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Assessment of indigenous farming practices for foxtail millet (*Setaria italica*) in North Cotabato, Philippines

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Abstract. *Habibun JF, Detalla MEB, Aradilla AA, Paulican MSM, Intong JD. 2026. Assessment of indigenous farming practices for foxtail millet (*Setaria italica*) in North Cotabato, Philippines. Asian J Agric 10 (1): g100162. https://doi.org/10.13057/asianjagric/g100162.* This study assessed and verified indigenous farming practices of Manobo farmers for foxtail millet (*Setaria italica*) production in President Roxas, North Cotabato, Philippines. A participatory on-farm trial was conducted to evaluate performance of farmers' practice (indigenous planting methods) and local millet lines in the on-farm environment. The experiment was laid out in strip plot in Randomized Complete Block Design (RCBD) arrangement with four replications. Three local millet lines (yellow, black and red) were tested in three planting methods; broadcast, hill and drill planting methods. Results showed no significant differences among millet lines and planting methods in terms of emergence (5.92-6.00 Days to emergence (DAS)), panicle emergence (81-82 DAS), maturity (103-104 DAS), plant height, and tillers number. However, planting method has a significant effect on yield and economic return of foxtail millet. The highest yield of 2,319.50 kg ha^{-1} and ROI of 124.15% was obtained from drill planting, followed by broadcast planting (2,189.08 kg ha^{-1}) but with significantly low yield from hill planting (1,667.25 kg ha^{-1}). Farmer feedback further confirmed that drill planting improved plant spacing, enhanced weed control, and promoted better soil moisture utilization under field conditions but more labor is required for planting. These findings support integrating validated indigenous practices into extension programs for sustainable agriculture.

Keywords: Arakan Valley, foxtail millet, Manobo Tribe, Manobo farmers practices

INTRODUCTION

Foxtail millet (*Setaria italica*) is one of the oldest domesticated cereal crops, with evidence of cultivation dating back more than 10,000 years in East Asia. It is widely recognized for its adaptability to marginal environments, including drought-prone and low-input agricultural systems (Diao 2017). In recent years, foxtail millet has gained renewed attention due to its resilience to climate variability, short growing duration, and high nutritional value, including significant levels of protein, dietary fiber, iron, and micronutrients (Lapuimakuni et al. 2018; Abedin et al. 2022; Karamang et al. 2023). These attributes make it a strategic crop for enhancing food security, particularly in developing countries facing climate-related production constraints.

Globally, foxtail millet ranks among the most important small millets, with major production concentrated in countries such as China, India, and parts of Africa (Nagaraja et al. 2023). Despite its global significance, the crop remains underutilized in the Philippines, where agricultural systems are still heavily dominated by rice and corn. However, in selected upland and indigenous communities, particularly among the Manobo people in Central Mindanao, foxtail millet continues to be cultivated using traditional farming practices. Locally known as Bat'tam, the crop plays a vital role not only in household food consumption but also in cultural traditions and livelihood systems.

Indigenous farming practices represent accumulated ecological knowledge developed through long-term interaction with local environments. These practices are often characterized by low external input use, reliance on local seed systems, and adaptation to specific agroecological conditions. Studies have shown that such knowledge systems can contribute to sustainable agriculture, biodiversity conservation, and climate resilience (Salvaña and Arnibal 2019; Daryono et al. 2020). However, despite their importance, indigenous practices are increasingly threatened by agricultural intensification, market-driven crop shifts, and generational knowledge loss. Younger farmers are gradually abandoning traditional crops like foxtail millet in favor of more commercially profitable alternatives, placing both the crop and associated knowledge systems at risk.

While previous studies have documented the cultural and ethnographic aspects of indigenous communities, there remains a significant lack of empirical research evaluating the agronomic performance and economic viability of indigenous farming practices for foxtail millet in the

Philippine context. In particular, there is limited quantitative evidence on how traditional planting methods influence key production parameters such as yield, plant growth, and resource-use efficiency under local field conditions. Moreover, comparative validation of these practices using scientific approaches is still insufficient.

Recent agronomic studies have emphasized the importance of planting geometry, plant density, and resource optimization in improving millet productivity. For instance, Li et al. (2022) and Zhang et al. (2022) reported that planting methods significantly influence growth performance and yield components in foxtail millet. Similarly, Zhao et al. (2022) and Zhong et al. (2024) highlighted that improved spatial arrangement enhances light interception, reduces intra-specific competition, and increases yield efficiency. However, these studies are largely conducted under controlled or non-indigenous farming systems, and their applicability to traditional, low-input farming contexts remains unclear.

Furthermore, while foxtail millet is known for its relatively stable phenological traits across environments (Upadhyaya et al. 2011), the interaction between indigenous practices and crop performance has not been sufficiently explored. This gap is particularly critical in regions such as North Cotabato, where farming systems are predominantly rainfed and resource-constrained, and where indigenous knowledge could play a crucial role in sustainable intensification.

Therefore, there is a need to systematically document, assess, and scientifically validate indigenous farming practices for foxtail millet production in this region. Understanding which practices are effective-and why-can provide a basis for integrating traditional knowledge with modern agronomic principles. This integration is essential not only for improving productivity and farmer income but also for preserving cultural heritage and promoting sustainable, climate-resilient agricultural systems (Food and Agriculture Organization (FAO 2021)).

In this context, the present study aimed to assess and verify the indigenous farming practices of Manobo farmers in President Roxas, North Cotabato, Philippines, by evaluating their effects on agronomic characteristics, yield performance, and economic returns of foxtail millet (*S. italica*). Specifically, the study seeks to identify which traditional practices can be optimized and promoted through extension programs to enhance both productivity and sustainability in upland farming systems.

MATERIALS AND METHODS

Study area

The study was conducted in a selected farmer's field engaged in foxtail millet planting at Datu Inda, President Roxas, North Cotabato, Philippines, with geographical coordinates of 7°9'16" North, 125°3'21" East from November 2018 to February 2019 (Figure 1). Farming in the area depended on rains and about 90% of the total cultivated area was under rainfed agro-ecosystem. The area was occupied by one of the tribal communities in Arakan Valley Complex, which cultivated foxtail millet lines and practiced local knowledge farming system.

The farmers were economically challenged and cannot afford the high cost of farm inputs required for energy-based agriculture. There were 15 randomly selected tribal farmers who participated in the on-farm trial with at least five years of experience in millet production. The farmer-participants, with a lead farmer, established and maintained the study area under the supervision of the researcher during the entire duration of the study.

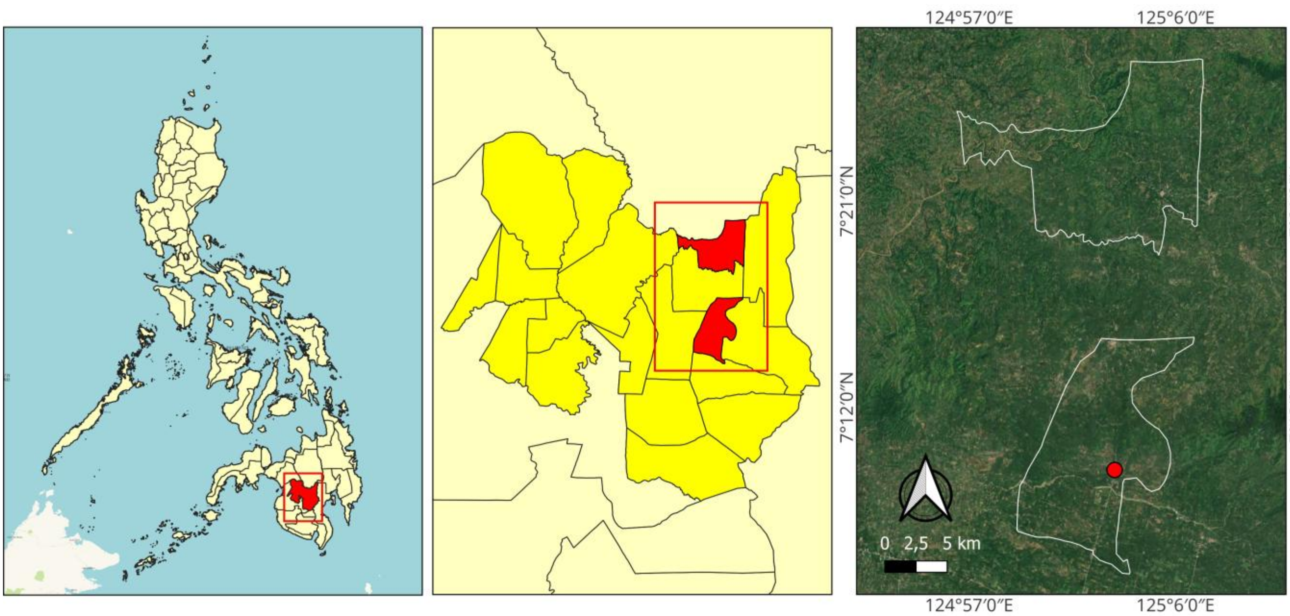

Figure 1. Location map of the study area at coordinates 7°9'16" N, 125°3'21" E in President Roxas, North Cotabato, Philippines

Verification methodology

To verify and assess indigenous production practices, the study utilized an on-farm participatory field trial involving 15 randomly selected Manobo farmers, each with a minimum of five years of experience in millet production. A lead farmer assisted in coordinating field activities. The trial was designed using a Randomized Complete Block Design (RCBD) in a strip plot arrangement with four replications. The vertical factor included three foxtail millet lines (yellow, black, and red), and the horizontal factor represented three traditional planting methods (broadcast, hill, and drill). Each treatment plot measured 4 × 5 m, and the total land area used was 1,054 m². Verification was conducted through yield comparison, economic analysis, and field observation. Throughout the experiment, researchers and farmers jointly monitored the plots. Validation was further ensured via farmer debriefing sessions, informal feedback discussions, and comparative analysis of indigenous versus modified methods, reinforcing the scientific rigor of traditional practices under real farm conditions.

The study employed a participatory on-farm verification approach, integrating indigenous knowledge with scientific experimental methods under actual field conditions. This approach ensured that the evaluation of practices was both scientifically valid and contextually relevant to local farming systems.

The experiment was established using a Randomized Complete Block Design (RCBD) in a strip plot arrangement with four (4) replications. The design allowed for the simultaneous evaluation of foxtail millet lines and planting methods while minimizing environmental variability across the field.

Materials

The materials used in this study included seeds of foxtail millet lines (yellow, red, and black). Additional tools consisted of draft animals with implements, plow, bolo, sickle, shovel, bamboo sticks, ruler, meter stick, weighing scale, camera, pen, and record book.

Experimental design and treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) in strip plot arrangement, replicated four times. The vertical factors (A) were the foxtail millet lines, and the horizontal factors (B) were the methods of planting. The vertical factors consisted of three lines of foxtail millet: yellow, red, and black while the horizontal factors consisted of three methods of planting: broadcast, hill/dibble and drill method. Each treatment combination was assigned to each plot with a dimension of 4 × 5 m with an alley of 2 m between blocks and 1 m between plots. A total land area of 1,054 m^2 was used for this experiment with the following treatments:

Vertical Factor (A): Foxtail Millet Lines
V_1: Yellow
V_2: Tapol/Black
V_3: Red
Horizontal Factor (B): Methods of Planting
M1: Broadcast
M2: Hill/Dibble
M3: Drill

Each experimental plot measured 4 × 5 m. Plots were spaced 1 m apart with 2 m between blocks, covering a total experimental area of 1,054 m².

Verification of indigenous practices was conducted through a combination of: (i) Field experimentation and yield comparison, wherein agronomic traits and grain yield were measured across treatments; (ii) Economic analysis, including computation of net income and return on investment (ROI); and (iii) Participatory validation, involving farmer observations, feedback sessions, and preference ranking of the evaluated practices.

Farmer-participants were actively involved throughout the cropping period, from land preparation to harvesting. Regular field monitoring was conducted jointly by the researcher and the farmers to ensure proper implementation of treatments and to document observations under real farming conditions.

The integration of farmer knowledge with scientific evaluation in the verification process aligns with participatory research approaches. This approach enhances the reliability and applicability of results in smallholder systems (FAO 2021).

Cultural and management practices

Land preparation

The land preparation on the farmer's field was thoroughly prepared. The existing vegetation was cut and stubbles were left in the field to decompose for one month. This served as source of organic matter. Minimum tillage was practiced in the field as practiced by farmers, and furrows were made, spaced 30 cm apart before sowing foxtail millet seeds.

Varietal selection, planting and thinning

The three foxtail millets obtained from Manobo farmers were used in the verification trial. For plots assigned in M_1, foxtail millet was broadcasted at the rate of 33 kg ha^{-1} or 2 gm $plot^{-1}$ (adopted from Salingay 2018). Plots assigned in M_2 were planted using the dibble method spaced at 30 cm between hills at three plants per hill using a pointed stick or "tudak". The plots that were assigned in M_3 were planted using the drill method at a row distance of 30 cm with ten plants per linear meter. Thinning of excess seedlings was done three weeks after emergence leaving three seedlings per hill for dibble and ten (10) seedlings per linear meter for drill method of planting.

Nutrient and pest management

In accordance with indigenous farming practices, no chemical fertilizers or pesticides were applied throughout the duration of the study. This approach ensured that the evaluation of planting methods reflected actual farmer conditions and allowed for the assessment of productivity under low-input systems.

Harvesting and post-harvest handling

The crop was harvested when 90% of the grains of the panicle in the total plant population per plot turned into brownish or golden color or when the leaves turned yellow. This was done by cutting the mature panicles using a traditional sickle. The harvested panicles were foot-threshed and grains were subsequently sundried for three days or until the moisture content reached 14%. Dried grains were placed in sacks before storage.

Data analysis

The data gathered were analyzed using the Analysis of Variance for Strip Plot in Randomized Complete Block design. The Honestly Significant Difference (HSD) test was used to compare differences among treatments that show significant results after the Analysis of Variance (ANOVA).

RESULTS AND DISCUSSION

Days to emergence, panicle emergence and maturity of foxtail millet lines as affected by methods of planting

Days to emergence (DAS)

Table 1 presents the data on days to emergence of foxtail millet lines in farmers' field. As shown, there were no significant differences on the days to emergence (DAS) of the yellow, black/tapol, and red foxtail millet lines when the three planting methods were used, (broadcast, hill, and drill methods). The observed mean values ranged from 5.92 to 6.00 DAS, indicating that emergence of foxtail millet is at around 6 DAS. On planting methods, no statistically significant differences were detected. Planting methods do not affect the emergence of foxtail millet. At planting, it was ensured that planting depths will not vary so much, hence, this could also be one reason for the comparable emergence periods.

The findings of Zhang et al. (2022) and Qiao et al. (2025), who investigated the effects of varied seeding depths on the days after sowing (DAS) of foxtail millet lines, are consistent with the present data. Their research discovered that spreading seeds at shallower depths had a substantial impact on the days to appearance of seedlings. Deeper seeding depths, were observed to delay seedling emergence. Although the current study did not specifically examine the effect of sowing depth, the similarity of emergence time across all planting methods suggests that sowing depth may not have had a major effect on the days to emergence of the foxtail millet lines studied.

Jung et al. (2018) and Sun et al. (2023) stressed the critical importance of accurate sowing depth in optimizing emergence and aiding crop establishment. It is critical to recognize that seed-sowing depth is a major variable in this situation.

Table 1. Days to emergence, panicle emergence and maturity of foxtail millet lines as affected by methods of planting

Treatments	Days to emergence (Das)	Days to panicle emergence (Das)	Days to maturity (Das)
Foxtail millet lines			
Yellow (V_1)	6.00	81.75	104.00
Black (V_2)	5.92	82.58	104.17
Red (V_3)	5.92	82.58	103.83
F-test (a)	ns	Ns	ns
CV (a) %	2.80	1.62	1.65
Planting methods			
Broadcast (M_1)	6.00		103.75
Hill (M_2)	6.00	82.17	104.50
Drill (M_3)	5.83	82.17	103.75
F-test (b)	ns	Ns	ns
CV (b) %	5.61	1.63	0.89
Treatment combinations			
V_1M_1	6.00	82.50	103.75
V_1M_2	6.00	81.25	104.75
V_1M_3	6.00	81.50	103.50
V_2M_1	6.00	82.50	103.75
V_2M_2	6.00	83.00	104.75
V_2M_3	5.75	82.25	104.00
V_3M_1	6.00	82.75	103.75
V_3M_2	6.00	82.25	104.00
V_3M_3	5.75	82.75	103.75
F-test (a x b)	ns	Ns	ns
CV (c) %	2.80	1.42	1.30

Note: ns: Not significant

Days to panicle emergence

Analysis of variance revealed no significant differences ($p>0.05$) in days to panicle emergence among the three foxtail millet lines (yellow, black, and red), with all lines reaching this growth stage between 81-82 DAS at the farmers' location. Similarly, neither planting methods nor their interaction with millet lines showed significant effects on emergence timing. This phenotypic stability across genotypes and agronomic treatments suggests panicle emergence in foxtail millet is primarily governed by conserved genetic mechanisms rather than environmental or management factors, as demonstrated in genomic studies of Setaria species (Doust et al. 2009). These findings align with Srikanya et al. (2020), who observed consistent panicle emergence periods (79-83 DAS) across different sowing dates, and with Upadhyaya et al. (2011)'s characterization of foxtail millet's stable phenology in diverse growing conditions. The observed developmental uniformity may represent an evolutionary adaptation to ensure reproductive success in variable environments (Vetriventhan et al. 2020), though further investigation is needed to determine if subtle variations (<24 hours) in emergence timing could affect yield potential under stress conditions. While this stability simplifies crop management, breeders targeting climate adaptation might need to identify rare alleles influencing phenological plasticity, as current germplasm appears highly conserved for this trait.

Days to maturity

Table 1 presents the data on the days to maturity of foxtail millet (*S. italica*) lines across planting methods. Among foxtail millet lines, no significant differences have been detected. Crop maturity was not also affected by planting methods. As shown in Table 1, foxtail millet matures 103-104 days after sowing. Moreover, even the interaction of foxtail millet lines and planting methods is not significant. This means that the technique of planting has no effect on the time required for a crop to mature. This is consistent with the findings of Zhang et al. (2022), who found also found no statistically significant differences on the days to maturity of foxtail millet lines.

These findings suggest that the choice of foxtail millet line has minimal influence on the crop's phenological development. Similarly, the planting method shows little effect under the given agro-climatic conditions.

Plant height (cm) at 30, 45, 60, 75 DAS, and at maturity of foxtail millet (*Setaria italica*) lines as affected by methods of planting

The plant height data of three foxtail millet lines (*S. italica*), yellow, black/tapol, and red, under three sowing methods, (broadcast, hill and drill) are shown in Table 2. In all data gathering periods until maturity, plant heights of the three foxtail millet lines did not differ significantly; neither did plant heights using the three methods of planting, including the interaction of foxtail millet lines and methods of planting. At 30 DAS, foxtail millets heights ranged from 52-53 cm, while at 45, 60 and 75 DAS plant heights ranged at 71-72 cm, 95-96 cm, and 118-119 cm, respectively. At maturity, foxtail millet lines had heights ranging from 133-135 cm.

Table 2. Plant height (cm) at 30, 45, 60, 75 DAS, and at maturity of foxtail millet (*Setaria italica*) lines as affected by methods of planting

Treatments	Plant height (cm)				
	30 DAS	45 DAS	60 DAS	75 DAS	Maturity DAS
Foxtail millet lines					
Yellow (V_1)	52.97	72.05	96.37	118.68	134.69
Black (V_2)	52.68	71.76	95.83	118.27	133.36
Red (V_3)	52.76	72.16	96.14	118.24	134.49
F-test (a)	ns	ns	ns	ns	ns
CV (a) %	5.12	3.09	1.85	0.5561	1.65
Planting methods					
Broadcast (M_1)	52.93	72.19	96.55	118.28	134.05
Hill (M_2)	51.53	71.86	95.43	118.06	133.79
Drill (M_3)	53.95	71.92	96.35	118.85	134.70
F-test (b)	ns	ns	ns	ns	ns
CV (b) %	10.08	3.48	1.81	1.31	0.8925
Treatment combinations					
V_1M_1	53.26	71.05	96.80	118.53	134.40
V_1M_2	50.63	71.85	95.23	118.33	133.78
V_1M_3	55.00	73.25	97.08	119.20	135.90
V_2M_1	52.20	72.53	96.06	118.28	133.18
V_2M_2	52.85	72.35	95.78	117.73	133.68
V_2M_3	53.00	70.40	95.65	118.80	133.23
V_3M_1	53.30	73.00	96.80	118.05	134.58
V_3M_2	51.13	71.38	95.30	118.13	133.93
V_3M_3	53.85	72.10	96.33	118.55	134.98
F-test (a x b)	ns	ns	ns	ns	ns
CV (c) %	4.25	2.75	1.46	0.4284	1.30

Note: ns: Not significant

The findings of this study align with previous studies that have explored the influence of planting methods on plant height of foxtail millet. Zhang et al. (2022) conducted a study evaluating various agronomic traits, including plant height, under different planting methods such as broadcast, hill, and drill. Their results were consistent with the presented data, demonstrating no significant differences in plant height among the planting methods. Genetic characteristics and adoptability of the foxtail millet line, data shows no significant differences observed.

Similarly, Zhang et al. (2022) investigated plant height in foxtail millet lines subjected to different planting methods, including broadcast, hill, and drill. Their findings also support the presented data, indicating no significant differences in plant height at different growth stages and maturity among the various planting methods. In line with the presented findings, Li et al. (2022) conducted a study assessing the effect of planting methods on agronomic traits, including plant height, in foxtail millet lines. They compared different planting methods, including broadcast, hill, and drill, for yellow, black/tapol, and red lines. The results of their study are consistent with the findings of this research that there are no significant differences in plant height among the foxtail millet lines or planting methods.

Number of productive tillers, length of panicle, and grain yield (kg/ha) of foxtail millet lines as affected by methods of planting

Number of productive tillers

The data on the number of productive tillers of foxtail millet lines established using three planting methods are presented in Table 3. There were no significant differences among foxtail millet lines but it is worth noting that the lines studied had 4 to 5 productive tillers. Comparing planting methods analysis show significant difference in number of productive tillers. The broadcast and drill methods of planting had significantly more productive tillers than dibble method.

These findings supports the study conducted by Jung et al. (2018), where foxtail millet lines were compared in terms of the number of productive tillers in different sowing methods. The investigation yielded comparable findings, since there were no statistically significant differences identified in the quantity of productive tillers among the tested lines.

Length of panicles (cm)

The data on panicle length are presented in Table 3. As presented the panicle length did not vary among foxtail millet lines, but it shows that under farmers' field condition foxtail millet produces panicles that are around 21-22 cm long. In support of these results, Varalakshmi et al. (2012) analyzed the yield and composition of foxtail millet genotypes. No significant differences in panicle length were observed between the genotypes examined. However, the different methods of planting of foxtail millet lines show highly significant differences which ranged from 19-23 cm long. The broadcast method of planting and the drill method had produced the longest panicle length while the lowest was observed in planting foxtail millet using dibble method. Moreover, the interaction foxtail millet lines and methods of planting do not differ as shown in Table 3. The findings of Sharma and Niranjan (2018) conform with the findings of this study, highlighting the absence of significant differences in panicle length among foxtail millet lines.

Table 3. Number of productive tillers, length of panicle, and grain yield (kg/ha) of foxtail millet lines as affected by methods of planting

Treatments	Number of productive tillers	Length of panicle (cm)	Grain yield (kg ha^{-1})
Foxtail millet lines			
Yellow (V_1)	5.22	21.58	2,049.75
Black (V_2)	5.16	22.17	2,051.83
Red (V_3)	5.14	21.17	2,082.25
F-test (a)	ns	ns	ns
CV (a) %	4.05	8.84	8.44
Planting methods			
Broadcast M_1)	5.32^a	23.33^a	2,189.08^a
Hill (M_2)	4.95^b	19.08^b	1,667.25^b
Drill (M_3)	5.25^a	22.50^a	2,319.50^a
F-test (b)	*	**	*
CV (b) %	5.42	8.63	18.55
Treatment combinations			
V_1M_1	5.33	23.25	2,240.25
V_1M_2	4.93	18.50	1,666.25
V_1M_3	5.40	23.00	2,242.75
V_2M_1	5.38	23.75	2,163.50
V_2M_2	4.93	19.75	1,623.50
V_2M_3	5.18	23.00	2,368.50
V_3M_1	5.25	23.00	2,185.00
V_3M_2	5.00	19.00	1,712.00
V_3M_3	5.18	21.50	2,349.75
F-test (a x b)	ns	ns	ns
CV (c) %	4.85	7.82	10.08

Note: Means in a column followed by the same letter(s) are not significantly different at 5% level of probability, HSD; ns: Not significant; *: Significant; **: Highly significant

Grain yield (kg/ha)

The grain yield performance of foxtail millet *(S. italica*) showed distinct patterns when evaluated across different lines and planting methods. While no significant differences emerged among the various foxtail millet lines, with yields consistently ranging from 2,049-2,082 kg ha^{-1}, the choice of planting method exerted a substantial influence on productivity. Broadcast (2,189.08 kg ha^{-1}) and drill (2,319.5 kg ha^{-1}) methods significantly outperformed hill planting (1,667.25 kg ha^{-1}), demonstrating 31-39% higher yields. These findings align with Zhao et al. (2022) and are supported by several physiological explanations from recent studies. Andrianary et al. (2021) attribute such yield advantages to improved plant spatial arrangement and reduced intraspecific competition in drill planting systems. Furthermore, Wang et al. (2020) demonstrated that broadcast methods enhance soil aeration and root development, while Zhong et al. (2024) found these methods achieve 15-20% better light distribution within the canopy. The consistent yield performance across genetic lines, as observed in our study, corroborates Upadhyaya et al.'s (2011) characterization of yield stability in foxtail millet germplasm. These collective findings emphasize that while foxtail millet maintains reliable yield potential across genotypes, substantial productivity gains can be achieved through optimized planting techniques, particularly in smallholder farming systems where resource efficiency is crucial (FAO 2021).

Economic analysis of foxtail millet production as affected by methods of planting

Table 4 presents the data on the cost and return analysis for different lines of foxtail millet (*S. italica*) and different methods of planting. The lines include yellow, black, and red, while the planting methods are as broadcast, hill, and drill. The gross income is calculated based on the grain yield and the current price of foxtail millet within the community of Datu Inda, President Roxas, North Cotabato which is Php 30 kg^{-1}. The production cost is subtracted from the gross income to calculate the net return. The ROI is then calculated as the ratio of the net return to the production cost.

The highest net income was obtained in plots planted with black foxtail millet line (V_2M_3) using the drilled method with (PhP 39,355.00), and the highest ROI of 124.15%. The lowest net income was observed in yellow foxtail millet planted using the dibble method (V_1M_2) with a net income of PhP 18,287.50. However, the tapol/black foxtail millet line planted in drilled method obtained the highest return of investment of 124.15% and the lowest was recorded in black millet line planted in dibble method with an ROI of 53.54%.

Looking into the data, it is evident that the drill method typically yields the highest net return across all lines, while the hill method often results in the lowest ROI due to its lower yield and high production cost compared to drill method. This attribute might be due to a more uniform in plant stand which has optimal spacing allowing a high photosynthetic efficiency.

The results show that drill sowing, while slightly more labor-intensive than broadcasting, consistently produced the highest grain yields and economic returns, aligning with farmer feedback that it promotes better plant spacing, aeration, and weed control. Its superior performance also reflects enhanced light penetration and reduced intraspecific competition, consistent with findings by Andrianary et al. (2021) and Zhong et al. (2024).

Broadcasting, though easy and familiar to many farmers, resulted in moderate yield performance due to uneven seed distribution and poor weed management. Despite this, its low labor demand makes it suitable in labor-scarce areas. On the other hand, the hill or dibble method had the lowest performance in terms of yield and farmer preference due to its high labor requirements and inconsistent plant spacing. These insights emphasize that indigenous practices, when refined (e.g., using the drill method), can be both scientifically sound and culturally acceptable. They offer a sustainable pathway to improve millet productivity in resource-limited upland ecosystems.

Summary of farmers feedback on indigenous practices

Table 5 presents the summary feedback of Manobo farmers on three indigenous planting methods, broadcasting, hill/dibble, and drill which was observed in a field day held two weeks before harvesting of foxtail millet. Broadcasting was rated as the easiest and fastest method, requiring less labor and commonly practiced in upland systems; however, farmers noted disadvantages such as high seed wastage, weed infestation, low water-use efficiency, and uneven crop stands, affecting yield. The hill/dibble method minimized seed wastage but was considered the most laborious and slowest, making it the least preferred.

The drill method required moderate effort but was favored due to better seed-use efficiency and uniform crop establishment from row planting. Farmers observed improved weed and moisture management, easier weeding, and better panicle development, leading to higher perceived yields. Consequently, drill planting emerged as the most preferred method. Despite continued use of broadcasting, farmers showed strong openness to adopting improved row planting systems for better productivity and resource-use efficiency.

Table 4. Economic analysis of foxtail millet production as affected by methods of planting

Treatments	Net income (PhP)	Return on investment (%)
V_1M_1	34,907.00	108.07
V_1M_2	18,287.50	57.69
V_1M_3	35,582.50	112.25
V_2M_1	32,605.00	100.94
V_2M_2	24,505.00	53.54
V_2M_3	39,355.00	124.15
V_3M_1	33,250.00	102.94
V_3M_2	19,660.00	62.01
V_3M_3	38,792.50	122.37

Note: Gross income was based on the current price of Php 30.00 kg^{-1} on foxtail millet within the community of Datu Inda, President Roxas, North Cotabato, Philippines. V1: Yellow line, V2: Black line, V3: Red

Table 5. Summary of farmer feedback on indigenous practices validated in the field trial

Aspect	Broadcasting	Hill/Dibble	Drill Method
Ease of implementation	Easy, quick	Laborious, slower	Moderate effort
Seed utilization	Higher seed wastage	Low wastage	Efficient, less seed needed
Weed management	Poor control; needs more labor	Fair	Good row alignment aids weed control
Moisture efficiency	Low, uneven distribution	Moderate	Good, uniform moisture use
Perceived yield	Acceptable but inconsistent	Low	High, uniform heads
Overall preference (farmer)	Acceptable	Least preferred	Most preferred

Table 6. Comparison of traditional and verified practices

Aspect	Traditional practice (Manobo)	Verified practice (Study-based)
Land preparation	Manual clearing, minimal tillage	Minimum tillage with furrow spacing (30 cm)
Seed source	Saved seeds from previous harvest	Selected lines (Yellow, Black, Red) from farmer stock
Planting method	Broadcast or dibble using "tudak"	Drill method with 30 cm row spacing
Seed rate	Approx. 2 g per plot	33 kg/ha (standardized)
Thinning	Not consistently practiced	Done at 3 weeks after emergence
Fertilization	None	None (to match traditional conditions)
Pest management	None	None (to reflect indigenous practice)
Harvesting	Manual sickle cutting	Manual sickle cutting
Threshing and drying	Foot-threshing, sun drying	Foot-threshing, sun drying to 14% moisture
Yield (kg/ha)	~1,600-1,700 (hill method)	2,189-2,319 (broadcast and drill methods)
ROI (%)	~53-62% (hill method)	Up to 124.15% (drill method with black line)

Table 6 shows the comparison between traditional Manobo farming practices and the verified field trial methods in foxtail millet cultivation shows that small refinements, particularly in planting method, row spacing, and thinning, can lead to substantial improvements in yield and economic returns. While traditional methods like broadcasting and dibbling are culturally rooted, the study-based drill method with standardized seed rate and row spacing produced the highest yield (up to 2,319 kg/ha) and ROI of 124.15%, nearly doubling returns compared to the traditional hill method.

The research results demonstrate that foxtail millet phenological development shows stability between different lines and planting methods because genetic traits determine these development stages which do not respond to the agricultural techniques used under current agro-climatic conditions. The height of plants maintained consistent measurement across all growth stages because the crop exhibited phenotypic stability throughout its development. The planting method had a significant impact on yield-related parameters because the broadcast and drill methods produced better results than the hill method. The black tapol foxtail millet line under drill planting achieved higher net returns and better return on investment because of its superior advantages. Overall, the findings show that farmers can maintain their traditional indigenous planting methods while using farmer-preferred planting methods because these methods help increase both productivity and profitability in their agricultural fields.

These results align with the findings of Andrianary et al. (2021), FAO (2021), and Zhong et al. (2024). They noted that optimized spacing and indigenous methods can enhance productivity and sustainability even without external inputs.

In conclusion, this study validated and quantified several indigenous foxtail millet farming practices among Manobo farmers in President Roxas, North Cotabato. Among the methods assessed, the drill planting method, an enhancement of traditional row planting, consistently yielded the highest productivity and profitability. Specifically, plots planted using the drill method achieved grain yields of up to 2,319.50 kg/ha and an ROI as high as 124.15%, particularly with the black foxtail millet line (V_2M_3). In contrast, the traditional hill or dibble method resulted in significantly lower yields (~1,667.25 kg/ha) and ROI (as low as 53.54%). Notably, no chemical fertilizers or pest management interventions were used in either traditional or verified practices, highlighting the agronomic potential and ecological sustainability of these indigenous methods when refined. Moreover, practices such as minimal tillage, manual sickle harvesting, foot-threshing, and sun drying remained unchanged, demonstrating the compatibility of modern field validation with traditional techniques. These findings suggest that with minimal technical intervention such as adopting uniform row spacing, standardized seed rates, and thinning protocols indigenous systems can be optimized to enhance both food security and rural incomes.

Recommendation

Based on the findings of this study, it is recommended that farmers adopt the drill planting method for foxtail millet cultivation, as it consistently resulted in the highest grain yield, net income, and return on investment, making it the most economically viable option. While no significant differences were observed in key agronomic traits across planting methods and millet lines, the superior yield performance and profitability of the drill method highlight its potential for improving production efficiency.

For future research, it is essential to investigate the interaction between planting methods and other agronomic practices, such as fertilization regimes, pest and disease management strategies, and irrigation schedules. Such studies would provide more integrated and practical recommendations for maximizing crop performance and sustainability. Additionally, evaluating the influence of environmental factors including soil types, rainfall distribution, and temperature variations on the growth and yield of foxtail millet under different planting methods would offer valuable insights for site-specific cultivation practices. Long-term studies are also recommended to assess the impact of various planting methods on soil health and agroecosystem sustainability, ensuring the continued productivity and resilience of foxtail millet farming systems. Therefore, it is also recommended that agricultural extension programs and Local Government Units (LGUs) integrate these validated practices into their outreach efforts, offering farmer training on drill sowing and participatory varietal selection. Moreover, policies supporting the conservation and improvement of traditional crop varieties, such as foxtail millet, can help preserve indigenous knowledge while addressing climate-resilient agriculture in upland and rainfed areas.

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