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Research Article

On Farm Performance of Finger Millet Varieties in Dera District of South Gondar Zone

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Abstract

Finger millet is an important food security crop and beneficial for human health. This study aimed to evaluate the on farm performance of the finger millet varieties in Dera district. The study took place in Korata Kebele and assessed grain yield and farmer feedback. The performance differences between the Necho variety (the demonstrated variety) and the farmers' variety were evaluated. Recent 10 years' grain yield data from the Dera district agriculture office was used to analyze the growth rates of area coverage, production, and productivity in the district using the compounded annual growth rate (CAGR). Furthermore, the performance of the Necho variety was compared to its potential and farmer variety using the technology gap, extension gap, and technology index. From 2014 to 2018, the annual growth rate of area coverage and productivity in Dera district declined by 1.6% and 1.7% per year, respectively. Moreover, from 2019 to 2023, the average annual growth rate of area coverage, production, and productivity decreased by 0.75%, 2.6%, and 3.4% per year, respectively. The technology index for the Necho variety in the production seasons of 2021, 2022, and 2023 was -4%, 16%, and 36%, respectively. The higher value in the 2023 season indicated a decline in the performance of the Necho variety compared to the farmer variety. This decline was attributed to the occurrence of blast disease. To address this issue, it is recommended to practice early planting and use recommended fungicides (Natura 250EW and Tilt 250EC). The district agriculture office must ensure easy accessibility of these fungicides in the market for farmers to utilize.

Keywords

Dera, Finger Millet, Growth Rate, On Farm Performance

1. Introduction

Finger millet (Eleusine coracana L.) Gaertn) is an economically important and widely cultivated cereal crop in the semi-arid and tropical regions of the world. The name finger millet is derived from the appearance of spikes, which seem be human fingers. Compared with other major cereals such rice, wheat, and barley, finger millet is relatively drought-tolerant due to its C4 photosynthesis system, which allows it to grow under harsh and marginal agro-ecologies [1]. It is cultivated in more than 25 countries in Africa and Asia. Ethiopia is the second-largest producer of finger millet in the world next to India [2].

Finger millet is the 6th most important crop, following tef, maize, wheat, sorghum, and barely in area coverage in Ethiopia [3]. Its productivity is 2.53 ton/ha and 2.57 ton/ha in the

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2021 and 2022 production seasons, respectively. It shares 4% and 3.7% of area coverage from cereals in the 2021 and 2022 production seasons, respectively. It shows that the area devoted to finger millet production is decreasing. It is a food security crop that is used to make food and local drinks; Its biomass (stalk) is used for livestock feed, construction, and fuel [1]. Finger millet also has human health benefits, such as reducing diabetes, obesity, anemia, malaria, and diarrhea [4-6]. Because the crop has a high level of calcium, iron, fiver, and is gluten free. The report by [7] showed that the processed grain of finger millet is used to make unleavened bread (locally named "*injera"*) and for malting to prepare alcoholic (*Areki* and *Tela*) and non-alcoholic drinks (*Karibu* and *Shamita*).

Despite the importance of finger millet for food security and the health of human beings, its productivity in Ethiopia is low (2.57 ton/ha) compared with the potential yield of the crop (6 ton/ha) [2, 3]. The low productivity of finger millet is due to the existence of abiotic, biotic, and farmer socioeconomic factors in Ethiopia. Head blast or finger millet blast, which is caused by *Magnaporthe grisea* is economically important and damaging disease, causing yield losses ranging from 7.32% to 54.07% depending on the environment and variety disease tolerance nature [8]. Yield losses due to termites, aphids, and pink stem borer are found to be 23%, 35.1%, and 56%, respectively [9, 10]. During the early growth stage of the plant, weeds can also result in significant yield losses. Economically important weed species in Ethiopia include *Digitaria ternata* (A. Rich.) Stapf, *Guizotia scabra* (Vis.) Chiov, *Cyperus rotundus* L., and *Striga hermonthica* (Delile) Benth [11]. To mention, weeds in finger millet production can result in a yield loss of 73.5%.

The Necho finger millet variety, which has a white grain color and competitive yield, was demonstrated on a large scale in Dera district. This demonstration aimed to assess the on-farm performance of Necho and gather feedback from farmers.

2. Literature Review

2.1. Opportunities of Finger Millet Production in Ethiopia

Ethiopia is rich in biodiversity and a center of origin for many crop species and diversities. The existence of diversified crops is due to the existence of a wide range of altitudes, temperatures, huge amounts of rainfall, and different soil characteristics [12]. Finger millet has a primary center of diversity in Ethiopia, where in situ conservation mechanisms are applied [13] This biodiversity conservation mechanism is the best strategy to sustain the genetic integrity of finger millet for generations. As a result, it has been about 5,000 years since finger millet production started in Ethiopia. Finger millet can be grown in potentially drought-exposed regions of the world to ensure food security. It is possible to get a higher finger millet yield than other crops under multiple stresses of drought, soil acidity, and land marginality. To mention, a reasonable amount of finger millet production can be recorded at 500 mm of rainfall level. Generally, it can be grown at an 800–1,000 mm rainfall level [14]. It has excellent storage quality and can be stored without any harm for a number of years. Finger millet grains are rarely attacked by pests, and their storage life can range up to a decade, as is commonly reported [14]. The study reports by [15] revealed that finger millet finger can be stored for more than ten years without any damage by storage pests. Since it can be grown in drought-exposed areas where feed sources are limited, its dry matter can be a big source of animal feed [16]. As a strength of the research system, a total of 29 improved finger millet varieties have been registered and released to be grown for different agro-ecologies. Research outputs of blast disease management were generated by Adet research center by 2021. These results showed that early and medium planting in combination with Natura 250EW and Tilt 250EC foliar spray gave maximum grain yield with reduced blast disease severity.

Table 1. *Finger millet varieties released in Ethiopia.*

No.	Variety	Release year	Altitude (m)	GY (t/ha)		Seed color	Releasing center
				On research station	On farmers field		
1	Padet	1999	1600-1900	2.4	-	Brown	Melkasa
2	Tadese	1999	1600-1900	2.5	-	Brown	Melkasa
3	Boneya	2002	1400-1900	2.5-3	2-2.4	Red	Bako
4	Degu	2005	1900-2500	2.3-3	1.7-2.1	Black	Adet
5	Wama	2007	1400-1900	1.7-3.5	1.6-2	Brown	Bako
6	Baruda	2007	1000-1500	3-3.5	-	Red	Pawe
7	Bareda	2009	1200-1900	2-2.8	1.8-2.5	Brown	Bako

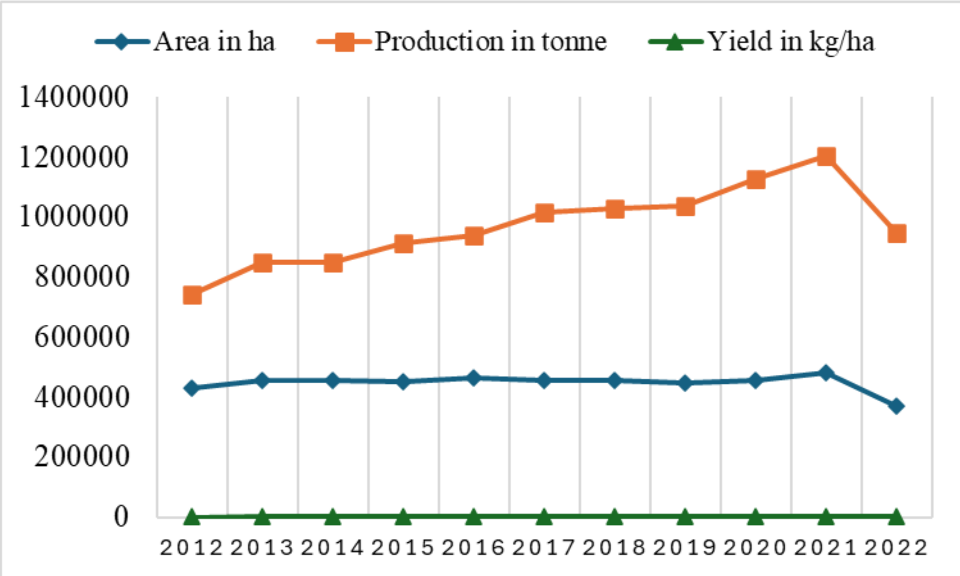
No.	Variety	Release year	Altitude (m)	GY (t/ha)		Seed color	Releasing center
				On research station	On farmers field		
8	Gutie	2009	1200-1900	2-3.5	2-3.2	Brown	Bako
9	Dibatie	2010	1100-1600	2-2.5	1.5-2	Brown	Pawe
10	Necho	2011	1900-2500	2-3	1.5-2	White	Adet
11	Mecha	2014	1900-2500	2-2.9	1.6-2.3	Red Brown	Adet
12	Tesema	2014	1600-1900	1.8-2.2	1.4-1.8	Brown	Melkasa
13	Gudeta	2014	1400-1900	2.1-2.3	2-2.1	Light brown	Bako
14	Addis-01	2015	1400-2200	2.6-4.2	2.5-3.1	Light brown	Bako
15	Kako-1	2015	1310-1700	2.6-2.95	1.6-2	Light brown	Jinka
16	Meba	2016	1600-1900	2.1-3.5	2.3	Brown	Melkasa
17	Axum	2016	1600-1900	2.2-3.6	2.1	Brown	Melkasa
18	Diga-1	2016	1600-2300	2.2-2.8	2.4-3.2	Black	Bako
19	Urji	2016	1600-2300	1.8-2.7	2.1-2.6	White	Bako
20	Mereb-1	2016	1300-2100	2.45-3.15	2.38-2.75	Light brown	Axum
21	Bako-09	2017	1400-2200	2.98	2.4-2.6	Light brown	Bako
22	Diga-2	2018	1200-2300	2.24-3.42	2.32-2.98	Black	Bako
23	Tekeze-1	2018	1350-2200	2.8-3.5	-	Brown	Shire
24	Jabi	2019	1900-2500	2.5-3	2-2.5	Reddish	Adet
25	Kumsa	2019	1500-2200	2.5-3.2	2.2-2.9	Light brown	Bako
26	Metekili	2020	1000-2000	2.8-3.8	2.6-3.0	Brown red	Pawe
27	Ikhulule	2021	1700-1900	6.3	3.8	Light brown	Mechara
28	Adet-05	2022	1700-2300	2.6-3.3	2.4-2.8	Black	Adet
29	Jabessa	2022	1500-2200	2.24-2.57	3.18	Light brown	Bako

2.2. Challenges of Finger Millet Production in Ethiopia

Despite its potential, the productivity of the crop is low in Ethiopia due to a number of factors. These includes unavailability of improved varieties, little research and development concern, low adoption level of released improved varieties, blast disease, which is the most serious disease that causes significant level of yield loss, lodging, and thresh ability [17, 18]. The report by [19] on farmers' knowledge and perception of finger millet blast disease in western Kenya showed that 94% of the respondents had finger millet blast in their farms, being considered by them as the most destructive disease of finger millet production. Weeds were the major constraints of finger millet production, which was accounted for 55%, of the production loss. On the other hand insects (termite), diseases (e.g. blast), and rat infestation had an impact on production loss with 23%, 16% and 16%, respectively [10]. The decline in production and consumption is related to the negative attitude attached to millets (including finger millet), which are often considered as the minor, poor man's crop or birdseed [20]. It is categorized as a neglected and underutilized plant in research systems [21]. The results by [22, 23] indicated that blast is a worldwide disease capable of devastating finger millet production. Losses of 10–90 % have been recorded in field studies in Uganda [24], 64 % in Kenya [25], 10.1- 41.4% in Ethiopia [23]. Although blast disease management results (Natura 250EW and Tilt 250EC foliar spray) are generated by Adet research center, these fungicides are not easily available in the market. As a result, farmers face challenges in accessing appropriate pest and disease management practices and affordable control measures.

2.3. Finger Millet Production Trends in Ethiopia

Finger millet is an important indigenous crop mainly grown in marginal areas, where the climate and interaction varies considerably. It is a staple food crop in drought-prone areas of the world and often considered as a component of food security strategies [26]. However, the finger millet yield is low due to the absence of high yielding improved varieties, little research emphasis, blast disease and lodging [18]. The absence of extended rainfall can also be the main cause of finger millet production fluctuation (see figure 1). As shown in the figure 1, The area under finger millet cultivation in Ethiopia has fluctuated over the years, with an overall increasing trend from 2012 to 2021. However, in 2022, the area under cultivation declined significantly, while the production of finger millet in Ethiopia has shown a more consistent increasing trend, rising from 2012 to 2021. Production levels remained relatively stable between 2013 and 2018, with a more substantial increase observed from 2019 onwards. Nonetheless, in 2022, the production sharply declined to the lowest level in the given time period. The average yield of finger millet in Ethiopia has shown a consistent increasing trend, indicating that technological advancements, improved farming practices, or other factors have contributed to enhancing the productivity of this crop. Overall, while the area under finger millet cultivation has fluctuated, the production has shown an increasing trend, driven primarily by improvements in yield. However, the sharp decline in both areas and production in 2022 highlights the need to investigate the underlying factors. The blast disease is a major factor contributing to the decline in finger millet production. Blast is a fungal disease caused by Magnaporthe grisea, which affects various cereal crops, including finger millet. The disease can result in significant yield losses if not properly managed. Implementing appropriate disease management strategies, such as crop rotation, use of resistant varieties, and timely application of fungicides, can help mitigate the impact of blast disease on finger millet production.



Source: Ethiopian Central Statistical Agency

Figure 1. *Trends of finger millet production in Ethiopia.*

3. Methodology

3.1. Description of the Study Area

Dera district is located in a geographically diverse area, with the Abay River, Lake Tana, Fogera, and Este serving as its borders to the south, west, north, and east, respectively. The district's altitude ranges from 1500 to 2600 meters above sea level. It experiences a mean annual rainfall between 1000 mm and 1500 mm, providing favorable conditions for agriculture. The annual temperature in the area ranges from 15 ℃ to 32 ℃. In terms of agricultural production, shallot cultivation is not widely practiced in Dera district. Instead, the primary crops cultivated in the area are maize, tef, and finger millet. The total cultivated land in Dera covers an area of 56882 hectares, with finger millet accounting for 22% of the overall production.

3.2. Site and Farmers Selection

A large-scale demonstration of improved finger millet varieties was implemented in Dera district, with the focus on

Korata kebele, which is recognized as having potential for finger millet production in the district. The demonstration utilized a farm clustering approach, where clusters of varying sizes were established each production season. In 2021, a 3-hectare cluster was set up, which expanded to 6.5 hectares in 2022 and further grew to 7 hectares in 2023. These dedicated clusters served as areas to demonstrate finger millet cultivation techniques and the benefits of the improved varieties to participating farmers. Over the three-year period, a total of 62 smallholder farmers were engaged in the demonstration. The number of participating farmers increased each year, from 16 in 2021 to 20 in 2022 and 26 in 2023. Farmers were selected based on their willingness to participate in the demonstration. They collaborated in sharing farmland, fertilizer, and the overall management of the demonstration fields.

This collaborative, cluster-based approach proved to be an effective way to engage a growing number of smallholder farmers in the Dera district and showcase the advantages of the improved finger millet varieties and cultivation practices. The increasing cluster size and farmer participation over the three-year period suggest that the demonstration was successful in promoting the adoption of better finger millet production techniques among the local farming community.

3.3. Approaches Followed

In 2018, a pre-extension demonstration of finger millet varieties (Tesema, Necho, and Jabi) was conducted in farmer fields to evaluate their performance. The Necho variety, preferred by smallholder farmers due to its white grain color, was chosen for large-scale promotion from 2021 to 2023. Prior to the large-scale demonstration, selected farmers and agricultural experts received training sessions in collaboration with the Adet Agricultural Research Center. The aim was to provide them with knowledge and skills related to the production practices of the Necho variety. During the demonstrations, a seed rate of 15 kg/ha and fertilizer rates of 121 kg NPS and 50 kg urea per hectare were applied, following recommended practices. Field days were organized to gather feedback from stakeholders and address challenges in finger millet production.

3.4. Data Collection and Analysis Methods

The study collected data from primary and secondary sources. Primary data included grain yield and farmers' opinions from host and non-host farmers, with the large-scale demonstration's grain yield measured by weighing the total produce of each farmer. Additionally, grain yield data on finger millet production was sourced from Ethiopian Central Statistical Agency and the Dera District Office of Agriculture (2022). The study analyzed the growth rates of area coverage, production, and productivity based on this data. Secondary data from books and journal articles provided insights into opportunities and challenges in finger millet production, gathered through a literature review. Line charts were used to visualize trends in area coverage, production, and productivity at Dera district. The study employed the compounded annual growth rate (CAGR) to assess the annual growth rate of area coverage, production, and productivity of finger millet over five-year intervals, using the following formula:

$$\text{CAGR} = ((\text{Ending Value} / \text{Starting Value}) \wedge (1 / \text{Number of Years})) - 1 \quad (1)$$

The study utilized the technology gap, extension gap, and technology index as analytical tools to assess the performance of the Necho variety compared to the local variety. The yield gap, a key measure of crop performance, quantifies the difference between the potential yield and the actual yield achieved by farmers. The potential yield represents the maximum achievable yield based on optimal inputs and best practices observed in experimental stations during a particular season. Farmers' yield refers to the actual yield obtained by farmers on their individual farms using their own management practices. The demonstration yield represents the yield observed in designated demonstration plots within the study area. The extension gap measures the mismatch between the knowledge and technologies provided by agricultural extension services and the specific needs and challenges faced by smallholder farmers. Lastly, the technology index provides a metric to assess the relative performance of the demonstrated yield compared to the potential yield. The extension gap, technology gap, and technology index (%) were estimated as follows:

$$\text{Technology gap} = \text{Potential yield} - \text{demonstration yield} \quad (2)$$

$$\text{Extension gap} = \text{Demonstration yield} - \text{Farmers yield} \quad (3)$$

$$\text{Technology index (\%)} = \frac{\text{Technology gap}}{\text{Potential yield}} \times 100 \quad (4)$$

4. Results and Discussion

4.1. Trends and Growth of Finger Millet Production in Dera District

Finger millet is the third-most important crop in the Dera district, with maize and tef being the top two crops. The trends in finger millet production over a 10-year period (2014-2023) are depicted in Figure 2, considering the area coverage, production, and productivity. The area covered by finger millet cultivation fluctuates between 11,460 hectares and 12,235 hectares during this period, representing a difference of 775 hectares between the minimum and maximum coverage. The productivity levels range from 2,600 kilograms to 3,000 kilograms per hectare. Despite these fluctuations, the overall trend indicates a decline in finger millet production, starting from the 2021 production season. Several factors could be contributing to this decline. Shifting agricultural practices, climate variability, and pest and disease outbreaks, particularly blast disease, are potential reasons for the decrease. Additionally, limited adoption of improved varieties and restricted access to inorganic fertilizers like NPS and urea may also be influencing the decline in production. It is worth noting that the slow uptake of finger millet technologies by smallholder farmers in Sub-Saharan Africa, including Ethiopia, has been observed in recent years, as mentioned in a study by [27]. Moreover, blast disease has emerged as the most common disease affecting finger millet production.

Based on the information provided in Table 2, it is evident that the annual growth rate of area coverage and productivity declined by 1.6% and 1.7% per year, respectively, over the five-year period from 2014 to 2018. In contrast, the growth rate of production remained constant during this time frame. Similarly, from 2019 to 2023, the average annual growth rate of area coverage, production, and productivity decreased by 0.75%, 2.6%, and 3.4% per year, respectively. These declining growth rates can be attributed to various factors, including the occurrence of blast disease and a tendency towards low input usage.

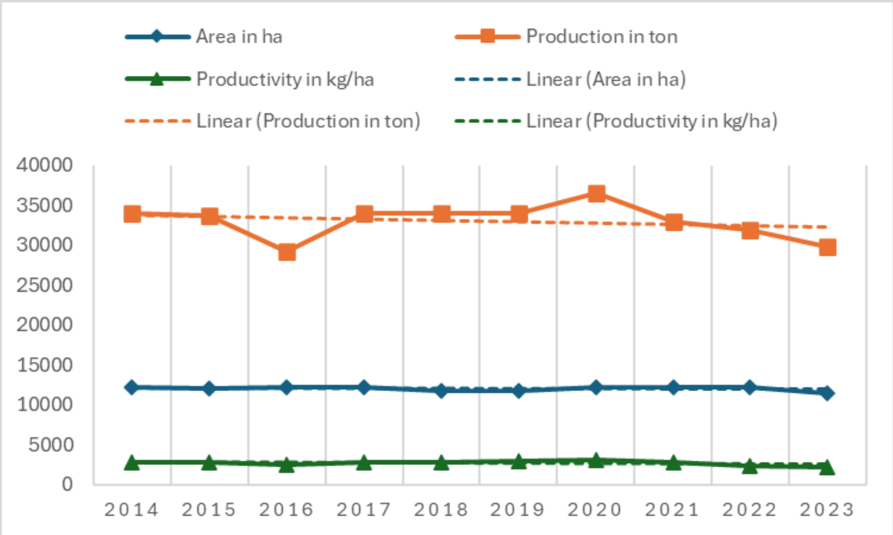


Figure 2. *Finger millet production trend in Dera district.*

Table 2. *Growth in finger millet area, production and productivity in Dera district.*

Particulars	**Compounded Annual Growth Rate (%)**	
	From 2014 to 2018	**From 2019 to 2023**
Area (ha)	-1.6	-0.75
Production (ton)	0.0	-2.6
Productivity (kg/ha)	-1.7	-3.4

Source: Author calculation based on data from Dera district office of Agriculture

4.2. The Performance of Necho Variety in Dera District

Table 3 summarizes the technology gap, extension gap, and technology index for the Necho variety over the years. The technology gap for the Necho variety was -1, 4, and 9 in 2021, 2022, and 2023, respectively. This indicates that in 2021, the demonstrated yield was slightly higher than the potential yield, resulting in a negative technology gap. However, in 2022 and 2023, the technology gap increased to 4 and 9, respectively, suggesting a larger disparity between the potential and demonstrated yields. The higher technology gap in 2023 can be attributed to the occurrence of a head blast in the demonstration field. This disease outbreak likely affected the yield potential and resulted in a larger difference between the potential and demonstrated yields. On the other hand, the lowest negative value of the technology gap was observed in 2021, indicating that the demonstrated yield in that year was closest to and greater than the potential yield. It is indicated that head blast was not a problem in the demonstrated field.

According to the table, the extension gap was estimated at 5, 1, and -3 in 2021, 2022, and 2023, respectively. A higher extension gap in 2021 suggests that the demonstrated yield exceeded the average farmer's yield by 5. This indicates that farmers were not able to achieve the same level of yield as demonstrated in the field trials. In contrast, the negative extension gap value of -3 in 2023 indicates that the average farmer's yield was higher than the demonstrated yield. This suggests that farmers were able to achieve a greater yield than what was demonstrated in the field trials. As mentioned earlier, the occurrence of a high level of head blast disease in 2023 in the Dera district of Korata kebele may have influenced the results. The local finger millet variety, which has been cultivated by smallholder farmers for a long period, was found to be more resistant to head blast disease compared to the demonstrated variety. This could explain why farmers were able to achieve higher yields despite the challenges posed by the disease.

According to the information provided, the technology index for the Necho variety in the production seasons of 2021, 2022, and 2023 was -4%, 16%, and 36%, respectively. In 2021, the negative technology index value of -4% indicates that the demonstrated yield of the Necho variety exceeded the potential yield. This suggests that the variety performed better than expected, resulting in a higher grain yield. In contrast, the positive technology index values of 16% and 36% in 2022 and 2023, respectively, indicate that the observed demonstrated yield was lower than the potential yield. These positive values imply that the variety's performance in terms of grain yield was lower than expected. As mentioned, the occurrence of head blast in the demonstrated yield was identified as the primary reason for the lower observed yields and the resulting positive technology index values in 2022 and 2023. The disease outbreak likely affected the potential yield and resulted in a reduced performance of the Necho variety.

Table 3. *Technology gap (TG), Extension gap (EG) and Technology index (TI).*

Year	Variety	Potential yield	Demonstrated yield	Farmer Yield	TG (PY-DY)	EG (DY-FY)	Technology Index (TG/PY)
2021	Necho	25	26	21	-1	5	-4%
2022	Necho	25	21	20	4	1	16%
2023	Necho	25	16	19	9	-3	36%

4.3. Farmers Feedback

Smallholder farmers in Dera district provided feedback on the finger millet varieties demonstrated and production challenges. They highlighted that the Necho variety, with its white grain color, is in high demand in the finger millet market, commanding a higher price compared to varieties with black or brown grain color. In seasons without blast disease, the Necho variety outperforms the local variety in terms of productivity. However, in 2022 and 2023, the Necho variety's performance declined due to the occurrence of head blast disease, locally known as "*abirikit*," in the demonstration field. The farmers identified this disease as a major challenge in finger millet production, leading to significant yield reductions. They requested management techniques for this disease and expressed concerns about the availability of recommended fungicides in the market.

5. Conclusion and Recommendations

The annual growth rates of area coverage and productivity in Dera district declined from 2014-2018 (-1.6% and -1.7% per year) and 2019-2023 (-0.75%, -2.6%, and -3.4% per year). During a three-year large-scale demonstration from 2021-2023, the Necho variety initially performed well but experienced a decline in production compared to its potential and farmer yields in 2023 due to blast disease. To address this issue, smallholder farmers should consider using early and medium planting techniques for finger millet and spray fungicides like Natura 250EW and Tilt 250EC. The District Agricultural Office must ensure that these fungicides are accessible in the market for utilization by smallholder farmers.

Abbreviations

CAGR Compounded Annual Growth Rate

Author Contributions

Ayele Tesfahun Gashu: Conceptualization, Formal Analysis, Methodology, Writing – original draft, Writing – review & editing

Adane Melak: Conceptualization, Investigation Methodology, Visualization

Misganaw Anteneh: Methodology

Conflicts of Interest

The authors declare no conflicts of interest.

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