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RESEARCH ARTICLE

Evaluating Soil Fertility, Management Practices, and Economic Viability of Arabica Coffee: A Comparative Study from Nagaland, India

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Abstract

Coffee is becoming an important income-generating crop for smallholder farmers in Nagaland. Nagaland coffee is known for its unique high-quality characteristics, but limited documentation is available about the status of its production. This survey investigated the soil physico-chemical properties, management practices, coffee yield, and income generation during 2020 to 2022 in Khar village and Veyili Keyiqha (V. K. area). Data were collected from 20 farmers through on-site field visits and personal interviews with farmers. Results showed that farmers in both locations practiced organic farming of Arabica coffee. The soil texture in both locations was found to be either loamy sand or sandy loam. Soil pH was found to be acidic. Soil available nitrogen in Khar village ranged from low to medium and very low to low in the V. K. area. Farm size was similar, with an average of 0.87 ha. Expenditure was greater in Khar with an average of ₹13400 spent mainly for labour cost and sapling purchase. Net income during the year 2020 – 2022 was similar between locations, with an average of ₹77200 ha⁻¹. In Khar, the average coffee yield of 522 kg ha⁻¹ in 2020 and 2021 was greater than the yield in 2022, 126 kg ha⁻¹. Coffee yield in V. K. was similar for all three years with an average of 385 kg ha⁻¹. Results from this study suggest that proper management practices and improving soil nutrient status are crucial to potentially increase coffee productivity for smallholder growers in the study areas.

Keywords: Arabica coffee, Nagaland coffee, Organic coffee, Smallholder farmers.

Introduction

Coffee is one of the widely recognised beverages all over the world (Davis *et al.*, 2012). As the second most transacted commodity in the world market, coffee plays a vital role in supporting the economies of more than 80 developing countries (Bongase, 2017; Santaram, 2018). The world coffee trade is dominated by two species: *Coffea arabica* L. (Arabica coffee) and *Coffea canephora* Pierre ex A. Froehner (Robusta coffee) (Bongase, 2017).

During the 1980s, the Nagaland Plantation Crops Development Corporation (NPCDC) collaborated with the Coffee Board of India in establishing coffee plantations in the state (Moa and Chakraborty, 2022). However, because of limitations in connectivity between the producer and the coffee market, NPCDC abandoned the plantations, leading to a decline in coffee farming in the state (Moa and Chakraborty, 2022). In 2015, the Department of Land Resources, Nagaland, partnered with the Coffee Board of India to revive and promote coffee production (Tseikha and Mere, 2019; Moa and Chakraborty, 2022). The Land Resources Department has sought to provide market support to coffee farmers by collaborating with the Nobel Cause Company (Pvt. Ltd), South Africa, for which a Memorandum of Agreement was signed between the company and the department to facilitate the sale of coffee produce,

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thereby enhancing the economic prospects for the farmers (Directorate of Land Resources, 2020).

An estimated 10,40,100 ha accounting for 63% of the state's total geographical area is considered suitable for coffee plantation in Nagaland (Tseikha and Mere, 2019; Moa and Chakraborty, 2022). The current coffee growing area in Nagaland stands at 6,180 ha, encompassing both Arabica and Robusta verities (Tseikha and Mere, 2019). This area is expected to increase over the coming years. The emphasis of reviving coffee farming in Nagaland is to encourage specialty organic coffee-based employment for farmers and

to promote conservation and mitigate widespread practice of shifting cultivation or jhum (Tseikha and Mere, 2019; Kiho, 2020). Nagaland coffee has great potential in the coffee market owing to its unique citrus flavour, and demand for Nagaland coffee in the market is steadily rising (Moa and Chakraborty, 2020).

Although Nagaland coffee is becoming more prominent in the local market and talks about coffee trade with non-local partners, little has been documented about its production and management aspects. This study was conducted to understand the production aspect from the farmers' perspectives in two coffee-growing areas in Nagaland, Khar village and V. K. area. The objectives of this study were (i) to determine the physico-chemical properties of soil at the coffee production sites, (ii) to conduct a comparative survey on cultivation and management practices employed by the farmers, (iii) to evaluate the coffee yield and (iv) to estimate the expenditure and income of coffee production at the two study locations.

Materials and Methods

Study site and design

The study was conducted in two areas: Khar village (26.46°N, 94.46°E) under Mokokchung District and V. K. area under Zunheboto District. The locations selected for the V. K. area were Litta New (26.16°N, 94.38°E), V. K. Hq (26.17°N, 94.41°N) and Phushimi village (26.15°N, 94.41°E). The study was conducted through a survey method and personal interviews with the farmers. Semi-structured interview method, including open-ended questions, was used for the collection of data (Newing *et al.*, 2011; Kallio *et al.*, 2016). An interview protocol was prepared based on research objectives and the same protocol was used with all the interviewees. Interviews were conducted in the local dialect and a follow-up telephonic interview was conducted where clarification was needed at the time of data processing. During the interview, notes were taken, interviews were audio recorded and transcripts were prepared. Free, prior and informed consent was obtained from all participants. A sample size of 10 farms each was randomly selected in both study sites that have been producing coffee for at least 3 years. Field surveys were carried out in 2022. Khar village and V. K. area were selected because these two locations are among the oldest coffee plantations, dating back to 1982 and export a significant volume of coffee at both national and international levels.

Data Collection

Quantitative data were collected on farm area, number of trees per hectare, plant spacing, coffee yield, expenditure and income. The size of the farm, number of trees and plant spacing were determined by inquiring with the farmers based on their approximation, taking into consideration their extensive experience in their farms over the years. Coffee yield was collected from the farmers for each year from 2020 to 2022. Estimation of income and expenditure was performed by collecting data on the number of labourers employed for weeding, the number of working days, labour cost for harvesting and processing, transportation, sapling purchase and income from the sale of harvested coffee. Qualitative data were collected on the field management practices, including nursery management, transplanting, manuring, pruning, weeding, disease management, and post-harvest management, including harvesting, coffee processing and storage.

Soil Physico-chemical Properties

Soil samples were collected from both the Khar village and the V. K. area to test the soil physico-chemical properties. Four random samples were taken from each field. In each field, multiple soil samples were collected from a depth of 0 to 15 cm. The samples were mixed homogeneously, and representative sub-samples were transferred to labelled sample bags. The soils were air-dried and their physicochemical properties were determined. The soil texture was analysed using the hydrometer method (Bouyoucos, 1962). The percent clay was calculated by taking the hydrometer reading at 6 hours 52 min multiplied by 100 and dividing by the weight of the sample. The percent silt was calculated by taking the corrected hydrometer reading at 40 seconds, multiplying it by 100, then dividing by the weight of the sample and subtracting it from the percent clay. The percent sand was calculated by subtracting the resultant value of percent silt and clay from 100. The pH reading and electrical conductivity of each soil sample were recorded using a digital multiparameter pH, EC meter (LABMAN, LMMP30) following protocols by Estefan *et al.* (2013). Air-dried soil of 20 g was dissolved in 40 mL of deionised water. The solution was carefully mixed and was then allowed to stand for 1 hour. The pH meter was calibrated using pH buffers of 4.00, 7.00, and 10.00 and the pH was recorded. For measuring electrical conductivity, air-dried soil of 10 g was dissolved in 50 mL of distilled water, mixed thoroughly, and then allowed to settle for 1 hour. The conductivity meter was calibrated using KCl solution. The temperature was adjusted to 25°C. The temperature probe and conductivity probe were inserted into the soil sample, and the conductivity reading was recorded for each soil sample. Air-dried soils were sent to the Soil and Water Conservation Department for testing the content of NPK and organic matter. Available N, P and K were determined using the Kjeldahl method (FAO, 2021), Bray's method (Bray and Kurtz, 1945) and flame photometer (Skoog *et al.*, 2000), respectively, and organic carbon was determined by the rapid titration method (Walkley and Black, 1934).

Statistical Analysis

The farm size, net income and expenditure between Khar village and V. K. area were analysed using a *t*-test in Microsoft Excel (Microsoft 365, Microsoft Corp., Redmond, WA, USA). The yield of coffee and gross income were analysed using two-way analysis of variance in Microsoft Excel (McHugh, 2011). The independent variables were location and year and the dependent variables were coffee yield and gross income. The homogeneity of variance was tested using Levene's test. Mean comparisons were performed using the Tukey-Kramer test. Simple linear regression was performed to find the relationship between the farm size and coffee yield and yield versus net income.

Results and Discussion

Cultivation History and Planting Density of Arabica Coffee

The type of coffee grown in both locations was identified as Arabica coffee. In Khar village, 80% of the fields were planted in 1982 and the rest in 2017. In the V.K. area, 40% was planted in 1982, 30% each was planted in 1986 and 2017. The planting density was about 2600 and 2500, respectively, for the Khar and V. K. area. This density is lower than the recommended density for optimum coffee production for Arabica coffee elsewhere (DaMatta *et al.*, 2008). Given that Arabica coffee is an upland species known to grow in a wide range of elevations, it was found to be suitably grown at Khar village and V. K area located at an elevation ranged from 785 to 974 m (Teketay, 1999).

Soil Physical and Chemical Properties

Seven parameters of soil physico-chemical properties were determined from the coffee production areas of Khar village and V. K. area (Table 1). The soil texture in both locations was found to be either sandy loam or loamy sand. The soil pH of both the locations was found to be acidic, ranging from pH 4.0 – 6.3. While the majority of the farms had pH greater than pH 5.0, but 20% of the farms across location had pH lower than 5.0. This indicates that most of the farms are within the favourable pH range of 5.0 – 6.5 for optimal coffee yield (Teketay, 1999; Massawe and Mrema, 2017). The electrical conductivity (EC) in both locations was low, ranging from 0.02 – 0.06 dS m^{-1}, despite most plantation consist of old stands. Across both locations, 30, 40 and 30% of the farms exhibited high, medium and low soil organic carbon content, respectively, ranging from 4 – 11.7 g kg^{-1} soil. The low to medium organic carbon content together with low soil pH in most sites is likely because most of the farms were planted as early as 1982 and 1986 and long term monocropping of coffee is reported to increase acidity and reduce organic matter content (Zhao *et al.*, 2018).

Nitrogen is an essential nutrient required in large quantities for optimum coffee production (Melke and Ittana,

Table 1: Soil physical and chemical characteristics evaluated from coffee production sites of Khar village and V. K. area. The mean and standard deviation (SD) were calculated from ten samples at each instance.

Soil properties	Khar village	V.K. area
Texture	Loamy sand (90%)	Loamy sand (30%)
	& Sandy loam (10%)	& Sandy loam (70%)
pH	4.0 – 6.3	4.4 – 6.2
Mean & SD	5.51, 0.67	5.19, 0.55
Electrical conductivity (dS m^{-1})	0.02 – 0.06	0.02 – 0.04
Mean & SD	0.04, 0.01	0.03, 0.007
Nitrogen[1] (kg ha^{-1})	225.72 – 288.72	200.64 – 238.26
Mean & SD	252.02, 26.07	221.96, 13.28
Phosphorus[2] (kg ha^{-1})	22.96 – 180.37	23.98 – 297.73
Mean & SD	53.73, 47.32	90.85, 95.75
Potassium[3] (kg ha^{-1})	82.238 – 1150.65	89.93 – 1076.224
Mean & SD	333.21, 324.72	269.27, 316.32
Organic carbon[4] (%)	0.4 – 0.95	0.43 – 1.17
Mean & SD	0.65, 0.23	0.63, 0.24

[1]Very low < 222 kg ha^{-1}, low = 222 – 277 kg ha^{-1}, medium = 277 – 556 kg ha^{-1}; [2]low < 36 kg ha^{-1}, medium = 36 – 68 kg ha^{-1}, high >68 kg ha^{-1}; [3]low <100 kg ha^{-1}, medium = 100 – 200 kg ha^{-1}, high >200 kg ha^{-1}; [4]low <0.5 %, medium = 0.5 – 0.75 %, high >0.75 %.

2014). However, N content in Khar was in the low to medium range, while in the V. K. area, it was found to be very low to low. The occurrence of very low to low ranges of soil N content is likely due to organic approach of coffee production without any external fertiliser input in both locations. Similar instance of low N content was reported among Ethiopian farmers in traditionally managed coffee farms (Melke and Ittana, 2014). The medium N content in some farms could be attributed to the accelerated breakdown and mineralization of organic matter as the farms with medium N were found to have high organic carbon content (Massawe and Mrema, 2017). Across the study locations, 50% of the farms had low available P content. Low content of P could be due to the fixation of P into unavailable forms (Trelo-Ges *et al.*, 2010). Furthermore, low available P accompanied with low pH may cause P related yield loss as P uptake by plant is restricted in acidic soils (Takala, 2019). Across both the study locations, the low content of available K was found only in three farms. The medium to high content of K might be due to weathering action of soil minerals and release of K from residues and vegetation left as mulch after weeding and pruning for decomposition (Kassa *et al.*, 2021).

Management Practices

Nursery management

Out of the total of 20 farmers interviewed, only three farmers were reported to maintain nurseries; one from Khar and the

other two from V. K. area. These farmers maintained nurseries out of personal interest and with the vision to expand and promote the coffee plantation. In both locations, seeds for maintaining the nurseries were procured from Kerala at a price of ₹ 500 kg⁻¹. In Khar, nursery was maintained in the year 2021 while in V. K. area, it was maintained in both 2021 and 2022. Seedlings were maintained in polybags in polyhouse environment. In Khar, preparation for sowing the seeds was done by collecting the topsoil and removing the stones and the finely cleaned topsoil were mixed with sand. The sand was added to ensure that seedlings could be uprooted easily without root damage. The heterogenous substrate was laid evenly on the soil and the seeds were sown. In contrast, in V. K. area, preparation was done by mixing topsoil, cow dung and vermicompost. In both locations, two leaves typically emerged after 40 – 45 days, making the ideal stage for transplanting the seedlings into polybags.

Transplanting
In Khar, the seedlings were transplanted in the month of June or July, while in V. K. area, seedlings transplanted in May or June. Transplanting is performed to coincide with the start of rainy season so that sufficient moisture is available naturally for the young plants to establish and develop roots before the commencement of the dry season. Transplanted seedlings were procured by the farmers from their own source, and some seedlings were received from the Department of Land Resources, Nagaland. There was no instance of planting new seedlings to replace the old stand in the study sites during the time of data collection. However, some farmers sold established seedling to other villagers looking to establish new plantations. Regarding pit preparation, 90% of farmers in Khar maintained a pit size of 40 cm³ and 10% of the farmers maintained 43 cm³ pit size. While in V. K. area, all ten farmers maintained 45 cm³ of pit size. The planting distance between the pits were 182 cm and 213 cm in Khar village and in V. K. area, a planting distance of 213 cm was maintained. The planting pits were usually prepared 20 – 30 days and 2 – 3 months before transplanting in Khar and V. K. area, respectively. The pits were usually prepared prior to transplanting to allow the soil to settle back into place and regain its stability. In Khar village, adding manures into the pit was not practiced due to its labour-intensive nature. While in V. K. area, a month after digging, topsoil was added into the pit to increase fertility.

Pruning and weeding
Pruning was practiced in both Khar and V. K. area, typically performed twice or thrice a year to maximise yield. Coffee plants were maintained at a height of 152 cm; once it attains the required height, the top of the branches was snapped off by hand to facilitate easier harvesting and management. Vertical shoots which emerge from the pruned stem were removed to maintained only a single stem. Whereas horizontal shoots emerging from the pruned stem were retained to provide new branches for future growth.

In Khar, weeding was done three to four times annually, while in V. K. area, it was performed two to four times. In both locations, weeding was exclusively carried out by female labourers, as the cost was lesser than those of male labourers. Both hand weeding and slash weeding were practiced at both locations. Slash weeding was carried out by removing the weeds with the help of grass cutter or sickle. Mulching was practiced by only two to three farmers in each location. This practice involves covering the top with organic residues; specifically, weeded grass was repurposed as mulch in both locations.

Disease and pest management
The coffee stem borer was the only pest observed in both the locations. According to the farmer's, the pest was identified as the white stem borer. The infestation usually first appears on the stem, evidenced by a small entry hole which can be seen upon close inspection. The borer gradually infects the other parts of the plant and shows symptoms like yellowing of leaves, dropping of leaves, drying of branches and stunted growth. In severe cases, the coffee plant may experience dieback where entire branches or parts of the plant die and fall off. Based on farmers' observations, the difference between the healthy and the borer infested plant shows no major differences unless the infestation is severe. Invagination of the coffee stem by the stem borer was observed in unshaded areas. In the study areas, stem borer infection had been noticed occasionally in the month of March, during rainy season or in some cases at any time of the year with no specific time or season of symptom appearance. According to the farmers, stem borer can infect any part of the stem. In both the Khar and V. K. area, the infected plants were controlled and managed by wrapping polythene around the borer infected portion up to 2- 3 feet long. This restricts the air entry leading to its suffocation and death. An alternative indigenous method adopted by the V.K. farmers to control the stem borer infection involves cutting the lower portion of the stem, applying ash to the cut surface and covering it with polythene. After a week, the wrapping is removed which encourages the emergence of new shoots. Another method is to completely uproot the entire plant and burn it immediately. Altogether the infected plants thus far observed in each farm were less than 10, according to the farmers' estimation. There was no instance of any replanting to recover the infected plants in both the Khar and V. K. area.

Post-harvest Management

Harvesting, processing and storage
The berries which ripen first (November) are from the first bloom (February/March) and the berries which ripen late

(January) are from the last bloom (April/May). The fruits take 7 – 9 months for its complete ripening. In both locations, the berries were hand harvested as it involves selective picking. The time of harvest varies between Khar village and V. K. area. In Khar, harvest starts from November to February/March, while in V. K. area, it starts from November and ends in January. The difference in harvest duration between Khar village and V. K. area is likely because of differences in method of coffee processing that necessitate either harvesting of only ripe or mixture of both ripe and the half ripe berries. In Khar, only the wet method of processing was practiced and only the fully ripe berries were harvested and thus it takes around 4 – 5 months for the berries to ripen completely for the last harvest. In V. K. area, both dry and wet processing methods was practiced. For dry method, semi-ripe berries were harvested for processing. Thus, harvesting of both the ripe and the semi-ripe berries shorten the month of harvest which takes only three months (November – January) in V. K. area as compared to Khar.

In dry method, instead of removing the outer pulp as in wet method, the entire berries including the pulp were dried out in the sun on tarpaulins, bamboo woven mats or on drying plates. Drying takes around 2 – 3 weeks depending on solar intensity. The dried coffee beans thus obtained by dry method are called as cherry coffee. Whereas in wet method the harvested ripe berries were placed in water; the defective berries are removed. The healthy, sinking berries were then pulped in pulping machine. These beans were then soaked in water overnight to eliminate the mucilage layer-a process often facilitated by natural fermentation. The soaked beans were washed and further soaked in water until the sticky mucilage is completely removed. Rainwater was used for processing the coffee. The processed coffee beans thus obtained through wet method are called as parchment coffee. The parchment coffee was then dried in the sun on tarpaulins, bamboo woven mats or on drying plates for 2 – 3 days or more depending on solar intensity. Extended periods of rainy weather can slow down the drying process. According to farmers in both Khar and V. K. area, the fore most factor to take into consideration while drying is that the beans should be spread evenly to obtain uniform drying. The dried coffee beans were stored in jute sacks to prevent moisture formation and were kept in a dry safe area away from sunlight. The stored beans were kept for 2 – 3 months until the buyers arrived for collecting it.

Farm size and yield of coffee

The farm size for Khar and V. K. area was statistically not different (Table 2 & 3). Across location, the average farm

Table 2: Significance for t-test and ANOVA for dependent variables of farm size, expenditure, net income, gross income, and yield tested for coffee farms at Khar village and V.K. area during 2020 to 2022 coffee production seasons.

Test statistics	Source of variation	Dependent variable				
		Farm size	Expenditure	Net income	Gross income	Coffee yield
				p-value		
t-test	Khar vs V.K.	0.26^{ns}	0.003^{*}	0.413^{ns}		
ANOVA	Location				0.562^{ns}	0.938^{ns}
	Year				0.413^{ns}	0.007^{*}
	Location x Year				0.011^{*}	0.010^{*}

^{ns} not significant, *significant at $P \leq 0.05$.

Table 3: Means comparison of coffee farm area, annual expenditure and net income between Khar and V.K. area; gross income and coffee yield as affected by location by year interaction.

Dependent variable	Location	Farm area (ha)	Annual expenditure (₹)	Net income (₹)
	Khar	$0.73\ a^{1}$	13400 a	68200 a
	V.K. area	1.01 a	5200 b	86200 a
		Year		
		2020	2021	2022
Gross income (₹)	Khar	94400 aAB	119000 aA	31500 bB
	V.K. area	91500 aA	72500 bA	110100 aA
Coffee yield (kg/ha)	Khar	472 aA	572 aA	126 bB
	V.K. area	362 aA	408 bA	386 aA

[1]Within a column, treatment means followed by different lowercase letters are statistically significant at $P \leq 0.05$. Within a row, treatment means followed by different uppercase letters are statistically significant at $P \leq 0.05$.

size was 0.87 ha (Table 3). The smallest and the largest farm size across location was 0.40 and 2.02 ha, respectively. The farm sizes in both the locations varies depending on the availability of land belonging to the farmers. In Khar, coffee cultivated area is a mix of private and village clan ownership. While in V. K area, all the cultivated areas are privately owned.

The coffee yield was influenced by the interaction effect between location and year (Table 2 & 3). In Khar, yield was similar in 2020 and 2021, averaging 522 kg ha^{-1}, but significantly lower in 2022 with 126 kg ha^{-1} (Fig. 1). Conversely, yield in V. K., remain consistent across three years, averaging 385 kg ha^{-1}. In 2020, yield of coffee was similar between Khar and V. K. with an average 417 kg ha^{-1}. In 2021, the yield was 572 kg ha^{-1} in Khar which was greater than V. K. by 163 kg ha^{-1}. V. K. area had greater yield than Khar by 260 kg ha^{-1} in 2022. In Khar, the yield of coffee was similar between 2020 and 2021 but was lesser in the year 2022. The lower yield of coffee in 2022 could be due to climatic condition where the farmers have encountered inconsistent rainfall pattern in the month of March, 2022. Shortage of seasonal rainfall is known to reduce yield of Arabica coffee production in other coffee producing areas (Wang *et al.*, 2015). The total yield of coffee for both the Khar and V. K. area during the year 2020 – 2022 was estimated to be 19.25 Mg which is greater than the average yield of Arabica coffee production in Nagaland, estimated to be 14.46 Mg during the year 2019 (Moa and Chakraborty, 2020).

The average total yield of coffee for Khar and V. K. area, during the year 2020 – 2022 was 388 kg ha^{-1} which is 44, 29 and 20% lesser than the Arabica coffee production in Karnataka, Kerala and Tamil Nadu, respectively, during the year 2017 – 18 (Vidya, 2018). The lower yield of coffee may be attributed to low plant density, age of the plant and low NPK content in coffee farms of Khar and V. K. area. Low plant density and poor soil nutrient status were reported to cause limitation to Arabica coffee yield in other coffee production systems (Wang *et al.*, 2015). The average coffee yield during 2020 – 2022 in the study location showed a positive linear
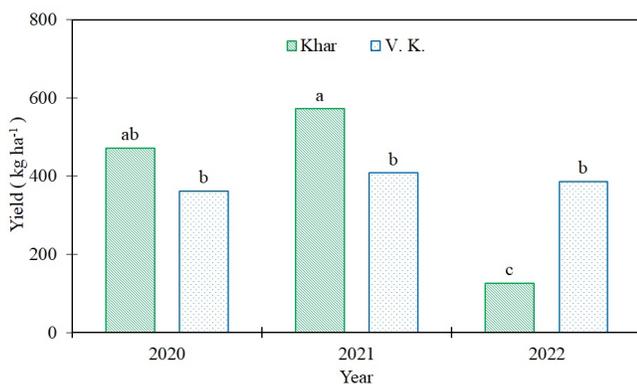
relationship with the number of plant stand (Fig. 2). This relationship was stronger in Khar with 88% of the variability in yield explained by the variations in number of trees stand.

Marketing
The coffee produced in Khar was only parchment coffee. While for V. K. area, both parchment and cherry coffee was produced. Coffee collected from all the farmers were sold in bulk to the same buyer in both the Khar and V. K. area. Coffee beans from both the Khar village and V. K. area, for the year 2020 and 2021 were exported to South Africa and Chennai. In 2022, coffee from both Khar and V. K area was taken by the Zizira company from Meghalaya. In Khar village, the price for parchment coffee for the year 2020, 2021 and 2022 was ₹ 200, ₹ 190 and ₹ 250 kg^{-1}, respectively (Table 4). While for V. K. area, the price for cherry coffee for the year 2020 and 2021 was ₹ 110 and ₹ 150 kg^{-1} for the year 2022. Out of the total 10 farmers interviewed from V. K. area, 2 farmers sold parchment coffee at a rate of ₹ 480 and ₹ 200 kg^{-1} for the year 2020 and 2021, respectively. While the remaining 80% farmers sold parchment at a rate of ₹ 200 and ₹180 kg^{-1} for the year 2020 and 2021 (Table 4). The variation in price observed over the years 2020, 2021 and 2022 can be attributed to marketing factors, where the coffee for each year was exported to different places i.e., South Africa, Chennai and Meghalaya. Coffee exported from both the Khar village and V. K. area during the year 2020 – 2022 was 19.25 Mg.

Income and expenditure
The gross income generated was from the sale of both saplings and coffee beans. The gross income was influenced by the interaction effect between location and year (Table 2; Fig. 3). The gross income in Khar was similar between 2020 and 2021 with an average ₹ 106,700 ha^{-1} and the gross income was lesser in 2022 with ₹ 31,500 ha^{-1}. In V. K., the gross income was similar between 2020 and 2021 with an average of ₹ 82,000 ha^{-1} and was highest in 2022 with ₹ 110,100 ha^{-1}. In 2020, the gross income was similar between Khar and V.

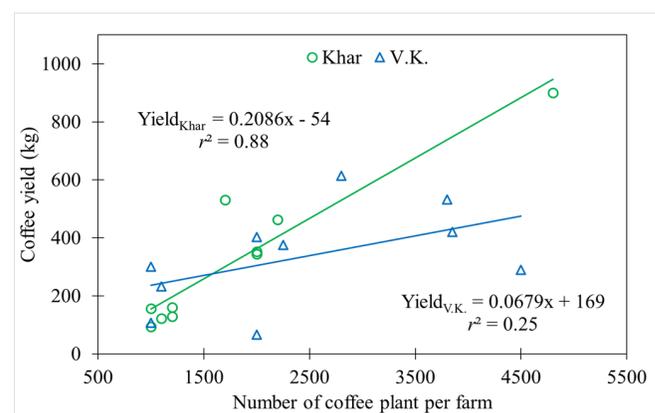**Fig. 1:** The yield of coffee at Khar village and V. K. area for the year 2020 – 2022. Different lowercase letters above the bar indicates statistical difference at $P \leq 0.05$.
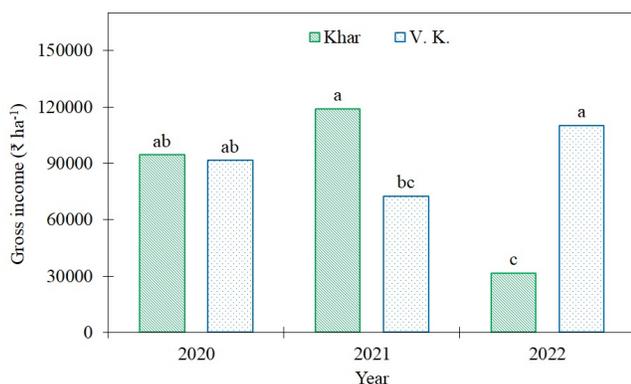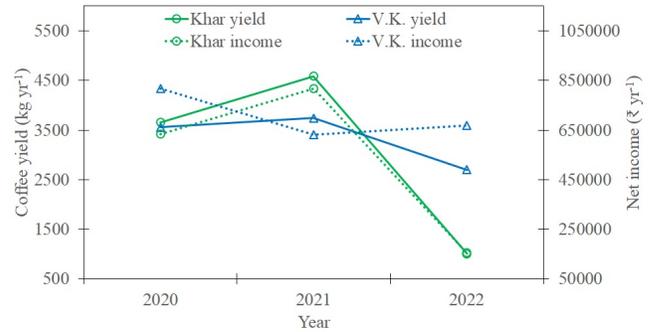

Fig. 2: Relationship between number of coffee trees and average coffee yield at Khar village and V.K. area during 2020 to 2022 (n=10).

Table 4: Price of parchment and cherry coffee during the year 2020 – 2022 in Khar village and V. K. area.

Location	Processed coffee type	Year	Price (₹ kg⁻¹)
Khar	Parchment coffee	2020	200
		2021	190
		2022	250
V.K. area	Parchment coffee	2020	200-480
		2021	180-200
		2022	300
	Cherry coffee	2020	110
		2021	110
		2022	150

Fig. 4: Trends of coffee yield and net income generation for the year 2020 – 2022 at Khar village and V. K. area (n=10)
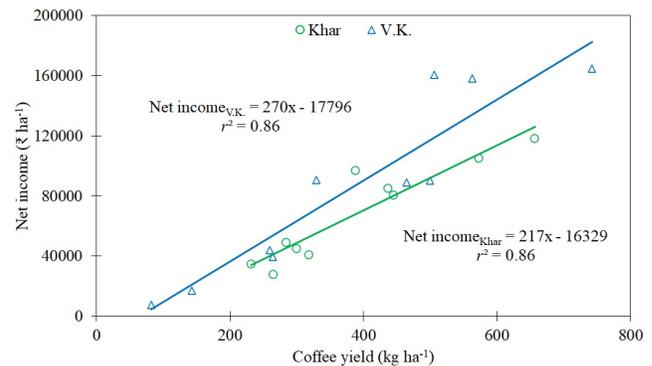
Fig. 5: Relationship between coffee yield and net income in Khar village and V. K. area for the year 2020 – 2022

K. with an average ₹ 93,000 ha⁻¹. In 2021, the gross income in Khar was ₹ 119,000 ha⁻¹ which was greater than V. K. by ₹ 46,600 ha⁻¹. V. K. area had greater gross income by ₹ 78,500 ha⁻¹ in 2022.

The expenditure for coffee production was statistically different between the Khar and V. K area (Table 2 & 3). The average annual expenditure, ₹ 13,400 ha⁻¹ of Khar was greater compared to V. K. with a difference of 88%. The expenditure obtained in this study is closely similar to the previous estimate report obtained for coffee maintenance by marginal coffee farmers in Nagaland (Pongener and Das, 2021). The difference between location in this study is attributed to more labour cost at Khar compared to V. K. The cost of labour for weeding per day in Khar and V. K. area was ₹ 400 and ₹ 300, respectively. The expenditure included labour cost for weeding and purchase of saplings. During the time of harvesting the farmers in both the Khar and V. K. area either performed the harvesting themselves or seek the assistance of their families or relatives. There was no expenditure on marketing cost as the buyers collect the product from the farm directly and pay their transportation expenses.

The average net income for the year 2020 – 2022 between the Khar village and V. K. area was statistically not significant (Table 2 & 3). Across location, the average net income for year 2020 – 2022 was ₹ 77,200 ha⁻¹. The net income from this study is 10% greater than the earlier estimates reported for average net income calculated for three districts in Nagaland (Pongener and Das, 2021). The total net income from the 10 farms in each village was calculated to look at the trend of income over the three years (Fig. 4). There was a sharp decline in the total net income in 2022 at Khar village as compared to 2021 with a difference of ₹ 660,300. This was attributed to the 78% reduction in coffee yield in 2022 due to inconsistent rainfall pattern. At V. K. area, a 6% increase of the net income was observed in 2022 compared to the net income of ₹ 630500 in 2021, but a 23% decrease compared to the net income of ₹ 817600 in 2020. A positive linear regression was observed between the coffee yield and net income in Khar village and V. K. area for the year 2020 – 2022 (Fig. 5). The differences in yield accounted for 86% of the differences in the total net income in Khar village and V. K. area.

Conclusion

Coffee farming in the state of Nagaland has exhibited promising growth, and the land area for coffee production has the potential to increase over the years. A comparative

Fig. 3: Gross income from the sale of saplings and coffee beans at Khar village and V. K. area for the year 2020 – 2022. Different lowercase letters above the bar indicates statistical difference at $P \leq 0.05$

study of coffee production was performed between Khar village and V. K. area to understand the soil physico-chemical properties, management approaches, yield and income generation. Results from this study showed that in both locations Arabica coffee is produced. Soil texture was loamy sand and sandy loam type with acidic pH ranged from 4.0 – 6.3, 85% of the fields having very low to low available N, 50% of the field with medium to high available P, 85% of the field with medium to high available K and 70% of the field with medium to high organic carbon. Variation in management practices such as timing of transplanting, plant spacing, weeding, nursery management, pruning and weeding were observed. Khar village practice wet method of coffee processing and V. K. practice both dry and wet methods. This processed product influences the income generation because the dry processed coffee has lower income potential ranged from ₹ 110 – 250 than the wet processed coffee earning ₹ 190 – 480. The net income generated was similar in both locations with an average ₹ 77,200 ha^{-1}. The annual expenditure was greater in Khar with a total expense of ₹ 13,400, mainly for labour cost for weeding and sapling purchase without any cost for transportation as the buyers bear their own expenses. Absence of transportation cost provides an added benefit to the smallholder farmers which is vital to enhance their business viability. The coffee yield was variable between location and year with greatest annual yield of 572 kg ha^{-1} recorded at Khar village in 2021. V. K. area had recorded consistent annual yield during 2020 – 2022 with an average 385 kg ha^{-1}. Results from this study indicates that factors such as poor soil nutrient status, acidic pH and low planting density are likely the limiting factors of coffee yield in the study locations. Coffee cultivation in Nagaland has gained prominence in recent years. Based on the prevailing climatic conditions in the state, Nagaland coffee is believed to produce one of the finest coffees owing to its unique citrus flavour, a characteristic that enhances its appeal in speciality markets and strengthens its marketing potential. Thus, along with efforts to improve the soil nutrient status to increase coffee yield, promotion of the Nagaland coffee quality can enhance the growth of coffee industry in Nagaland.

Acknowledgements

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