

Impact of Kinnow Production on the Socio-Economic Conditions of Farmers in the Agra Region

Abstract

The cultivation of Kinnow, a hybrid mandarin fruit, in the Agra region has significantly impacted the socio-economic conditions of local farmers. This study examines the effects of Kinnow production on farmer livelihoods in 10 selected villages within the Agra district. Data collected from 100 Kinnow-growing farmers revealed that the crop contributes substantially to income generation, improving the financial stability of farmers. Factors such as landholding size, access to credit, and market linkages influence the profitability of Kinnow orchards. Despite challenges like market fluctuations and environmental conditions, the introduction of Kinnow has provided an alternative source of income for farmers in a semi-arid region. Additionally, this study outlines the costs involved in establishing and maintaining Kinnow orchards, highlighting the initial high investments required, followed by a significant return as orchards mature. The findings suggest that Kinnow production is a viable and profitable agricultural enterprise that can contribute to both economic growth and social development in the region.

Keywords: Kinnow cultivation, Agra district, socio-economic, farmer income, orchard.

Introduction

The most important commercial citrus species in India are the mandarin (*Citrus reticulata*), Sweet orange (*Citrus sinensis*) and acid lime (*Citrus aurantifolia*) sharing 41, 23 and 23 % respectively of all citrus fruits produced in the country. Kinnow, which can be easily identified from a distance by its attractive bright orange colour, is being seen everywhere these days and customers are also buying it in large numbers. (Kumar *et al.*, 2017). Earlier, this fruit was imported from Punjab, but now farmers are cultivating it in many areas of the state and earning good profits. This year (2016-17), it is expected that about 36 thousand metric tonnes of Kinnow will be produced in 1800 hectares in the state. While on one hand it is still time for the local oranges to arrive, on the other hand Kinnow has taken its place in the fruit markets. Many farmers in the state thought about cultivating oranges, but due to the lack of suitable climate for oranges, it was not possible. After this, farmers started cultivating Kinnow.

Kinnow can be cultivated according to the climate of the state. Director, Horticulture and Food Processing Department, UP, said, "At this time, Kinnow is mostly coming to the market. Farmers are growing Kinnow in Hamirpur, Gorakhpur, Kushinagar, Agra, Chitrakoot, Etawah, Jhansi etc. areas of the state. Its fruit is ready in November while no other fruit is available at that time, even oranges are not ready by that time. Anonymous. (2021-22). This is why its demand remains in the markets. Kinnow plant can be planted twice a year. Once in February or March and the second time in July or August. A farmer can earn up to two lakh rupees from one acre in Kinnow cultivation. The best time to pluck the fruit from the orchards is December. After this, it can be plucked till February. Fruit can be produced from a Kinnow tree for 15 years. Along with this, its plant starts bearing fruit in three years. Kinnow plants were planted here one and a half years ago. At present, about eight kinnow plants are planted. These plants will start bearing fruits within one or two years. The production of Kinnow (also known as sweet orange) in Agra region has been an important aspect of the socio-economical condition of the farmers. Kinnow is a major cash crop that is grown extensively in Agra region due to its high demand in the national and international markets. This study aims to analyze the effect of Kinnow production on the socio-

economical condition of Kinnu growing farmers in the Agra region. Phosphorus regulates protein synthesis in plants, because it is a component of the complex nucleic acid structure. Phosphorus is also important in cell division and development of new tissues. (Singh *et al.*, 2022). Presently, development of new varieties for higher yields has reached a plateau and no further increase is achieved unless biotechnological interventions are made. Lodging is the state of permanent displacement of the stems from their upright position. (Archna, *et al.*, 2023). The total reported population is 3.62 million with density of 899/ km² and literacy of 62.60%. The total reported area of the district is 398460 ha, out of which net sown area is 285496 ha and irrigated area is 235063 ha with cropping intensity of 139.51%. Mousumi *et al.*, (2020).

Natural variations and outside factors, such as variations in solar radiation, volcanic eruptions, and natural variability within the climate system, have influenced the Earth's climate throughout its history and contribute to the overall natural variability of the climate system. These changes persist over long periods, frequently spanning decades or even longer. But over the past few centuries, human activity particularly since the industrial revolution has significantly altered the makeup of the atmosphere. In spite of a changing climate, climate-resilient agronomy aims to maintain sustainable food production and stable livelihoods for farmers. (Singh *et al.*, 2023). By fixing atmospheric nitrogen, both in conjunction with plant roots and independently, biofertilizers solubilize insoluble soil phosphates and generate plant growth components in the soil, so contributing significantly to improved soil fertility. (Lokendra *et al.*, 2024).

Materials and Methods

The field experiment was carried out during season of 2019-24 at 10 village in Barauli Aheer block in Agra Region (U.P.). The soils of the district are loam sandy loam ravines and wasteland. The fertility status of the soil is poor to very poor. In this study, data was collected from the Kinnu growing farmers in the Agra region through a structured questionnaire. The questionnaire covered various aspects such as demographic information, land holding size, Kinnu production practices, access to credit, market linkages, and socio-economic condition of the farmers. A total of 100 farmers were selected randomly from the regions who are involved in Kinnu production. The production of kinnow (a type of mandarin orange) in the Agra region has a significant impact on the socio-economic conditions of farmers growing this crop. Here are the key effects: Economic Impact (Income Generation, Diversification of Income, Financial Stability), Social Impact (Improved Living Standards, Community Development, Empowerment and Skills Development, Empowerment and Skills Development) and Challenges and Recommendations (Market Fluctuations, Climate and Environmental Issues, Access to Resources) ect. Agra district is situated in South-West semi-arid zone of UP. It is located at altitude of 27.20 North and longitude of 77.90 easts. River Chambal makes the southern boundary of district and flows from West to East separating district Bhind (M.P) In the North Agra is bounded by districts of Firozabad and Etawah. The average rainfall (annual) of the district is 750 mm. Temperature varies from 4⁰C (During December-January) to 48⁰C (During May-June) respectively. The district is comprised of six thesils, 15 blocks and 904 villages.

Results and Discussion

The results of the study showed that Kinnu production has a positive impact on the socio-economical condition of Kinnu growing farmers in the Agra region. The majority of the farmers (78%) reported that Kinnu production has helped them in increasing their income and improving their livelihood. Moreover, farmers who had larger land holdings and access to credit were found to have a higher income from Kinnu production as compared to the ones with smaller land

holdings and no access to credit. The study also revealed that market linkages play a significant role in increasing profitability for Kinnu farmers.

Study Area: Selected Villages in Agra District.

Table 1 presents data on Kinnow orchards in selected villages within the Agra district, focusing on various parameters, including the number of farmers, land area, plant density, yield, and gross returns. Number of Farmers: Each selected village has 10 farmers engaged in Kinnow cultivation. Area Under Cultivation (ha): The area allocated to Kinnow orchards per village varies, with a range from 5 hectares (Mahua Kheda) to 10 hectares (Barauli Gujar, Tanora Noorpur, and others). The average area cultivated across villages is 7.9 hectares. Plant Density (ha^{-1}): The number of plants per hectare remains constant across all villages, at 333 plants per hectare. Yield per Plant (kg): Yield per plant varies slightly, with a minimum of 85 kg per plant (Mahua Kheda, Samogar) and a maximum of 95 kg per plant (Visarna). The average yield is 88.4 kg per plant. Yield (q/ha): The yield in quintals per hectare fluctuates between 286 q/ha in Barauli Gujar and 300 q/ha in Higot Kheriya, with an average yield of 294.0 q/ha across all villages. Gross Returns: This represents the monetary returns from Kinnow orchards. The highest gross returns are in Visarna (₹ 632700), while the lowest are in Mahua Kheda (₹ 566100).

Table-1 Study Area: Selected Villages in Agra District.

S.No	Selected Village in Agra District	No. of farmers	Growing in Kinnu crop area in ha^{-1}	No. of plant ha^{-1}	Plant ⁻¹ Yield (kg)	Yield. (q/ha)	Gross returns (Rs./ha)
1	Mahua Kheda	10	5	333	85	283	566100
2	Etmadpurmadara	10	8	333	88	293	586080
3	Higot Kheriya	10	7	333	91	300	599400
4	Samogar	10	5.5	333	85	283	566100
5	Nadota	10	7.5	333	90	300	599400
6	Tanora Noorpur	10	10	333	88	293	586080
7	Mehranaharganj	10	8	333	90	300	599400
8	Visarna	10	10	333	95	216	632700
9	Sarbatpur	10	8	333	87	290	579420
10	Barauli Gujar	10	10	333	86	286	572760
	Average	100	7.90	333	88.40	294	588744

On average, the gross returns per village stand at ₹ 588744. Variation in Area and Yield: While the plant density is uniform across all villages, differences in the area under cultivation and the yield per plant contribute to the variation in the overall yield and returns. Villages like Visarna and Higot Kheriya show higher yields per plant, leading to higher gross returns. Impact of Area on Gross Returns: The table suggests that larger areas under cultivation do not necessarily correlate with higher gross returns. For instance, Barauli Gujar, with one of the largest areas under cultivation (10 hectares), has the lowest gross returns due to lower yield per plant and yield per hectare. Consistency in Plant Density: The uniform plant density across all villages indicates a standard practice in orchard management, which helps in comparing the productivity and profitability of different villages on a level field. Gross Return Trends: Villages with higher yield per hectare like Higot Kheriya and Sarbatpur generally show higher gross returns, suggesting that productivity improvements can directly enhance financial outcomes for farmers. These results are in conformity with the findings of Gangwar *et al.*, (2005) and Bhat *et al.*, (2011).

Establishment cost of Kinnow orchard

The Cost structure for the Kinnow orchards in the study region worked out to be about ₹ 55658 per hectare, however there are major components which made significant contributions to this average. The largest cost incurred, which was for the construction of pond, cost (₹ 12865) which is 23.1% of total costs incurred which demonstrates the significance of constructing structures for managing water in the orchard instead. Other important costs consist of that of buying plants (₹ 6358) and preparing the land (₹ 6987), which implies that actual groundwork and planting materials are crucial. Per hectare establishment figure of ₹ 55,658 although daunting could be affordable to big farmers and economically assisted farmers. On the other hand, this could be too much for the tears of small farming units. Government intervention in the form of subsidies or cooperative farming may be necessary to increase the appeal of Kinnow orchards to potential growers. The inclusion of displacement costs and replacement plant costs is not only realistic with respect to the operation of sustaining a fruit orchard over time but also can even help reduce some of the costs incurred.

The overall irrigation costs (₹ 1051) represent a low proportion (1.9%) of the total costs incurred. This figure together with the other cost of in-pond construction integument of the orchard explains the essence of water resources storage and control in dry lands. This shows that there is an agricultural system in place that is meant to protect the water resources of the orchard and maintain its productivity. The high costs incurred in prescription construction of ponds demonstrates the proactive measures in place to control water especially in regions such as Agra that receive scanty precipitation. The farmer is able to insulate himself from the adverse effects of unpredictable rains by putting up a pond, which guarantees a source of water. This is a welcome situation, particularly for the orchard in question, as this investment will pay off for years to come in terms of quantity and quality of the produce. Such strategies are consistent with climate-resilient agriculture that places emphasis of water management.

Table.2 Establishment cost of Kinnow orchard in Agra (Uttar Pradesh)

S. No.	Particulars	Value (₹)/ ha.
1	Preparation of land and lay out	6987
2	Digging and filling of pits	5343
3	Cost of irrigation	1051
4	Cost of plant	6358
5	Cost of replacement plant	965
6	Manures and fertilizer	4737
7	Transportation of plant	4659
8	Plantation cost	2963
9	Intercultural operation	1469
10	Construction of pond	12865
11	Cost of equipment	5874
12	Miscellaneous	2387
	Total	55658

Labor and Machinery Costs: Labor items include those for mechanical works such as digging and backfilling pits (₹ 5343) as well as colony establishment (₹ 2963), and the total of these items is 15 percent of the total costs incurred. This means that there will be much of planting labor required at the early stage of the project. The machinery costs (₹ 5874) also show

that there is need for some level of mechanization and accounted for 10.5% of the total costs. It has been noted that labor costs, including those incurred for such activities as digging and planting, bear a significant cost during the first stage of plantation establishment. It may be an issue in areas with high wages or labor difficulty as all these determinants will present a challenge. Nevertheless, the costs of machines as seen are quite affordable hence it might be possible to minimize the labor requirement especially in tasks that command doing repeatedly such as digging pits or intercultural operations.

Manure, Fertilizers and Sustainability: Another significant component of costs is manures and fertilizers (₹ 4737), which account for 8.5% of the total costs. This feature included in the cost outlay at the time of establishment shows that there is a strategy in place to improve the soil health and also promote early growth of Kinnow plants. One of the main measures for plant production and soil improvement in the early years of the orchard is the timely application of manures and fertilizers. Organic fertilizers should help to reduce the long-term usage of chemicals which has adverse effects on the environment. In addition to this, it is essential to replenishing the nutrient levels in the soil to support the growth of Kinnow plants so that they can root well and produce optimally.

Regional Agricultural Development: There are certain possible advantages towards the development of agriculture in the region with the introduction of Kinnow plantations into the agriculture in Agra region. On one hand, adjusting to the orchard farming may lead to increased crop diversification in the area which in turn can enhance the earnings of the farmers. As a high-value tree borne citrus fruit, Kinnow would also open up better market opportunities for the farmers. Nevertheless, the achievement of this goal is likely to be translated, albeit with caveats, to the presence of a market, post-harvest services, and low-cost management during the time of establishing the orchard. These results are in conformity with the findings of Gangwar *et al.*, (2005) and Bhat *et al.*, (2011) Mousumi *et al.*, (2020)

Operational cost of Kinnow orchard in Agra

Table 3 presents the yearly operational costs involved in maintaining a Kinnow orchard in Agra over the period from 2019 to 2024. The table captures key operational activities, including the application of manure and fertilizers, plant protection, pruning, intercultural operations, irrigation, labor charges, and other miscellaneous expenses.

Manure and Fertilizer: Gradually increases from ₹ 3,127 in 2019 to ₹ 3764 in 2024, reflecting rising input prices and the growing nutrient needs of maturing trees. **Plant Protection:** A significant expense that rises steadily from ₹ 3256 in 2019 to ₹ 3681 in 2024, emphasizing the need for ongoing pest and disease control as the orchard matures. **Pruning and Cutting:** Starts at ₹ 3,411 in 2019, reaching ₹ 3,964 in 2024, necessary for managing tree growth and ensuring healthy production. **Intercultural and Hoeing:** Increases from ₹ 4,847 to ₹ 4,253, indicating the rising labor and maintenance costs associated with orchard management. **Irrigation:** Costs escalate from ₹ 4,498 in 2019 to ₹ 4,791 in 2024, highlighting the importance of water management in sustaining orchard productivity in Agra's climate. **Labour Charges:** One of the most significant cost components, starting at ₹ 5,023 in 2019 and surging to ₹ 10,321 in 2024, reflecting both the intensity of manual work required and the rising cost of labor. **Replacement and Casualty:** Represents the cost of replacing dead or damaged plants, rising from ₹ 1,437 in 2019 to ₹ 2,396 in 2024. **Staking:** Begins only in 2022 with a cost of ₹ 3,500, rising to ₹ 4,192 in 2024, associated with supporting the growth of young trees. **Miscellaneous:** Includes additional small expenses, rising from ₹ 1,724 in 2019 to ₹ 2,785 in 2024. The total operational cost of

maintaining the orchard shows a substantial increase over the years, starting from ₹ 27153 in 2019 and reaching ₹ 39147 by 2024.

The operational costs of a Kinnow orchard in Agra show a sharp upward trend over the years, particularly driven by rising labor charges, plant protection, and irrigation expenses. By 2024, the operational costs escalate almost fivefold compared to 2019, which is indicative of the growing intensity of labor, resource management, and maintenance as the orchard matures. Labor charges stand out as the most significant cost, especially in the later years.

Table-3 Operational cost of Kinnow orchard in Agra Value (₹ /hectare)

Sr. No	Particulars	Years					
		2019	2020	2021	2022	2023	2024
1	Manure and fertilizer	3127	3258	3423	3568	3694	3764
2	Plant protection	3256	3250	3242	3234	3241	3681
3	Pruning and cutting	3241	3481	3173	3245	3741	3964
4	Intercultural and hoeing	4252	4468	4631	4863	4521	4847
5	Irrigation cost	4498	4120	4961	4546	4276	4791
6	Replacement and casualty	1437	1654	2145	2754	2124	2396
7	Labour charge	5023	10413	10421	10323	10531	10321
8	Staking	0	0	0	3500	3800	4192
9	Miscellaneous	1724	1923	2149	2465	2563	2785
	Total operational cost	27153	31467	33445	37398	37791	39147

The leap from ₹ 5,023 in 2019 to ₹ 10,321 in 2024 reflects the high labor requirement for various activities such as pruning, hoeing, irrigation, and other manual tasks critical to maintaining the orchard. This spike could be attributed to increased labor rates and the need for more hands-on management as trees reach peak production. Plant protection costs also increase significantly, demonstrating the growing need to protect the orchard from pests and diseases as it matures. The jump from ₹ 3,256 in 2019 to ₹ 3,681 in 2024 shows that as the trees grow, their exposure to potential risks rises, demanding more resources for protection. Irrigation and intercultural operations represent a substantial part of the overall cost, especially in the context of Agra's semi-arid climate. The increase from ₹ 4,498 to ₹ 4,791 for irrigation and from ₹ 4,253 to ₹ 4,847 for intercultural operations reflects the consistent need for efficient water management and ground maintenance to sustain tree health and productivity. Manure and fertilizer costs also exhibit a steady rise, underlining the increasing nutrient demands of the orchard as the trees mature and require more inputs for sustained growth and fruiting. Pruning and cutting, starting at ₹ 3,241 and reaching ₹ 3,964, further underscore the importance of canopy management as the trees grow. Regular pruning helps ensure that the trees produce high-quality fruit and maintain proper growth. The total operational cost rises dramatically, reaching ₹ 39147 in 2024 from ₹ 27153 in 2019. This significant cost escalation indicates that while initial investments might be lower during the early years of orchard establishment, maintaining a mature orchard requires substantial resources. As the trees reach full production, the higher costs also suggest that the potential revenue from fruit production must offset these operational expenses for the orchard to

be economically viable (Table 3). These results are in conformity with the findings of Gangwar *et al.*, (2005) and Bhat *et al.*, (2011) Mousumi *et al.*, (2020)

Economic Analysis of Kinnow Orchards

Table 4 provides a breakdown of the costs and returns associated with Kinnow orchard cultivation in Agra over the years 2019 to 2024. Maximizing Yield and Returns: There is a noticeable growth in yield per quintal from the years 2021 to 2024 with yield per tree increasing from 58 kg to 85 kg. In this case, there is an increase in yield per hectare, for example 193 quintals in the year 2022 rising to 283 quintals by the year 2024. As a result, returns from Kinnow production jump from ₹ 386,000 in 2022 to ₹ 566,000 in 2024, reflecting the high profitability of mature orchards. Such an increase in revenue is also important to farmers in the long run since it helps in bettering their standards of living. It has been observed that the farmers are benefitting from intercropping and this is an area of their activities that infers income to them, and the orchard is not quite there yet. The figures on the intercropping revenue vary between ₹ 70,422 in the year 2019 and ₹ 76,876 in the year 2024 which assists in ensuring farmers remain their income levels even in the years before the Kinnow trees become fully productive. This practice of applying two crops in one land lowers the chances of losses and generates an important income cushion.

Table.4 Economic Analysis of Kinnow Orchards in Agra Value (₹ / hectare)

Sr. No.	Particulars	Years					
		2019	2020	2021	2022	2023	2024
1	Crop load (fruits/tree)	0	0	0	253	276	450
2	Av. fruit weight (g)	0	0	0	159	168	176
3	Yield (kg/tree)	0	0	0	58	72	85
4	No. of plant ha ⁻¹	333	333	333	333	333	333
5	Yield (q/ha)	0	0	0	193	240	283
6	Price (₹) per Quintal	1600	1700	1800	2000	2000	2000
7	Return from Kinnow	0	0	0	386000	480000	566000
8	Return from inter cropping	70422	72673	75124	70977	73545	76876
9	Gross returns	70422	72673	75124	456977	553545	642876
10	Total Cost of cultivation	27153	31467	33445	37398	37791	39147
	Net Return	43269	41206	41679	419579	515754	603729

The gross returns as well as the net returns display an upward trend – which is more pronounced as from the year 2022 when the orchard is at that time embarking on heavy production. In 2024, net return per hectare is estimated at ₹ 603,729 which is an enormous increase from the previous periods. This shows that when the orchard is properly managed and established then the chances of making profits are very high which means that the farmers are able to benefit greatly economically. As explained in the establishment phase, the expense of investing in Kinnow orchard (₹ 55,658) in addition to the recurring expenses of maintenance tends to stretch the finances particularly in the first few years (2019-2021) which do not yield any productivity. Farmers do not earn anything out of Kinnow itself during these years and so they practice intercropping or depend on other means of livelihoods. Most small farmers may fear venturing into Kinnow farming due to the long waiting periods before any money starts trickling in unless there are some financial supports or bailouts.

Kinnow price has shown an increasing trend where in price per quintal for Kinnow was ₹ 1,600 in 2019 and increased to ₹ 2,000 in 2022 which is a few years of market rise. On the

other hand, the price offered in markets does not always remain stable and can be affected by several external factors such as equitable distribution of supply and demand, competing playing fields of other citrus fruits, and climatic seasons. Such varying conditions may impact yields, as they tend to rely on how the markets perform to get better chances of fortune. Various environmental aspects including rainfall patterns, temperature ranges, as well as plant resistance to diseases and insects, are likely to have adverse effects on Kinnow production. For instance, irregular rainfall coupled with poor irrigation system may result to poor growth or lower Kinnow production. Also, the occurrence of pests may escalate the cost of farming activities as a portion of the expenditure will go to acquire pest control measures resulting in less profit.

Factors Influencing Profitability:

Introduction of optimal management techniques such as conserved irrigation schedules, nutrient and pest control timing, and other crop husbandry practices significantly impacts yield and returns. Farmers who are in a position to use such agronomic inputs including irrigation infrastructure are likely to be more profitable as opposed to those who cannot utilize such resources who are likely to be less productive and profitable. Efficient post-harvest handling of Kinnow fruits that ranges from harvesting, storing, processing, transporting and selling them at the opportune moment is essential of achieving better prices in the market. The unavailability of appropriate storage infrastructure results in wastage of products after harvest particularly at times of high harvest volumes and low market prices where access to the market is so easy. Such Farmers who have links to cold storages, available transport systems and vast markets would be able to accrue more profits. The provision of grants, financial assistance, or any form of government support towards small scale farmers can act as a reward for embracing Kinnow growing. The combination of supportive policies that alleviate the financial stress of the farmers when establishing Kinnow orchards, provision of technical expertise, and markets, can help transform the livelihood of farmers.

Market Price Fluctuations: Although there is an increase in price per quintal Kinnow fruit from ₹ 1,600 in 2019 to ₹ 2,000 in 2022 and tends to remain constant, the level of profitability is very sensitive to changes in the market price. Factors such as the balance of demand and supply, the ability to export, and the overall amount consumed within the country affect the pricing. If the prices fall due to excess supply or low demand, the farmers' margins would be negatively affected. This is, however, why it is very important that prices do not fluctuate and the market stay favorable in order for profits to be consistent.

Water Availability and Climate Risks: Ponds and horizontal expansion whereas Kinnow expenses are incurred to erect the irrigation system. It emphasizes water management in Kinnow farming. However, weather variations such as unpredicted rainfall and high temperatures remain a danger. Such risks will have to be handled by farmers through enhanced irrigation systems (drip irrigation for example), rain harvesting and improving management of the pests. Practices that are resistant to climate change should be promoted to reduce the effects of environmental changes.

Socio-Economic Consequences:

Impact on Small Scale Farmers: Kinnow growing has a very attractive financial profit potential; however, the financial aspects especially in the first years would be somewhat challenging for those small-scale farmers. Most of the Kinnow farmers will lack the ability to finance large establishment and maintenance expenditures due to lack of returns within the first

three years. This situation emphasizes the need for government support in the form of subsidies, loans, or even the establishment of Kinnow growing cooperatives for the small holder farmers.

Implementation of Intercropping For Income Generation: Intercropping is one of the ways a farmer can overcome the burden caused by the years that do not produce any income. For example, this system helps farmers grow different crops and generates income while waiting for the trees to mature. It also mitigates the risk of completely relying on Kinnow yield in the first few years of the establishment. With the active implementation of these policies, intercropping practices do not become a barrier for many farmers venturing into orchards farming.

Policy and Institutional Framework: Need for Government and Institutional Support: In view of the higher initial investment and the delay in returns, government support in the form of subsidies, grants, credits, etc. becomes important. Alongside, agronomic training, technical assistance, and marketing support would be very important in helping the farmers cope with the various challenges of Kinnow production, ensuring better returns. Additionally, extension services oriented towards sustainable agricultural practices, efficient water usage, and access to markets will be of additional benefit.

Market Infrastructure and Export Potential: Market infrastructure such as cold chain facilities, processing units, and transportation will encourage farmers on Kinnow production. Kinnow fruit export markets, which are on the rise especially in countries where the demand for citrus fruits is on the upsurge, would give a chance for an increased profitability for the farmers. It is these opportunities that Government policies that promote the initiatives of exports, cut down on the cost of logistics, and enhance the management of the produce after harvesting will be useful in realizing. These results are in conformity with the findings of Gangwar *et al.*, (2005) and Bhat *et al.*, (2011) Mousumi *et al.*, (2020)

Profitability Analysis:

Initial Losses and Investment: During the establishment phase (2019-2021), the orchard faces net losses because of the non-productive phase of Kinnow trees. While there are returns from intercropping during these years, they are insufficient to cover the high operational costs, such as labor, irrigation, and plant protection. This period represents the initial investment needed to establish the orchard, and losses are expected as the trees do not yet bear fruit.

Turning Point in Year 2022: The turning point arrives in 2022 when the Kinnow trees begin bearing fruit, leading to a significant increase in returns. By this year, the orchard produces a yield of 193 quintals per hectare, and the crop load per tree reaches 253 fruits, contributing to a gross return of ₹ 456977. Despite the still-high cost of cultivation (₹ 37398), the orchard achieves a net return of ₹ 419579. This marks the start of the orchard's profitability, as revenues from fruit sales finally surpass the costs.

Rapid Growth in Profit (2023-2024): By 2023, the orchard reaches a productive phase with increased yields and higher fruit prices. The yield per hectare grows to 240 quintals, and the price per quintal of Kinnow increases to ₹ 2,000. This results in a gross return of ₹ 553545, with a net return of ₹ 515754 after deducting cultivation costs (₹ 37791). This trend continues into 2024, where the orchard reaches its full potential. With a yield of 283 quintals per hectare and a price of ₹ 2,000 per quintal, the gross returns reach an impressive ₹ 642876. Despite the increasing cost of cultivation (₹ 39147), the net return peaks at ₹ 603729.

Economic Viability:

The data reveals that Kinnow orchards become highly profitable once they enter their productive phase. By 2024, the high net return of over ₹ 642876 per hectare indicates that the initial losses and operational costs are more than compensated by the orchard's yield and market

prices. The consistent increase in fruit prices further enhances the orchard's profitability, making it a lucrative venture in the long term.

Factors Contributing to Profitability:

Increased Yield: As the trees mature, their ability to produce larger crop loads and heavier fruits significantly boosts the yield per hectare. The jump from 193 quintals in 2022 to 283 quintals in 2024 underscores the importance of orchard maturity for maximizing production.

Rising Market Prices: The sharp increase in the price per quintal, from ₹ 1,600 in 2019 to ₹ 2,000 in 2024, plays a crucial role in enhancing profitability. Favorable market conditions, combined with quality fruit production, ensure that the orchard can command higher prices in the market

Initial Losses and Investment: During the establishment phase (2019-2021), the orchard faces profit because of the non-productive phase of Kinnow trees. While there are returns from intercropping during these years, they are sufficient to cover the high operational costs, such as labor, irrigation, and plant protection. This period represents the initial investment needed to establish the orchard, and profit is expected as the trees do not yet bear fruit. **Sustained Costs:** Although the cost of cultivation rises each year, particularly due to labor, plant protection, and irrigation, the corresponding rise in yields and prices offsets these increases. Efficient management practices can further optimize costs and improve profitability. **Intercropping as Supplementary Income:** During the non-productive years, intercropping provides a valuable source of supplementary income, helping to mitigate some losses. While intercropping income decreases in later years (as Kinnow production becomes the primary focus), it still contributes to overall returns, especially in the initial years. These results are in conformity with the findings of Gangwar *et al.*, (2005) and Bhat *et al.*, (2011) Mousumi *et al.*, (2020)

Conclusion:

The study highlights the transformative role of Kinnow cultivation in improving the socio-economic conditions of farmers in the Agra region. Kinnow has emerged as a highly profitable cash crop, especially in areas where traditional crops face climatic limitations. Despite the initial high costs of establishing orchards, including land preparation, irrigation setup, and plant procurement, the long-term benefits far outweigh the investments. Farmers who adopt proper management practices, leverage market linkages, and secure access to credit enjoy higher returns, as evidenced by increased yields and substantial gross income over time. The success of Kinnow production not only boosts individual income but also enhances community development by providing employment opportunities and fostering skills in horticulture. However, challenges like fluctuating market prices, climate vulnerabilities, and resource accessibility remain critical concerns that need addressing to sustain growth. By overcoming these challenges and promoting best practices, Kinnow cultivation can continue to drive economic development and improve the quality of life for farmers in Agra, making it a promising avenue for agricultural diversification in semi-arid regions.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Details of the AI usage are given below:

1.

2.

3.

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