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Adaptation and Popularization of Foxtail Millet Cultivation at Kotalipara, Gopalganj

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Abstract

The present field investigation was conducted at the agricultural farm of Rural Development Academy (RDA), Gopalganj during 01 November, 2023 to 21 April, 2024 to estimate and compare the yield performance of important foxtail millet (*Setaria italica*) varieties in this region (AEZ-14) and to find out the best foxtail millet variety for this region (AEZ-14) and to extend the foxtail millet cultivation at local area. BARI Kaon-2, BARI Kaon-3, and Titas (a BARI released variety) were used for the experiment. Plant height during harvesting was varied from 47.75cm to 109.03cm. BARI Kaon-2 gave highest number of effective tillers per plant (1.40), maximum ear length (19.68cm), highest weight of main ear (6.24gm) and maximum thousand seed weight (2.54gm). But In case of total number of tillers per plant BARI Kaon-3 was performed best. Titas variety was the best in terms of crop duration. The highest grain yield (2.79 t/ha) was performed by BARI Kaon-2. It also produced the highest straw yield and maximum biomass (8.51 t/ha). As a result, it can be commented that the BARI Kaon-2 was the best variety for this AEZ-14 and so it can be extended to the local area of gopaganj district. It will increase the proper use of their fellow, marginal land and it will be helpful for introducing a new minor cereal crop in the existing cropping pattern of the respected area.

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Introduction

Millets are small-seeded annual cereal crops primarily cultivated for human consumption, animal feed, forage, and fuel (Kothari et al., 2005). Among the most commonly grown millet species worldwide are foxtail millet (*Setaria italica* L.), proso millet (*Panicum miliaceum* L.), pearl millet (*Pennisetum glaucum* L.R. Br.), finger millet (*Eleusine coracana*), kodo millet (*Paspalum setaceum*), little millet (*Panicum sumatrense*), and barnyard millet (*Echinochloa utilis*). Foxtail millet is one of the oldest domesticated crops, with cultivation dating back to around 8700 years ago in China (Liu et al., 2009). It is the second most widely produced millet globally and serves as a crucial food staple for millions in southern Europe and Asia (Marathee, 1993). This millet is grown extensively in Asia, Europe, North America, Australia, and North Africa for its grain and forage (Austin, 2006). In Bangladesh, the total area under the cultivation of Cheena and Kaon is approximately 1541 acres, yielding about 617 metric tons (BBS, 2019). Foxtail millet thrives in cooler and drier regions compared to other millets (Koch, 2002) and has adapted to withstand challenging environmental conditions like drought and poor soil fertility (Nadeem et al., 2020). Millet crops are typically grown in low-input agricultural systems, especially on marginal lands

where other major cereal crops often perform poorly (Amadou et al., 2013). Foxtail millet has gained global attention for its resilience to pests and diseases, high salinity tolerance, efficient photosynthesis, and excellent nutritional profile (Liu et al., 2011; Vetriventhan et al., 2012). The grains are rich in starch, proteins, lipids, and a variety of vitamins and minerals, making them a valuable addition to the human diet (Bai et al., 2008). Additionally, foxtail millet is a good source of dietary fiber, iron, and β-carotene, while its low glycemic index makes it particularly suitable for individuals with diabetes. The plant also produces soft straw, which is useful as animal feed (Saleh et al., 2013; Zhang, 2015).

In addition to its adaptability to adverse agro-climatic conditions, foxtail millet is increasingly recognized for its remarkable nutritional and health-promoting properties, which contribute to both food and nutritional security. As a rich source of dietary fiber, resistant starch, and essential micronutrients, foxtail millet is particularly beneficial for managing lifestyle-related disorders such as type 2 diabetes and cardiovascular disease (Yang et al., 2022; Arora et al., 2023). Advanced processing techniques such as extrusion, superfine grinding, microbial fermentation, and heat-moisture treatment have been shown to enhance the functional properties of foxtail millet, improving its digestibility, solubility, and antioxidant activity while lowering its glycemic index. These technological innovations can diversify millet-based food products, increasing consumer acceptability and expanding market potential, particularly among health-conscious populations. In the Bangladeshi context, recent nutritional profiling of local foxtail millet varieties confirmed their excellent composition of protein (11.65 g/100 g), carbohydrates (75.33 g/100 g), dietary fiber, and key minerals like iron, calcium, and potassium, along with high antioxidant capacity, further reinforcing their value as a functional food (Abedin et al., 2022). Moreover, foxtail millet's physiological and biochemical resilience to abiotic stresses such as drought and soil salinity has been well documented. Studies have demonstrated the crop's ability to regulate osmotic potential and maintain grain yield under varying salinity and moisture regimes, making it an ideal choice for cultivation in salinity-prone areas such as the Gopalganj district (Ma et al., 2023). Molecular studies also highlight the role of specific calcium-dependent protein kinase (CDPK) genes such as SiCDPK24 in enhancing drought tolerance by modulating the expression of stress-related genes (Yu et al., 2018). Additionally, research into sustainable cultivation practices has revealed that the integration of bacterial consortia and bio-enhancers with chemical fertilizers significantly improves soil biological activity and enzyme function, which can promote healthier root environments and improve nutrient uptake in foxtail millet (Veerendra et al., 2022). These findings suggest that beyond variety selection, appropriate agronomic and biotechnological interventions can further optimize millet productivity in regions facing environmental constraints, thereby supporting efforts to integrate this underutilized crop into Bangladesh’s cropping systems for improved resilience and food security.

For the above reasons the foxtail millet can be an important crop in southern area of Bangladesh for its saline tolerance and adaptive nature in adverse environment. Most of the cultivable area of kotalipara upazila is inundated by water about 6-8 months in a year. Only rice has been cultivated in those areas in boro season. New crop will help to develop the new cropping pattern in kotalipara upazila of Gopalganj district. Foxtail millet is a short duration crop and so it can be suitable for introduce a new crop in different cropping systems especially in the monocropped area of Gopalganj district. After all, the yield of different variety varied significantly due to different Agro-Ecological Zones (AEZs). The productivity and quality of foxtail millet can be improved by detecting the proper variety for proper region. For this reason, BARI (Bangladesh Agricultural Research Institute) released three important foxtail millet varieties was selected for the experiment to find out the best variety for the Gopalganj district of Bangladesh. The specific objectives of the action research were as follows: To estimate and compare the yield performance important foxtail millet varieties in this region (AEZ-14), to find out the best foxtail millet variety for this region (AEZ-14) and to extend and popularize the foxtail millet cultivation at local area.

Literature Review

Foxtail millet (*Setaria italica*) is an ancient cereal crop that has recently gained renewed attention due to its exceptional nutritional value, resilience under harsh agroclimatic conditions, and potential contribution to food and nutritional security in marginal farming areas. Originating in East Asia, foxtail millet has historically been cultivated across Asia and parts of Africa, especially in drought-prone and low-input agricultural systems. The grain is rich in protein, dietary fiber, minerals such as iron, calcium, and zinc, and bioactive compounds that have been associated with various health benefits. These attributes have made foxtail millet a viable alternative to major cereals such as rice and wheat, particularly in areas susceptible to climate variability and resource constraints. In the context of Bangladesh, where arable land is shrinking and climate stresses are intensifying, the integration of climate-resilient crops like foxtail millet into cropping systems could play a significant role in sustainable agriculture. Sharma and Niranjan (2018) conducted a comprehensive review on foxtail millet, emphasizing its physicochemical properties and health-promoting attributes. Their study noted that the millet contains substantial amounts of crude protein, dietary fiber, and micronutrients, which contribute to its low glycemic index and antioxidant potential. These characteristics make it particularly suitable for diabetic and cardiovascular patients. However, despite its nutritional potential, the crop remains underutilized due to limited consumer awareness and lack of large-scale processing technologies. The authors suggested that increased research and development into foxtail millet-based products could stimulate demand and broaden its cultivation.

In terms of improving food value through processing, Yang et al. (2022) reviewed various methods such as heat-moisture treatment, extrusion, fermentation, and superfine grinding. These techniques were found to positively influence the nutritional and functional attributes of foxtail millet, enhancing protein digestibility, increasing resistant starch, and improving antioxidant activity. These findings suggest that food processing innovations can significantly increase the acceptability and market potential of foxtail millet by transforming it into value-added products suitable for modern consumer preferences. Building on this idea, Arora et al. (2023) investigated the nutritional and sensory evaluation of eight foxtail millet-based food products. The study revealed that millet-based products like kheer, laddoo, and energy bars not only maintained high nutritional content but also scored well in sensory evaluations related to taste, texture, and appearance. Importantly, most of the products developed had low glycemic indices and high resistant starch content, making them appropriate for health-conscious populations. This research highlights the versatility of foxtail millet in food product development, which could be an essential driver for consumer acceptance in Bangladesh and beyond. Focusing on the local context, Abedin et al. (2022) explored the physical, functional, and antioxidant properties of foxtail millet cultivated in Bangladesh. Their findings confirmed that indigenous foxtail millet varieties possess favorable nutritional and functional traits, including significant protein and mineral content, water absorption capacity, and high antioxidant activity. These attributes reinforce the suitability of the crop for both food security and nutritional interventions in rural Bangladesh. Given that Bangladesh is actively exploring alternative crops to ensure sustainable farming in climate-sensitive zones, these findings provide strong evidence for expanding millet cultivation in the country. Agronomic performance and environmental adaptability are equally critical when assessing millet varieties for specific regions. Zhang et al. (2023) conducted a multi-season analysis to evaluate the impact of weather variables such as rainfall, sunshine duration, and temperature on foxtail millet yield. Their study found that sunshine duration and diurnal temperature range were the most significant factors influencing grain yield, particularly under water-stressed conditions. This finding is particularly relevant for regions like Gopalganj, located within Agro-Ecological Zone 14 (AEZ-14), where erratic rainfall and high humidity are common. Understanding the interaction between weather and millet performance is essential for selecting suitable varieties for local cultivation. Water and soil salinity are additional factors that influence millet productivity. Ma et al. (2023) explored the effects of different salinity levels and irrigation regimes on foxtail millet's physiological traits and yield. They discovered that moderate salinity,

coupled with adequate irrigation, could enhance osmotic adjustment and yield stability. However, excessive salt stress significantly reduced biomass and grain output. Their findings underscore the need to identify salinity-tolerant millet varieties, which could be critical in districts like Gopalganj where saline intrusion into agricultural lands is becoming more frequent due to climate change and upstream water management practices.

In terms of soil health and nutrient management, Veerendra et al. (2022) evaluated the impact of integrating chemical fertilizers with bio-agents on soil microbial dynamics and enzyme activities in millet cropping systems. The application of microbial consortia along with recommended fertilizers significantly improved soil microbial biomass, enzyme activities (such as dehydrogenase and phosphatase), and overall soil fertility. Such integrated nutrient management approaches can not only sustain millet yield but also improve long-term soil health, which is crucial for maintaining productivity in regions with fragile soil ecosystems like AEZ-14. On a molecular level, genetic studies are providing deeper insights into the stress tolerance mechanisms of foxtail millet. Yu et al. (2018) conducted a genome-wide analysis of calcium-dependent protein kinases (CDPKs), identifying *SiCDPK24* as a key gene involved in drought resistance. Overexpression of this gene in model plants like Arabidopsis significantly improved drought tolerance. Such findings open new avenues for developing improved millet varieties through marker-assisted selection and genetic engineering, which could be highly beneficial for stress-prone regions. Taken together, the existing body of research affirms foxtail millet's considerable potential as a climate-resilient, nutritionally rich, and versatile crop. The studies reviewed provide essential insights into its nutritional qualities, processing benefits, environmental adaptability, and genetic traits. These findings lay a strong foundation for evaluating the agronomic performance of different foxtail millet varieties, such as BARI Kaon-2, BARI Kaon-3, and Titas, under the unique agroecological conditions of AEZ-14 in Gopalganj, Bangladesh. Such comparative studies are essential for guiding local adaptation strategies and promoting the crop in diversified farming systems.

Research Method

The field experiment was carried out at the agricultural farm of the Rural Development Academy (RDA) in Gopalganj, from November 1, 2023, to April 21, 2024. The site is located between 21°51' and 23°10' north latitude, and 89°56' and 90°10' east longitude, within Agro-Ecological Zone (AEZ)-14. The farm area features medium-high land with sandy loam soil. The region experiences an average temperature range of 12.1°C to 36.1°C, with heavy rainfall occurring during the rainy season. BARI Kaon-2, BARI Kaon-3, and Titas (a BARI released variety) were used for the experiment. Seed was collected from Bangladesh Agriculture Research Institute (BARI), Joydebepur, Gazipur, Bangladesh. The four cross ploughing was done by a rotary plough by four times and raised plot was prepared. The seed was sown during 20 November, 2023. Seed was sown in broadcasting method and seed rate was 10 kg/ha. Before sowing the plot was prepared by cleaning the wastage from the field. Total 12 plots were prepared. The size of the plot was (6.5m×8m) and about 50 cm drain was kept between two plots. Randomized Completely Block Design (RCBD) was used with 4 replications of three important varieties. Varieties were-

V_1= BARI Kaon-2
V_2= BARI Kaon-3
V_3= Titas (a BARI released variety)

Fertilizer was used as the recommendation of Krishi Projukti Hatboi (2019). Urea 170 kg/ha, TSP 125 kg/ha, MoP 90 kg/ha, Zypsum 55 kg/ha, Zinc Sulphate 4 kg/ha was the fertilizer dose. All fertilizers and ½ of Urea was applaied as a basal dose during land preparation. Rest of Urea was applied after 35-40 days of seed sowing. Thinning and weeding were done to maintain the optimum population. Irrigation and drainage were done at proper time. The crop was attacked by fungal disease which was controlled by spraying proper fungicide. Harvesting time is a very important and critical for foxtail millet. The symptoms of the maturity of the foxtail millet were:

The ear of the foxtail millet was taken the color of the straw and the grain made a sound when threshed with teeth. Harvested crop was taken in the laboratory of the RDA, Gopalganj.

Data collection was a very important for a research work. In case of the present study data was recorded on the following parameters: Plant height (cm) during harvesting, Crop duration, Total number of tillers per plant, Effective tillers per plant, Ineffective tillers per plant, Ear length (cm), Weight of main ear (gm), Thousand Seed weight (gm), Grain yield (t/ha), Straw yield (t/ha) Biological yield (t/ha), Harvest index (%). All data was taken carefully at proper time. Data was collected from the experimental plot and the laboratory of Rural Development Academy (RDA), Gopalganj. The collected data was analyzed by using STAR (Statistical Tool for Agricultural Research) software. The mean values for all the parameters were calculated and gave input into the software. The Analysis of Variance (ANOVA) was performed for Randomized Complete Block Design (RCBD). The significance of the difference among the treatment means was estimated by the at 5 % levels of probability.

Results and Discussion:

Plant height during harvesting (cm)

Plant height during harvesting was varied 109.03cm to 47.75cm (Table-1). Maximum plant height during harvesting was recorded with V_1 (109.03cm). The minimum plant height during harvesting was recorded in V_2 (47.75cm). The V_3 gave 71.15cm plant height during harvesting. As a result, the BARI Kaon-2 gave the maximum plant height during harvesting and the BARI Kaon-3 gave the lowest plant height during harvesting. Short plant height has an advantage during high speed wind. It can protect itself from lodging. Azad *et.al.* (2019) observed that, the plant height of BARI Kaon-2 and BARI Kaon-3 were 100cm and 45-50cm respectively. In the research of screening of foxtail millet, Rahman et.al. (2020) found that the highest plant height at harvest (136 cm) was registered under RC-170 while BD-998 was the lowest plant height during harvesting (105 cm).

Table-1: Plant height (cm) during harvesting, Total number of tillers per plant, Effective tillers per plant, Ineffective tillers per plant, Ear length (cm), Weight of main ear (gm)

Variety	Plant height (cm) during harvesting	Total number of tillers per plant	Effective tillers per plant	Ineffective tillers per plant	Ear length (cm)	Weight of main ear (gm)
BARI Kaon-2 (V_1)	109.03a	1.50	1.40	0.15	19.68a	6.24a
BARI Kaon-3 (V_2)	47.75c	1.55	1.35	0.20	16.07b	5.28b
Titas (a BARI released variety) (V_3)	71.15b	1.25	1.15	0.10	14.30b	5.39b
CV (%)	4.58	17.56	20.99	91.62	7.21	7.34
F-test	*	NS	NS	NS	*	*

**Significant at 5% level of significance; NS= Non Significant*

** In a column, figure with same letter do not differ significantly;*

Source: *Data were collected from the experimental plot and analyzed using the STAR (Statistical Tool for Agricultural Research) software.*

Total number of tillers per plant

Total number of tillers per plant was varied 1.55 to 1.25 (Table-1). Maximum number of tillers per plant was recorded with V_2 (1.55) and the minimum number of tillers per plant was recorded with V_3 (1.25) which was statistically similar with each other. The BARI Kaon-2 gave the 1.50 tillers per plant and BARI Kaon-3 gave the 1.55 tillers per plant but there was no significant different among the varieties at 5% level of significance.

Effective tillers per plant
The number of effective tillers per plant was varied from 1.40 to 1.15 (Table-1). The maximum effective tillers per plant was recorded with V_1 (1.40) and the minimum number of effective tillers per plant was recorded with V_3 (1.15) which was statistically identical with each other. BARI Kaon-2 gave the maximum total number of effective tillers per plant and titas variety gave the minimum total number of effective tillers per plant but there was no significant different among the varieties at 5% level of significance. Rahman *et.al.* (2020) found that the effective tillers per plant was not significantly varied among the foxtail millet varieties.

Ineffective tillers per plant
The number of ineffective tillers per plant was varied from 0.20 to 0.10 (Table-1). The maximum ineffective tillers per plant was recorded with V_2 (0.20) and the minimum number of ineffective tillers per plant was recorded with V_3 (0.10) which was statistically similar. BARI Kaon-2 gave 0.15 ineffective tillers per plant and there was no significant different among the varieties at 5% level of significance. Rahman *et.al.* (2020) reported that the ineffective tillers per plant was not significantly varied among the foxtail millet varieties.

Ear length (cm)
Ear length was investigated from 19.68cm to 14.30cm (Table-1). The Maximum ear length was found in V_1 (19.68cm) and the minimum ear length was found in V_3 (14.30cm) which was statistically similar with V_2 (16.07cm). As a result, the BARI Kaon -2 gave the maximum ear length and titas variety gave the minimum ear length. According to Azad *et.al.* (2019) the ear length of the BARI Kaon-2 was 20cm-25cm and the BARI Kaon-3 was 17.0cm.

Weight of main ear (gm)
The weight of main ear was varied from 6.24gm to 5.28gm (Table-1). The maximum weight of main ear was recorded with V_1 (6.24gm) and the minimum weight of main ear was recorded in V_2 (5.28gm). The V_2 (5.28gm) and V_3 (5.39 gm) were statistically identical in case of weight of main ear. As a result, we decided that the BARI Kaon -2 gave the highest weight of main ear and the BARI Kaon-3 gave the lowest weight of main ear.

Thousand seed weight (gm)
The thousand seed weight was varied from 2.54gm to 2.30gm (Table-2). The maximum thousand seed weight was recorded with V_1 (2.54gm). The minimum thousand seed weight was found in V_2 (2.30gm) which was statistically similar with V_3 (2.38gm). It means that the BARI Kaon -2 gave the highest thousand seed weight and the BARI Kaon -3 gave the lowest thousand seed weight. Azad *et.al.* (2019) reported that the thousand seed weight of titas variety, BARI Kaon-2 and BARI Kaon-3 were 2.3gm-2.5gm, 2.55gm and 2.36gm respectively. In case of thousand seed weight the highest (3.39 gm) were recorded under BD-954 and the lowest (1.50 gm) was recorded in BD-1086 by Rahman *et.al.* (2020). Kim and Yoon (2017) reported that the thousand seed weight of foxtail millet was varied from 2.39gm to 3.17gm under different paddy-upland rotation systems.

Crop duration (days)
The duration of crop was varied from 126.50 days to 108.50 days (Table-2). The maximum crop duration was recorded with V_2 (126.50 days) which was statistically identical with V_1 (121.0 days). The minimum crop duration was recorded in V_3 (108.50 days). As a result, titas variety was comparatively short duration crop than other varieties (BARI Kaon-3 and the BARI Kaon-2). The days required to complete the life cycle of a variety is an inherent and unique character. Generally, it varies species to species, variety to variety. Sometimes it may be affected by the environmental factors such as season to season, irrigation condition, soil fertility etc. However, it was observed that the crop duration of titas variety, BARI Kaon-2 and BARI Kaon-3 were was 105-115 days, 120-125days and 120-125 days respectively by BARI (Azad *et.al.*, 2019). Kim and Yoon (2017)

observed the 111 days to 134 days crop duration for foxtail millet under different paddy-upland rotation systems.

Table-2: Thousand Seed weight (gm), Crop duration (days after sowing), Grain yield (t/ha), Straw yield (t/ha), Biological yield (t/ha), Harvest index (%).

Variety	Thousand Seed weight (gm)	Crop duration (days after sowing)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (ton/ha)	Harvest index (%)
BARI Kaon-2 (V_1)	2.54a	121.0a	2.79a	5.72a	8.51a	32.79
BARI Kaon-3 (V_2)	2.30c	126.50a	2.44b	4.58b	7.02b	34.76
Titas (a BARI released variety) (V_3)	2.38b	108.50b	2.10c	4.80b	6.90b	30.44
CV (%)	1.73	4.74	3.73	11.67	15.78	14.73
F-test	*	*	*	*	*	NS

**Significant at 5% level of significance; NS= Non Significant*
** In a column, figure with same letter do not differ significantly;*
Source: *Data was collected from the experimental plot and data was analyzed by using STAR (Statistical Tool for Agricultural Research) software*

Grain yield (t/ha)
Yield is an important factor in case of crop cultivation. The grain yield was varied from 2.79 t/ha to 2.10 t/ha (Table-2). The maximum grain yield was recorded with V_1 (2.79 t/ha) and the minimum grain yield was found in V_3 (2.10 t/ha). The V_2 gave 2.44 t/ha in case of grain yield. As a result, it can be concluded that the BARI Kaon -2 was the best variety in terms of grain yield. Azad *et.al.* (2019) found that, the grain yield of titas variety, BARI Kaon-2 and BARI Kaon-3 were 2.0-2.5 t/ha, 2.75-3.0 t/ha and 2.5-3.0 t/ha respectively. Rahman *et.al.* (2020) reported the yield of foxtail millet was varied from 2.41 to 3.52 t/ha among the 11 foxtail millet varieties.

Straw yield (t/ha)
The straw yield was varied from 5.72 t/ha to 4.58 t/ha (Table-2). The maximum straw yield was recorded with V_1 (5.72 t/ha). The minimum straw yield was found in V_2 (4.58 t/ha) which was statistically identical with V_3 (4.80 t/ha). As a result, the BARI Kaon-2 produced the highest straw yield and BARI Kaon-3 produced the lowest straw yield.

Biological yield (t/ha)
Biological yield is the total biomass production. It comprises with grain yield and straw yield. The biological yield was varied from 8.51 t/ha to 6.90 t/ha (Table-2). The maximum biological yield was recorded with V_1 (8.51 t/ha). The minimum biological yield was found in V_3 (6.90 t/ha) which was statistically identical with V_2 (7.02 t/ha). As a result, it can be said that the BARI Kaon-2 produced the maximum biomass.

Harvest Index (%)
Harvest index is the ratio of economic yield and biological yield. Here, the economic yield was the grain yield and the biological yield was the total biomass production. The harvest index was varied from 34.76% to 30.44% (Table-2). The maximum harvest index was recorded with V_2 (34.76%) which was statistically similar with V_1 (32.79%) and V_3 (30.44%). There was no significant different among the varieties at 5% level of significance. The variety which performed higher grain yield also performed higher biological yield and the harvest index was the ratio of grain yield and biological yield. As a result, the harvest index was not varied significantly among the three varieties called titas, BARI Kaon-2 and the BARI Kaon-3.

Conclusion

The results of the present study highlighted significant variations in the agronomic traits of the three foxtail millet varieties tested under the agro-ecological zone (AEZ-14) of Gopalganj district. Among the varieties, BARI Kaon-2 emerged as the superior cultivar for most of the measured traits. It recorded the maximum plant height (109.03 cm), ear length (19.68 cm), weight of main ear (6.24 g), and thousand seed weight (2.54 g), demonstrating its robust growth and productive potential. The high plant height and ear length of BARI Kaon-2 make it a promising variety for maximizing yield potential in the region. Despite these advantages, the Titas variety demonstrated a relatively shorter crop duration (108.50 days), which could offer benefits for farmers looking for a quicker turnaround crop, allowing for a shorter cropping cycle and better integration into diverse cropping systems. However, in terms of total number of tillers per plant, effective tillers per plant, ineffective tillers per plant, and harvest index, there were no significant differences among the three varieties, suggesting that these factors may not be the primary determinants of performance for this specific study area.

BARI Kaon-2 also outperformed the other varieties in terms of both grain yield (2.79 t/ha) and straw yield (5.72 t/ha), translating into the highest total biomass production (8.51 t/ha). This makes BARI Kaon-2 an excellent choice for farmers in AEZ-14, as it offers both high grain production and substantial biomass, which can be valuable for both food security and additional uses such as fodder or soil improvement. The variety's superior performance in grain yield and biomass production highlights its potential for not only improving crop productivity but also contributing to the overall sustainability of farming systems in the region. Moreover, although BARI Kaon-2 showed the highest performance in terms of grain yield and biomass, it is important to note that all three varieties, including BARI Kaon-3 and Titas, have their own merits depending on specific farming needs. Titas, for instance, may be suitable for regions where a shorter crop duration is desired, while BARI Kaon-3 showed promising results in other areas despite its slightly lower performance in comparison to BARI Kaon-2.

Based on the findings, BARI Kaon-2 is recommended as the most suitable variety for cultivation in the Gopalganj district under the prevailing agro-ecological conditions. Its superior yield and biomass production make it an ideal choice for enhancing food production and farmer incomes. The introduction of BARI Kaon-2 can also play a vital role in diversifying local cropping systems, improving soil health, and increasing overall farm resilience. Further studies could explore the potential of these varieties in different ecological zones or under varying management practices to confirm their adaptability and to refine best practices for their cultivation. Moreover, the adoption of BARI Kaon-2 in Gopalganj, along with targeted support for its integration into the local farming systems, is likely to contribute significantly to sustainable agricultural development in the region. The extension of this variety for local farmers should be accompanied by adequate training and support to ensure optimal cultivation practices and maximum benefit from the crop.

Recommendations for the farmers

Farmers in the Gopalganj district are strongly encouraged to consider the cultivation of foxtail millet, particularly the variety BARI Kaon-2, on their marginal lands. This variety has demonstrated exceptional performance in terms of grain yield, biomass production, and adaptability to the local agro-ecological zone (AEZ-14). BARI Kaon-2 has shown the highest grain yield (2.79 t/ha) and biomass production (8.51 t/ha) among the tested varieties, making it an ideal choice for maximizing productivity in areas with limited soil fertility or marginal conditions. Its ability to thrive under such circumstances makes it a valuable crop, especially when compared to traditional cereals that may not perform as well in similar conditions. Additionally, BARI Kaon-2 is characterized by its relatively short duration compared to other varieties, with a crop duration of approximately 121 days. This characteristic can offer farmers more flexibility in their cropping schedules, enabling them to plant foxtail millet within a rotation system that fits with other seasonal crops. The introduction of foxtail millet can diversify the existing cropping pattern,

reducing the dependency on monocropping, improving soil health, and increasing overall farm resilience against climate variability. Furthermore, the cultivation of foxtail millet can provide an alternative income source for farmers, as it is a drought-tolerant crop that requires relatively low inputs in terms of water and fertilizer compared to other cereal crops. This could help reduce the cost of production, especially in areas prone to water scarcity or where irrigation is not widely available. Moreover, foxtail millet can be an excellent crop for improving food security, as it is rich in nutrients like iron, zinc, and fiber, and can serve as a dietary supplement in rural households. Introducing foxtail millet into the cropping system may also have ecological benefits. The crop's deep-root system helps improve soil structure, reducing soil erosion and enhancing water retention in the soil, thus benefiting the broader agricultural ecosystem. Therefore, farmers should be encouraged to take advantage of the potential benefits of foxtail millet, particularly BARI Kaon-2, for its high productivity, adaptability, and suitability for marginal lands. Moreover, extension services should provide necessary training and technical support to farmers, ensuring they are well-equipped to adopt this new crop and integrate it successfully into their farming practices. In doing so, they can improve both their livelihoods and the sustainability of their agricultural systems.

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