the socio-economic characteristics of the study area using primary data are highlighted. Data were collected from 300 kiwifruit growers through a well-designed and pre-tested survey method in three major kiwifruit-growing districts of Himachal Pradesh i.e. Sirmaur, Solan, and Kullu (Plate 4.1). The survey gathered detailed information about demographic features, socio-economic status, total production, marketing channels, and the challenges faced by the growers in the marketing process.

4.1.1 Socio-economic profile of kiwifruit growers

Socio-economic characteristics have a moderate influence on farm management and market supply (Bharti et al. 2016). Effective farm management enhances the socio-economic status of the grower's family and vice versa. Understanding the social and economic profiles of households engaged in kiwifruit growing is essential. This section attempts to explore the demographic and socio-economic characteristics of the sampled orchardists.

4.1.1.1 Size and structure of family

The composition and size of the family, among sampled farmers significantly influence fruit production, at the village level. These elements are crucial for determining the socio-economic well-being of families and play a key role in farming and marketing activities. Table 4.1.1.1 illustrates the demographic profile of sampled households in the study area.

From Table 4.1.1.1, it was observed that among marginal farmers, 55.17% belong to joint families, while 44.83% belong to nuclear families. Among small farmers, 36.96% are joint families, and 63.04% are nuclear families. For medium farmers, 65.22% are joint families, and 34.78% are nuclear families. Overall, 52.67% of the families are joint families, while 47.33% are nuclear families.

Table 4.1.1.1: Farm category wise demographic profile of sampled households in the study area

Particulars	Farm categories			
	Marginal	Small	Medium	Overall
No. of sampled households (No.)	116	92	92	300
Type of Family				
Joint family (%)	55.17	36.96	65.22	52.67
Nuclear family (%)	44.83	63.04	34.78	47.33
Adults				
Male (No.)	1.97	1.79	2.00	1.93
Female (No.)	1.70	1.60	1.80	1.70
Children				
Male (No.)	0.97	0.85	0.89	0.90
Female (No.)	0.76	0.70	0.82	0.76
Average family size (No.)	5.40	4.93	5.51	5.29
Sex Ratio(No.)	835.78	868.31	906.02	867.29

The average family size across all categories was 5.29 members. Medium households had the highest family size as 5.51, followed by marginal households as 5.40, and small families as 4.93 members. The overall sex ratio was 867.29, with the highest sex ratio found in medium households (906.02), followed by small households (868.31) and marginal households (835.78).

4.1.1.2 Educational status

Cultivation of kiwifruit requires special attention to scientific farm management and an understanding of modern inputs and production techniques. Education is a crucial factor for every farm family, as it plays a significant role in the development process. In agriculture, literate individuals are generally better equipped than illiterate ones to understand and adopt new advancements.

Table 4.1.1.2 and Figure 4.1 provide an analysis of the general educational status of the studied households. The data indicates that, overall, 7.13% of farmers were illiterate, 17.28% had primary education, 19.46% had middle school education, 18.05% had higher secondary education, 19.85% had senior secondary education, 8.40% were graduates, and 9.83% were non-school going.

In the illiterate category, the highest number of households were found in marginal households (7.40%), followed by medium households (7.04%) and small households (6.82%). The households with primary education were highest in small households (18.91%)), followed by marginal households (17.71%) and medium households (14.08%). Small households had the highest number with middle school education (20.86%), compared to marginal (20.03%) and medium farm (16.34%) categories. Higher secondary education was most prevalent in marginal households (18.29%), followed by small households (17.93%) and medium households (17.75%).

The highest number of households with senior secondary education was in marginal households (21.04%), compared to small (19.30%) and medium (18.31%) farm categories. The highest number of graduate households was found in medium households (14.37%), followed by small (7.41%) and marginal (6.10%) households. The medium farm category had the highest percentage of non-school going households (12.11%), compared to marginal (9.43%) and small (8.77%) households. The majority of farmers had attained higher secondary education.

Table 4.1.1.2: Distribution of sampled households according to their educational status

(Per cent)

Literacy Status	Farm Categories			
	Marginal	Small	Medium	Overall
Illiterate	7.40	6.82	7.04	7.13
Primary	17.71	18.91	14.08	17.28
Middle	20.03	20.86	16.34	19.46
Higher Secondary	18.29	17.93	17.75	18.05
Senior Secondary	21.04	19.30	18.31	19.85
Graduate & above	6.10	7.41	14.37	8.40
Non-school going	9.43	8.77	12.11	9.83

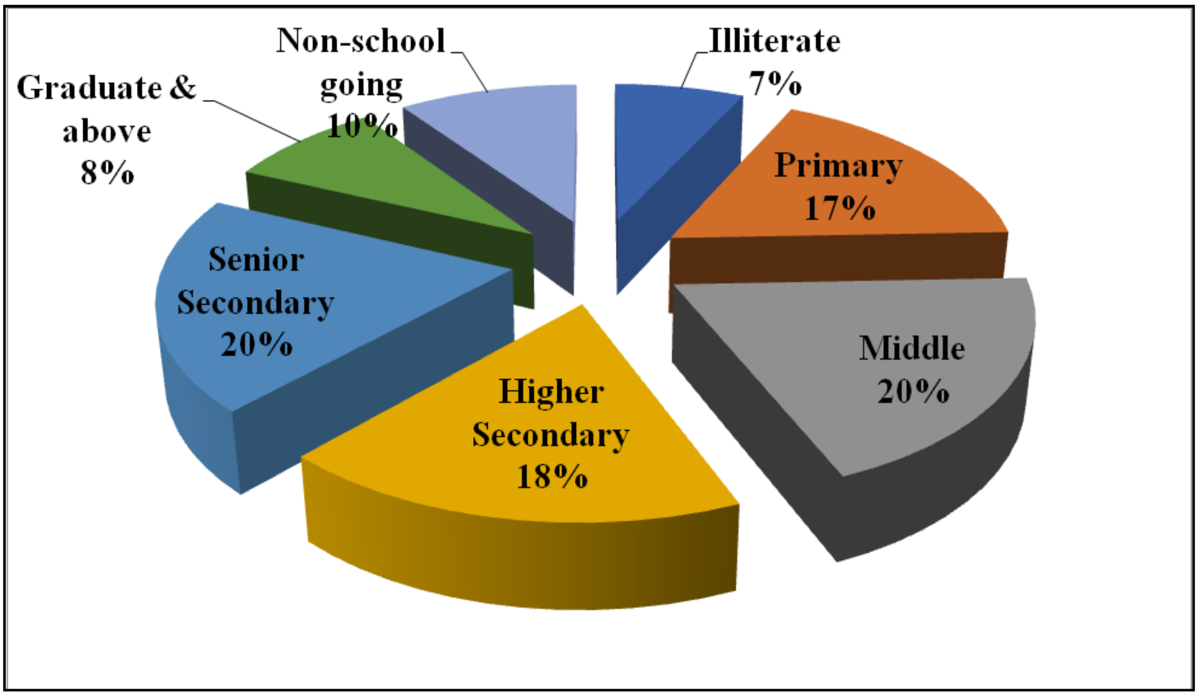

Figure 4.1 Educational status of sampled households

4.1.1.3 Occupational distribution

The distribution of the working population across various sectors of the economy is known as the occupational structure. In hilly regions, where farming is often the primary occupation, people frequently seek additional sources of income to supplement their family's earnings. Table 4.1.1.3 and Figure 4.2 presented the occupational structure of the sampled families. The data from Table 4.1.1.3 revealed that agriculture was the most common form of employment, with 39.00% of the workforce engaged in farming as a primary occupation. Additionally, 29.67% of households worked in the service sector, 24.00% were business owners, and 7.33% were employed in other categories of occupation as a secondary occupation.

Medium households were predominantly engaged in the agriculture sector, with 53.26% involved, compared to 35.87% of small households and 30.17% of marginal households. In the service sector, marginal households had the highest share at 36.21%, followed by small households at 32.61% and medium households at 18.48%. Business ownership was most prevalent among marginal households (25.00%), followed by small households (23.91%) and medium households (22.83%).

Table 4.1.1.3: Farm category wise occupational distribution of sampled households

(Per cent)

Occupation	Marginal (116)	Small (92)	Medium (92)	Overall (300)
Agriculture	30.17	35.87	53.26	39.00
Service	36.21	32.61	18.48	29.67
Business	25.00	23.91	22.83	24.00
Others	8.62	7.61	5.43	7.33

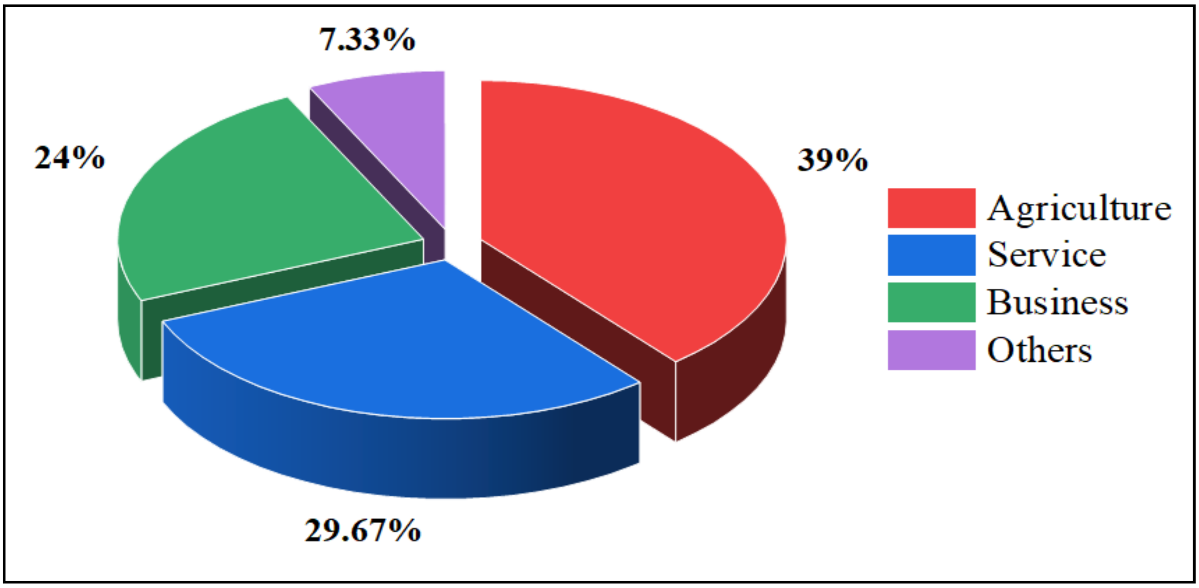

Figure 4.2 Occupational distribution of the sampled households

4.1.1.4 Land use pattern

Land is a critical resource in the agricultural economy, and its scarcity will become more pronounced as the global population increases. Therefore, land usage analysis is a vital aspect of agricultural development research. The type of farming system in a region is influenced by land use patterns. Table 4.1.1.4 and Fig 4.3 provided a summary of the land use patterns among the sampled farmers. The average total land holding for medium households was 3.25 ha, small households (1.35 ha) and marginal households (0.55 ha). 0.94 ha of the total area was cultivated for purposes other than orchards, 0.27 ha was used for orchard area under kiwifruit, 0.20 ha was under orchard area under other fruits, the total operational area was 1.41 ha, 0.11 ha was under grasslands (ghasnis), and 0.19 ha was used for non-agricultural purposes.

Average cultivated area other than orchard area varies from 2.07 ha for medium households, 0.61 ha for small and 0.14 ha for marginal households. The maximum average kiwifruit orchard area was recorded for medium households (0.31 ha), compared to small (0.27 ha) and marginal households (0.23 ha). The average orchard area under other fruits was maximum for medium households as 0.32 ha followed by small households as 0.21 ha and marginal households as 0.08 ha respectively. The average total operational area varied among different farm types, ranging from 0.45 ha for marginal households to 2.70 ha for medium households. The average area under ghasnis for medium households was 0.18 ha, small (0.10 ha) and marginal (0.06 ha) households. The average land used for non-agricultural purposes was highest for medium households (0.37 ha), compared to small (0.16 ha) and marginal (0.04 ha) households.

Table 4.1.1.4: Land use pattern of selected kiwifruit growers in study area (in ha)

Land use	Farm size			
	Marginal	Small	Medium	Overall
Cultivated area other than orchard area	0.14	0.61	2.07	0.94
Kiwifruit orchard area	0.23	0.27	0.31	0.27
Other fruits orchard area	0.08	0.21	0.32	0.20
Total operational area	0.45	1.09	2.70	1.41
Ghasnis/Pastures	0.06	0.10	0.18	0.11
Land under non-agriculture use	0.04	0.16	0.37	0.19
Total land holding	0.55	1.35	3.25	1.72

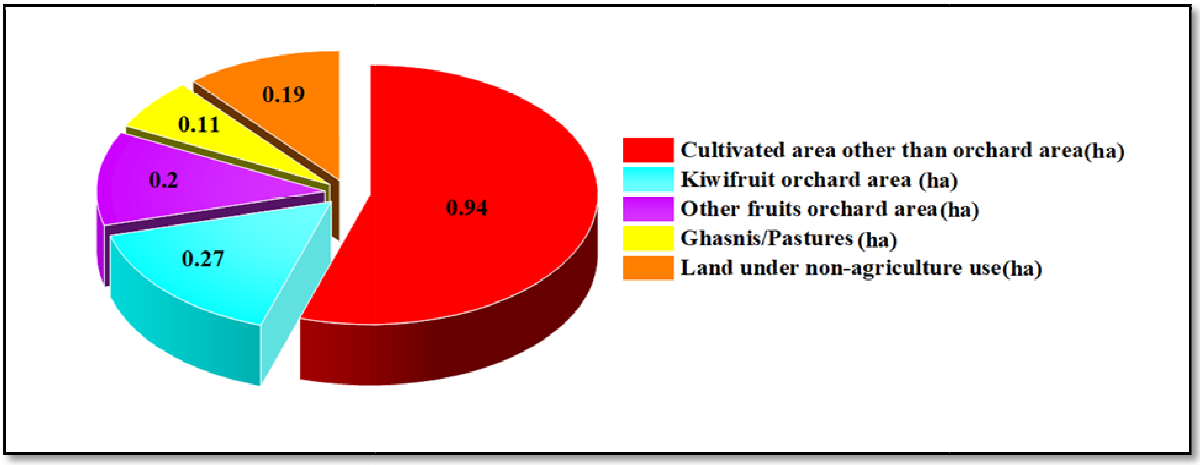

Figure 4.3 Landuse pattern of the sampled households

4.1.1.5: Marketable Surplus

The data from Table 4.1.1.5 revealed that medium farmers had the largest average under kiwifruit landholding per household at 0.310 ha, followed by small farmers with 0.270 ha, and marginal farmers with 0.230 ha. Overall, the average landholding per household across all categories was 0.270 ha. In terms of total production per household, medium farmers produced the most with 34.766 q, which was higher than the 6.661 q produced by small farmers and the 3.554 q produced by marginal farmers. The overall average production per household was 14.078 q.

When it came to home consumption per household, medium farmers consumed more, at 0.122 q, compared to 0.076 q for small farmers and 0.048 q for marginal farmers, with the overall average being 0.078 q. For gifts per household, medium farmers gave away the most at 0.064 q, followed by small farmers at 0.034 q and marginal farmers at 0.025 q, with an overall average of 0.041 q. In terms of total marketable surplus per household, medium farmers had the highest surplus at 34.580 q, exceeding the 6.551 q for small farmers and 3.481 q for marginal farmers, with an overall average of 13.959 q.

Despite having sufficient area under kiwifruit cultivation, marginal and small farmers had low production because their orchards contained bearing plants below 7 years of plantation, which yield fewer kiwifruits and are still in the progressive stage of farming. On the other hand, medium farmers had bearing plants in their orchards above 7 years of plantation, which yield more kiwifruits.

Table 4.1.1.5: Total production, Family requirements and marketable surplus per household

Categories	Marginal (116)	Small (92)	Medium (92)	Overall (300)
Total Area (ha)	0.230	0.270	0.310	0.270
Total Production (q)	3.554	6.661	34.766	14.078
Home Consumption (q)	0.048	0.076	0.122	0.078
Gifts (q)	0.025	0.034	0.064	0.041
Total Marketable Surplus(q)	3.481	6.551	34.580	13.959

4.1.2 MARKETING OF KIWIFRUIT

Marketing is a crucial component of the production process, and its success is determined by the successful delivery of produce to the end consumer (Bharti and Devi

2023). Marketing organizations play a significant role in influencing production incentives by impacting remunerative prices. From the producer's perspective, an efficient marketing system is one that ensures maximum returns while minimizing marketing costs. Effective marketing strategies, especially for horticultural produce like kiwifruit, depend on decisions regarding where, when, how, and how much to sell in the market, ultimately affecting enterprise profitability.

However, marketing kiwifruit remains challenging throughout the production process. This section aims to delve into important aspects of kiwifruit marketing, including the roles of various marketing agencies and the analysis of marketing costs and margins.

4.1.2.1 Marketing functions

Various marketing functions are performed by the kiwifruit growers for marketing the produce (Plate 4.2). The product has to be prepared for the market which involves picking, assembling, grading, packing, transportation, loading/ unloading, storage etc. All these factors have been found to be important determinants of prices which kiwifruit fetch in the market, and great care has to be ensured at every step. Any carelessness at any stage in marketing channel may lower the prices and hence affect net returns adversely.

a) Picking and assembling

Picking kiwifruit at the correct time is essential to ensure quality production and maximum storage life. Kiwifruit should be harvested when mature but not yet fully ripe. Indicators of maturity include firmness, the level of soluble solids, changes in skin color, seed color, and fruit size. The stage of picking also depends on the time lag between harvesting and the fruit's expected arrival at the market. The fruit is picked by hand and placed in a picking basket. The contents of the picking basket are then emptied into a kilta, a conical basket. Once the kilta is filled, it is carried to a storage area and carefully emptied into a heap by lifting each fruit by hand. Rough handling can cause damage, which accelerates deterioration and reduces the value of the produce.

b) Grading

After picking, grading is the next important marketing function. Grades and standards constitute an agreed-upon market language, which can greatly simplify the marketing process and reduce costs. Kiwifruit is graded according to size into three categories: Grade A, Grade

a) Vine girth

b) Fruit length

c) No. of fruits/shoot

d) No. of flowers/shoot

Plate 4.3 Recording of morphological characters

B, and Grade C. Grade A consists of fruits weighing more than 70 grams each, Grade B consists of fruits weighing 50-60 grams each, and Grade C consists of fruits weighing 40-50 grams each.

c) Packing

Packaging is a very useful function in marketing. Good quality kiwifruit is typically packed in corrugated fiberboard (CFB) cartons. The number of fruits per carton varies according to the size grades. These CFB cartons are telescopic, consisting of two pieces—inner and outer—that adjust to accommodate fruits of different sizes. After packaging, the boxes are strapped, sealed, and marked. Good quality kiwifruit is usually packed in CFB cartons with plastic trays, while lower grade kiwifruit is often packed in plastic crates.

d) Transportation

Transportation is another important marketing function which adds place utility to produce. The adequate arrangements for quick transportation of fruits to every nook and corner of the country are essential for realizing better returns from the produce. Various modes of transportation were used to carry fruits from orchards to road head. From road head to terminal markets the fruit is carried in trucks and utility vehicles.

4.1.2.2 Identification of marketing agencies

These agencies serve as professional functionaries in the execution of various marketing duties. Each marketing official's involvement in the marketing of kiwifruit is detailed below:

a) Producer

Grower is one of the important market functionaries involved in the kiwifruit selling process. He is in charge of selecting, assembling, and grading the fruit, as well as making preparations for material packing and transporting the produce from orchard to road head and, finally, to market destinations.

b) Commission agents

Commission agents are persons that specialize in various marketing tasks such as buying, selling, storage, and so on. The commission agent then sells the produce to retailers and industrial clients, but not to end users.

c) Retailer

The retailer purchases produce directly from commission agent for resale to ultimate consumers. He makes money from the difference between the sale and purchase prices.

d) Market information agencies

Market intelligence ensures that marketing activities run smoothly and efficiently. Accurate, suitable, and timely demand estimations make determining when and where to sell the fruit easier. The National Horticultural Board gathers prices for various fruits, varieties, and grades from different market places around the country and distributes them to farmers, pre-harvest contractors, forwarding agents, wholesalers, retailers, and consumers via All India Radio Shimla and monthly bulletins.

4.1.2.3 Marketing Channels

Marketing channel is the path that a commodity takes to travel from the producer to the end consumer. Because of the existence of numerous agencies functioning between producer and consumer, the studied area has a variety of marketing channels. The agencies participating in the kiwifruit marketing research are wholesalers and retailers.

Table 4.1.2.3: Quantity of kiwifruit marketed through various channels

Marketing Channels	Marketing intermediaries	% Share in total in Quantity marketed
Channel-A	Producer – Consumer	7.51
Channel-B	Producer – Commission agent – Retailer – Consumer	68.33
Channel-C	Producer – Retailer – Consumer	24.16

The Table 4.1.2.3 illustrated the distribution of kiwifruit quantities marketed through three distinct channels, showing that the majority of kiwifruit is marketed through Channel-B, i.e. Producer → Commission agent→ Retailer → Consumer, accounting for 68.33% of the total quantity. Channel-A, i.e., Producer → Consumer, represented only 7.51% of the total quantity marketed. Channel-C, i.e. Producer → Retailer → Consumer accounts for 24.16%.

The dominance of Channel-B was attributed due to its wider reach facilitated by the involvement of commission agents and retailers who help in bulk transactions, market distribution, risk mitigation, and providing better market information. This channel's ability to connect producers with a larger consumer base and manage market fluctuations makes it the most effective and widely used marketing channel for kiwifruits in Himachal Prdaesh.

4.1.2.4 Marketing costs

Marketing cost incurred by various marketing functionaries was calculated and presented in Table 4.1.2.4 and discussed in the following sub heads;

i) Marketing cost incurred by producers

Table 4.1.2.4 provides a detailed summary of the marketing costs and margins for various functionaries involved in different marketing channels. The table revealed that in channel A, the total marketing cost borne by the producer was Rs. 348.33 per quintal. In channel B, the total marketing expenses incurred by the growers amounted to Rs. 506.00 per quintal and in channel C, the total marketing cost borne by the producer was Rs. 379.00 per quintal. These figures highlight the varying costs associated with different marketing channels for producers.

ii) Marketing cost incurred by commission agent

The commission agent was identified in marketing channel B. The most significant items of marketing costs for wholesalers were commissions, and mandi fees which accounted for Rs. 590.42 per qtl.

ii) Marketing cost incurred by retailer

The retailer was identified within marketing channels B, where they incurred substantial marketing costs due to commission fees, transportation charges, and market fees. Specifically, retailers spent Rs. 2276.61 per quintal on marketing in channel B. Commission fees and transportation costs emerged as the most significant components of these expenses. In channel C they incurred marketing cost of Rs. 210.00 per quintal.

Table 4.1.2.4: Marketing costs and margins of various functionaries in the different marketing channels of kiwifruit in Himachal Pradesh

(Rs. / Quintal)

S.No.	Particulars	A	B	C
I.	**Marketing cost incurred by Producers**			
1	Net price received by farmer	27701.67	25535.67	25353.48
2	Transportation cost	83.33	126.00	49.00
3	Packing material cost	250.00	350.00	300.00
4	Loading/Unloading	15.00	30.00	30.00
	Total	348.33	506.00	379.00
	Farmer's selling price	28050.00	26041.67	25732.48
II.	**Marketing cost incurred by Commission agent**			
A	Gross price paid by Commission agent		26041.67	
B	Cost components of Commission agent			
1	Loading/Unloading		50.00	
2	Shop charges		250.00	
5	Mandi fees		260.42	
6	Miscellenous charges		30.00	
C	Total		590.42	
D	Commission agent Margin		2748.00	
E	Commission agent selling price		29380.09	
III.	**Marketing cost incurred by Retailer**			
A	Gross price paid by retailer		29380.09	25732.48
B	Cost components of retailer			
1	Loading/Unloading		60.00	60.00
2	Telephone charges		10.00	10.00
3	Transportation cost		150.00	140.00
4	Mandi fees		293.80	---
5	Commission charge		1762.81	---
C	Total		2276.61	210.00
D	Retailer's margin		2484.00	3749.44
E	Retailer's selling price		34140.69	29691.92
IV.	**Consumer's Purchase Price**	28050.00	34140.69	29691.92

4.1.2.5 Price spread and marketing efficiency among different marketing channels

The Table 4.1.2.5 provides data on the price spread and marketing efficiency of Kiwifruit among different marketing channels in Himachal Pradesh. For Channel A, the producer's net receipt was Rs. 27,701.67, and the consumer's price was Rs. 28,050.00, resulting in a gross marketing margin (GMM) of Rs. 348.33. The net marketing cost for Channel A was also Rs. 348.33, with no net market margin. The total gross marketing margin percentage stood at 1.24%, with both the marketing cost and marketing margin percentages at 1.24% and 0.00%, respectively. The producer's share in the consumer's rupee was 98.76%, leading to a marketing efficiency of 79.53%.

For Channel B, the producer's net receipt was Rs. 25,535.67, with a consumer's price of Rs. 34,140.69. The GMM for Channel B was significantly higher at Rs. 8,605.02, with a net marketing cost of Rs. 3,373.02 and a net market margin of Rs. 5,232.00. The total gross marketing margin percentage for Channel B was 25.20%, with marketing cost and marketing margin percentages at 9.88% and 15.32%, respectively. The producer's share in the consumer's rupee for Channel B was lower at 74.80%, resulting in a lower marketing efficiency of 2.97%.

Table 4.1.2.5: Price spread and marketing efficiency of Kiwifruit among the different marketing channels of Himachal Pradesh

Particulars	Marketing channels		
	A	B	C
Producer net receipt (Rs.)	27701.67	25535.67	25353.48
Consumer's price (Rs.)	28050.00	34140.69	29691.92
Gross marketing margin (GMM)(Rs.)	348.33	8605.02	4338.44
Net marketing cost (Rs./q)	348.33	3373.02	589.00
Net market margin (Rs./q)	---	5232.00	3749.44
Total gross marketing margin (%)	1.24	25.20	14.61
Marketing cost (%)	1.24	9.88	1.98
Marketing margin (%)	---	15.32	12.63
Producer's shares in consumer’s rupee (%)	98.76	74.80	85.39
Marketing efficiency (Ratio)	79.53	2.97	5.84

For Channel C, the producer's net receipt was Rs. 25,353.48, and the consumer's price was Rs. 29,691.92, resulting in a GMM of Rs. 4,338.44. The net marketing cost for Channel C was Rs. 589.00, and the net market margin was Rs. 3,749.44. The total gross marketing margin percentage stood at 14.61%, with the marketing cost and marketing margin percentages at 1.98% and 12.63%, respectively. The producer's share in the consumer's rupee was 85.39%, leading to a marketing efficiency of 5.84%.

The analysis reveals that Channel A had the highest marketing efficiency and a higher producer's share as it eliminates intermediaries, reducing costs and allowing producers to retain a larger share of the final price, while offering lower prices to consumers, while Channel B involved higher costs and margins but offered higher producer receipts and consumer prices (Shekhaliya and Mishra, 2024).

4.1.2.6 Production and Marketing Problems faced by the kiwifruit growers

An informal discussion with the surveyed kiwifruit growers revealed that there are a few difficulties with kiwifruit production and marketing. The findings of an investigation regarding the challenges encountered by growers in kiwifruit production and marketing are presented in Table 4.1.2.6.

Table 4.1.2.6: Problems faced by kiwifruit farmers in the study area

(Multiple response %)

S.No.	Problems	Farm Size				
		Marginal	**Small**	**Medium**	**Overall**	**Chi-square Value**
	No. of farmers	**116**	**92**	**92**	**300**	
1	**Labour**					
	Non availability of labour at peak operation time	34.48	43.48	36.96	38.00	1.13
	Higher wage rates	8.62	27.17	33.70	22.00	**14.62***
	Shortage of skilled labour	4.31	10.87	42.39	18.00	**43.19***
	Lack of technical knowledge	72.41	54.35	41.30	57.33	**8.71***
2	**Chemical Fertilizer and Plant Protection Chemicals**					
	High transportation cost	8.62	10.87	15.22	11.33	1.95
	High prices of chemicals	25.86	17.39	14.13	19.67	3.83
3	**Non availability of healthy plant material**	18.10	18.48	23.91	20.00	1.05
4	**Other problems**					
	Limited supply of FYM	29.31	27.17	51.09	35.33	**8.70***
	Perennial supply of irrigation not available	43.10	32.61	34.78	37.33	1.67
	Diseases management	8.62	10.87	10.87	10.00	0.33
	Lack of irrigation facilities	38.79	32.61	18.48	30.67	**7.24***
5	**Marketing problems**					
	Lack of storage facilities	51.72	43.48	32.61	43.33	4.31
	Markets very far off	17.24	10.87	11.96	13.67	1.74

Based on the data in Table 4.1.2.6, farmers for higher wage rates, shortage of skilled labour, lack of technical knowledge, limited supply of FYM and lack of irrigation facilities across all categories face significant challenges that ultimately increase the cost of production. These issues exhibited substantial variations depending on the size of the farm, indicating that these challenges were perceived differently by marginal, small, and medium-sized farmers. Table 4.1.2.6 shows that major significant problem faced by 57.33 per cent of farmers was lack of technical knowledge followed by limited supply of FYM (35.33 %), lack of irrigation facilities (30.67 %), Higher wage rates was reported by about 22 per cent of kiwifruit growers and Shortage of skilled labour reported by 18.00 per cent growers. These issues collectively contributed to higher production costs for farmers.

4.2 To determine the approximate optimum strata boundaries for obtaining efficient estimates of kiwifruit production in Himachal Pradesh

The stratified random sampling yields unbiased estimate of the population mean and its standard error provide confidence interval in which the possible value of the population mean lies. The primary data on 300 respondents according to the sampling approach described in the materials and methods, with the initial objective of the study being "**To determine the approximate optimum strata boundaries for obtaining efficient estimates of kiwifruit production in Himachal Pradesh**." Through a well-designed and pre-tested survey approach, data on area and production of kiwifruit, as well as socio-economic status, were obtained from three districts in Himachal Pradesh viz. Sirmaur, Solan and Kullu. This study aims to address several aspects of optimum stratification for estimating kiwifruit production in the selected districts.

4.2.1 Construction of Approximate Optimum Strata Boundaries

Construction of approximate optimum strata boundaries is of the most importance as it demarcates the optimum points of stratification on the frequency distribution such that the variance is minimum. The best characteristic to find these optimum strata boundaries is with the study variable itself. The next best presumably is the frequency distribution of some other variable highly correlated to the study variable. The basic goal of stratification is to provide a better cross-section of the population in order to increase relative accuracy. The approximate optimum strata boundaries were found by using study variable “area under kiwifruit cultivation” as the stratification variable. It has been seen that it is always profitable in terms of precision that the variance of the estimate decreases as there is increase in number of strata.

To check the gain in precision at varying number of strata (2, 3 and 4) formed by demarcation of optimal points of stratification with the following four methods i) Equalization of Strata Total ii) Equalization of cumulative $\sqrt{f(y)}$ iii) Equalization of cumulative $\sqrt[3]{f(y)}$ and iv) Equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$, under Equal allocation, Proportional allocation and Neyman allocation. However, the methods do not provide exactly optimum boundaries but are approximately optimum.

Equalization of Strata Total

$N_h\mu_h$ and cumulative $N_h\mu_h$ were calculated for construction of strata boundaries by equalization of strata total method and are presented in Table 4.2.1. Approximate strata demarcation points were calculated and presented in Table 4.2.2. These optimum boundaries were calculated for two, three and four number of strata (L).

For L=2, one point of demarcation was 0.50 ha. The percentage of respondents that fall in 1st and 2nd stratum was found to be 84.67 and 15.33 per cent. For L=3, two points of demarcation were found to be 0.12 ha and 0.84 ha with 39.00, 54.67 and 6.33 per cent of respondents that fall in 1st, 2nd and 3rd stratum respectively. For L=4, three demarcation points were calculated and found to be 0.23 ha, 0.50 ha and 0.85 ha with 52.00, 32.67, 9.00 and 6.33 per cent of respondents that fall in 1st, 2nd, 3rdand 4th stratum respectively.

Equalization of cumulative $\sqrt{f(y)}$

$\sqrt{f(y)}$ and cumulative $\sqrt{f(y)}$ were calculated for stratification through equalization of cumulative $\sqrt{f(y)}$ method and are presented in Table 4.2.1. The demarcation points and percentage of respondents that fall in the respective stratum were also calculated and are presented in Table 4.1.2.

For L=2, one point of demarcation was 0.38 Ha. The percentage of respondents that fall in 1st and 2nd stratum was found to be 83.00 and 17.00 per cent. For L=3, two points of demarcation were found to be 0.13 ha and 0.79 ha with 42.00, 46.00 and 12.00 per cent of respondents that fall in 1st, 2nd and 3rd stratum respectively. For L=4, three demarcation points were calculated and were found to be 0.18 ha, 0.38 ha and 0.89 ha with 47.67, 35.33, 11.00 and 6.00 per cent of respondents that fall in 1st, 2nd, 3rd and 4th stratum respectively.

Table 4.2.1 (a): Frequency Distribution and Cumulative total of respondents by using different stratification methods

Area under kiwifruit (ha)	Frequency N_h	Cum. N_h	Mid values μ_h(Ha)	Equalization of Strata Total		Equalization of cumulative $\sqrt{f(y)}$		Equalization of cumulative $\sqrt[3]{f(y)}$		Equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$			
				$N_h\mu_h$	Cum. $N_h\mu_h$	$\sqrt{f(y)}$	Cum.$\sqrt{f(y)}$	$\sqrt[3]{f(y)}$	Cum.$\sqrt[3]{f(y)}$	r(y)	r(y)+f(y)	$\frac{1}{2}[r(y) + f(y)]$	Cum. $\frac{1}{2}[r(y) + f(y)]$
<0.20	145	145	0.10	14.50	14.50	12.04	12.04	5.25	5.25	53.00	198.00	99.00	99.00
0.20-0.40	104	249	0.30	31.20	45.70	10.20	22.24	4.70	9.96	91.01	195.01	97.50	196.50
0.40-0.60	10	259	0.50	5.00	50.70	3.16	25.40	2.15	12.11	94.66	104.66	52.33	248.83
0.60-0.80	5	264	0.70	3.50	54.20	2.24	27.64	1.71	13.82	96.49	101.49	50.74	299.57
0.80-1.00	22	286	0.90	19.80	74.00	4.69	32.33	2.80	16.62	104.53	126.53	63.26	362.84
1.00-1.20	2	288	1.10	2.20	76.20	1.41	33.74	1.26	17.88	105.26	107.26	53.63	416.47
1.20-1.40	2	290	1.30	2.60	78.80	1.41	35.16	1.26	19.14	105.99	107.99	54.00	470.46
1.40-1.60	1	291	1.50	1.50	80.30	1.00	36.16	1.00	20.14	106.36	107.36	53.68	524.14
1.60-1.80	6	297	1.70	10.20	90.50	2.45	38.61	1.82	21.96	108.55	114.55	57.27	581.42
1.80-2.00	1	298	1.90	1.90	92.40	1.00	39.61	1.00	22.96	108.91	109.91	54.96	636.37
>2.00	2	300	1.00	2.00	94.40	1.41	41.02	1.26	24.22	109.65	111.65	55.82	692.20
Total	**300**			**94.40**		**41.02**		**24.22**				**692.20**	

Equalization of cumulative $\sqrt[3]{f(y)}$

$\sqrt[3]{f(y)}$ and cumulative $\sqrt[3]{f(y)}$ were calculated for stratification through equalization of cumulative $\sqrt[3]{f(y)}$ method and are presented in Table 4.2.1. Approximate OSB and percentage of respondents that fall in the respective stratum were also calculated and are presented in Table 4.2.2.

For L=2, one point of demarcation was 0.60 ha. The percentage of respondents that fall in 1st and 2nd stratum was found to be 86.33 and 13.67 per cent. For L=3, two points of demarcation were found to be 0.31 ha and 0.88 ha with 79.33, 14.33 and 6.33 per cent of respondents that fall in 1st, 2nd and 3rd stratum respectively. For L=4, three demarcation points were calculated and were found to be 0.22 ha, 0.60 ha and 1.12 ha with 51.67, 34.67, 9.00 and 4.67 per cent of respondents that fall in 1st, 2nd, 3rd and 4th stratum respectively.

Table 4.2.1(b): Approximate optimum strata boundaries and percentage of kiwifruit growers that fall in respective stratum

Strata	Equalization of Strata Total				Strata	Equalization of cumulative $\sqrt{f(y)}$			
	I	**II**	**III**	**IV**		**I**	**II**	**III**	**IV**
2	0.50				**2**	0.38			
%	**84.67**	**15.33**			%	**83.00**	**17.00**		
3	0.12	0.84			**3**	0.13	0.79		
%	**39.00**	**54.67**	**6.33**		%	**42.00**	**46.00**	**12.00**	
4	0.23	0.50	0.85		**4**	0.18	0.38	0.89	
%	**52.00**	**32.67**	**9.00**	**6.33**	%	**47.67**	**35.33**	**11.00**	**6.00**
Strata	**Equalization of cumulative $\sqrt[3]{f(y)}$**				**Strata**	**Equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$**			
	I	**II**	**III**	**IV**		**I**	**II**	**III**	**IV**
2	0.60				**2**	0.79			
%	**86.33**	**13.67**			%	**88.00**	**12.00**		
3	0.31	0.88			**3**	0.47	1.06		
%	**79.33**	**14.33**	**6.33**		%	**83.67**	**11.67**	**4.67**	
4	0.22	0.60	1.12		**4**	0.28	0.79	1.29	
%	**51.67**	**34.67**	**9.00**	**4.67**	%	**79.00**	**9.00**	**8.67**	**3.33**

Equalization of cumulative $\frac{1}{2}[\mathbf{r(y)+f(y)}]$

$g(y) = \frac{1}{2}[r(y) + f(y)]$ and cumulative $g(y)$ were calculated for stratification through equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$ method and are presented in Table 4.2.1. Approximate OSB and percentage of respondents that fall in the respective stratum were also calculated and are presented in Table 4.2.2.

For L=2, one point of demarcation was 0.79 ha. The percentage of respondents that fall in 1st and 2nd stratum was found to be 88.00 and 12.00 per cent. For L=3, two points of demarcation were found to be 0.47 ha and 1.06 ha with 83.67, 11.67 and 4.67 per cent of respondents that fall in 1st, 2nd and 3rd stratum, respectively. For L=4, three demarcation points were calculated and were found to be 0.28 ha, 0.79 ha and 1.29 ha with 79.00, 9.00, 8.67 and 3.33 per cent of respondents that fall in 1st, 2nd, 3rd and 4th stratum respectively.

4.2.1.2 Estimate of variance under optimum stratification

The area under kiwifruit cultivation (ha) which is correlated with the study variable kiwifruit production (MT) was subjected to stratification. Equal, proportional and Neyman allocation methods were used to estimate the variances of $\hat{\bar{y}}$ with varying number of strata (L=2, 3 and 4) under four methods of stratification are presented in the Table 4.2.3, 4.2.4 and Table 4.2.5.

Minimum estimated variance of $\hat{\bar{y}}$ of kiwifruit area of all the four-stratification method for varying strata and sample sizes under Equal allocation was found to be 0.0008 in equalization of cumulative $\sqrt[3]{f(y)}$ rule for n =90 and L=4. It is justifiable to observe in Table 4.2.3 that the estimate of variance is decreasing as the sample size (n) and number of strata (L) is increasing under all stratification methods which prove their optimality. Under method of Equalization of strata total, minimum estimate of the variance was found to be 0.0016 from n =90 and L=4. Under the rule equalization of cumulative $\sqrt{f(y)}$ rule, minimum variance was found to be 0.0009 in n =90 and L=4. The minimum estimate of variance of $\hat{\bar{y}}$ was found to be 0.0013 in case of equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$.

Proportional allocation is always precise as compared to Equal allocation. Minimum estimated variance of $\hat{\bar{y}}$ of kiwifruit area (ha) of all the four-stratification method for varying strata and sample sizes under proportional allocation was found to be 0.0005 in equalization of cumulative $\sqrt[3]{f(y)}$ rule for n =90 and L=4. It is justifiable to observe in Table 4.2.4 that the estimate of variance is decreasing as the sample size (n) and number of strata (L) is increasing under all stratification methods which prove their optimality. Under method of Equalization of strata total, minimum estimate of the variance was found to be 0.0009 from n =90 and L=4. Under the rule equalization of cumulative $\sqrt{f(y)}$ rule, minimum variance was found to be 0.0006 in n =90 and L=4. The minimum estimate of variance of $\hat{\bar{y}}$ was found to be 0.0007 in case of equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$.

Table 4.2.3: Estimate of variance of $\hat{\bar{y}}$ using Equal allocation

Equalization of Strata Total				**Equalization of cumulative $\sqrt{f(y)}$**			
Sample	**Strata**			**sample**	**Strata**		
	2	**3**	**4**		**2**	**3**	**4**
30	0.0175	0.0174	0.0152	**30**	0.0180	0.0176	0.0153
60	0.0051	0.0045	0.0041	**60**	0.0051	0.0050	0.0042
90	0.0019	0.0018	0.0016	**90**	0.0020	0.0017	0.0009
Equalization of cumulative $\sqrt[3]{f(y)}$				**Equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$**			
Sample	**Strata**			**sample**	**Strata**		
	2	**3**	**4**		**2**	**3**	**4**
30	0.0160	0.0141	0.0123	**30**	0.0167	0.0156	0.0141
60	0.0047	0.0042	0.0033	**60**	0.0048	0.0045	0.0034
90	0.0017	0.0013	0.0008	**90**	0.0017	0.0011	0.0013

Table 4.2.4: Estimate of variance of $\hat{\bar{y}}$ using Proportional allocation

Equalization of Strata Total				**Equalization of cumulative $\sqrt{f(y)}$**			
Sample	**Strata**			**sample**	**Strata**		
	2	**3**	**4**		**2**	**3**	**4**
30	0.0162	0.0156	0.0126	**30**	0.0139	0.0122	0.0118
60	0.0047	0.0040	0.0036	**60**	0.0037	0.0028	0.0024
90	0.0013	0.0010	0.0009	**90**	0.0011	0.0008	0.0006
Equalization of cumulative $\sqrt[3]{f(y)}$				**Equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$**			
Sample	**Strata**			**sample**	**Strata**		
	2	**3**	**4**		**2**	**3**	**4**
30	0.0154	0.0135	0.0131	**30**	0.0157	0.0134	0.0101
60	0.0035	0.0028	0.0017	**60**	0.0044	0.0039	0.0033
90	0.0013	0.0007	0.0005	**90**	0.0010	0.0008	0.0007

Table 4.2.5: Estimate of variance of $\hat{\bar{y}}$ using Neyman allocation

Equalization of Strata Total				Equalization of cumulative $\sqrt{f(y)}$			
Sample	**Strata**			**sample**	**Strata**		
	2	**3**	**4**		**2**	**3**	**4**
30	0.0134	0.0129	0.0118	**30**	0.0122	0.0104	0.0091
60	0.0029	0.0028	0.0022	**60**	0.0035	0.0030	0.0025
90	0.0011	0.0010	0.0008	**90**	0.0011	0.0010	0.0005
Equalization of cumulative $\sqrt[3]{f(y)}$				**Equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$**			
Sample	**Strata**			**sample**	**Strata**		
	2	**3**	**4**		**2**	**3**	**4**
30	0.0068	0.0058	0.0050	**30**	0.0093	0.0084	0.0077
60	0.0017	0.0014	0.0013	**60**	0.0027	0.0026	0.0022
90	0.0005	0.0004	0.0003	**90**	0.0011	0.0009	0.0006

Neyman allocation is always more precise as compared to proportional allocation. Minimum estimate of variance of $\hat{\bar{y}}$ of kiwifruit area (ha) was found to be 0.0003 in equalization of cumulative $\sqrt[3]{f(y)}$ rule for n =90 and L=4. Table 4.2.5 reveals that as the number of strata (n) and sample size (n) increases, the variance is uniformly decreasing. Under method of Equalization of strata total, minimum estimate of the variance was found to be 0.0008 from n =90 and L=4. Under the rule equalization of cumulative $\sqrt{f(y)}$ rule, minimum variance was found to be 0.0005 for n =90 and L=4. The minimum estimate of variance of $\hat{\bar{y}}$ was found to be 0.0006 in case of equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$.

4.2.1.3 Percentage gain in efficiencies due to optimum stratification

To check the gain in efficiency due to stratification over no stratification, percentage gain of varying strata and sample sizes using all four methods were calculated. The percentage gain in efficiency due to Equal and Proportional allocation over no stratification of kiwifruit area (ha) are presented in Table 4.2.6 and Table 4.2.7. The percentage gain in efficiency for kiwifruit area (ha) under Neyman allocation are presented in Table 4.2.8. In order to assess the gain in efficiency the estimates were compared with estimates obtained through Simple random sampling without replacement of the respective sizes. It can be seen from the mentioned tables that there is percent gain in efficiency as the number of strata (L) and sample size (n) is increasing.

Table 4.2.6 indicated that there is considerable gain in efficiency due to stratification, but the maximum gain in efficiency is estimated when the strata are considered through the equalization of cumulative $\sqrt[3]{f(y)}$ method. It is observed that this gain in efficiency increases with the increase in the number of strata and sample size. For estimation of kiwifruit area (ha) by using equal allocation, maximum gain in efficiency was estimated to be 185.36 per cent using the equalization of cumulative $\sqrt[3]{f(y)}$ rule when number of strata was 4 and sample size was 90 followed by Equalization of cumulative $\sqrt{f(y)}$ (164.55 %), Equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$ (79.48 %), and Equalization of strata total method (54.08%).

Table 4.2.6: Percentage gain in efficiency due to stratification under Equal allocation

Equalization of Strata Total				**Equalization of cumulative $\sqrt{f(y)}$**			
sample	**Strata**			**sample**	**Strata**		
	2	**3**	**4**		**2**	**3**	**4**
30	8.73	9.40	25.65	**30**	5.75	8.32	24.15
60	14.00	29.29	38.79	**60**	13.96	15.05	36.54
90	23.67	35.07	54.08	**90**	21.81	39.91	164.55
Equalization of cumulative $\sqrt[3]{f(y)}$				**Equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$**			
sample	**Strata**			**sample**	**Strata**		
	2	**3**	**4**		**2**	**3**	**4**
30	19.16	35.27	54.31	**30**	13.72	21.96	34.59
60	22.95	36.16	72.62	**60**	21.19	28.04	69.13
90	41.12	81.43	185.36	**90**	37.14	121.14	79.48

Table 4.2.7: Percentage gain in efficiency due to stratification under Proportional allocation

Equalization of Strata Total				**Equalization of cumulative $\sqrt{f(y)}$**			
Sample	**Strata**			**sample**	**Strata**		
	2	**3**	**4**		**2**	**3**	**4**
30	17.81	22.25	51.18	**30**	37.11	56.01	60.97
60	22.00	43.85	59.44	**60**	54.31	103.55	140.67
90	90.75	141.53	161.66	**90**	119.63	216.55	320.32
Equalization of cumulative $\sqrt[3]{f(y)}$				**Equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$**			
Sample	**Strata**			**sample**	**Strata**		
	2	**3**	**4**		**2**	**3**	**4**
30	24.01	41.39	45.26	**30**	21.45	42.50	88.60
60	63.93	105.65	238.42	**60**	30.08	49.20	74.98
90	85.68	220.35	423.76	**90**	139.45	198.58	256.36

For estimation of kiwifruit area (ha) by using Proportional allocation, maximum gain in efficiency was estimated to be 423.76 per cent using the equalization of cumulative $\sqrt[3]{f(y)}$ rule when number of strata was 4 and sample size was 90 followed by Equalization of cumulative $\sqrt{f(y)}$ (320.32%), Equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$ (256.36 %), and Equalization of strata total method (161.66 %).

Table 4.2.8: Percentage gain in efficiency due to stratification under Neyman allocation

Equalization of Strata Total				**Equalization of cumulative $\sqrt{f(y)}$**			
sample	**Strata**			**sample**	**Strata**		
	2	**3**	**4**		**2**	**3**	**4**
30	42.39	47.28	60.90	**30**	56.53	82.98	108.69
60	100.43	106.98	167.72	**60**	65.11	91.78	133.56
90	111.38	147.73	209.23	**90**	127.65	135.13	364.43
Equalization of cumulative $\sqrt[3]{f(y)}$				**Equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$**			
sample	**Strata**			**sample**	**Strata**		
	2	**3**	**4**		**2**	**3**	**4**
30	180.19	229.85	281.98	**30**	104.47	126.56	148.09
60	243.10	321.16	334.81	**60**	110.20	118.39	163.51
90	432.08	495.23	589.69	**90**	120.73	181.79	334.46

For estimation of kiwifruit area (ha) by using Neyman allocation, maximum gain in efficiency was estimated to be 589.69 per cent using the equalization of cumulative $\sqrt[3]{f(y)}$ rule when number of strata was 4 and sample size was 90 followed by Equalization of cumulative $\sqrt{f(y)}$ (364.43%), Equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$ (334.46 %), and Equalization of strata total method (209.23 %). The results of the study suggests that with precise sampling technique such as stratified random sampling with stratification methods like equalization of cumulative $\sqrt[3]{f(y)}$ can provide efficient estimate for the kiwifruit area (ha) in the state which was close affinity with the finding of estimation of kinnow production in Himachal Pradesh through standardized sampling techniques by Verma et al. (2017).

4.3 To assess the relative contribution and comparison of morphological characteristics of kiwifruit vine towards the yield

The primary data were recorded on morphological characteristics i.e. vine girth (mm), number of canes/vine, number of leaves/shoot, number of flowers/shoot, duration of flowering, number of fruits/shoot, fruit weight (g), fruit length (mm), fruit width (mm), graded fruit yield (Kg), total fruit yield (Kg/vine) and from these characteristics leaf/fruit ratio, yield efficiency, shape index, TSS/TA ratio were computed to assess the relative contribution of morphological characteristics of kiwifruit vine towards the yield (Plate 4.3).

4.3.1 Variability analysis

The variability analysis of kiwifruit vine parameters for different locations showed significant differences across Sirmaur, Solan, and Kullu. Characteristics of *Actinidia deliciosa* var. allison were evaluated 210 kiwifruit vines during 2023 in Sirmaur, Solan and Kullu districts of Himachal Pradesh.

4.3.1.1 Bartlett test

Bartlett Chi-square test was applied for location wise comparison of variance and results are presented in Table 4.3.1.1.

Table 4.3.1.1: Variability analysis of various parameters of *Actinidia deliciosa* var. allison for different locations

Characteristics	Sirmaur		Solan		Kullu		$\chi2_{0.05}$
	Variance	SE	Variance	SE	Variance	SE	
Vine girth	2109.82	5.49	2415.18	5.87	2225.01	5.64	0.32
Number of canes/vine	48.10	0.83	31.90	0.68	43.30	0.79	0.03
Number of leaves/shoot	17.64	0.50	13.54	0.44	14.02	0.45	0.07
Number of flowers/shoot	61.55	0.94	71.23	1.01	79.39	1.06	0.17
Number of fruits/shoot	1.98	0.17	2.04	0.17	2.37	0.18	0.05
Leaf Fruit Ratio	0.58	0.09	0.11	0.04	0.41	0.08	0.09
Duration of flowering	3.15	0.21	5.35	0.28	6.33	0.30	0.06
Fruit weight	122.77	1.32	129.62	1.36	113.29	1.27	1.52
Fruit length	23.80	0.58	53.13	0.87	37.57	0.73	0.71
Fruit width	13.06	0.43	11.65	0.41	10.51	0.39	0.16
Shape Index	0.03	0.02	0.04	0.02	0.03	0.02	0.06
Total Fruit Yield	132.98	1.38	138.26	1.41	92.61	1.15	1.31
Yield Efficiency	2.95	0.21	3.29	0.22	5.95	0.29	0.08
TSS/ TA Ratio	0.97	0.12	4.77	0.26	7.19	0.32	0.20

Based on Bartlett's test results, no significant variation was found among the morphological characteristics i.e. vine girth, number of canes/vine, number of leaves/shoot, number of flowers/shoot, number of fruits/shoot, duration of flowering, leaf fruit ratio, fruit weight, fruit length, fruit width, shape index, total fruit yield, yield efficiency and TSS/TA

Plate 4.1: Data collection from kiwifruit growers

a) Picking of kiwifruits

b) Assembling and Grading of kiwifruits

c) Packing of kiwifruits

Plate 4.2: Different marketing functions performed by the kiwifruit growers

ratio at different locations. Thus, it was concluded that all the locations have same variance for these characteristics.

4.3.1.2 Performance of *Actinidia deliciosa* var. allison in different locations

The study examined the mean values of various characteristics of the kiwifruit (*Actinidia deliciosa* var. allison) across three locations: Sirmaur, Solan, and Kullu. The parameters that show statistical significance, indicated by the F statistic, includes number of canes/vine, number of fruits/ shoot, leaf fruit ratio, fruit weight, fruit length, shape index, total fruit yield (kg), and the TSS/TA ratio.

Table 4.3.1.2 Mean of different characteristics of *Actinidia deliciosa* var. allison for different locations

Characteristics	Mean			CD (0.05)	F statistic
	Sirmaur	Solan	Kullu		
Vine Girth (mm)	176.36	176.04	171.74	NS	0.24
Number of canes/vine	29.33	27.29	26.11	2.23	**4.19***
Number of leaves/shoot	15.52	16.33	15.77	NS	0.71
Number of flowers/shoot	20.74	22.39	23.52	NS	2.18
Number of fruits/shoot	7.17	7.39	6.77	0.48	**3.31***
Leaf Fruit Ratio	10.16	9.38	10.33	0.21	**45.90***
Duration of flowering	14.33	14.54	13.89	NS	1.47
Fruit weight (g)	80.62	87.84	87.39	3.82	**8.75***
Fruit length (mm)	81.93	71.86	70.83	1.93	**78.86***
Fruit width (mm)	47.84	48.10	48.78	NS	1.44
Shape Index	1.72	1.51	1.47	0.06	**43.33***
Total Fruit Yield (Kg)	59.14	60.30	68.36	3.65	**14.84***
Yield efficiency	2.91	3.17	3.61	NS	2.50
TSS /TA ratio	4.32	6.08	8.31	0.61	**85.07***

**significant at 0.05 level of significance*

From Table 4.3.1.2, it was found that the mean number of canes per vine varied significantly, with Sirmaur having the highest number (29.33) and Kullu the lowest (26.11). The number of fruits/shoot ratio also varied significantly, being highest in Solan (7.39) and lowest in Kullu (6.77). The leaf fruit ratio was maximum in Kullu (10.33) and minimum in Solan (9.38). The average fruit weight was highest in Solan (87.84 g) and lowest in Sirmaur (80.62 g), varying significantly. The mean fruit length also showed a significant difference, being highest in Sirmaur (81.93 mm) and lowest in Kullu (70.83 mm). The shape index varied significantly, being highest in Sirmaur (1.72) and lowest in Kullu (1.47). The average total fruit yield was highest in Kullu (68.36 Kg) and lowest in Sirmaur (59.14 Kg), with a significant difference observed. The TSS/TA ratio showed a significant difference, being highest in Kullu (8.31) and lowest in Sirmaur (4.32).

These findings indicated that several characteristics of *Actinidia deliciosa* var. Allison were significantly influenced by location, suggesting that environmental conditions and agricultural practices in these regions had a substantial impact on the growth and fruiting characteristics of this kiwifruit variety.

4.3.2 Correlation analysis

Correlation studies are highly significant because identifying strong correlations between yield and other economic traits can guide selective plant breeding. The correlation coefficients of various morphological characters were estimated to identify potential relationships, determining if one character could simultaneously influence other characters. This analysis measures the linear relationship between two variables. Understanding the linear associations among different morphological characters is crucial for effective selection programs and for determining the components of complex traits like yield per vine. Thus, knowledge of these associations is essential in the crop improvement selection process.

Karl Pearson's correlation coefficient was calculated between various morphological characters, as shown in Table 4.3.2. The analysis revealed the highest positive and significant correlation between shape index and fruit length with $r = 0.829$, followed by fruit weight and leaf/fruit ratio with $r = 0.775$, and number of leaves/shoot and leaf fruit ratio with $r = 0.641$. Total fruit yield showed positive and significant correlations with number of fruits/shoot and fruit width, with values of 0.196 and 0.185, respectively. Yield efficiency had a positive and significant correlation with vine girth, $r = 0.465$ and with the duration of flowering, $r = 0.536$. Conversely, there was a negative and significant correlation of number of fruits/shoot with fruit weight as $r = -0.489$ and Leaf Fruit Ratio as $r = -0.429$.

These findings align with the studies on correlation coefficients conducted by Bharti et al. (2016). Their research on *Malus domestica* (apple) revealed that apple yield had significant positive correlations with fruit weight, trunk girth, tree height, canopy spread, Flower Density Index, and fruit set.

Table 4.3.2: Correlation matrix of various morphological characteristics of kiwifruit vines

	Vine Girth (mm)	Number of canes/ vine	Number of leaves/ shoot	Number of flowers/ shoot	Number of fruits/ shoot	Leaf Fruit Ratio	Duration of flowering	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Shape Index	Total Fruit Yield (Kg)	Yield efficiency	TSS/ Acidity ratio
Vine Girth (mm)	1													
Number of canes/vine	0.128	1												
Number of leaves/shoot	0.136*	0.034	1											
Number of flowers/shoot	0.105	-0.023	0.214**	1										
Number of fruits/shoot	0.015	0.044	0.379**	-0.012	1									
Leaf Fruit Ratio	0.143*	0.012	0.641**	0.209**	-0.429**	1								
Duration of flowering	0.411**	0.022	-0.018	0.020	-0.016	0.010	1							
Fruit weight (g)	0.097	-0.102	0.471**	0.217**	-0.489**	0.775**	0.033	1						
Fruit length (mm)	0.044	0.295**	-0.124	-0.054	-0.084	-0.027	0.170*	-0.108	1					
Fruit width (mm)	0.037	0.028	0.010	0.051	0.047	-0.001	0.015	-0.101	-0.033	1				
Shape Index	0.075	0.208**	-0.100	-0.074	-0.093	-0.016	0.155*	-0.027	0.829**	0.580**	1			
Total Fruit Yield (Kg)	0.107	0.034	0.092	0.045	0.196**	-0.067	0.129	-0.063	-0.115	0.185**	0.194**	1		
Yield efficiency	0.465**	-0.001	0.005	0.105	0.048	-0.027	0.536**	-0.036	-0.050	0.032	-0.069	0.197**	1	
TSS TA ratio	0.122	0.227**	0.047	0.013	0.077	-0.016	0.244**	0.072	0.529**	0.014	0.438**	0.284**	0.257**	1

**significant at 0.05 level of significance*
***significant at 0.01 level of significance*

4.3.3 Path coefficient analysis

Path coefficient analysis, developed by Dewey and Lu (1959), partitions the correlation coefficient into direct and indirect effects, allowing for a critical evaluation of each trait's relative importance. Traits may contribute to yield either directly or indirectly through their relationships with other traits. To understand these effects, both individually and in combination, the present investigation computed direct and indirect effects using path coefficient analysis between total fruit yield and various morphological characters i.e. vine girth, number of canes per vine, number of leaves per shoot, number of flowers per shoot, duration of flowering, number of fruits per shoot, fruit weight, fruit length, fruit width, leaf/fruit ratio, and shape index.

From Table 4.3.3, it was observed that several morphological characteristics had varying effects on the total fruit yield of kiwifruit plants. Vine girth (0.216), number of canes per vine (0.074), number of flowers per shoot (0.044), number of fruits per shoot (0.236), leaf/fruit ratio (0.002), duration of flowering (0.202), fruit weight (0.088), shape index (0.069) and fruit width (0.143) all exhibited direct and positive effects on the total fruit yield. Conversely, the number of leaves per shoot (-0.030) and fruit length (-0.025) showed direct and neagtive effects on the total fruit yield.

The number of fruits per shoot had the most substantial impact on total fruit yield, as indicated by its positive and significant correlation of 0.196 with fruit yield. This suggested that an increase in the number of fruits per shoot is strongly associated with a higher total fruit yield. Similarly, fruit width (0.185) and shape index (0.194) also had notable positive and significant correlation indicating their importance in yield optimization.

The number of fruits per shoot is the most influential factor in increasing total fruit yield, directly translating to more harvested fruits per plant (Miller *et al.*, 2001). Other important factors include fruit width, shape index, and flowering duration, which optimize yield through better resource utilization and longer development time (McPherson et al., 2001). Conversely, too many leaves can reduce yield due to competition for nutrients and light, while excessive fruit length can divert resources from overall fruit quality. These insights emphasize the need for balanced growth and careful management of morphological traits to maximize kiwifruit production, enhancing both quantity and quality.

Table 4.3.3 Direct and indirect effects of various morphological characters of kiwifruit plants

	Vine Girth (mm)	No. of canes /vine	No. of leaves /shoot	No. of flowers /shoot	No. of fruits /shoot	Leaf fruit ratio	Duration of flowering	Fruit Weight	Fruit Length	Fruit Width	Shape Index	r*
Vine Girth (mm)	**0.216**	-0.009	0.004	-0.005	0.004	0.000	-0.083	-0.009	-0.001	-0.005	-0.005	0.107
Number of canes/vine	-0.028	**0.074**	-0.001	-0.001	0.012	0.000	0.004	-0.009	-0.007	0.004	-0.014	0.034
Number of leaves/shoot	-0.029	0.002	**-0.030**	0.009	0.089	0.001	-0.003	0.042	0.003	0.001	0.007	0.092
Number of flowers/shoot	-0.023	-0.002	-0.006	**0.044**	-0.005	0.000	0.005	0.019	0.001	0.007	0.005	0.045
Number of fruits/shoot	0.004	0.004	-0.011	-0.001	**0.236**	-0.001	-0.006	-0.044	0.002	0.007	0.006	**0.196****
Leaf Fruit Ratio	-0.031	0.001	-0.020	0.009	-0.100	**0.002**	0.002	0.068	0.001	0.000	0.001	-0.067
Duration of flowering	-0.089	0.002	0.000	0.001	-0.007	0.000	**0.202**	0.003	0.004	0.002	0.011	0.129
Fruit weight (g)	-0.021	-0.008	-0.014	0.010	-0.117	0.001	0.007	**0.088**	0.003	-0.014	0.002	-0.063
Fruit length (mm)	0.009	0.022	0.004	-0.002	-0.017	0.000	-0.034	-0.010	**-0.025**	-0.005	-0.057	-0.115
Fruit width (mm)	-0.008	0.002	0.000	0.002	0.011	0.000	0.003	-0.009	0.001	**0.143**	0.040	**0.185****
Shape Index	-0.016	-0.015	-0.003	0.003	0.019	0.000	0.031	0.002	0.021	0.083	**0.069**	**0.194****

r*-Correlation with Fruit yield

The direct and indirect effects presented in the table provided valuable insights for breeding programs and cultivation practices aimed at improving kiwifruit yield.

4.3.4 Multivariate Techniques

In practical situations, we frequently come across large set of data with more than two variables that are highly correlated with each other. So, in this situation multivariate technique is extremely helpful in assisting researchers in making sense of large, complicated, and complex datasets that contain many variables measured on a large number of experimental units. In the present study two independent methodologies viz. Discriminant analysis and Principal component analysis has been discussed

4.3.4.1 Discriminant Analysis

It is a common practice in horticultural experiments to categorize plants as low/high yielders on the basis of a single characteristic. This approach of categorization is statistically weak. The need was, therefore, felt to define a systematic and statistically valid procedure for categorisation of plants as ‘low’ and ‘high’ yielders. The essence of the discriminant analysis is to categorize the observations into desired number of groups. In the present study, the observations were first divided into two groups namely ‘high yielder’ and ‘low yielder’ on the basis of practice in vogue. In the second stage, on the basis of total yield, the observations were divided into two groups and discriminant function was fitted. The discriminant function was found to be:

$$TFY = -12.659 - 0.103\ (VG) + 0.265\ (LFR)$$

Where TFY stands for total fruit yield, VG for vine girth and LFR for leaf fruit ratio . Thus, this equation reveals that the characters VG and LFR are the most important characters that discriminate the kiwifruit plants into two groups i.e. high and low yielder. The value of Wilk’s lambda (λ) was obtained to be 0.463 and which in turn, gave the computed value of chi square (χ^2) as 156.02 and the orchards were assigned to group 1 (High yielder) if $D \geq m$ otherwise to group 2 (low yielder), where $m = -0.297$ is the average of group centroids.

The results of discriminant analysis revealed that the kiwifruit orchards from Solan and Naggar blocks were found to be high yielder whereas Kandaghat, Pachhad, Rajgarh and Kullu blocks were found to be low yielder.

Table 4.3.4 Unstandardized canonical Discriminant function coefficients

Plant characteristics	Canonical Discriminant Function Coefficients	Wilks' Lambda	Sig.
Vine Girth (mm)	-0.013	0.741	**<0.01***
Number of canes/vine	-0.059	0.991	0.18
Number of leaves/shoot	0.035	0.997	0.46
Number of flowers/shoot	0.020	0.987	0.09
Number of fruits/shoot	-0.023	0.999	0.62
Leaf Fruit Ratio	0.265	0.591	**<0.01***
Duration of flowering	-0.017	1.000	0.93
Fruit weight (g)	-0.077	0.999	0.70
Fruit length (mm)	0.184	0.998	0.51
Fruit width (mm)	0.135	0.998	0.57
Shape Index	5.236	0.997	0.45
Constant	-12.659		

4.3.4.2 Principal Component Analysis

The goal of principal component analysis (PCA) is to understand the variance-covariance structure of a set of variables through a few linear combinations of these variables. Its primary objectives are data reduction and interpretation. By reducing the number of variables to a smaller set of linear combinations, PCA allows for an effective and meaningful interpretation of the data. Thus, PCA was used to condense the measured variables into a smaller number of principal components that account for most of the variability in the observed variables. The relative variance of each component, expressed as a percentage, indicates the component's importance in explaining the variance of the traits being studied.

Population-I (High Yielder):

Table 4.3.5 showed that five out of the eleven principal components (PCs) had eigenvalues greater than one, indicating their significant importance to the analysis. This decision was based on Kaiser’s criterion (1958), which suggests discarding principal components from the correlation matrix if their eigen values are less than one (Fig. 4.3.1). Consequently, the first five principal components were retained in the analysis, explaining 79.109% of the total variance. The first principal component had an eigen value of 2.926, accounting for 26.599% of the total variance. The second principal component had an eigenvalue of 2.267, accounting for 20.606% of the total variance. The third principal component had an eigenvalue of 1.325, accounting for 12.048% of the total variance. The fourth principal component had an eigen value of 1.182, accounting for 10.750% of the total variance. Finally, the fifth principal component had an eigen value of 1.002, accounting for 9.105% of the total variance.

Table 4.3.5: Eigen vectors of the Principal Component Analysis of high yielder group

Variables	PC1	PC2	PC3	PC4	PC5
Vine Girth (mm)	-.0143	0.010	0.158	-0.024	**0.506**
Number of canes/vine	0.211	-0.131	-0.030	**0.266**	0.144
Number of leaves/shoot	0.118	0.333	-0.176	0.031	**0.429**
Number of flowers/shoot	0.088	**0.251**	-0.147	0.122	-0.120
Number of fruits/shoot	-0.189	0.147	-0.394	0.288	**0.348**
Leaf Fruit Ratio	-0.047	-0.181	0.222	-0.398	**0.534**
Duration of flowering	**0.254**	0.164	0.112	-0.275	-0.118
Fruit weight (g)	0.212	-0.230	0.027	**0.392**	0.182
Fruit length (mm)	-0.018	0.096	**0.562**	0.510	0.039
Fruit width (mm)	**0.261**	0.188	0.162	-0.167	0.220
Shape Index	0.198	-0.267	**-0.341**	0.008	0.141
Eigen Value	2.926	2.267	1.325	1.182	1.002
Proportion	26.599	20.606	12.048	10.750	9.105
Cum. per cent of Variance	26.599	47.205	59.254	70.004	79.109

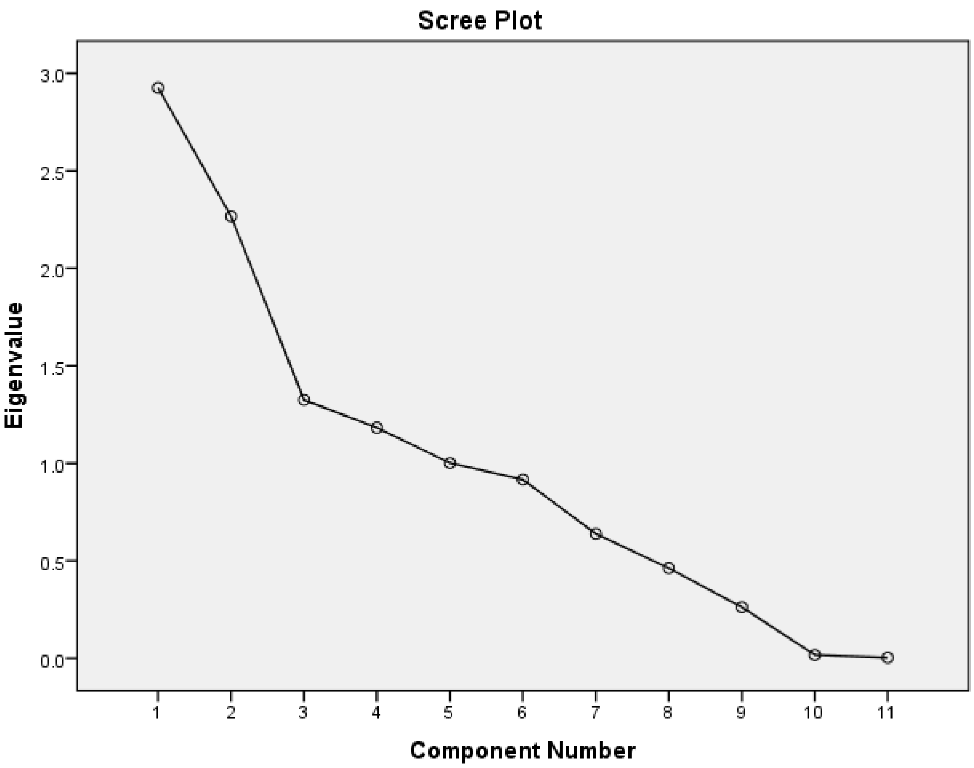

Figure 4.3.1: Scree plot for high yielder group

The PC1 is linear combination of duration of flowering and fruit width. The PC2 consists of linear combination of number of flowers/shoot. The PC3 is linear combination of fruit length and shape index. The PC4 is linear combination of number of canes/vine and fruit weight. The PC5 is linear combination of vine girth, number of leaves/shoot, number of fruits/shoot and leaf/fruit ratio.

4.4 To develop statistical models for forecasting kiwifruit yield

4.4.1 To develop statistical model for area under kiwifruit cultivation in Himachal Pradesh

The area under kiwifruit cultivation over time in Himachal Pradesh was estimated by using various linear and non- linear models namely: linear, quadratic, cubic, compound, power, and exponential. The best model was selected based on the indices of goodness of fit and validity of forecast. The coefficients, standard error of coefficients, t-statistic of all prediction models namely: linear, quadratic, cubic, compound, power, and exponential are presented in Table 4.4.1.1. The value of R^2, Adj. R^2, root mean square error (RMSE), and Theil's inequality coefficient (U) of all prediction models are presented in 4.4.1.2. The actual and predicted area under kiwifruit cultivation for different prediction models from the years 1997 to 2022 are presented in Table 4.4.1.3.

Table 4.4.1.1 shows that the prediction models namely: linear, compound, cubic, power, and exponential had statistically significant regression coefficients. The standard error and t- statistic values for the regression coefficient in these models are also shown in the table. Table 4.4.1.2 shows that all these six models were well fitted for the prediction of area under kiwifruit cultivation as $\overline{R}^2$ values range from (0.505 to 0.951). The highest value of $\overline{R}^2$(0.944) was found in the cubic model whereas the lowest value 0.484 was found in the case of compound and exponential models. The lowest RMSE value was found to be 10.008 for the cubic model and it was highest to be 0.037 in the case of compound and exponential models. Low values of Theil's inequality coefficient were found for cubic model and ranged between (0.037 to 0.084) which reflected the good power of these models for forecasting area under kiwifruit cultivation in Himachal Pradesh.

Table 4.4.1.1: Coefficients, Standard error of coefficients, t-statistic of various models to predict area under kiwifruit cultivation in Himachal Pradesh

Statistical Models		**Coefficient**	**Standard Error**	**t- test statistic**
Linear	a	53.643	8.292	6.469*
	b	5.160	0.537	9.611*
Quadratic	a	59.692	13.257	4.497*
	b	3.881	2.263	1.715
	c	0.047	0.081	0.582
Cubic	**a**	**2.719**	**9.541**	**0.285**
	b	**27.013**	**3.003**	**8.996***
	c	**-2.055**	**0.256**	**-8.030***
	d	**0.052**	**0.006**	**8.322***
Compound	a	53.096	9.050	5.867*
	b	1.056	0.012	90.611*
Power	a	26.767	4.873	5.493*
	b	0.603	0.073	8.271*
Exponential	a	53.096	9.050	5.867*
	b	0.055	0.011	4.946*

Table 4.4.1.2: R^2, $\bar{R}^2$, RMSE and Theil's Inequality (U) for the prediction models for the area under kiwifruit cultivation in Himachal Pradesh

Statistical Models	**R^2**	**$\bar{R}^2$**	**RMSE**	**Theil's inequality (U)**
Linear	0.794	0.785	20.533	0.076
Quadratic	0.797	0.779	20.383	0.075
Cubic	**0.951**	**0.944**	**10.008**	**0.037**
Compound	0.505	0.484	22.777	0.084
Power	0.740	0.729	22.046	0.081
Exponential	0.505	0.484	22.777	0.084

Based on R^2, Adj. R^2, root mean square error (RMSE) and Theil's inequality coefficient (U), cubic model was found to be the best prediction model to forecast the area under kiwifruit cultivation among all the six prediction models because the cubic model has highest value of R^2 (0.951), $\bar{R}^2$ (0.944) and has lowest value of RMSE (10.008), Theil's inequality coefficient (U) (0.037) which was in close confirmity with the findings of trend analysis of mango area, production and productivity in Andhra Pradesh by Murthy *et al* (2018) and Statistical modeling on area, production and productivity of papaya crop in Andhra Pradesh by Shafiya *et al* (2022). Thus area under kiwifruit can be predicted by $Y_t = 2.719 + 27.013t – 2.055t^2 + 0.052t^3$

Table 4.4.1.3: Trend value of various prediction models for area (ha) under kiwifruit cultivation in Himachal Pradesh

Year	Total area (ha)	Linear	Quadratic	Cubic	Compound	Power	Exponential
1997	9	59	64	28	56	27	56
1998	62	64	68	49	59	41	59
1999	78	69	72	67	63	52	63
2000	87	74	76	81	66	62	66
2001	94	79	80	93	70	71	70
2002	95	85	85	102	74	79	74
2003	105	90	89	109	78	87	78
2004	111	95	94	114	82	94	82
2005	113	100	98	117	87	101	87
2006	118	105	103	119	92	107	92
2007	120	110	108	120	97	114	97
2008	128	116	113	121	102	120	102
2009	132	121	118	121	108	126	108
2010	123	126	123	121	114	132	114
2011	120	131	128	121	120	137	120
2012	117	136	134	122	127	143	127
2013	113	141	139	123	134	148	134
2014	121	147	145	126	142	153	142
2015	123	152	150	130	150	158	150
2016	123	157	156	136	158	163	158
2017	145	162	162	145	167	168	167
2018	182	167	168	155	176	173	176
2019	183	172	174	169	186	178	186
2020	187	177	180	185	197	182	197
2021	197	183	186	205	208	187	208
2022	220	188	193	228	220	191	220

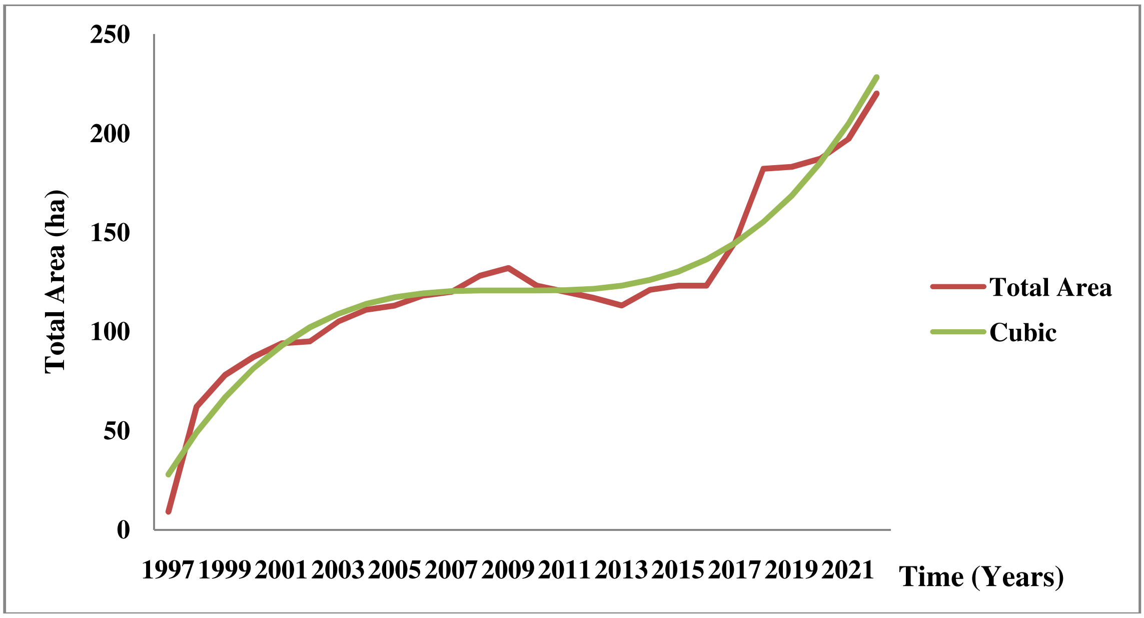

Figure 4.4.1.1: Actual and predicted values of cubic model for area under kiwifruit cultivation in Himachal Pradesh

The observed and predicted area under kiwifruit cultivation for different years during the studied period 1997 to 2022 are shown in Table 4.4.1.3. It can be clearly observed from the Table 4.4.1.3 and Figure 4.4.1.1 the observed and predicted area under kiwifruit cultivation is close in case of cubic model as compare to the other five models.

Table 4.4.1.4: Autocorrelation function of the area under kiwifruit cultivation in Himachal Pradesh

Lag	Autocorrelation	Standard Error
1	0.562*	0.185
2	0.435*	0.182
3	0.337	0.178
4	0.139	0.174
5	0.132	0.170

The area under kiwifruit cultivation was also estimated by using an autoregressive model. Table 4.4.1.4 presented the autocorrelation and standard error up to five lags. The area under kiwifruit cultivation in consequent years was found to be significantly autocorrelated in first two lags only. It can also be observed from the Table 4.4.1.4 that the maximum value of autocorrelation was 0.562 for the first lag and then decreased with an increase in lag and corresponding values of the second, third, fourth, and fifth lags were 0.435, 0.337, 0.139 and 0.132 respectively.

Table 4.4.1.5: Coefficients, Standard error, t- statistic, R^2, $\bar{R}^2$ of autoregressive model of the area under kiwifruit cultivation in Himachal Pradesh

Order of Autoregressive Model	Coefficient of Different Lags	Value of coefficient	Standard Error	t- statistic	R^2	$\bar{R}^2$
1st order	Φ_1	0.896	0.066	13.611*	0.890	0.885
2nd order	Φ_1	**1.330**	**0.167**	**7.969***	**0.938**	**0.932**
	Φ_2	**-0.280**	**0.150**	**-1.867***		

Table 4.4.1.5 presents the coefficient of autoregressive models along with their standard error and t-statistic, R^2, $\bar{R}^2$. The t- statistic was used to test the significance of coefficient in autoregressive models. It was revealed that the second order autoregressive model has significant regression coefficient Φ_2 . The R^2 value was 0.938 and $\bar{R}^2$ value was 0.932. Same model was also found to be best fit for forecasting of area and production of mango in Himachal Pradesh by Kumar and Gupta (2020). The actual and

predicted value of area under kiwifruit cultivation by second order autoregressive model are presented in Table 4.4.1.6.

Table 4.4.1.6: Trend values of 2nd order autoregressive model for the area (ha) under kiwifruit cultivation in Himachal Pradesh

Year	Total area (ha)	2nd order autoregressive
1997	9	--
1998	62	--
1999	78	78.08
2000	87	84.54
2001	94	92.04
2002	95	98.83
2003	105	98.21
2004	111	111.23
2005	113	116.41
2006	118	117.39
2007	120	123.49
2008	128	124.75
2009	132	134.83
2010	123	137.91
2011	120	124.82
2012	117	123.35
2013	113	120.20
2014	121	115.72
2015	123	127.48
2016	123	127.90
2017	145	127.34
2018	182	156.60
2019	183	199.66
2020	187	190.65
2021	197	195.69
2022	220	207.87

The estimated area under kiwifruit cultivation for the period 1997 to 2022 was also computed using the second-order autoregressive model. The predicted area under kiwifruit cultivation and observed area under kiwifruit cultivation have been shown in Table 4.4.1.6. It can also be seen from Table 4.4.1.6 that the observed values are nearer to the predicted area under kiwifruit cultivation using second-order autoregressive model.

4.4.2: To develop statistical model for the estimation of kiwifruit production in Himachal Pradesh:

The estimation of kiwifruit production was done by taking the time as explanatory variable. The kiwifruit production over the time was estimated by using various linear and nonlinear models namely: linear, quadratic, cubic, compound, power, exponential, and the best model was selected based on the indices of goodness of fit and validity of forecast. The coefficient, standard error of coefficients, t- statistic of all models namely: linear, quadratic, cubic, compound, power and exponential are presented in Table 4.4.2.1. The value of R^2, Adj.R^2, root mean square error (RMSE), and Theil's inequality coefficient (U) of all models are presented in Table 4.4.2.2. The actual and predicted kiwifruit production for different models from years 1997 to 2022 are presented in Table 4.4.2.3

Table 4.4.2.1: Coefficients, Standard error of coefficients, t- statistic of various models to predict kiwifruit production in Himachal Pradesh

Statistical Models		Coefficient	Standard Error	t- statistic
Linear	a	-54.323	56.995	-0.953
	b	22.622	3.691	6.130*
Quadratic	a	115.654	79.528	1.454
	b	-13.801	13.574	-1.017
	c	1.349	0.488	2.765
Cubic	a	-63.518	103.665	-0.613
	b	59.047	32.625	1.810*
	c	-5.271	2.780	-1.896*
	d	0.163	0.068	2.412*
Compound	a	26.656	7.833	3.403*
	b	1.138	0.022	52.553*
Power	a	7.494	2.644	2.835*
	b	1.279	0.141	9.044*
Exponential	a	26.656	7.833	3.403*
	b	0.129	0.019	6.788*

Table 4.4.2.2: R^2, $\bar{R}^2$, RMSE and Theil's Inequality (U) for the various models for prediction of kiwifruit production in Himachal Pradesh

Statistical Models	R^2	$\bar{R}^2$	RMSE	Theil's inequality (U)
Linear	0.610	0.594	141.137	0.214
Quadratic	0.707	0.682	122.276	0.183
Cubic	**0.769**	**0.737**	**108.739**	**0.161**
Compound	0.658	0.643	118.344	0.176
Power	0.773	0.764	142.147	0.229
Exponential	0.658	0.643	118.344	0.176

Table 4.4.2.1 shows that the prediction models namely: linear, cubic, compound, power, and exponential models had statistically significant regression coefficients. The standard error and t- test statistic values for the regression coefficients in these models are also shown. Table 4.4.2.2 shows that all these six models were fitted for the estimation of

kiwifruit production as R^2 values range from (0.610 to 0.769). The highest value of R^2 was found in the power model whereas it was lowest in case of linear model. $\overline{R}^2$ values range from (0.594 to 0.764) in this highest value was found in power model whereas lowest value was found in case of linear model. Lowest RMSE value was found to be 108.739 for the cubic model and it was highest in case of power model. Low values of Theil's inequality coefficient was found in cubic model (0.161) and ranged between (0.161 to 0.229) which reflected good power of these models for the prediction of kiwifruit production.

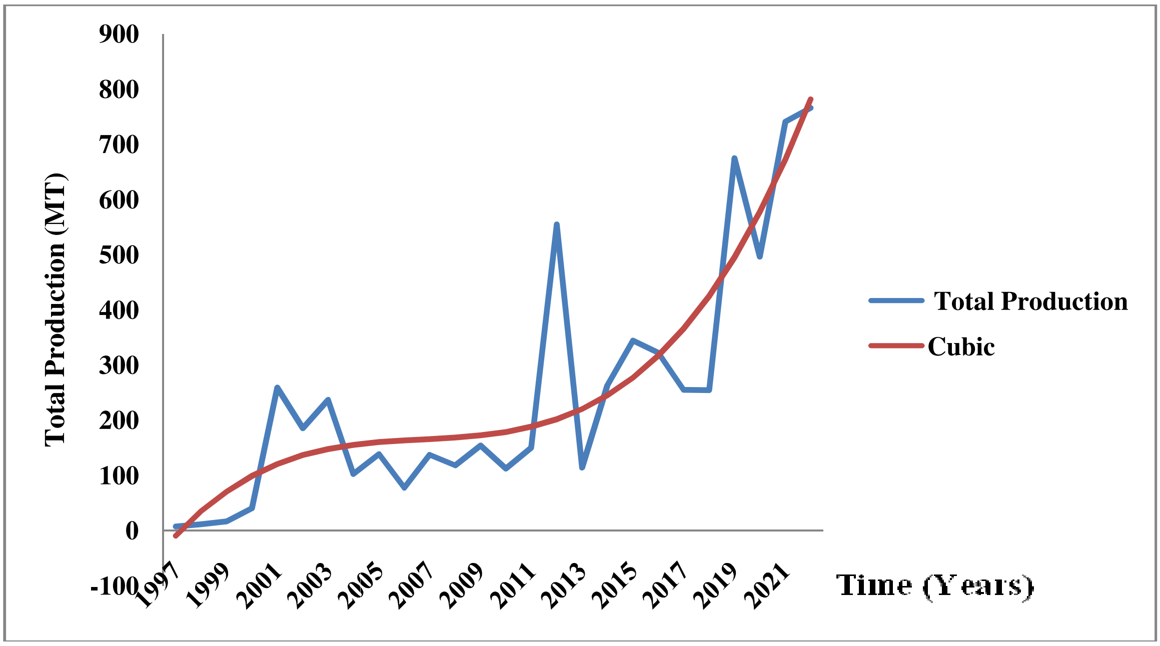

Figure 4.4.2.1: Actual and predicted values of cubic model for the kiwifruit production in Himachal Pradesh

Based on R^2, $\overline{R}^2$, RMSE, and Theil's inequality (U), cubic model was found to be the best prediction model for kiwifruit production among all six prediction models because the cubic model has second highest value of $\overline{R}^2$ (0.737) and has lowest value for RMSE (108.739) and Theil's inequality coefficient (U) (0.161) which has in close affinity with the finding trends of area, production and productivity of turmeric in Assam by Chaudhary and Kalita (2018) and forecasting guava cultivation using statistical models for area, production, and productivity in Gujarat by Raj *et al* (2023). Prediction model for kiwifruit production is $Y_t = -63.518 + 59.047t - 5.271t^2 + 0.163t^3$

The observed and predicted values of kiwifruit production for different years during the studied period 1997 to 2022 are shown in Table 4.4.2.3. It can be clearly observed from the Table 4.4.2.3 and Figure 4.4.2.1 that the observed and predicted kiwifruit production is closed in case of cubic model as compared to other five models.

Table 4.4.2.3: Trend values of various prediction models for the kiwifruit production (MT) in Himachal Pradesh

Year	Total production	Linear	Quadratic	Cubic	Compound	Power	Exponential
1997	7	----	103.20	----	30.33	7.49	30.33
1998	11	----	93.45	34.80	34.51	18.18	34.51
1999	16	13.54	86.39	70.60	39.27	30.53	39.27
2000	40	36.17	82.03	98.80	44.69	44.11	44.69
2001	259	58.79	80.37	120.38	50.85	58.67	50.85
2002	185	81.41	81.41	136.33	57.86	74.07	57.86
2003	237	104.03	85.15	147.62	65.84	90.21	65.84
2004	102	126.65	91.58	155.23	74.91	107.00	74.91
2005	138	149.28	100.71	160.14	85.24	124.39	85.24
2006	77	171.90	112.54	163.34	96.99	142.33	96.99
2007	137	194.52	127.07	165.81	110.37	160.78	110.37
2008	118	217.14	144.30	168.52	125.58	179.70	125.58
2009	154	239.77	164.22	172.46	142.90	199.06	142.90
2010	112	262.39	186.84	178.60	162.60	218.84	162.60
2011	150	285.01	212.16	187.94	185.02	239.03	185.02
2012	555	307.63	240.18	201.44	210.53	259.59	210.53
2013	114	330.25	270.90	220.10	239.56	280.51	239.56
2014	263	352.88	304.31	244.88	272.59	301.78	272.59
2015	344	375.50	340.42	276.78	310.17	323.37	310.17
2016	322	398.12	379.24	316.77	352.94	345.29	352.94
2017	255	420.74	420.74	365.83	401.60	367.52	401.60
2018	254	443.37	464.95	424.94	456.97	390.04	456.97
2019	675	465.99	511.85	495.09	519.98	412.85	519.98
2020	496	488.61	561.46	577.25	591.67	435.94	591.67
2021	741	511.23	613.76	672.40	673.25	459.30	673.25
2022	766	533.85	668.76	781.54	766.07	482.92	766.07

Kiwifruit production was also estimated by using autoregressive model. Table 4.4.2.4 presented the autocorrelation and standard error up to five lags. The kiwifruit production in consequent years were found to be significantly autocorrelated upto third lags. It can also be observed from the Table 4.4.2.4 that the maximum value of autocorrelation was 0.709 for first lag and then decrease with an increase in lag and corresponding values of second, third, fourth and fifth lags were 0.540, 0.406, 0.275 and 0.132 respectively.

Table 4.4.2.4: Autocorrelation function of kiwifruit production in Himachal Pradesh

Lag	Autocorrelation	Standard Error
1	0.709*	0.185
2	0.540*	0.182
3	0.406*	0.178
4	0.275	0.174
5	0.132	0.170

Table 4.4.2.5 presents the coefficient of autoregressive models along with their standard error and t- statistic, R^2, $\overline{R}^2$. The t-statistic was used to test the significance of coefficient in autoregressive models. It was revealed that the second order autoregressive model have significant coefficients Φ_1 and Φ_2.The $\overline{R}^2$ value was 0.485 and R^2 value was 0.530. Same model was also found to be best fit for the estimation of area and production of mango in Himachal Pradesh by Kumar and Gupta (2020). The actual and predicted value of kiwifruit production by second order autoregressive model are presented in Table 4.4.2.6.

Table 4.4.2.5: Coefficients, Standard error, t- statistic, R^2, $\overline{R}^2$ of autoregressive model of kiwifruit production in Himachal Pradesh

Order of Autoregressive Model	Coefficient of Different Lags	Value of coefficient	Standard Error	t- statistic	R^2	$\overline{R}^2$
1st order	Φ_1	0.730	0.173	4.207*	0.435	0.410
2nd order	Φ_1	**0.458**	**0.197**	**2.320***	**0.530**	**0.485**
	Φ_2	**0.528**	**0.227**	**2.328***		
3rd order	Φ_1	0.319	0.223	1.426	0.543	0.471
	Φ_2	0.451	0.236	1.910		
	Φ_3	0.335	0.256	1.312		

The estimated kiwifruit production for period 1997 to 2022 were also computed using the second order autoregressive model. The predicted kiwifruit production and observed kiwifruit production have been shown in Table 4.4.2.6. It can also be seen from Table 4.4.2.6 that the observed values are nearer to predicted kiwifruit production using second order autoregressive model.

Table 4.4.2.6: Trend value of 2nd order autoregressive model for the kiwifruit production (MT) in Himachal Pradesh

Year	Actual production	2nd order autoregressive
1997	7	--
1998	11	--
1999	16	59.81
2000	40	64.21
2001	259	77.83
2002	185	190.69
2003	237	272.47
2004	102	257.19
2005	138	222.88
2006	77	168.07
2007	137	159.17
2008	118	154.41
2009	154	177.40
2010	112	183.84
2011	150	183.63
2012	555	178.84
2013	114	384.20
2014	263	396.28
2015	344	231.60
2016	322	347.33
2017	255	380.03
2018	254	337.76
2019	675	301.93
2020	496	494.01
2021	741	634.41
2022	766	651.99

Table 4.4.2.7 presented the predicted area and production of kiwifruit in Himachal Pradesh for year 2025 by using different prediction models.

Table 4.4.2.7: Predicted area and production of kiwifruit of Himachal Pradesh for year 2025

Statistical models	Area (ha)	Production(MT)
Linear	203.29	601.72
Quadratic	212.01	849.94
Cubic	323.99	1202.60
Compound	258.58	1128.64
Power	204.22	555.28
Exponential	258.58	1128.64

4.4.3 Forecasting of area and production of kiwifruit by using Exponential smoothing

Exponential smoothing is a specific type of moving average technique used on time series data to generate smoothed values for forecasting. In this method, one or more smoothing parameters be explicitly determined, which in turn dictate the weights assigned to the observations.

4.4.3.1: Forecasting of area under kiwifruit cultivation by using Browns Exponential smoothing

Brown's linear exponential smoothing using SPSS software has been applied to forecast the area under kiwifruit cultivation in Himachal Pradesh. This model is appropriate for series in which there is a linear trend and no seasonality. Its smoothing parameters are level and trend, which are assumed to be equal. Brown's model is therefore a special case of Holt's model. Brown's exponential smoothing is most similar to an ARIMA model with zero orders of autoregression, two orders of differencing, and two orders of moving average, with the coefficient for the second order of moving average equal to the square of one-half of the coefficient for the first order.

Table 4.4.3.1.1: Parameters and smoothing constant value of area under kiwifruit cultivation by using Brown exponential smoothing model

Brown Exponential smoothing model	Estimate	Standard Error	t-statistic	Significance
α (Smoothing constant)	0.982	0.055	17.979	< 0.01

Table 4.4.3.1.1 indicated that the value of (smoothing constant) α was found to be 0.982 and the value of standard error was found to be 0.055. The value of t- statistic was found to be significant by applying brown exponential smoothing model.

Table 4.4.3.1.2: R^2 , RMSE, MAPE, MAE and Normalized BIC value of area under kiwifruit cultivation by using Brown exponential smoothing model

R^2	0.914
RMSE	13.027
MAPE	7.911
MAE	8.635
Normalized BIC	5.259

Table 4.4.3.1.2 suggested that the value of R^2 was found to be 0.914 provides confirmatory evidence that brown exponential smoothing model was best fit in case of area

under kiwifruit cultivation. The value of RMSE was found to be 13.027 and the value of MAPE was found to be 7.911. MAE and Normalized BIC value was found to be 8.635 and 5.259.

Table 4.4.3.1.3: Forecasted values of area under kiwifruit cultivation by using Brown exponential smoothing model

Year	Forecasting value of area under kiwifruit cultivation (ha)
2023	242.52
2024	265.04
2025	287.57

Table 4.4.3.1.3: showed the forecasted values of area under kiwifruit cultivation for the year 2023, 2024 and 2025.

4.4.3.2: Forecasting of kiwifruit production by using Exponential smoothing

Brown's linear exponential smoothing model is a time series forecasting method suitable for data with a linear trend but no seasonality. This model is particularly useful for forecasting series that exhibit a linear trend over time. This method has been utilised to forecast the kiwifruit production using IBM SPSS software. The model is implemented by using two smoothed series: the level and the trend which are assumed to be equal.

Table 4.4.3.2.1: Parameters and smoothing constant value of kiwifruit production by using Brown exponential smoothing model

Brown Exponential smoothing model	Estimate	Standard Error	t-statistic	Significance
α (Smoothing constant)	0.241	0.079	3.040	< 0.01

Table 4.4.3.2.1 indicated that the value of smoothing constant was found to be 0.241 and the value of standard error was found to be 0.079. The value of t- statistic was found to be significant by applying brown exponential smoothing model.

Table 4.4.3.2.2: R^2 , RMSE, MAPE, MAE and Normalized BIC value of kiwifruit production (MT) by using Brown exponential smoothing model

R^2	0.558
RMSE	147.232
MAPE	145.928
MAE	95.988
Normalized BIC	10.109

Table 4.4.3.2.2 suggested that the value of R^2 was found to be 0.558 provides confirmatory evidence that brown exponential smoothing model was best fit in case of kiwifruit production. The value of RMSE was found to be 147.232 and the value of MAPE was found to be 145.928. MAE and Normalized BIC value was found to be 95.988 and 10.109. Also, Table 4.4.3.2.3 showed the forecasted values of kiwifruit production for the year 2023, 2024 and 2025.

Table 4.4.3.2.3: Forecasted value of kiwifruit production by using brown exponential smoothing model

Year	Forecasting value of kiwifruit production (MT)
2023	755.19
2024	805.39
2025	855.59

Table 4.4.3.2.4 : Actual and Forecasted Values of area and production under kiwifruit cultivation in Himachal Pradesh using Brown Exponential Smoothing Model

Year	Total Area (ha)	Forecasted Area (ha)	Production (MT)	Forecasted Production (MT)
1997	9	10.93	7	133.28
1998	62	58.8	11	91.15
1999	78	114.88	16	63.94
2000	87	95.35	40	47.61
2001	94	96.29	259	47.96
2002	95	101.08	185	153.47
2003	105	96.22	237	184.59
2004	111	114.68	102	227.63
2005	113	117.14	138	187.74
2006	118	115.15	77	177.18
2007	120	122.89	137	139.35
2008	128	122.11	118	142.93
2009	132	135.78	154	135.47
2010	123	136.14	112	147.55
2011	120	114.48	150	134.58
2012	117	116.79	555	144.16
2013	113	113.99	114	345.62
2014	121	109.04	263	260.74
2015	123	128.56	344	275.32
2016	123	125.21	322	322.1
2017	145	123.08	255	339.67
2018	182	166.2	254	316.39
2019	183	218.43	675	298.94
2020	187	185.3	496	489.6
2021	197	190.93	741	523.66
2022	220	206.78	766	659.97

Table 4.4.3.2.4 showed the actual and forecasted values of area and production under kiwifruit cultivation in Himachal Pradesh using Brown Exponential Smoothing Model. The Figure 4.3.1 and Figure 4.3.2 showed that the forecasted values are closely related to the actual values of area and production of kiwifruit in Himachal Pradesh. The studies of forecasting area and production of kiwifruit using time series analysis were similar and supported with the findings of Eyduran *et al* (2020), Bhagat *et al* (2023), Akin and Eyduran (2017).

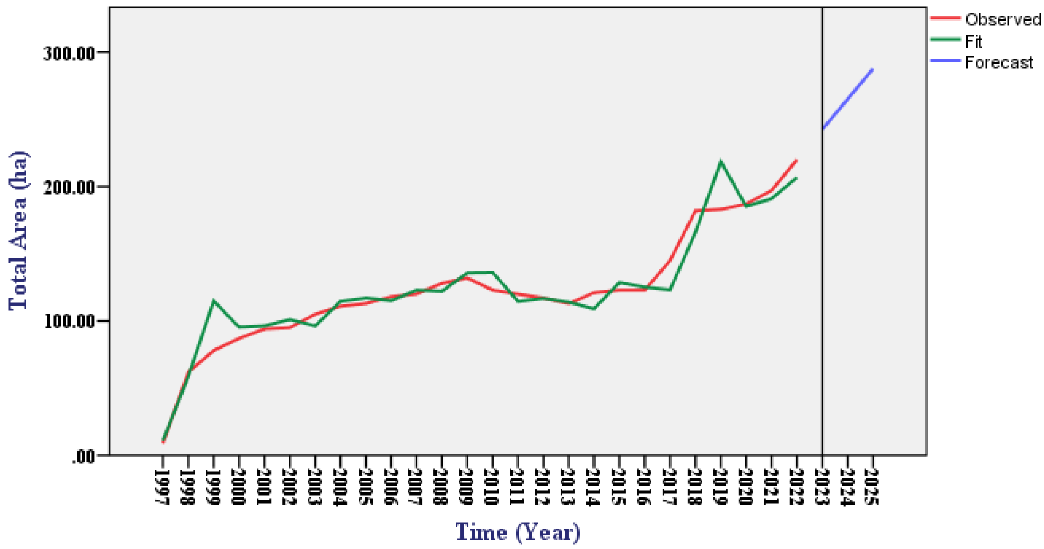

Figure 4.3.1: Forecast for area under kiwifruit cultivation in Himachal Pradesh using Brown Exponential Smoothing Model

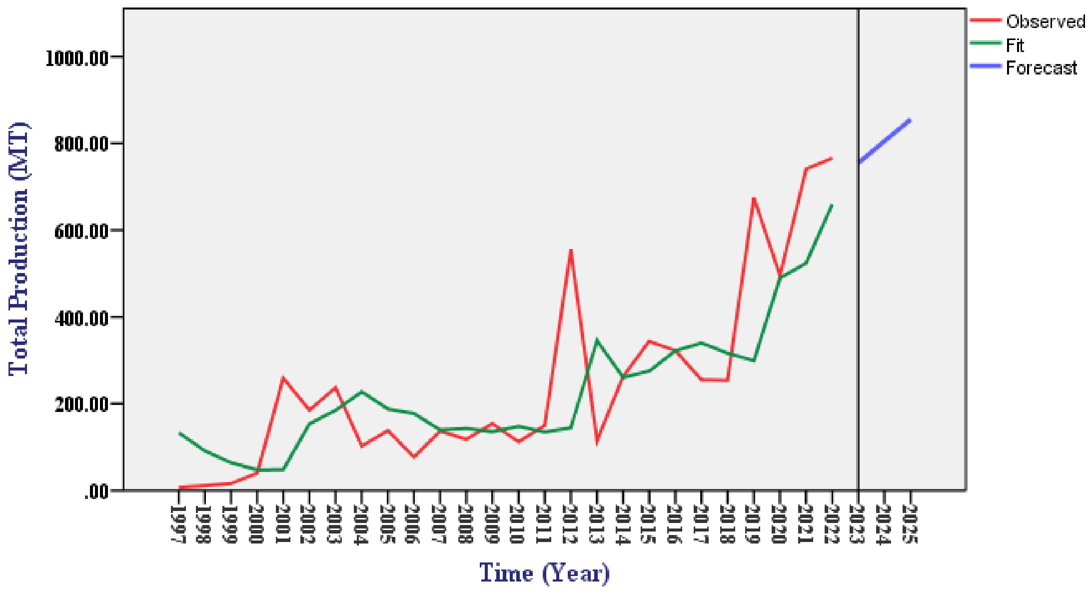

Figure 4.3.2: Forecast for kiwifruit production in Himachal Pradesh using Brown Exponential Smoothing Model

Chapter-5

SUMMARY AND CONCLUSION

The results of the present research entitled "**Statistical Investigation on Socio-Economic Status of Kiwifruit Growers and Factors Influencing Kiwifruit Production in Himachal Pradesh"** are summarized as:

The primary data on 300 respondents were collected from three major kiwifruit producing districts of Himachal Pradesh, viz., Sirmaur, Solan and Kullu. From each districts, two blocks, were selected randomly, i.e. Rajgarh and Pachhad blocks from Sirmaur district, Kandaghat and Solan blocks from Solan district, Kullu and Naggar blocks from Kullu district. It was found that joint families constituted 52.67% of the sample, while nuclear families made up 47.33%. The average family size was 5.29 members, with a sex ratio of 867.29. Educational status varied, with 19.85% of individuals having completed senior secondary education and 8.40% having graduated or attained higher qualifications.

Occupational distribution showed that 39.00% of the households were primarily engaged in agriculture, followed by 29.67% in service and 24.00% in business. The land use pattern indicated that the overall average total operational area was 1.41 ha per household, with 0.87 ha per household dedicated to cultivated land other than orchards, 0.27 ha per household to kiwifruit orchards and 0.20 ha per household to other fruits orchard.

Total kiwifruit production across the sample amounted to 4223.40 quintals, with marketable surplus accounting for 4187.70 quintals after deducting home consumption and gifts. Marketing analysis indicated that most of the growers preferred channel-B, i.e. Producer → Commission agent→ Retailer → Consumer, accounting for 68.33% of the total quantity of the produce. Marketing costs and margins varied, with Channel A had a producer's net receipt of Rs. 27,701.67 and a consumer's price of Rs. 28,050.00, with a GMM of Rs. 348.33, a producer's share of 98.76%, and a marketing efficiency of 79.53%. Channel B had a producer's net receipt of Rs. 25,535.67 and a consumer's price of Rs. 34,140.69, with a GMM of Rs. 8,605.02, a producer's share of 74.80%, and a marketing efficiency of 2.97%. Channel C had a producer's net receipt of Rs. 25,353.48 and a consumer's price of Rs. 29,691.92, with a GMM of Rs. 4,338.44, a producer's share of 85.39%, and a marketing efficiency of 5.84%.

The major significant problem faced by 57.33 per cent of growers was lack of technical knowledge followed by limited supply of FYM (35.33%), lack of irrigation facilities (30.67 %), Higher wage rates was reported by 22 per cent of kiwifruit growers and Shortage of skilled labour reported by 18.00 per cent growers. These issues like higher transportation cost, higher price of chemicals, lack of storage facilities collectively contributed to higher production costs for farmers.

The estimate of the $v(\hat{\bar{y}})$ for varying number of strata (2, 3 and 4) formed by demarcation of approximate optimal strata points with four methods viz. i) Equalization of Strata Total ii) Equalization of cumulative $\sqrt{f(y)}$ iii) Equalization of cumulative $\sqrt[3]{f(y)}$ and iv) Equalization of cumulative $\frac{1}{2}[r(y) + f(y)]$, under Equal allocation, Proportional allocation and Neyman allocation was computed. The area under kiwifruit cultivation (ha) was taken as a study variable which was subjected to stratification. The results of the study suggests that with precise sampling technique such as stratified random sampling with stratification methods equalization of cumulative $\sqrt[3]{f(y)}$ can provide efficient estimate for the kiwifruit production in the state.

Morphological characteristics of kiwifruit vines towards yield were evaluated for 210 kiwifruit vines across Solan, Sirmaur, and Kullu districts in 2023. Karl Pearson's correlation coefficient was calculated between various morphological characters, as shown in Table 4.3.2. The analysis revealed the highest positive and significant correlation between shape index and fruit length with r = 0.829, followed by fruit weight and leaf/fruit ratio with r = 0.775, and number of leaves/shoot and leaf fruit ratio with r = 0.641. Total fruit yield showed positive and significant correlations with number of fruits/shoot and fruit width, with values of 0.196 and 0.185, respectively. Yield efficiency had a positive and significant correlation with vine girth, r = 0.465 and with the duration of flowering, r = 0.536. Conversely, there was a negative and significant correlation of number of fruits/shoot with fruit weight as r = -0.489 and Leaf Fruit Ratio as r = -0.429. Vine girth (0.216), number of canes per vine (0.074), number of flowers per shoot (0.044), number of fruits per shoot (0.236), leaf/fruit ratio (0.002), duration of flowering (0.202), fruit weight (0.088), shape index (0.069) and fruit width (0.143) all exhibited direct and positive effects on the total fruit yield. Conversely, the number of leaves per shoot (-0.030) and fruit length (-0.025) showed direct and neagtive effects on the total fruit yield.

The data of morphological characters was subjected to discriminant analysis. In the present study, the observation of different morphological characters of 210 kiwifruit vines were divided into two groups namely 'high yielder' and 'low yielder' on the basis of total fruit yield and discriminant function was fitted. The discriminant function was found to be:

$$TFY = -12.659 - 0.103\ (VG) + 0.265\ (LFR)$$

Where TFY stands for total fruit yield, VG for vine girth and LFR for leaf/fruit ratio. Thus, this equation reveals that the characters VG and LFR are the most important characters that discriminate the kiwifruit plants into two groups i.e. high and low yielder. The value of Wilk's lambda (λ) was obtained to be 0.463 and which in turn, gave the computed value of chi square (χ^2) as 156.02 and the orchards were assigned to group 1 (High yielder) if $D \geq m$ otherwise to group 2 (low yielder), where $m = -0.297$ is the average of group centroids.

The results of discriminant analysis revealed that the kiwifruit orchards from Solan and Naggar blocks were found to be high yielder whereas Kandaghat, Pachhad, Rajgarh and Kullu blocks were found to be low yielder.

The principal component analysis (PCA) showed that the first five principal components explained a cumulative variance of 79.109%. Among the morphological characteristics, vine girth, number of canes per vine, number of leaves per shoot, and fruit weight were found to be the most significant contributors to the yield. The eigenvectors of PCA for the high yielder group indicated that PC1 (26.599% variance) had the highest loadings on leaf/fruit ratio (-0.047) and duration of flowering (0.254), PC2 (20.606% variance) on number of leaves/shoot (0.333) and fruit width (0.188), and PC3 (12.048% variance) on fruit length (0.562) and fruit width (0.162).

Various linear and non-linear models, including linear, quadratic, cubic, compound, power, and exponential models were fitted for forecasting area under kiwifruit cultivation and kiwifruit production in Himachal Pradesh. The models were evaluated on standard error, t-statistics, R^2, adjusted R^2, root mean square error (RMSE), and Theil's inequality coefficient (U). Among the six models, the cubic model emerged as the best for predicting the area under kiwifruit cultivation. Thus area under kiwifruit can be predicted by $Y_t = 2.719 + 27.013t - 2.055t^2 + 0.052t^3$ and Prediction model for kiwifruit production is $Y_t = -63.518 + 59.047t -$

$5.271t^2 + 0.163t^3$. The area under kiwifruit cultivation and kiwifruit production can be predicted by using second order autoregressive model $\overline{Y}_t = 1.330 \times \overline{Y}_{t-1} - 0.280 \times \overline{Y}_{t-2}$ and $Y_t = 0.458 \times Y_{t-1} + 0.528 \times \overline{Y}_{t-2}$, respectively.

Brown's linear exponential smoothing model was used for forecasting area under kiwifruit cultivation and kiwifruit production. This method is suitable for data with a linear trend but no seasonality. The forecasted values for the area under kiwifruit cultivation and kiwifruit production for the years 2023, 2024, and 2025 were provided using the Brown exponential smoothing model. The Brown's linear exponential smoothing model was found to be best fit for area under kiwifruit cultivation and kiwifruit production as per the high value of R^2, low value of MAPE and Normalized BIC. The forecasted values closely aligned with the actual values, indicating the reliability of the models used.

The following conclusions are made from the study:

- ❖ The results from marketing and production analysis revealed that the total kiwifruit production was 4223.40 quintals, with 4187.70 quintals being marketable surplus in the study area for year 2023. Most of the farmers preferred Channel B (Producer → Commission agent → Retailer → Consumer), accounting for 68.33% of the total quantity produced.
- ❖ Equalization of cumulative $\sqrt[3]{(f(y))}$ method showed the least variance among four stratification rules and is efficient for estimating kiwifruit production.
- ❖ Significant variations were found in the number of canes per vine, and yield-related characteristics among 210 kiwifruit vines. Positive correlations between total fruit yield and factors such as the number of fruits per shoot and fruit width were found. There are negative correlations between fruit weight and the number of fruits per shoot.
- ❖ The results from discriminant analysis identified vine girth and leaf/fruit ratio as critical factors distinguishing high and low yielders. The kiwifruit orchards from Solan and Naggar blocks were found to be high yielder whereas Kandaghat, Pachhad, Rajgarh and Kullu blocks were found to be low yielder.
- ❖ The results reveal that principal component analysis (PCA) indicated vine girth, number of canes per vine, and fruit weight are significant contributors to yield, with the first five principal components explaining 79.109% of the variance.
- ❖ Cubic model was found to be the best for forecasting area under kiwifruit cultivation and production among various linear and non-linear models. Brown's linear exponential smoothing model provided reliable future predictions for forecasting area under kiwifruit cultivation and production in the state.

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APPENDIX-I

Household schedule for the Study **Date of interview...............**
Code No............................

1. General Information

- Name of the Respondent:
- Age:
- Education:
- Sex:
- Economic status: APL/ BPL
- Panchayat:
- Block:
- District:
- Family Type: Joint/Nuclear
- No of family members: male female children

Sr. No	Relationship with Head	Age	Gender M/F	Education I/P/M/H/D/S/NS	Occupation			
					Main		Subsidiary	
					Particular	Income (Rs.)	Particular	Income (Rs.)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								

DOB- Date of Birth, M-Male,F-Female, I-Illiterate, P- Primary, M- Middle, H-High/Sr.Secondary, D- Degree & Above, S-School going, NS-Non-School Going.

2. Social participation

Member of Cooperatives/ SHG/ NGO/ Mahila Mandal/ Yuvak Mandal/ Devta Committee/Panchayat/ any others (specify):

Designation	Name of social organization	Since when you are member	Duties

3. Land Utilization Pattern (Bigha or ha)

Sr. No.	Particulars of land	Area(bigha)	Source of Irrigation
1.	Total land holding(owned)		
2.	Cultivated area		
3.	Kiwifruit orchard Area		
4.	Other fruits orchard Area		
5.	Total operational area		
6.	Ghasnis/ Pastures land		
7.	Land under non-agricultural use		
8.	**Total holding**		

4. Inventory of buildings

Sr. No.	Particulars	Kucha		Pukka		Remarks Own/Project Assistance*
		No. & Year of construction	Cost (Rs.)	No. & Year of construction	Cost (Rs)	
1	Residential House					
2	Cattle shed					
3	Implement Shed					
4	Motor shed					
5	Store room					
6	Manure pit					
7	Others (specify)					

5. Variety wise age, number of plants and area under kiwifruit

Variety	Number of plants	Area	Age

6. Marketing channels of kiwifruit

Quantity Sold ………………………… Harvesting time ………………………………….
No. of Picking ………………………. Length of marketing season ………………………

Particular	Family labour days/hr.		Hired labour days/hr.		Animal labour days/hr.		Machinery/Vehicles		Material cost/service charges		
	M	F	M	F	M	F	Days/hr	Days/hr	Qty	Rate	Value
1. Assembling											
2.Grading											
3. Packing cost											
i) Boxes											
ii) Gunny bags											
iii) Labelling											
iv) others											
4. Transportation											
i. Field to road head											
ii. Road head to distant market											
iii. Loading/unloading											
iv. Others (specify)											
5. Storage											
1. Other charges											
i. Octroi											
ii. State mix											
iii. Union Charge											
iv. Market fee											
v. Commission of agent											
vi. weighment charge											
vii. other charges											

Mode of Transportation: (i) Human back (ii) Bus (iii) Others

7. Problems Faced by Farmers:

S.No.	Problems	Response		Rank				
		Yes	No	I	II	III	IV	V
	No. of farmers							
1	**Labour**							
	Non availability at peak operation time							
	Higher wages rates							
	Shortage of skilled labour							
	Lack of technical knowledge							
2	**Chemical Fertilizer and Plant Protection Chemicals**							
	High transportation cost							
	High prices of chemicals							
4	**Non availability of healthy plant material**							
5	**Other problems**							
S	Limited supply of FYM							
	Perennial supply of irrigation not available							
	Diseases management							
	Lack of irrigation facilities							
6	**Marketing problems**							
	Lack of storage facilities							
	Markets very far off							

I-very high, II– high, III- medium, IV- low, V- very low

APPENDIX-II

ANOVA for morphological characters of kiwifruit vine (Table: 4.3.1.2)

Source of variation	df	MSS													
		Vine girth	No. of canes /vine	No. of leaves /shoot	No. of flowers/ shoot	No. of fruits /shoot	Leaf fruit ratio	Duration of flowering	Fruit weight	Fruit length	Fruit width	Shape index	Total fruit yield	Yield efficiency	TSS/TA ratio
Replication	69	2860.88	34.52	12.10	86.90	2.20	0.32	4.16	104.32	47.76	12.50	0.04	126.20	5.29	6.34
Treatment	2	467.91	185.94	11.99	136.63	6.93	17.90	7.86	1144.13	2631.05	16.38	1.30	1763.62	8.65	279.90
Error	138	1944.60	44.39	16.88	62.64	2.10	0.39	5.34	130.68	33.36	11.36	0.03	118.82	3.45	3.29

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Title of the thesis	**:**	**"Statistical Investigation on Socio-Economic Status of Kiwifruit Growers and Factors Influencing Kiwifruit Production in Himachal Pradesh"**
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Admission Number	**:**	F-2021-45-D
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Major Discipline	**:**	Agricultural Statistics
Minor Discipline	**:**	Agricultural Economics
Date of Thesis Submission	**:**	
Total Pages of the Thesis	**:**	122+iv
No. of words in Abstract	**:**	329

ABSTRACT

The present study, entitled **"Statistical Investigation on Socio-Economic Status of Kiwifruit Growers and Factors Influencing Kiwifruit Production in Himachal Pradesh,"** was carried out across the three major kiwifruit-producing districts of Himachal Pradesh i.e. Sirmaur, Solan, and Kullu. Simple random sampling technique was employed for the selection of sampling units. The primary data were collected on socio-economic characteristics, land use patterns, production, marketing channels, challenges faced by kiwifruit growers and for standardization of sampling technique for estimation of kiwifruit production in Himachal Pradesh. Total kiwifruit production in the study area was 4223.40 quintals, with 4187.70 quintals being marketable surplus. Marketing analysis indicated that most of the farmers preferred channel-B, i.e. Producer → Commission agent→ Retailer → Consumer, accounting for 68.33% of the total quantity of the produce. Equalization of cumulative $\sqrt[3]{f(y)}$ method of construction of strata boundaries showed least variance among four stratification rules and can be efficiently used for estimation of kiwifruit production in the study area. The morphological evaluation of 210 kiwifruit vines, reveals significant variations in vine girth, number of canes per vine, and yield-related characteristics. Positive correlations were found between total fruit yield and factors such as the number of fruits per shoot and fruit width, while negative correlations were noted between fruit weight and the number of fruits per shoot. Discriminant analysis identified vine girth and leaf/fruit ratio as critical factors distinguishing kiwifruit plants as high and low yielders. Principal Component Analysis (PCA) indicated that vine girth, number of canes per vine, and fruit weight are significant contributors to yield, with the first five principal components explaining 79.109% of the variance. Various forecasting models, including linear, quadratic, cubic, compound, power, and exponential, were evaluated for predicting kiwifruit cultivation and production. The cubic model was found the best for forecasting, supported by the Brown's linear exponential smoothing model, which provided reliable future predictions. The findings offer valuable insights for policymakers and stakeholders to enhance kiwifruit production and address the challenges faced by growers in the region.

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