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Impact of mulching techniques and biofertilizers on nutrient uptake pattern of finger millet (Var. Vl mandua 379)

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Abstract
A field experiment was conducted at Himalayan University farm, Jullang, Itanagar, Arunachal Pradesh, during the *kharif* season of 2023 with 8 treatments replicated thrice in randomized block design, to determine the effect of different types of mulching and biofertilizer nutrient uptake pattern of finger millet (*Eleusine coracana*.). The available soil nutrient status showed high nitrogen (N), low phosphorus (P), and medium potassium (K) levels. The experiment included the following treatments T_1-Control, T_2-Karanj leaf mould at + *Azotobacter*, T_3-Karanj leaf mould + *PSB*, T_4-Neem leaf mould + *Azotobacter*, T_5-Paddy straw + jute bag + *Rhizobium*, T_6-Paddy straw + *PSB*, T_7-Black polythene + *Azotobacter* and T_8-Saw dust + *Rhizobium.* The highest N uptake (Kg ha^{-1}) recorded was 29.89 Kg ha^{-1}, highest P uptake (Kg ha^{-1}) recorded was 17.94 Kg ha^{-1} and highest K uptake (Kg ha^{-1}) recorded was 29.61 Kg ha^{-1} were observed with treatment T_5-Paddy straw + jute bag + *Rhizobium.*

Keywords: Finger millet, mulching, biofertilizer, nutrient uptake, nitrogen, phosphorus, potassium

1. Introduction

One of the most widely grown millets is finger millet (*Eleusine coracana*), and India accounts for 41% of global production, making it a major player on the production map. Africa comes in second. After sorghum, pearl millet, and foxtail millet, finger millet is the fourth most important millet in the world (Chandra *et al*., 2016) [2].

In Southern Karnataka, finger millet is the traditional staple grain. It is even grown up to 2100-2300 meters above mean sea level in the hilly areas of Himachal Pradesh and Uttar Pradesh. The crop can tolerate drought and heat stress and is highly adapted to extreme weather conditions. Because finger millet grains are higher in nutrients than many other types of cereal, they are referred to as "Nutri cereal." Protein makes up 9.2 percent, carbs make up 76.32 percent, while fat makes up 1.29 percent. It has a high mineral content (2.70 percent), including iron (3.90 mg/100g) and calcium (452 mg/1000g) (Pandey and Kumar, 2005) [10].

Mulching is the act of covering the ground or soil to create more conducive circumstances for plant development, growth, and productive crop production. Although natural mulches like leaves, straw, dead leaves, and compost have been utilized for generations, the introduction of synthetic materials in the past 60 years has changed the benefits and techniques of mulching (Sharma and Bhardwaj, 2017) [11].

The employment of microorganisms to meet nutritional needs is referred to as "biofertilizer" in India, whereas "microbial bioinoculant" is used in other countries (Mitter *et al*., 2021) [8]. The bioavailability and bio accessibility of nutrient uptake in plants can be enhanced by biofertilizers, which are bio-based organic fertilizers derived from either plant or animal sources or from dormant or alive microbial cells (Lee *et al*., 2018; Abbey *et al*., 2019) [6, 1].

The purpose of this research is to evaluate the impact of different mulching techniques and biofertilizers on the nutrient uptake patterns of finger millet, aiming to identify sustainable practices that can enhance crop yield, improve soil health and promote efficient resource use. By studying these techniques, the research seeks to develop climate-resilient farming practices that can improve the productivity and nutritional quality of finger millet, a crucial crop for food security in regions facing resource constraints and changing environmental conditions.

2. Materials and Methods

2.1 Soil: The experiment was conducted in the *Kharif* season of 2023 at Himalayan University in Itanagar. The Crop Research Farm is located in Jullang on the university campus at 27.14°N latitude and 93.62°E longitude, with an altitude of 320 meters above sea level. The site is part of the Eastern Himalayan region, and the agro-climatic zone falls under the sub-tropical zone of Arunachal Pradesh. The physio-chemical properties of soil in the experimental field, Himalayan University is presented in Table 1.

Table 1: Physio-chemical properties of soil in the experimental field, Himalayan University

Particulars	Value	Methods Employed
Sand (%)	54.2%	International Pipette Method
Silt (%)	29.5%	
Clay (%)	16.3%	
Soil Texture	Sandy Loam	
Soil pH	4.25	Potentiometric method
Organic carbon	1.59%	Walkley and Black wet oxidation method (Jackson, 1973) [13]
Electrical conductivity	0.452 dS/m	Conductivity bridge (Jackson, 1973) [13]
Available Nitrogen	613.5 Kg/ha	Alkaline permanganate method (Subbaiah and Asija, 1956) [14]
Available Phosphorus	4.86 Kg/ha	Bray's method. (Jackson, 1973) [13]
Available Potassium	218.4 Kg/ha	Flame photometer method (Jackson, 1973) [13]

2.2 Weather and Climate

The climatic condition of Itanagar is sub-tropical. The rainy season usually starts from May and it extends up to September and retreats from October onwards. The meteorological data of weather parameter, temperature, rainfall, relative humidity and sunshine hours recorded during the period of experimentation from July to November during the year 2023 were obtained from meteorological observatory, for the period of the experimentation have been presented in table 2 and illustrated graphically in fig 1. The mean minimum and maximum temperature recorded during the cropping season was 24.38 °C and 21.56 °C, respectively. The average relative humidity in the morning hours was 83.2% and 80.3% in the evening. The average bright sunshine hour was 8.2.

Table 2: Meteorological data of weather parameters and total rainfall during the cropping season (Kharif, 2023)

Months	Temperature (°C) Max./Min		Relative humidity (%) Max./Min		Total rainfall (mm)	Average sunshine (hr.)
July	26.3 °C	24.3 °C	89%	87%	453 mm	8.0 hr.
August	26.5 °C	24.3 °C	87%	84%	370 mm	8.0 hr.
September	25.7 °C	23.3 °C	86%	83%	305 mm	8.0 hr.
October	23.5 °C	20.1 °C	80%	79%	118 mm	9.0 hr.
November	19.9 °C	15.8 °C	74%	71%	20 mm	8.0 hr.

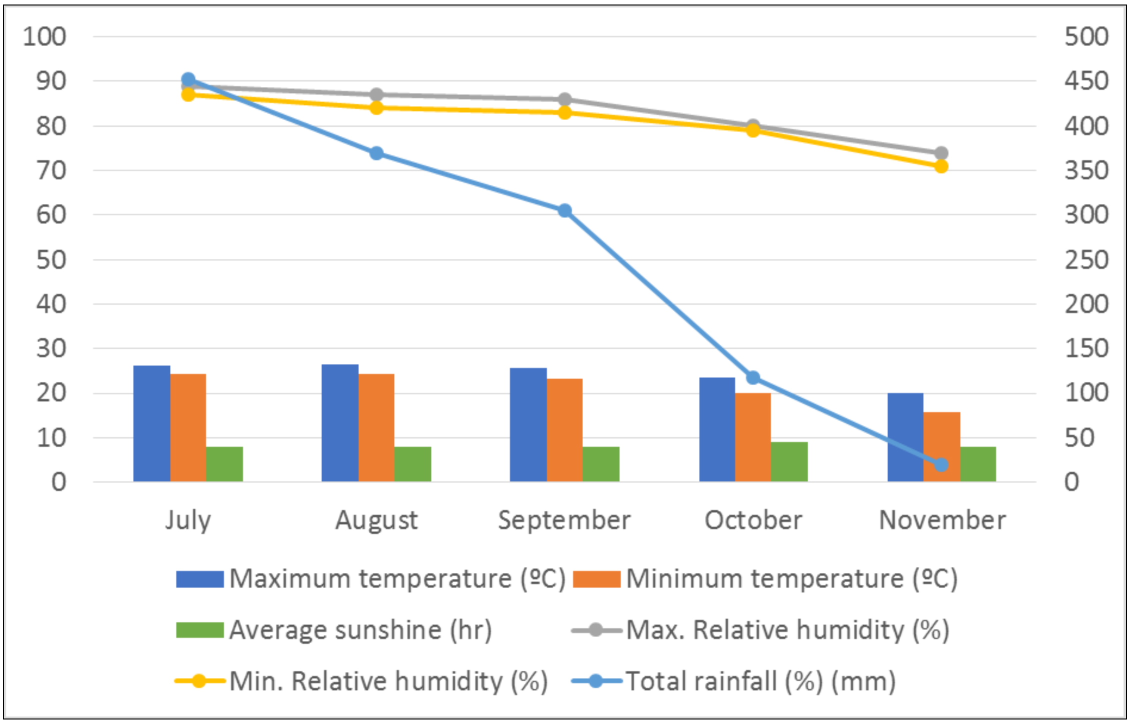

Fig 1: Meteorological observations and total rainfall during the experimental period (*kharif*, 2023)

2.3 Cropping history of the experimental field
The cropping sequences followed for the previous years on the experimental plot before the investigation are presented in Table 3.

Table 3: Cropping history of the experimental field

	Kharif	Rabi	Zaid
2016-2017	Fallow	Wheat	Fallow
2017-2018	Maize	Pea	Fallow
2018-2019	Paddy	Maize	Fallow
2019-2020	Fresh bean	Chickpea	Black gram
2020-2021	Soyabean	Mustard	Fallow
2021-2022	Maize	White Mustard	Fallow
2022-2023	Maize	Pea	Fallow
2023-2024	Finger millet (Experimental Crop)		

2.4 Plant nutrient uptake
Plant samples collected at harvest were air-dried then in a hot air oven at 70 ±5 ºC for 48 hours and ground into fine powder and samples were drawn for NPK analysis. The results were expressed in Kg ha^{-1}. The method followed is given below:

Nutrient	Method	Reference
Nitrogen	Modified micro Kjeldahl method	Jackson *et al.* 1973 [13]
Phosphorus	Vanado-molybdo phosphoric yellow colour method using spectrophotometer	
Potassium	Flame Photometry	

$$\text{Nutrient uptake kg ha}^{-1} = \frac{\text{Nutrient content (\%) x Biological yield (kg ha}^{-1}\text{)}}{100}$$

3. Results
The nutrient uptake Kg ha^{-1} (NPK) recorded is graphically represented in Figure 2.

3.1 Available Nitrogen
Significantly higher available nitrogen at harvest (29.89 kg ha^{-1}) was recorded with T_5 (Paddy straw+ Jute bag+ Rhizobium) followed by T_8 (saw dust + Rhizobium) (27.60 kg ha^{-1}), T_6 (26.44 kg ha^{-1}) and T_7 Black polythene + Azotobacter (23.80 kg ha-1). However, significantly the lowest available nitrogen (12.80 kg ha^{-1}) was recorded with absolute control (T_1).

3.2 Available Phosphorus
Significantly higher available phosphorus at harvest (17.94 kg ha^{-1}) was recorded with T_5 (Paddy straw+ Jute bag+ Rhizobium) followed by T8 (saw dust + Rhizobium) (15.86 kg ha^{-1}), T_6 (14.82 kg ha^{-1}) and T_7 Black polythene + Azotobacter (14.28 kg ha^{-1}). However, significantly the lowest available phosphorus (8.61 kg ha^{-1}) was recorded with absolute control (T_1).

3.3 Available Potassium
Significantly higher available potassium at harvest (29.61 kg ha^{-1}) was recorded with T_5 (Paddy straw+ Jute bag+ Rhizobium) followed by T_8 (saw dust + Rhizobium) (27.27 kg ha^{-1}), T6 (26.20 kg ha^{-1}) and T_7 Black polythene + Azotobacter (23.36 kg ha^{-1}). However, significantly the lowest available potassium (12.30 kg ha^{-1}) was recorded with absolute control (T_1).
The nutrient uptake Kg ha^{-1} (NPK) recorded is graphically represented in Figure 1.

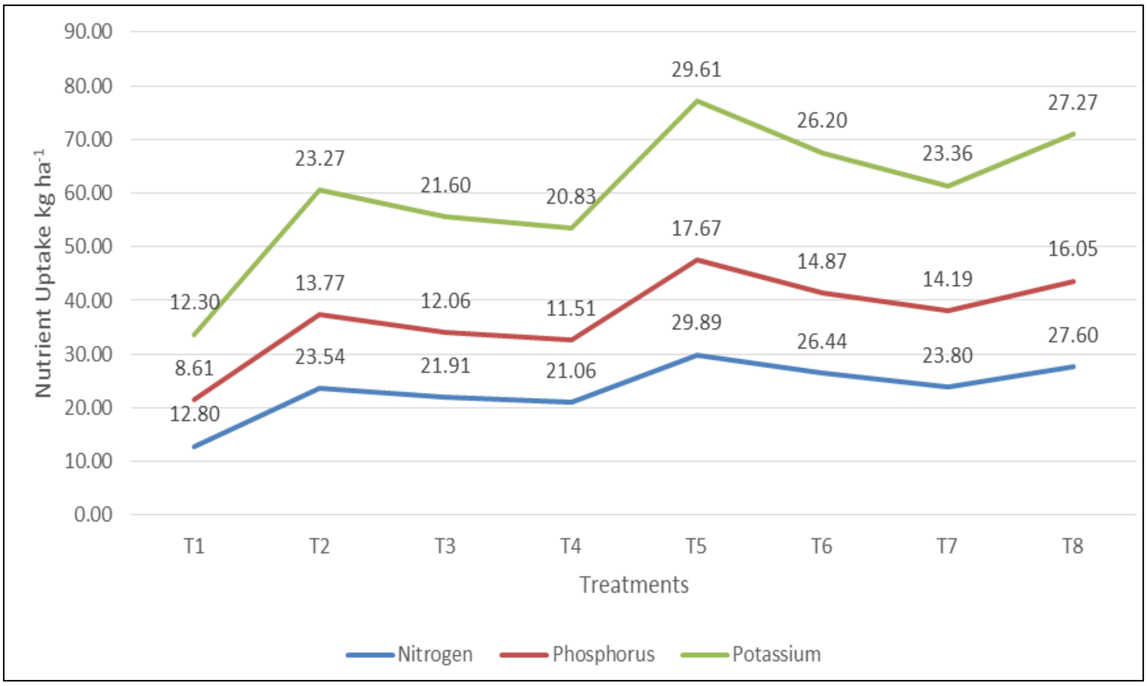

Fig 2: Effect of different types of mulching and biofertilizer on nutrient uptake pattern of finger millet

4. Discussions

The probable reason for higher N recorded in T5 (Paddy straw+ Jute bag+ Rhizobium) is because availability of nutrients was higher with the increasing level of applied nutrients. The significant build-up of the available N due to different levels of mulching application could be attributed to increased activity of nitrogen fixing bacteria with addition of rhizobium thereby resulting in higher accumulation of nitrogen (Kumar, 2002) [5].

In addition, the increase in nitrogen uptake in T_5 (Paddy straw+ Jute bag+ Rhizobium) is due to the application of Rhizobium biofertilizer which promotes biological nitrogen fixation process, where Rhizobium bacteria convert atmospheric nitrogen into ammonia, a form readily absorbed by plants. This symbiotic relationship not only enhances nitrogen availability but also stimulates root growth, leading to more extensive root systems that improve overall nutrient and water absorption. Additionally, Rhizobium biofertilizers improve soil health by enhancing microbial activity and organic matter content. This sustainable nitrogen source supports robust plant growth and health, making plants more efficient at nutrient uptake and promoting long-term soil fertility. Similar finding were reported by Mane *et al*. (1993) [7]. Increase in available P under mulch over unmulched control is inconsonance with the findings of Himerlrick *et al*., (1993) [3] who reported increased available nutrient contents in soil after three years, when organic mulch residues was incorporated. Organic mulches and residues are rich source of P; therefore, the available P was likely to rise. In addition, the increase in phosphorus uptake in T_5 (Paddy straw+ Jute bag+ Rhizobium) is due to the addition of Rhizobium which enhances root development, which allows for greater access to soil phosphorus, and improved soil structure and microbial activity that facilitate nutrient cycling. Rhizobium bacteria also interact synergistically with other microorganisms, such as phosphate-solubilizing bacteria and mycorrhizal fungi, to mobilize and solubilize phosphorus. Additionally, the production of organic acids by Rhizobium bacteria helps convert bound phosphorus into more absorbable forms, while the overall enhancement of plant health and nutrient uptake mechanisms further increases phosphorus absorption efficiency. Similar findings were reported by Kant *et al*. (2017) [4].

The enhancement in the availability of K under T_5 (Paddy straw+ Jute bag+ *Rhizobium*) could be attributed to the favorable hydrothermal regimes. These findings are similar to those of Sinkeviciene *et al*. (2009) [12] who also reported that mulches helped to reduce soil temperature during the hotter period of crop growth and also increased the availability of K which resulted in higher crop yield Increase in available K contents might be associated with increased moisture content. In addition, the increase in potassium uptake in finger millet due to the addition of Rhizobium is primarily due to enhanced root development, which increases the plant's ability to access potassium from the soil. Rhizobium also improves soil structure and microbial activity, promoting better nutrient cycling and availability. Additionally, Rhizobium facilitates synergistic interactions with other microorganisms, such as potassium-solubilizing bacteria and mycorrhizal fungi, further enhancing potassium mobilization. Moreover, the overall improvement in plant health and nutrient uptake mechanisms, along with enhanced water uptake, ensures more efficient absorption of potassium, contributing to better growth and development. Similar findings were reported by Najafi *et al* (2018) [9].

5. Conclusion

The study reveals that combining mulching with biofertilizers, particularly the T_5 treatment (paddy straw, jute bags, and *Rhizobium*), significantly boosts nitrogen, phosphorus, and potassium uptake in finger millet. This is attributed to the favorable soil conditions created by organic mulches, such as improved moisture retention and microbial activity, alongside the nitrogen-fixing benefits of *Rhizobium*. Enhanced root development and nutrient cycling improve nutrient absorption, with increased availability of phosphorus and potassium. These findings underscore the value of using mulching and biofertilizers as sustainable, cost-effective strategies to enhance soil fertility and crop productivity, especially for smallholder farmers. This approach not only supports higher yields but also promotes long-term soil health, making it a valuable practice for environmentally conscious, resource-efficient agriculture.

6. Competing Interests

Authors have declared that no competing interests exist.

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