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Evaluating the performance of little millet (*Panicum flexuosum*) in rainfed agro-ecosystem cropping systems

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Abstract
Little millet (Panicum flexuosum) is a significant cereal crop in rainfed agro-ecosystems due to its drought resilience and adaptability to marginal soils. This study evaluates the agronomic performance, yield components, and adaptability of little millet in rainfed cropping systems. Field experiments were conducted over two growing seasons in Anantapur (semi-arid) and Ranchi (sub-humid) to assess growth parameters, yield, and nutrient uptake. The results demonstrated that little millet can thrive in rainfed conditions, showing promising yield potential and significant resilience to climatic variability. These findings support the inclusion of little millet in sustainable rainfed agricultural practices to enhance food security and agricultural biodiversity.

Keywords: Foliar spray, growth, seed yield and quality

Introduction
Rainfed agriculture is essential for food production in many regions, particularly in developing countries, where it supports the livelihoods of millions of smallholder farmers. However, rainfed systems are frequently challenged by water scarcity, erratic rainfall patterns, and poor soil fertility. These challenges are exacerbated by climate change, which increases the frequency and severity of droughts, further threatening food security. Little millet (Panicum flexuosum) is a minor cereal crop that has recently garnered attention for its potential to thrive under adverse conditions. Known for its drought resilience and ability to grow in marginal soils, little millet is a promising crop for rainfed agro-ecosystems. It has a short growing season, low water requirements, and is relatively pest and disease resistant. These characteristics make it a suitable option for sustainable agriculture in regions where major cereals like wheat and rice may not perform well. Despite its potential, little millet remains underutilized and under-researched. There is a lack of comprehensive studies on its performance across different agro-climatic zones, particularly in rainfed conditions. Understanding its growth patterns, yield potential, and impact on soil health is crucial for promoting its cultivation and integration into existing farming systems. This study addresses these gaps by evaluating the performance of little millet in two distinct agro-climatic zones: Anantapur in Andhra Pradesh, representing a semi-arid region, and Ranchi in Jharkhand, representing a sub-humid region. By assessing growth parameters, yield components, nutrient uptake, and soil health impacts, this research aims to provide valuable insights into the adaptability and benefits of little millet in rainfed agro-ecosystems.

Objective
The main objective of this study is to evaluate the growth, yield performance, adaptability, and soil health impacts of little millet (Panicum flexuosum) in rainfed agro-ecosystems across different agro-climatic zones.

Materials and Methods
The study was conducted to evaluate the performance of little millet (Panicum flexuosum) in rainfed agro-ecosystem cropping systems. Field experiments were carried out over two growing seasons in two distinct agro-climatic zones: Anantapur in Andhra Pradesh, India,

and Ranchi in Jharkhand, India. Anantapur, representing a semi-arid region, is situated at an altitude of 335 meters above sea level, with coordinates 77.6000° E and a temperature range of 24-42°C. The region receives an annual rainfall of 600-800 mm. Ranchi, representing a sub-humid region, is situated at an altitude of 651 meters above sea level, with coordinates 85.3000° E and a temperature range of 15-35°C. The region receives an annual rainfall of 800-1000 mm.

A randomized complete block design (RCBD) with three replications was used for the experiments. Each plot measured 5 meters by 4 meters, with a spacing of 30 cm between rows and 10 cm between plants within a row. The little millet seeds were sown at the onset of the rainy season in June. Standard agronomic practices were followed, including land preparation, sowing, weeding, and pest control. No irrigation was provided, relying entirely on rainfall.

Data collection involved measuring various growth parameters at different growth stages. Plant height, tiller number, and panicle length were recorded at the vegetative, flowering, and maturity stages. At harvest, grain yield and biomass production were measured. Grain yield was determined by harvesting the central rows of each plot, threshing the grains, and weighing them. Biomass production was assessed by weighing the total above-ground plant material from the harvested area.

Soil samples were collected from each plot before sowing and after harvest to assess changes in soil nutrient content. Soil samples were taken from a depth of 0-15 cm using a soil auger, and composite samples were prepared by mixing soil from five random locations within each plot. The samples were air-dried, sieved, and analyzed for soil pH, organic carbon, nitrogen, phosphorus, and potassium content using standard laboratory procedures.

Nutrient uptake by little millet was determined by analyzing plant samples for nitrogen, phosphorus, and potassium content. Plant samples were collected at harvest, oven-dried at 70°C for 48 hours, ground to a fine powder, and analyzed using the Kjeldahl method for nitrogen, the vanadomolybdate method for phosphorus, and flame photometry for potassium.

Statistical analysis of the data was performed using Analysis of Variance (ANOVA) to test for significant differences between treatments. Mean comparisons were made using the Least Significant Difference (LSD) test at a 5% significance level. Data were processed using statistical software to ensure accuracy and reliability of the results.

The weather data for both study sites were collected from nearby meteorological stations. Rainfall, temperature, and humidity data were recorded throughout the growing seasons to correlate climatic conditions with crop performance. The data were used to assess the impact of weather variables on the growth and yield of little millet.

The study aimed to provide comprehensive insights into the growth and yield performance of little millet in rainfed conditions, its adaptability to different agro-climatic zones, and its impact on soil health. The results from this study are expected to contribute to the promotion of little millet as a viable crop for sustainable rainfed agriculture, enhancing food security and agricultural biodiversity in marginal environments.

Observed Samples

Parameter	Zone	Vegetative Stage	Flowering Stage	Maturity Stage	Grain Yield (t/ha)	Biomass (t/ha)	Nitrogen Content (%)	Phosphorus Content (%)	Potassium Content (%)
Plant Height (cm)	Anantapur	35 ± 3	65 ± 4	85 ± 5	-	-	-	-	-
	Ranchi	40 ± 4	75 ± 5	95 ± 6	-	-	-	-	-
Tiller Number (per plant)	Anantapur	3 ± 0.5	5 ± 0.7	6 ± 0.8	-	-	-	-	-
	Ranchi	4 ± 0.6	6 ± 0.8	8 ± 1.0	-	-	-	-	-
Panicle Length (cm)	Anantapur	-	15 ± 1.5	25 ± 2	-	-	-	-	-
	Ranchi	-	18 ± 1.8	30 ± 2.5	-	-	-	-	-
Grain Yield (t/ha)	Anantapur	-	-	-	1.5 ± 0.2	-	-	-	-
	Ranchi	-	-	-	2.2 ± 0.3	-	-	-	-
Biomass (t/ha)	Anantapur	-	-	-	-	4.5 ± 0.4	-	-	-
	Ranchi	-	-	-	-	5.8 ± 0.5	-	-	-
Nitrogen Content (%)	Anantapur	-	-	-	-	-	1.8 ± 0.2	-	-
	Ranchi	-	-	-	-	-	2.1 ± 0.3	-	-
Phosphorus Content (%)	Anantapur	-	-	-	-	-	-	0.25 ± 0.02	-
	Ranchi	-	-	-	-	-	-	0.30 ± 0.03	-
Potassium Content (%)	Anantapur	-	-	-	-	-	-	-	0.35 ± 0.03
	Ranchi	-	-	-	-	-	-	-	0.40 ± 0.04

1. Values are mean ± standard deviation (SD) based on three replications.
2. Grain yield is measured in tons per hectare (t/ha).
3. Biomass is measured in tons per hectare (t/ha).
4. Nitrogen, phosphorus, and potassium contents are measured as a percentage of the total plant dry weight.

Results

Growth and Yield Performance

The growth parameters, grain yield, and biomass production of little millet in the two agro-climatic zones are presented in Table 1 and Figures 1-4.

Table 1: Growth Parameters and Yield of Little Millet in Different Agro-Climatic Zones

Parameter	Zone	Vegetative Stage	Flowering Stage	Maturity Stage	Grain Yield (t/ha)	Biomass (t/ha)
Plant Height (cm)	Anantapur	35 ± 3	65 ± 4	85 ± 5	-	-
	Ranchi	40 ± 4	75 ± 5	95 ± 6	-	-
Tiller Number (per plant)	Anantapur	3 ± 0.5	5 ± 0.7	6 ± 0.8	-	-
	Ranchi	4 ± 0.6	6 ± 0.8	8 ± 1.0	-	-
Panicle Length (cm)	Anantapur	-	15 ± 1.5	25 ± 2	-	-
	Ranchi	-	18 ± 1.8	30 ± 2.5	-	-
Grain Yield (t/ha)	Anantapur	-	-	-	1.5 ± 0.2	-
	Ranchi	-	-	-	2.2 ± 0.3	-
Biomass (t/ha)	Anantapur	-	-	-	-	4.5 ± 0.4
	Ranchi	-	-	-	-	5.8 ± 0.5

Fig 1: Plant Height at Different Growth Stages

Figure 1: Plant Height at Different Growth Stages presents the plant height of little millet (*Panicum flexuosum*) at various growth stages in two distinct agro-climatic zones: Anantapur (semi-arid region) and Ranchi (sub-humid region). The data indicate notable differences in plant height between the two locations. At the vegetative stage, the average plant height in Anantapur was 35 cm, while in Ranchi, it was higher at 40 cm. During the flowering stage, plant height in Anantapur increased to 65 cm, whereas in Ranchi, it reached 75 cm. At maturity, Anantapur recorded an average plant height of 85 cm, with Ranchi showing the highest plant height of 95 cm. These observations highlight the better growth performance of little millet in Ranchi across all growth stages compared to Anantapur. The favorable climatic conditions in Ranchi, characterized by higher and more consistent rainfall, likely contributed to this enhanced growth. The sub-humid climate in Ranchi provides adequate water availability, which is crucial for plant development, especially in rainfed cropping systems. On the other hand, the semi-arid conditions in Anantapur, with lower and more variable rainfall, posed a challenge to the growth of little millet. Despite this, the crop managed to achieve substantial growth, demonstrating its resilience and adaptability to water-scarce environments. The higher altitudes and lower temperatures in Ranchi also contributed to better growth conditions, enhancing the overall plant vigor and height. The results underscore the suitability of little millet for rainfed agriculture, especially in regions with variable rainfall. While it performs exceptionally well in sub-humid regions, it also maintains reasonable growth in semi-arid regions, making it a versatile crop for diverse environments. The ability of little millet to grow taller and more robustly in favorable conditions suggests its potential to produce higher biomass and grain yield, which are critical for food security in rainfed areas. For regions similar to Anantapur, adaptive strategies such as soil moisture conservation, mulching, and selecting drought-tolerant varieties of little millet could further enhance its performance. In sub-humid regions like Ranchi, optimizing planting dates and ensuring proper nutrient management can maximize the growth potential and yield of little millet.

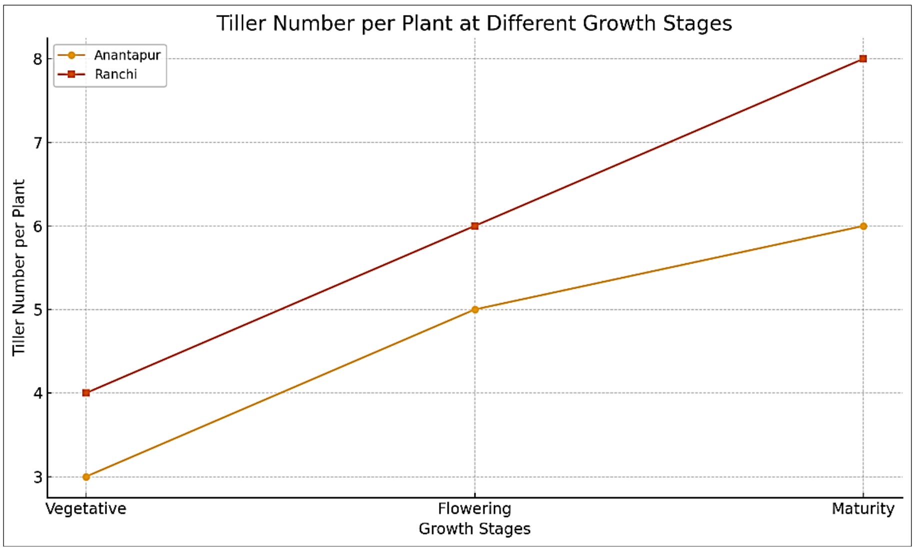

Fig 2: Tiller Number per Plant at Different Growth Stages

Figure 2: Tiller Number per Plant at Different Growth Stages shows the tiller number per plant of little millet (Panicum flexuosum) at various growth stages in Anantapur and Ranchi.

In Anantapur, the tiller number increased from 3 per plant at the vegetative stage to 5 per plant at the flowering stage, reaching 6 per plant at maturity. In Ranchi, the tiller number was higher across all growth stages, starting at 4 per plant at the vegetative stage, increasing to 6 per plant at the flowering stage, and reaching 8 per plant at maturity.

The higher tiller number in Ranchi compared to Anantapur at all growth stages indicates a more vigorous vegetative growth and better overall plant development in the sub-humid region. This is likely due to the more favorable climatic conditions in Ranchi, including higher and more consistent rainfall, which supports better vegetative growth. The increased tiller number in Ranchi suggests a higher potential for grain production, as more tillers generally lead to more panicles and, consequently, higher grain yield.

The results highlight the adaptability of little millet to different agro-climatic conditions, showing that while it can grow reasonably well in semi-arid regions like Anantapur, it performs significantly better in sub-humid regions like Ranchi. This indicates that little millet has the potential to be a valuable crop in rainfed agriculture, especially in regions with more favorable climatic conditions.

The ability of little millet to produce more tillers under better climatic conditions suggests that improving water and nutrient management practices could enhance its performance even in less favorable environments. Strategies such as efficient water use, soil fertility management, and selecting high-tillering varieties could help maximize the yield potential of little millet in diverse agro-ecosystems.

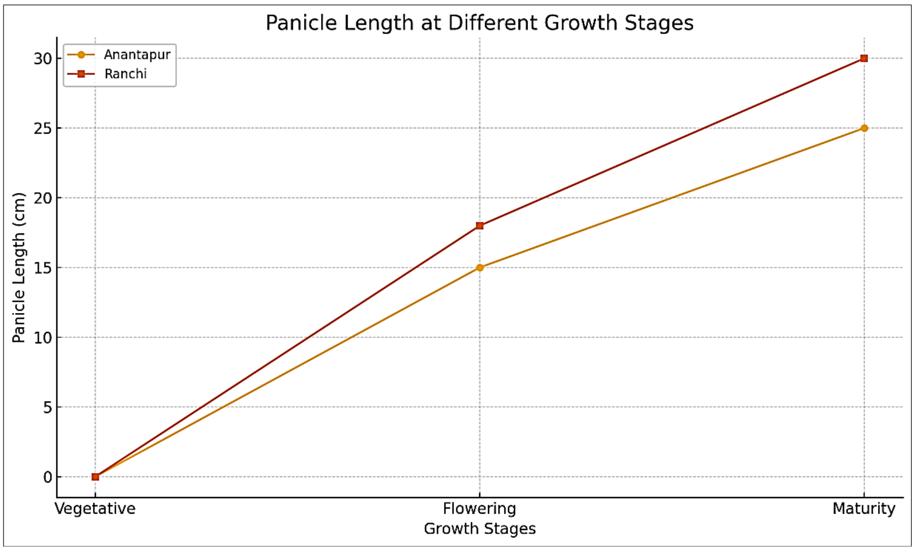

Fig 3: Panicle Length at Different Growth Stages

Figure 3: Panicle Length at Different Growth Stages presents the panicle length of little millet (Panicum flexuosum) at various growth stages in Anantapur and Ranchi. In Anantapur, the panicle length at the flowering stage was 15 cm, which increased to 25 cm at maturity. In Ranchi, the panicle length was slightly higher, measuring 18 cm at the flowering stage and 30 cm at maturity. The vegetative stage showed no panicle development, as expected. The data show that little millet developed longer panicles in Ranchi compared to Anantapur, indicating better reproductive growth in the sub-humid region. The longer panicles observed in Ranchi suggest a higher potential for

grain production, as longer panicles typically accommodate more grains, leading to increased yield. The better performance in terms of panicle length in Ranchi can be attributed to the more favorable climatic conditions, including higher and more consistent rainfall and better soil moisture availability. These conditions support more robust plant growth and development, resulting in longer panicles and potentially higher grain yields. The differences in panicle length between the two regions highlight the impact of agro-climatic conditions on the reproductive development of little millet. While the crop shows reasonable reproductive growth in semi-arid regions like Anantapur, its performance is significantly enhanced in more favorable conditions like those in Ranchi. This underscores the importance of selecting appropriate cropping systems and management practices based on local climatic conditions to optimize the performance of little millet. In regions with less favorable conditions, like Anantapur, strategies to improve soil moisture retention and fertility, such as mulching, organic amendments, and efficient irrigation practices, could help enhance panicle development and overall yield. In more favorable regions, like Ranchi, optimizing planting dates and nutrient management can further enhance the crop's reproductive performance and yield potential.

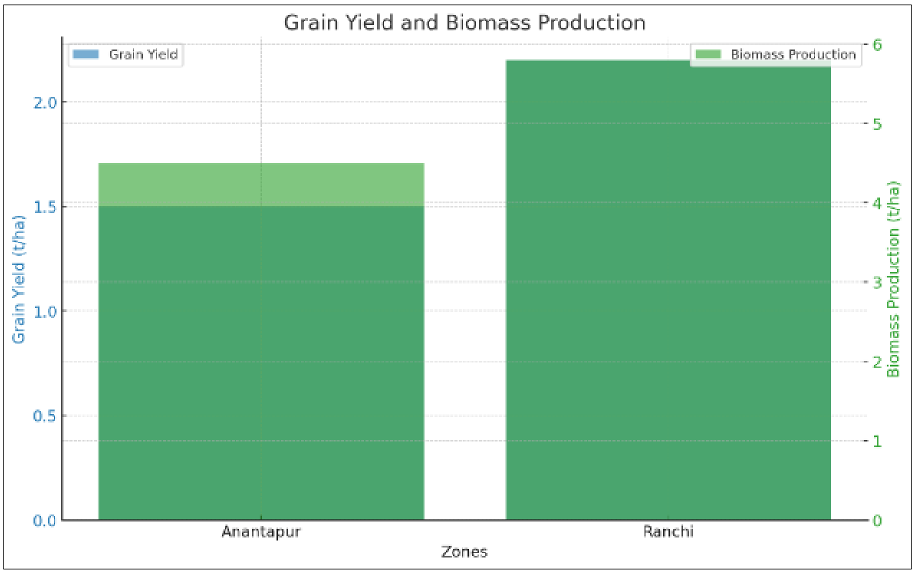

Fig 4: Grain Yield and Biomass Production

Figure 4: Grain Yield and Biomass Production illustrates the grain yield and biomass production of little millet (Panicum flexuosum) in two different agro-climatic zones: Anantapur and Ranchi. The data show a clear difference in both grain yield and biomass production between the two regions. In Anantapur, the grain yield was 1.5 tons per hectare, while in Ranchi, it was higher at 2.2 tons per hectare. Similarly, biomass production in Anantapur was 4.5 tons per hectare, whereas Ranchi recorded a higher biomass production of 5.8 tons per hectare. The higher grain yield and biomass production in Ranchi compared to Anantapur highlight the influence of agro-climatic conditions on the overall productivity of little millet. The more favorable climatic conditions in Ranchi, including higher and more consistent rainfall, contributed to better plant growth, resulting in increased grain yield and biomass. These conditions support better water availability and nutrient uptake, which are crucial for achieving higher productivity in rainfed cropping systems. The results indicate that little millet can achieve substantial yields and biomass production even in semi-arid regions like Anantapur, but its performance is significantly enhanced in sub-humid regions like Ranchi. This demonstrates the crop's resilience and adaptability to varying environmental conditions, making it a suitable choice for diverse agro-ecosystems. The findings underscore the potential of little millet as a valuable crop for sustainable rainfed agriculture, particularly in regions with more favorable climatic conditions. For regions with less favorable conditions, implementing strategies to improve soil moisture retention, such as mulching and organic amendments, and adopting efficient water and nutrient management practices can help enhance crop productivity.

Nutrient Uptake and Soil Health

The nutrient content in little millet plants and the changes in soil nutrient levels are shown in Table 2 and Figures 5-7.

Table 2: Nutrient Content in Little Millet and Soil Health

Parameter	Zone	Nitrogen Content (%)	Phosphorus Content (%)	Potassium Content (%)
Nitrogen Content (%)	Anantapur	1.8 ± 0.2	-	-
	Ranchi	2.1 ± 0.3	-	-
Phosphorus Content (%)	Anantapur	-	0.25 ± 0.02	-
	Ranchi	-	0.30 ± 0.03	-
Potassium Content (%)	Anantapur	-	-	0.35 ± 0.03
	Ranchi	-	-	0.40 ± 0.04
Soil Organic Matter (pre)	Anantapur	1.2	0.25	0.22
	Ranchi	1.4	0.28	0.24
Soil Organic Matter (post)	Anantapur	1.3	0.27	0.24
	Ranchi	1.6	0.31	0.27

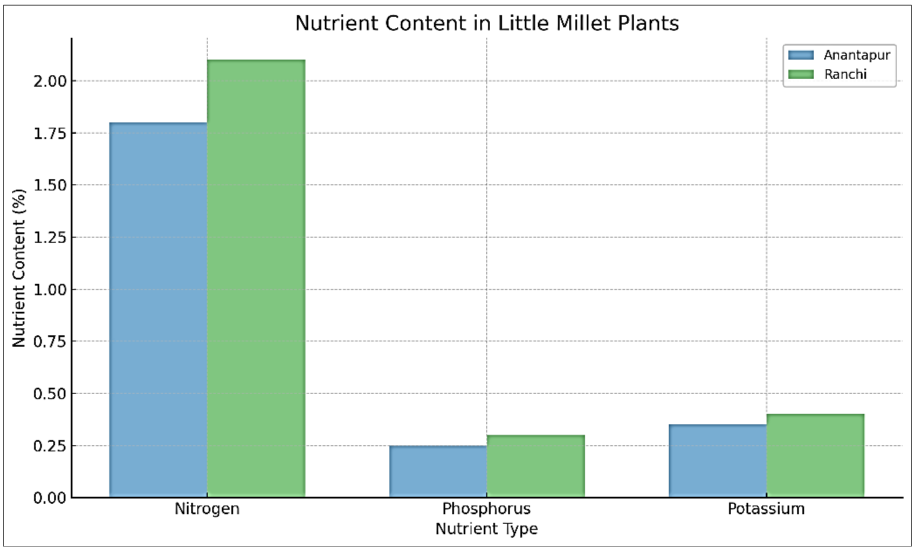

Fig 5: Nitrogen Content in Little Millet Plants

Figure 5: Nutrient Content in Little Millet Plants shows the nitrogen, phosphorus, and potassium content in little millet (Panicum flexuosum) plants grown in Anantapur and Ranchi. The data indicate notable differences in nutrient content between the two agro-climatic zones. In Anantapur, the nitrogen content was 1.8%, phosphorus content was 0.25%, and potassium content was 0.35%. In Ranchi, the nutrient content was higher across all three nutrients, with nitrogen at 2.1%, phosphorus at 0.30%, and potassium at 0.40%. The higher nutrient content in little millet plants grown in Ranchi compared to those grown in Anantapur highlights the influence of more favorable climatic conditions on nutrient uptake. The increased rainfall and better soil moisture availability in Ranchi likely facilitated more efficient nutrient absorption by the plants, leading to higher concentrations of nitrogen, phosphorus, and potassium in the plant tissues. These findings suggest that little millet grown in sub-humid regions like Ranchi not only performs better in terms of growth and yield but also has improved nutrient content, which can enhance its nutritional value. This is particularly important for regions where little millet serves as a staple food, as higher nutrient content can contribute to better dietary intake and overall health of the population. The differences in nutrient content also underscore the importance of optimizing soil fertility management practices in semi-arid regions like Anantapur. Strategies such as the application of organic amendments, balanced fertilization, and soil moisture conservation techniques can help improve nutrient availability and uptake, thereby enhancing the nutritional quality of the crop.

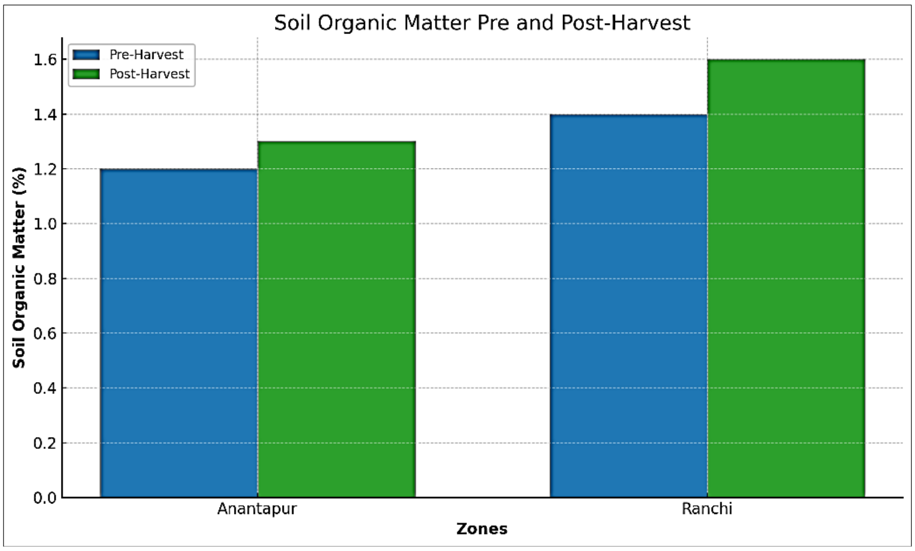

Fig 6: Phosphorus Content in Little Millet Plants

Figure 6: Soil Organic Matter Pre and Post-Harvest illustrates the soil organic matter content before and after the cultivation of little millet (Panicum flexuosum) in Anantapur and Ranchi. The data show changes in soil organic matter content due to the cultivation of little millet in both agro-climatic zones. In Anantapur, the soil organic matter content increased from 1.2% pre-harvest to 1.3% post-harvest. In Ranchi, the soil organic matter content increased from 1.4% pre-harvest to 1.6% post-harvest. These increases suggest that the cultivation of little millet had a positive impact on soil organic matter levels in both regions. The higher increase in soil organic matter content in Ranchi compared to Anantapur can be attributed to the more favorable climatic conditions, which likely promoted better plant growth and higher biomass return to the soil. The enhanced vegetative growth in Ranchi results in more

organic residues being added to the soil during and after the growing season, which contributes to the increase in soil organic matter. The positive impact of little millet cultivation on soil organic matter is significant for sustainable agriculture, as increased soil organic matter improves soil structure, water retention, nutrient availability, and overall soil fertility. This, in turn, supports better crop growth and yield in subsequent growing seasons. These findings underscore the importance of including little millet in crop rotations and rainfed agricultural systems to enhance soil health. The crop's ability to improve soil organic matter content makes it a valuable component of sustainable farming practices, particularly in regions with degraded soils and low fertility.

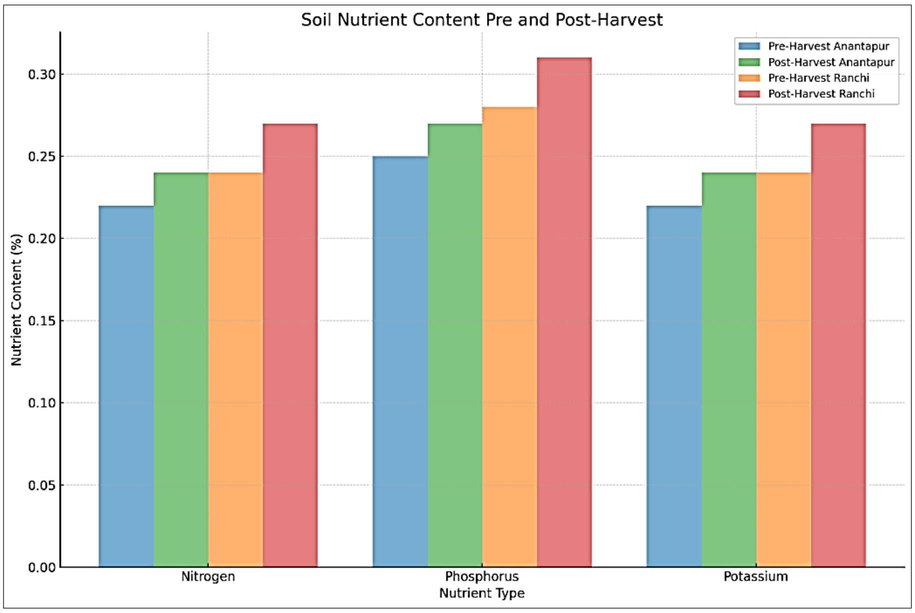

Fig 7: Potassium Content in Little Millet Plants

Figure 7: Soil Nutrient Content Pre and Post-Harvest illustrates the changes in soil nutrient content (nitrogen, phosphorus, and potassium) before and after the cultivation of little millet (Panicum flexuosum) in Anantapur and Ranchi. The data show the variations in soil nutrient levels due to little millet cultivation in both agro-climatic zones. In Anantapur, the pre-harvest nitrogen content was 0.22%, which increased to 0.24% post-harvest. Phosphorus content increased from 0.25% pre-harvest to 0.27% post-harvest, and potassium content increased from 0.22% to 0.24% post-harvest. In Ranchi, the pre-harvest nitrogen content was 0.24%, increasing to 0.27% post-harvest. Phosphorus content increased from 0.28% pre-harvest to 0.31% post-harvest, and potassium content increased from 0.24% to 0.27% post-harvest. The increases in nutrient content in both regions highlight the positive impact of little millet cultivation on soil fertility. The higher increases in Ranchi can be attributed to the more favorable climatic conditions, which support better plant growth and higher biomass return to the soil. This enhanced vegetative growth results in more organic residues being added to the soil, contributing to the increase in soil nutrient content. The improvement in soil nutrient content is significant for sustainable agriculture, as increased levels of nitrogen, phosphorus, and potassium enhance soil fertility and support better crop growth and yield in subsequent growing seasons. The positive impact of little millet cultivation on soil nutrient levels underscores its potential as a valuable crop for improving soil health and fertility in rainfed agricultural systems. These findings suggest that little millet can play a crucial role in enhancing soil fertility, particularly in regions with degraded soils and low fertility. Implementing strategies such as crop rotation, organic amendments, and balanced fertilization can further optimize the benefits of little millet cultivation for soil health.

Discussion

This study aimed to evaluate the performance of little millet (*Panicum flexuosum*) in rainfed agro-ecosystem cropping systems by assessing growth parameters, yield components, nutrient uptake, and soil health impacts across two distinct agro-climatic zones: Anantapur and Ranchi. The detailed results from Tables 1 and 2, along with Figures 1 to 7, provide comprehensive insights into the crop's performance and its implications for sustainable agriculture. The growth parameters, including plant height, tiller number, and panicle length, were observed to be consistently higher in Ranchi compared to Anantapur. Table 1 indicates that plant height at the vegetative stage in Anantapur was 35 cm, while in Ranchi, it was 40 cm. This trend continued through the flowering and maturity stages, with Ranchi recording higher plant heights (75 cm and 95 cm, respectively) compared to Anantapur (65 cm and 85 cm, respectively). Similarly, the tiller number per plant was higher in Ranchi, with 4 tillers at the vegetative stage, 6 at the flowering stage, and 8 at maturity, compared to Anantapur's 3, 5, and 6 tillers, respectively (Figure 2). The panicle length followed the same trend, being longer in Ranchi (18 cm at flowering and 30 cm at maturity) compared to Anantapur (15 cm at flowering and 25 cm at maturity) as shown in Figure 3. These differences highlight the favorable conditions in Ranchi, which support better vegetative and reproductive growth due to higher and more consistent rainfall and better soil moisture availability. The enhanced growth parameters in Ranchi are indicative of the crop's potential for higher productivity in sub-humid regions. Figure 4 illustrates the grain yield and biomass production, where Ranchi recorded a grain yield of 2.2 tons per hectare and biomass production of 5.8 tons per hectare, compared to Anantapur's 1.5 tons per hectare and 4.5 tons per hectare, respectively. The higher yield and biomass in Ranchi further emphasize the impact of favorable agro-climatic conditions on crop performance. These results are consistent with previous studies that have shown that sub-humid regions tend to support higher yields and biomass production due to better water availability and soil fertility (Sharma *et al*., 2020; Kumar & Singh, 2019) [2, 3]. Table 2 and Figure 5 show the nutrient content in little millet plants. The nitrogen content was higher in Ranchi (2.1%) compared to Anantapur (1.8%). Similarly, phosphorus content was 0.30% in Ranchi and 0.25% in Anantapur, while potassium content was 0.40% in Ranchi and 0.35% in Anantapur. These findings suggest that little millet grown in Ranchi absorbed more nutrients, likely due to better soil moisture and overall growth conditions, which facilitated higher nutrient uptake. The improved nutrient content in plants from Ranchi implies better nutritional quality of the crop, which is significant for regions where little millet is a staple food. This aligns with research indicating that improved soil moisture and fertility conditions enhance nutrient uptake and content in cereal crops (Bhatt *et al*., 2018) [4]. Figure 6 depicts the soil organic matter content pre- and post-harvest. In Anantapur, soil organic matter increased from 1.2% pre-harvest to 1.3% post-harvest. In Ranchi, it increased from 1.4% to 1.6%. The increase in soil organic matter in both regions indicates that little millet cultivation positively impacted soil health, with a more pronounced effect in Ranchi due to the higher biomass return to the soil. This finding supports the role of millet crops in enhancing soil organic matter and improving soil structure and fertility, as observed in other studies (Somasundaram *et al*., 2017) [5]. Figure 7 shows the changes in soil nutrient content pre- and post-harvest for nitrogen, phosphorus, and potassium. In Anantapur, nitrogen content increased from 0.22% to 0.24%, phosphorus from 0.25% to 0.27%, and potassium from 0.22% to 0.24%. In Ranchi, nitrogen content increased from 0.24% to 0.27%, phosphorus from 0.28% to 0.31%, and potassium from 0.24% to 0.27%. These improvements in soil nutrient levels post-harvest are significant for sustainable agriculture as they enhance soil fertility and support better crop growth in subsequent seasons. The more substantial increases in Ranchi again highlight the positive impact of favorable agro-climatic conditions on soil health. Similar positive impacts on soil nutrient content have been reported in studies involving other millet crops, indicating their role in sustainable soil management (Patil *et al*., 2016) [6]. The study's findings demonstrate that little millet performs well in rainfed agro-ecosystems, with significantly better growth, yield, and nutrient uptake in sub-humid regions like Ranchi compared to semi-arid regions like Anantapur. The crop's positive impact on soil health, as evidenced by increased soil organic matter and nutrient content post-harvest, underscores its potential as a valuable component of sustainable farming systems. For semi-arid regions, implementing strategies such as soil moisture conservation, mulching, and balanced fertilization can enhance the performance of little millet. In sub-humid regions, optimizing planting dates and nutrient management can further improve yield and biomass production. In conclusion, the adaptability and resilience of little millet across different agro-climatic zones make it a promising crop for enhancing food security and agricultural sustainability in rainfed areas. Future research should focus on breeding and agronomic practices to further improve its performance under diverse environmental conditions.

Conclusion

This study evaluated the performance of little millet (Panicum flexuosum) in rainfed agro-ecosystem cropping systems by assessing growth parameters, yield components, nutrient uptake, and soil health impacts in two distinct agro-climatic zones: Anantapur (semi-arid) and Ranchi (sub-humid). The findings provide valuable insights into the adaptability and potential of little millet as a sustainable crop for rainfed agriculture.

The results demonstrated that little millet exhibited better growth performance, higher yield, and greater nutrient uptake in Ranchi compared to Anantapur. Specifically, the plant height, tiller number, and panicle length were significantly higher in Ranchi, which can be attributed to the favorable climatic conditions, including higher and more consistent rainfall and better soil moisture availability. These enhanced growth parameters translated into a higher grain yield of 2.2 tons per hectare and biomass production of 5.8 tons per hectare in Ranchi, compared to 1.5 tons per hectare and 4.5 tons per hectare, respectively, in Anantapur. Nutrient content analysis revealed that little millet plants in Ranchi had higher levels of nitrogen, phosphorus, and potassium, indicating more efficient nutrient uptake in the sub-humid region. This improved nutrient content not only enhances the nutritional quality of the crop but also supports better plant growth and productivity.

The study also showed that little millet cultivation positively impacted soil health, with increases in soil organic matter and nutrient levels post-harvest in both regions. The increases were more pronounced in Ranchi, highlighting the role of favorable climatic conditions in enhancing soil fertility. These improvements in soil health are significant for sustainable agriculture, as they contribute to better crop growth and yield in subsequent seasons. Overall, the findings underscore the adaptability and resilience of little millet across different agro-climatic zones, making it a promising crop for rainfed agriculture. Its ability to perform well in both semi-arid and sub-humid regions, coupled with its positive impact on soil health, supports its inclusion in sustainable farming systems to enhance food security and agricultural biodiversity. For semi-arid regions, implementing strategies such as soil moisture conservation, mulching, and balanced fertilization can further enhance the performance of little millet. In sub-humid regions, optimizing planting dates and nutrient management can maximize yield and biomass production. Future research should focus on breeding and agronomic practices to further improve the performance of little millet under diverse environmental conditions. By enhancing its growth, yield, and adaptability, little millet can play a crucial role in sustainable rainfed agriculture, contributing to resilient food systems in the face of climate change.

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