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Pre-extension demonstration of black pepper (*Piper nigrum* Linn.) technologies in selected districts of Ethiopia

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A B S T R A C T

Black pepper (*Piper nigrum* Linn.), known as the "King of Spices," is a high-value crop with significant economic and medicinal importance. This study evaluates the pre-extension demonstration of black pepper technologies in selected districts of Southwest Ethiopia and Gambella Region, focusing on two improved varieties, Gacheb and Tato, under real-world farming conditions. The study involved 66 farmers across Yeki, Sheko, and Godere districts, aiming to enhance farmers' knowledge and skills in black pepper production, management, and post-harvest handling. Data were collected on agronomic performance, economic viability, and farmer perceptions. Results showed that both varieties adapted well to local conditions, with Gacheb exhibiting higher yield potential (2-3 kg/vine/year) compared to Tato (1.5-2.5 kg/vine/year). Economic analysis revealed a benefit-cost ratio of 4.71 for Gacheb and 4.29 for Tato, indicating profitability. Farmers expressed positive perceptions of black pepper's adaptability and financial benefits, ranking it second in priority after coffee. However, challenges such as pests, diseases, and inadequate knowledge in certain cultivation practices were identified. The study recommends capacity-building programs, development of resilient varieties, scaling-up demonstrations, and strengthening research-extension-farmer linkages to promote sustainable black pepper production. These efforts can enhance productivity, improve livelihoods, and support the wider adoption of black pepper technologies in Ethiopia.

Keywords: Black pepper, Gacheb, Tato, Economic viability, Farmer perception

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Introduction

Ethiopia's diverse climate and soil types provide ideal conditions for the growth of various indigenous and exotic spices, herbs, medicinal plants, and essential oil-bearing plants. Among these, black pepper (*Piper nigrum* Linn.), a perennial woody climber from the Piperaceae family, stands out as one of the most important spices (Kumar *et al.*, 2021). Introduced from India, black pepper has been successfully adopted in the lowland regions of Ethiopia, and it is locally known as 'kundo berbere'.

Black pepper is highly valued for its pungent flavor, aromatic qualities, and medicinal properties. It is often referred to as the "King of Spices" and is considered "black gold" due to its durability and economic value (Preethy *et al.*, 2018). The spice is primarily traded in two forms: black pepper, made by drying ripe or unripe berries under the sun, and white pepper, produced by soaking, treating, and removing the outer skin of the berries before drying (Singh *et al.*, 2021).

In Ethiopia, black pepper has been used as a condiment in traditional dishes even before its formal introduction into the country's agro-ecology. The Jimma and Tepi spice research teams evaluated the adaptability of over 13 introduced black pepper cultivars in various locations in southwestern Ethiopia, including Jimma, Tepi, Bebeka, Wonago, and Metu. Among these, two cultivars—4/80

(Gacheb) and 3/80 (Tato)—performed exceptionally well in Tepi and Bebeka, demonstrating superior growth, yield, spike length, and quality.

To promote these improved varieties, pre-extension demonstrations were conducted on farmers' fields in selected districts of the Southwest Ethiopia Peoples Region State (SWEPRS) and Gambella Region. The demonstrations aimed to: i) Evaluate the performance of Gacheb and Tato under real-world farming conditions. ii) Enhance farmers' knowledge and skills in black pepper production, management, and post-harvest handling. iii) Collect feedback from farmers to support the wider adoption and scaling out of these technologies.

Materials and Methods

Selection of demonstration sites

The Yeki, Sheko, and Godere districts were selected as demonstration sites based on specific criteria: their unique agro-climatic conditions favorable for black pepper cultivation, their existing potential in other spice crops like turmeric, ginger, cardamom, and kororima, and their potential for expanding production in the spice sector. These factors made them ideal locations to showcase and promote black pepper cultivation. These districts feature tropical rainforest, humid subtropical and tropical monsoon climates, respectively, characterized by consistent temperatures (20°C to 35°C), high humidity, and annual rainfall ranging from 1,500 to 2,500 mm, distributed across distinct wet seasons. The well-drained, fertile soils, rich in organic matter with a slightly acidic to neutral pH (5.5 to 7.0), combined with mid-altitude ranges (1,000 to 1,800 meters above sea level); create optimal growing conditions for black pepper. The selection of kebeles from Yeki, Sheko, and Godere districts was based on criteria of accessibility and representativeness. Accessibility ensured that the kebeles were easy to reach when conducting demonstrations. Representativeness guaranteed that the chosen kebeles reflected the characteristics of other kebeles in the area, allowing for broader applicability of the findings.

Selection of farmers

Farmers were selected based on their interest in black pepper cultivation, access to suitable land, experience in cultivating other spices, and willingness to adopt new agricultural practices. These criteria were crucial to ensure active engagement and the successful implementation of the initiatives. Accordingly, 66 (55 male and 11 female) farmers were selected for the demonstration activity. The selection process involved collaboration between researchers, extension agents, and local administrative bodies.

Training

Table 1 outlines the training conducted over a consecutive three-year demonstration period on black pepper production for a diverse group of participants, including farmers, development agents (DAs), experts, researchers, and others. A total of 86 participants attended, with 66 being farmers (55 male and 11 female), 8 DAs (6 male and 2 female), and 3 others (all male). The sessions aimed to improve participants' knowledge and skills to enhance productivity, sustainability, and profitability in black pepper farming. The training covered essential topics such as best agronomic practices for black pepper cultivation (land preparation, planting, spacing, mulching), pest and disease management, soil fertility enhancement, harvesting and post-harvest handling. To ensure comprehension, all training materials were provided in local languages.

Table 1. Training participants on black pepper production.

Participants	M	F	Total
Farmers	55	11	66
DAs	6	2	8
Experts	3	1	4
Researcher	4	1	5
Other	3	0	3

Methodical approach of planting

The demonstration utilized 66 plots ranging from 0.125 to 1 hectare, divided into uniform 2.5 x 2.5 square meter sections to ensure efficient space utilization. Under expert guidance, farmers prepared 50 cm square and 50 cm deep planting holes at each corner of the lots, providing ample space for root development. A support tree

was established and allowed to grow for one year prior to planting, as black pepper is a climbing plant requiring structural support. Seedlings were planted at the onset of the rainy season to leverage optimal moisture conditions, ensuring their survival and growth.

Field management

In black pepper demonstrations, farmers carry out essential maintenance activities such as regular weeding, mulching, pruning, and pest and disease management under the close supervision of researchers to ensure healthy vine growth, maximize yield, and improve overall crop quality.

Data types

The data types collected including agronomic data (e.g., vine length, branches, flowering, fruiting, yield in kg/ha, pests, and diseases) to assess crop performance; economic data (e.g., input costs, labor, yield output, market prices) to evaluate financial viability; farmer perception data (e.g., adaptability, cultivation ease, challenges) to understand practical farming experiences; and adoption data (e.g., willingness to adopt new technologies, variety preferences) to inform scaling strategies and dissemination of innovations.

Tools for data collection

The tools used in data collection included Field Observation Sheets for recording agronomic data, Questionnaires to gather farmer feedback and perceptions, Focus Group Discussions (FGDs) to collect qualitative data on challenges and preferences.

Data analysis

Data analysis techniques included descriptive statistics, cost-benefit analysis (CBA) to evaluate the profitability of improved black pepper technologies, thematic analysis of qualitative data from FGDs and questionnaires to identify farmer perceptions and preferences, and calculation of percentages and frequencies to assess adoption levels and willingness to adopt the technologies.

Results and Discussion

Training outcomes

As seen in Fig. 1, a total of 97 farmers were trained, with 81 being male (83.51%) and 16 being female (16.49%). The training program focused on five essential topics: site selection, planting, field management, harvesting, and post-harvest handling. Overall, most farmers reported high satisfaction levels, indicating that the training effectively enhanced their knowledge and skills in these areas.

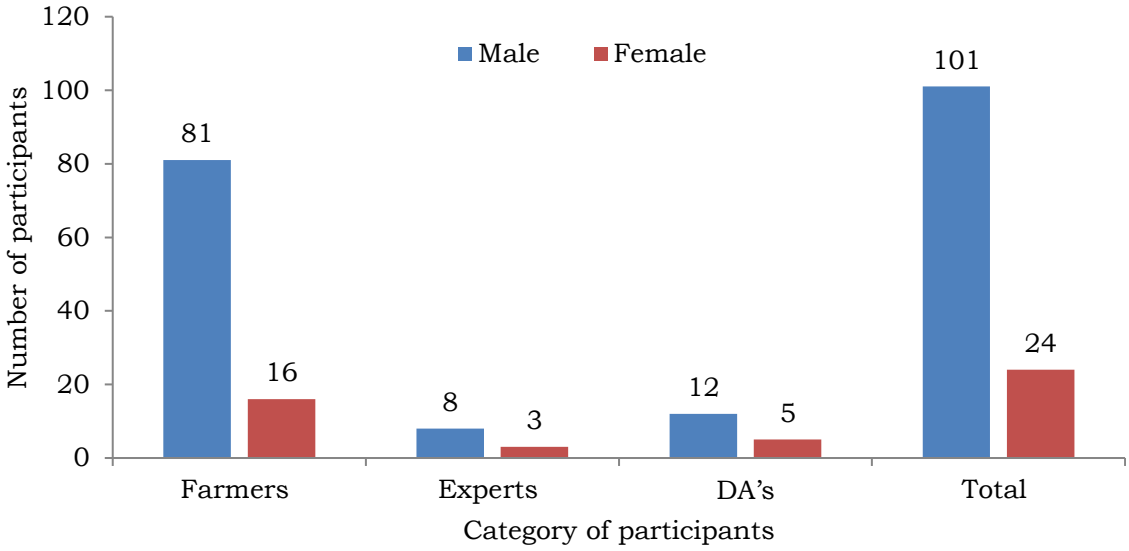

Fig. 1. Beneficiaries of training on black pepper production technologies.

Fig. 2. Practical training on black pepper production postharvest hndling.

Varieties and amounts of seedlings demonstrated

Table 1 presents data on the distribution of seedlings across three districts (Yeki, Sheko, and Godere) for two varieties, Gacheb and Tato. In terms of frequency, Gacheb seedlings were distributed more frequently than Tato, with a total of 20,400 Gacheb seedlings distributed compared to 8,600 Tato seedlings. The area covered by Gacheb (12.75 ha) was also significantly larger than that of Tato (5.375 ha). In terms of beneficiaries, Gacheb reached a total of 49 individuals (40 male and 7 female), representing approximately 82% of the total beneficiaries, while Tato reached 17 individuals (15 male and 2 female), and accounting for about 18%. This indicates that Gacheb was the more widely distributed and impactful variety in terms of both area coverage and beneficiary reach.

Table 2. Varieties and amounts of seedlings demonstrated.

Districts	Varieties	No of seedlings distributed	Area covered (ha)	Beneficiaries		
				Male	Female	Total
Yeki	Gacheb	9600	6	20	5	25
	Tato	4000	2.5	5	1	6
Sheko	Gacheb	8000	5	15	2	17
	Tato	2400	1.5	5	-	5
Godere	Gacheb	2800	1.75	5	2	7
	Tato	2200	1.375	5	1	6

Performance of black pepper under farmers' condition

The demonstrated black pepper varieties, Gacheb and Tato, have shown good adaptation to the demonstration districts of Yeki, Godere, and Sheko. Gacheb exhibits vigorous growth, producing longer and larger spikes, which contribute to its high yield potential of 2–3 kg of dry pepper per vine annually under favorable conditions. In contrast, Tato displays moderate growth with a compact vine structure, making it easier to manage and more space-efficient, though it yields slightly less at 1.5–2.5 kg of dry pepper per vine annually. These observations of varietal differences in growth, yield components, and overall productivity are consistent with findings from researchers like Krishnamurthy *et al.* (2019) and Utpala and Parthasarathy (2020), who also reported significant variations among black pepper genotype. The yield of black pepper obtained from the demonstrations under farmers' condition is comparable with the global average. On average, global productivity ranges from 0.5 to 2.5 tons per hectare. Productivity of black pepper in Vietnam and Brazil is averaging 2.0–2.5 tons and 1.5–2.0 tons per hectare, respectively (FAO, 2021). The ability to achieve yields comparable to these global benchmarks under good local management echoes the conclusions of Nybe and Mini (2018), who highlighted the impact of improved agronomic practices.

Both varieties demonstrate moderate resistance to common diseases such as foot rot and anthracnose. This aligns with disease screening studies, such as those by (Kumar *et al.*, 2021), which have identified black pepper lines with varying degrees of tolerance to such prevalent pathogens. However, Gacheb's higher yield potential makes it more suitable for farmers in well-suited areas. To optimize the performance of both varieties, effective farm management practices are essential. Farmers should consider their specific conditions and resources when choosing between Gacheb and Tato to maximize productivity and economic returns. This underscores the importance of integrated crop management, as emphasized by Vanaraj *et al.* (2022), and the need for farmer-centric varietal selection based on local conditions and resources, a principle supported by Sivakumar and George (2023).

Fig. 3. Photos showing the status from seedling distribution to current status on field.

Economic feasibility of black pepper

Benefit cost analysis was undertaken to evaluate the economic benefit of black pepper under farmers' condition. To perform a benefit-cost analysis for growing Gacheb and Tato, we need to calculate the total benefits and compare them with the total costs over the three-year period.

1. Parameters

i. Productivity:

- Gacheb: Yield = 1650 kg/hectare, Price = 800 ETB/kg.
- Tato: Yield = 1500 kg/hectare, Price = 800 ETB/kg.
- the analysis was undertaken with the harvesting after 3 years of initial harvesting.

ii. Production costs

Total costs:

a. Initial setup costs (IC): Land preparation, planting, etc.
b. Maintenance costs (MC): Fertilizers, labor, irrigation, etc., over 3 years.
c. Harvesting and post harvesting costs (HPHC): Labor, transportation, etc.

- ✓ IC= 100,000 ETB/hectare.
- ✓ MC: 50,000 ETB/hectare/year for 3 years = 150,000 ETB/hectare.
- ✓ HPHC: 30,000 ETB/hectare.
- ✓ Total Costs= IC + MC + HPHC = 100,000+150,000+30,000=280,000ETB/hectare

iii. Benefits

Total Revenue (Benefits):

Total revenue (TR) = Yield (kg/hectare) x Price (ETB/kg)

- ➢ Gacheb:

Total Revenue=1650kg/hectare×800ETB/kg=1,320,000ETB/hectare

- ➢ Tato:

Total Revenue=1500kg/hectare×800ETB/kg=1,200,000ETB/hectare

iv. Net revenue

Net Benefit=Total Revenue−Total Costs

- ➢ Gacheb:

Net Benefit=1,320,000−280,000=1,040,000ETB/hectare

- ➢ Tato:

Net Benefit=1,200,000−280,000=920,000ETB/hectare

v. Benefit-Cost Ratio (BCR)

$$BCR=\frac{\textbf{\textit{total benefits/revenue}}}{\textbf{\textit{total costs}}}$$

Gacheb:

$$BCR=\frac{total\ benefits/revenue}{total\ costs}=\frac{1,320,0,000}{280,000}=4.71$$

Tato:

$$BCR=\frac{total\ benefits/revenue}{total\ costs}=\frac{1,200,000}{280,000}==4.29$$

The analysis clearly demonstrates that both black pepper varieties are profitable under the specified conditions, with Gacheb showing superior economic performance in terms of both absolute net benefits.

Fig. 4. Photos of harvesting and sun drying.

Challenges

Farmers identified several challenges, including diseases (e.g., foot rot), pests, and difficulties in harvesting and post-harvest handling. Addressing these challenges will be critical for the sustainable scaling up of black pepper production.

Farmer perceptions

Farmers have expressed strong positive feedback on the performance and importance of black pepper under local conditions, highlighting its adaptability and economic benefits. Many have noted that black pepper thrives well in their region's warm and humid climate, producing high-quality yields with proper management. The high market demand and favorable prices for black pepper have further reinforced its importance as a cash crop, significantly improving their livelihoods. Overall, farmers view black pepper as a resilient and rewarding crop that aligns well with local conditions and offers substantial economic potential.

Farmer preferences between Gacheb and Tato pepper varieties

Farmers generally perceive Gacheb as a more favorable variety compared to Tato due to its higher yield potential, which translates to greater economic returns. Gacheb's ability to produce 2–3 kg of dry pepper per vine annually makes it a preferred choice for those aiming to maximize productivity, especially in well-suited areas like Yeki, Godere, and Sheko districts. This high yield, coupled with its adaptability and moderate disease resistance, increases farmers' willingness to adopt Gacheb. On the other hand, while Tato is also well-adapted to the same regions and offers moderate resistance to diseases, it's slightly lower yield of 1.5–2.5 kg per vine makes it less attractive to farmers seeking higher profitability. As a result, Tato is often seen as a secondary option, particularly for those who may prioritize other factors over maximum yield.

Prioritization of black pepper farming among participant farmers

Table 2 presents the prioritization of black pepper farming among participant farmers compared to other agricultural activities, including coffee, turmeric, ginger, cereals, fruits, and livestock. Black pepper is ranked 2nd in priority, indicating it is highly valued but secondary to coffee, which holds the 1st rank. Coffee dominates all other activities, as it is preferred over black pepper and the rest. The prioritization is based on pairwise comparisons, where a "1" indicates that the row activity is prioritized over the column activity, and a "0" indicates that it is not. The "*" symbol denotes a comparison of an activity with itself, which is not applicable. The data reflects the relative preferences and economic focus of the farming community.

Table 3. Prioritization of black pepper farm among participant farmers.

	Black pepper	Coffee	Turmeric	Ginger	Cereals	Fruits	Livestock	Rank
Black pepper	*	0	1	1	1	1	1	2nd
Coffee	1	*	1	1	1	1	1	1st
Turmeric	0	0	*	1	0	0	1	5th
Ginger	0	0	0	*	0	0	0	7th
Cereals	0	0	1	1	*	1	1	3rd
Fruits	0	0	1	1	0	*	1	4th
Livestock	0	0	0	1	0	0	*	6th

Perception of farmers on knowledge and skill adequacy level on black pepper production

The Table 3 summarizes farmers' self-assessed adequacy levels in various aspects of black pepper cultivation. A significant majority (72.8%) feel confident in site selection, rating their skills as "outstanding," while only 8.3% feel inadequate in this area. However, layout skills are a concern, with 45% feeling adequate and 33% inadequate, indicating a need for improvement in this area. Pitting and planting skills show a mixed response, with 37.8% rating them as outstanding and 40% as adequate, but 12.2% still feel inadequate (Table 4). Harvesting and post-harvest handling skills are the most challenging, with 56% of farmers feeling inadequate and only 11% rating themselves as outstanding. These highlight critical gaps in knowledge and skills, particularly in layout, harvesting, and post-harvest handling, suggesting a need for targeted training programs to enhance farmers' proficiency in these areas.

Table 3. Adequacy level of farmers in various aspects of black pepper cultivation.

Area of Adequacy	Frequency	Level of Adequacy
Site Selection	72.8%	Outstanding
	18.9%	Adequate
	8.3%	Inadequate
Layout	22.0%	Inadequate
	45.0	Adequate
	33.0	Inadequate
Pitting and Planting	37.8%	Outstanding
	40.0%	Adequate
	12.2%	Inadequate
Harvesting and Post-Harvest Handling	11%	Outstanding
	33%	Adequate
	56%	Inadequate

One farmer in the focus group discussion shared, *"Black pepper has become a game-changer for my family. With proper care, the vines produce consistently for many years, and the income from selling the spice has helped us improve our living conditions. However, managing pests and diseases remains a challenge, and we need more training on how to handle these issues effectively to maximize our yields."* This statement reflects both the optimism and the practical challenges faced by farmers in adopting black pepper cultivation.

Conclusion

The pre-extension demonstration of black pepper technologies in Southwest Ethiopia and Gambella Region highlights the potential of improved varieties, particularly Gacheb and Tato, for adoption and scalability due to their adaptability and economic viability. Gacheb, with its higher yield potential, and Tato, with its favorable benefit-cost ratio, offer smallholder farmers a profitable opportunity to diversify income sources alongside coffee. Farmers expressed optimism about the crop's adaptability, profitability, and compatibility with intercropping, though challenges such as pest management and knowledge gaps in cultivation and post-harvest handling remain critical barriers. Addressing these challenges through targeted training, resilient variety development, and strengthened research-extension-farmer linkages is essential for sustainable scaling. By prioritizing black pepper as a secondary cash crop, Ethiopia can enhance economic resilience, improve livelihoods, and promote sustainable agricultural development.

Recommendations

Based on the findings of the study, here are four main recommendations to promote sustainable black pepper production and enhance its adoption in Ethiopia:

Capacity-Building Programs: Develop and implement targeted training programs for farmers, focusing on improving their knowledge and skills in critical areas such as nursery preparation, layout, pitting and planting, pest and disease management, and post-harvest handling. These programs should include hands-on workshops, demonstrations, and follow-up sessions to reinforce learning and address practical challenges.

Development of Resilient Varieties: Invest in research to develop and introduce black pepper varieties that are more resistant to pests and diseases, particularly foot rot and anthracnose. This will help reduce crop losses and improve overall yield stability, making black pepper cultivation more attractive to farmers.

Scaling-Up Demonstrations: Expand pre-extension demonstration activities to more districts and regions with suitable agro-climatic conditions for black pepper cultivation. This will help more farmers gain firsthand experience with improved varieties and technologies, increasing the likelihood of wider adoption.

Strengthening Research-Extension-Farmer Linkages: Enhance collaboration between researchers, extension agents, and farmers to ensure that the latest technologies and best practices are effectively disseminated and adopted. This can be achieved through regular field visits, farmer feedback sessions, and the establishment of farmer cooperatives or groups to facilitate knowledge sharing and collective problem-solving.

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