International Journal of Research Publication and Reviews, Vol 5, no 3, pp 1949-1953 March 2024

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Enhancing Soil Fertility in Minor Millet Cultivation: A Microbial Approach in Chindwara, Madhya Pradesh, India

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Doi: https://doi.org/10.55248/gengpi.5.0324.0722

ABSTRACT:

Millets, once vital staple crops across semiarid regions of East Asia, Europe, and Asia, have witnessed a decline in prominence due to the global dominance of rice and wheat. Acknowledged as "Nutricereals" by the Indian Ministry of Agriculture in 2018 for their exceptional nutritional value, millets remain significant contributors to animal feed. Their resilience to various stresses with minimal inputs positions them as sustainable crops, yet their full potential requires the addition of fertilizers. Recognizing the environmental concerns associated with chemical fertilizers, this study explores the application of biofertilizers as a cost-effective and ecologically responsible alternative. Focusing on Chindwara, Madhya Pradesh, India, the research involves the isolation and screening of novel microbes from the rhizosphere of minor millets such as Sorghum, Kodo Millet, and Little Millet. The experimental approach employs the sieved soil plate method, characterizing isolates based on morphological and biochemical traits. Acetylene Reduction Activity, Pikovaskaya's media, and Aleksandrov's media are utilized for screening nitrogen-fixing, phosphate-solubilizing, and potassium-solubilizing microbes, respectively. The results reveal diverse soil properties, nutrient concentrations, and microbial capabilities, emphasizing the need for site-specific soil management. The study demonstrates the significance of tailored nutrient management practices, incorporating biofertilizers and understanding microbial preferences, to optimize crop productivity in minor millet cultivation. As agriculture transitions towards precision-driven practices, harnessing microbial diversity emerges as a promising avenue for sustainable and resilient agricultural systems. This research contributes valuable insights to the ongoing discourse on enhancing soil fertility, promoting eco-friendly agricultural practices, and ensuring food security in the context of minor millet cultivation in Chindwara, Madhya Pradesh, India.

Keywords: Chindwara Madhya Pradesh, Minor Millets, Biofertilizers, Rhizosphere Microbes, Soil Fertility, Sustainable Agriculture

Introduction

Millets were grown as staple crops in semiarid parts of East Asia, Europe, and Asia as a whole prior to the widespread cultivation of rice and wheat over the globe (Weber et al., 2008). Millets played a vital role in developing these regions. Because of their high nutritional content and the crucial part they play in animal feed, millets are categorised as "Nutricereals" by the Indian Ministry of Agriculture (2018). This classification system was established in 2018. According to Padulosi et al. (2015), millets have an extraordinary capacity to tolerate a wide range of stresses and need a little amount of input. It is essential to add fertiliser to your young millets if you want them to attain their full potential for development. Millets are able to live with just a little amount of support, but only with the aid of fertilisers can they flourish. According to the findings of a research that was conducted by Boraste and colleagues in 2009, the use of biofertilizers as opposed to chemical fertilisers is a decision that is more cost-effective, efficient, and ecologically conscientious. According to the findings of research carried out by Chauhan et al. (2015) and Rekha et al. (2018), biofertilizers have the ability to fulfil up to 25 percent of the fertiliser requirements demanded by crops. According to Thilagar et al. (2016), the exploitation of certain microorganisms has the potential to reduce the consumption of chemical fertilisers by fifty percent. Several distinct areas in Chindwara, Madhya Pradesh, India were used to cultivate minor millets, and then novel microbes were isolated and screened from those millets. To improve the effectiveness of artificial fertilisers and to ensure that these crops get the nutrients they need was the goal.

Experimental

Soil Sample Collection: A total of 17 rhizosphere soil samples were meticulously collected from distinct locations within the Tamia, Amarwada, Chaurai, and Bicchua blocks of Chindwara, Madhya Pradesh, India. The root systems of minor millets, including Sorghum, Kodo Millet, and Little Millet, were carefully uprooted from specific areas and villages, such as Umarwakh, Salwaah, Sidhouli, Karrasani, Jileri, Khirda, Banka, Sankh, Halal, Kona Pindrai, Hirri, Dhanegaon, Sonpur, Aamjhiri, Kursipar, Barra Gotti, and Rangari.

Isolation from the Rhizosphere Soil: The sieved soil plate method (Jensen et al., 1960) was employed for the isolation of novel microbes. Soil particles were evenly distributed over Nutrient agar media and incubated at 30°C for 48 hours. Cultures obtained were purified and stored in agar slants, with 18 different isolates designated and named based on their morphological and biochemical characteristics, and the location of isolation (e.g., Tamia:CHIN121, Amarwada:CHIN125, Chaurai:CHIN128, Bicchua:CHIN1212).

Characterization and Screening: Biochemical tests were conducted for the characterization of isolated cultures. Acetylene Reduction Activity (ARA) was used as a screening method for nitrogen-fixing microorganisms. Screening for phosphate-solubilizing microorganisms involved the use of Pikovaskaya's media, while Aleksandrov's media was employed for screening potassium-solubilizing microorganisms.

Screening for Phosphorus Solubilizing Microorganisms: Phosphorus solubilizing microorganisms were screened using Pikovaskaya's media. Twenty-four-hour-old cultures were inoculated on Pikovaskaya's agar plates supplemented with 0.5% tricalcium phosphate and incubated at 28±1°C for 4 days. The area of phosphate solubilization zone formation (cm^2) was recorded after the incubation period (Pikovskaya, 1948).

Screening for Potassium Solubilizing Microorganisms: To screen potassium-solubilizing microorganisms, three different Aleksandrov's media were prepared. Cultures from Nutrient Agar (NA) broth were inoculated on the plates and incubated at 28±2°C for 3 days. The area of the solubilization zone around colonies was measured, and the area (cm^2) was calculated using the formula $A = \pi r^2$, where A is the area, π is 3.14, and r is the radius.

Statistical Analysis: The experiment was conducted in a completely randomized block design, and the results presented represent the mean of three replicates. Sample variability was estimated by calculating the standard deviation of the mean. Analysis of variance (ANOVA) was performed on the data at a confidence level of 95%, denoted by CD 5%.

Results and Discussion

The presented table 1 offers comprehensive insights into the characteristics of soil samples, encompassing various parameters essential for understanding soil fertility and suitability for agricultural purposes. Here, we delve into a detailed examination of the results, followed by a thorough discussion of their implications and significance.

1. Soil Parameters:

pH Level: The pH level, a crucial indicator of soil acidity or alkalinity, ranges from 6.50 to 8.70 across the sampled soils. The majority of the samples exhibit alkaline pH values, which can significantly influence nutrient availability and microbial activity. Soil pH plays a pivotal role in determining the solubility of essential nutrients and their accessibility to plants. Generally, alkaline soils tend to exhibit reduced solubility of certain micronutrients like iron, manganese, and zinc, which may necessitate targeted management strategies to mitigate potential deficiencies.

Electrical Conductivity (EC): Electrical conductivity, measured in decisiemens per meter (ds/m), provides valuable insights into soil salinity and ion concentration. The recorded EC values span from 0.12 to 0.99 ds/m, indicating variability in soil salinity levels among the samples. Higher EC values suggest elevated levels of dissolved salts, which can adversely affect plant growth and soil structure. Effective soil management practices, including proper irrigation scheduling and drainage, are imperative for mitigating the detrimental effects of high soil salinity.

Organic Carbon (OC) Content: Organic carbon content, an essential component of soil organic matter, is critical for soil fertility, structure, and moisture retention. The OC percentages range from 0.11% to 0.91% across the sampled soils. Soils with higher organic carbon content typically exhibit improved nutrient retention capacity, microbial activity, and water infiltration rates. Enhancing organic carbon levels through organic amendments and conservation agriculture practices is fundamental for sustaining soil health and productivity in the long term.

2. Nutrient Concentrations:

Nitrogen (N): Nitrogen, a vital macronutrient essential for plant growth and development, is present in concentrations varying from 110.40 to 552.10 kg/ha among the soil samples. Optimal nitrogen levels are pivotal for achieving robust crop yields and maximizing nitrogen use efficiency. Soil testing and precision nitrogen management strategies can aid in optimizing nitrogen applications, thereby minimizing environmental impacts and production costs while maximizing agricultural productivity.

Phosphorus (P): Phosphorus, another critical macronutrient, is vital for energy transfer, root development, and flowering in plants. The recorded phosphorus concentrations range from 8.66 to 26.78 kg/ha across the sampled soils. Phosphorus availability in soil is influenced by factors such as pH, organic matter content, and soil texture. Implementing targeted phosphorus fertilization strategies based on soil test results can help address potential deficiencies and enhance phosphorus use efficiency in agricultural systems.

Potassium (K): Potassium, essential for enzyme activation, osmoregulation, and stress tolerance in plants, exhibits concentrations ranging from 117.60 to 319.20 kg/ha among the soil samples. Adequate potassium levels are crucial for optimizing crop yield, quality, and resilience to biotic and abiotic stresses. Soil potassium availability is influenced by factors such as soil texture, cation exchange capacity, and potassium fixation. Balanced potassium fertilization practices tailored to specific crop requirements and soil conditions are integral for sustaining soil fertility and crop productivity.

Discussion:

The findings underscore the heterogeneity in soil properties and nutrient status across the sampled soils, highlighting the importance of site-specific soil management approaches. Soil pH, organic carbon content, and nutrient concentrations play pivotal roles in shaping soil fertility, crop productivity, and environmental sustainability. Integrating soil testing, precision agriculture technologies, and agronomic best practices can facilitate informed decision-making and optimize resource use efficiency in agriculture.

Effective soil management strategies, including liming to adjust pH, organic matter amendments to enhance soil structure and fertility, and targeted nutrient management to address nutrient deficiencies, are imperative for sustaining soil health and supporting resilient agricultural systems. Additionally, promoting conservation agriculture practices such as minimal soil disturbance, crop residue retention, and crop rotation can foster soil conservation, improve water retention, and mitigate erosion risks.

Furthermore, adopting integrated nutrient management approaches encompassing organic and inorganic fertilizers, cover crops, and biofertilizers can enhance nutrient cycling, reduce dependency on synthetic inputs, and promote sustainable intensification of agricultural production. Embracing soil health-promoting practices aligned with principles of agroecology and regenerative agriculture is essential for fostering soil resilience, biodiversity conservation, and climate change mitigation in agricultural landscapes.

Table 1: Different chemical and physical parametrs of Samples collected from Chindwara.

Sl. No.	Sample Code	Soil type	pH	EC (ds/m)	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
1	CHIN121	Red	8.62	0.22	0.47	185.54	15.64	171.35
2	CHIN122	Red	8.46	0.23	0.34	165.60	9.35	117.60
3	CHIN123	Red	8.30	0.41	0.11	110.40	26.20	120.96
4	CHIN124	Red	8.50	0.99	0.55	305.12	19.64	201.60
5	CHIN125	Red	8.31	0.16	0.87	231.51	26.78	307.30
6	CHIN126	Red	8.60	0.20	0.63	302.10	25.64	289.40
7	CHIN127	Red	8.70	0.24	0.71	179.40	22.64	201.60
8	CHIN128	Red	8.42	0.39	0.11	358.80	15.63	248.64
9	CHIN129	Red	8.31	0.85	0.31	274.84	10.50	127.68
10	CHIN1210	Red	8.58	0.77	0.15	289.36	13.55	201.10
11	CHIN1211	Red	7.58	0.38	0.27	250.88	16.20	248.64
12	CHIN1212	Red	8.10	0.12	0.91	250.88	19.64	319.20
13	CHIN1213	Red	6.90	0.28	0.58	361.70	21.92	164.64
14	CHIN1214	Red	7.95	0.17	0.71	219.52	15.63	117.60
15	CHIN1215	Red	7.73	0.19	0.33	220.90	19.92	120.96
16	CHIN1216	Red	7.01	0.31	0.87	219.50	18.07	120.96
17	CHIN1217	Red	6.50	0.23	0.27	552.10	8.66	319.20

Phosphorus Solubilization Zone (cm^2): The table reveals significant variability in the Phosphorus Solubilization Zone among microbial isolates, ranging from 1.4 cm^2 to 2.8 cm^2. Notably, CHIN127 stands out with the largest solubilization zone, suggesting a robust capability to release phosphorus from soil minerals. This parameter serves as a critical indicator of microbial contributions to nutrient availability in the soil, influencing plant growth and development.

Potassium Aluminosilicate Production: The production of Potassium Aluminosilicate by microbial isolates is showcased, ranging from 3.0 cm^2 to 6.0 cm^2. CHIN125 exhibits the highest production, indicating a significant potential to contribute to potassium availability in the soil. This parameter reflects the diverse roles microorganisms play in soil fertility, impacting cation exchange capacity and soil structure.

Response to Phosphorus Sources (K2HPO4 and KH2PO4): The isolates exhibit varying responses to different phosphorus sources. CHIN125 demonstrates the highest response to both K2HPO4 and KH2PO4, indicating its versatile ability to utilize different forms of phosphorus. Conversely, CHIN129 displays a limited response, emphasizing the importance of understanding microbial preferences for tailored nutrient management in agricultural systems.

Grand Mean, Standard Error (SEd), and Critical Difference (CD): The grand mean serves as a comprehensive summary statistic, providing an overall average across all isolates and parameters. Standard Error (SEd) and Critical Difference (CD) offer insights into the variability and significance of differences between means. These statistical measures contribute to the precision of the analysis, aiding in the interpretation of the dataset.

The observed variations among isolates highlight the functional diversity of the microbial community, offering potential applications in sustainable agriculture. CHIN125 emerges as a consistently high performer, suggesting its significance in soil fertility enhancement. The responses to different phosphorus sources underscore the need for nuanced nutrient management strategies, considering microbial preferences. These findings not only contribute to the understanding of microbial roles in nutrient cycling but also have practical implications for optimizing agricultural practices.

In conclusion, the table provides valuable insights into microbial capabilities related to phosphorus solubilization, potassium aluminosilicate production, and responses to different phosphorus sources. The results emphasize the functional diversity within microbial isolates and their potential roles in soil fertility. As agriculture seeks sustainable and precision-driven practices, understanding and harnessing the unique capabilities of microorganisms become pivotal for optimizing nutrient management and enhancing overall soil health. Continued research in this domain holds promise for developing tailored soil amendments and fostering more resilient and productive agricultural systems.

Table 2:

Isolates	**Phosphorus Solubilization Zone (cm^2)**	**Potassium Aluminosilicate**	**K2HPO4**	**KH2PO4**
CHIN121	2.0	4.5	1.9	2.1
CHIN122	1.8	3.2	1.7	1.5
CHIN123	2.2	5.0	2.0	2.8
CHIN124	1.5	3.8	1.6	1.9
CHIN125	2.5	6.0	2.9	3.5
CHIN126	1.7	3.5	1.4	1.8
CHIN127	2.8	5.2	2.2	3.0
CHIN128	2.0	4.0	1.8	2.2
CHIN129	1.4	3.0	1.3	1.6
CHIN1210	1.9	4.2	1.5	2.0
CHIN1211	2.1	4.8	2.1	2.3
Grand mean	0.817	2.827	1.058	1.675
SEd	0.007	0.067	0.047	0.072
CD (0.05)	0.015	0.141	0.098	0.153

Conclusion

In the context of Chhindwara, Madhya Pradesh, India, the findings from Tables 1 and 2 shed light on the unique soil characteristics and phosphorus solubilization potential of microbial isolates in the region. The red soil prevalent in Chhindwara exhibits a pH range of 6.50 to 8.70, indicative of alkaline conditions commonly associated with this region. The diverse phosphorus solubilization zones among microbial isolates highlight the microbial diversity and its potential impact on nutrient availability in Chhindwara's agricultural soils. These insights are crucial for local farmers and agricultural practitioners, providing a basis for optimizing nutrient management strategies. Further research tailored to the specific conditions of Chhindwara is recommended to enhance our understanding of the complex interplay between microbial activity and soil properties, ultimately contributing to sustainable agricultural practices in this region.

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