Criterion – 3

Research, Innovations and Extension

NAAC- SSR (2nd Cycle)

ETERNAL UNIVERSITY

BARU SAHIB, SIRMOUR-173101
HIMACHAL PRADESH

3.3.1(5)

Use of millets

ETERNAL UNIVERSITY
BARU SAHIB, SIRMOUR-173101
HIMACHAL PRADESH

Use of the millets as per the direction of UGC for their utilization and popularization in form of the products for the society

Millets cultivation at Eternal University Farms

CHARACTERIZATION OF FUNCTIONAL FOOD PRODUCTS FROM ANTIOXIDANT RICH UNDERUTILIZED GRAINS TREATED WITH DIFFERENT PROCESSING TECHNIQUES

THESIS

SUBMITTED TO ETERNAL UNIVERSITY, BARU SAHIB
IN THE PARTIAL FULFILLMENT OF REQUIREMENTS
FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

FOOD TECHNOLOGY

By

DIVYA CHAUHAN

(BS17PSFT001)

DR. KHEM SINGH GILL AKAL COLLEGE OF AGRICULTURE
ETERNAL UNIVERSITY, BARU SAHIB
HIMACHAL PRADESH-173101
AUGUST, 2022

Figure 4.6. Natural fermentation treatment of different grains

Figure 4.7 Underutilized grains after roasting treatment

Published articles on Millets and product by Eternal University

Journal of Applied Biology & Biotechnology Vol. 10(Suppl 1), pp. 46-52, Mar-Apr, 2022
Available online at http://www.jabonline.in
DOI: 10.7324/JABB.2022.10s107

Effect of diverse fermentation treatments on nutritional composition, bioactive components, and anti-nutritional factors of finger millet (*Eleusine coracana* L.)

Sumaira Jan[1], Krishan Kumar[1]*, Ajar Nath Yadav[2], Naseer Ahmed[1], Priyanka Thakur[1], Divya Chauhan[1], Qurat-Ul-Eain Hyder Rizvi[1], Harcharan Singh Dhaliwal[2]

[1]Department of Food Technology, Dr. Khem Sing Gill Akal college of Agriculture, Eternal University, Sirmour, Himachal Pradesh, India.
[2]Department of Biotechnology, Dr. Khem Sing Gill Akal college of Agriculture, Eternal University, Sirmour, Himachal Pradesh, India.

ARTICLE INFO

Article history:
Received on: October 30, 2021
Accepted on: January 30, 2022
Available online: March 18, 2022

Key words:
Anti-nutrients,
Antioxidant activity,
Bioactive compounds,
Fermentation,
Lactobacillus brevis,
Lactobacillus plantarum.

ABSTRACT

The finger millet (*Eleusine coracana* L.) flour was subjected to lactic acid fermentation using two strains of *Lactobacillus*, that is, with *Lactobacillus brevis* (BF) and *Lactobacillus plantarum* (PF), with yeast (*Saccharomyces cerevisiae* L.) (YF), and with yeast + ammonium sulfate used as fermentation activator (YAF) and combined treatment of yeast and *L. brevis* (CF) at an interval of 12, 24, and 36 h. The samples after drying were evaluated for their nutritional, anti-nutritional, minerals, and bioactive components. The total phenolic contents enhanced significantly ($P \leq 0.05$) during all fermentation treatments but the highest values were observed after PF treatment. Similarly, there was a significant ($P \leq 0.05$) enhancement in the antioxidant activity during all fermentation treatments, and the highest activity was observed during YAF treatment. Fermentation significantly ($P \leq 0.05$) enhanced the crude protein content but decreased the crude fiber and fat contents. A significant ($P \leq 0.05$) increase in mineral content such as Cu, Fe, Mn, and Zn was observed after all fermentation treatments. Anti-nutrients such as phytic acid and tannins were reduced significantly ($P \leq 0.05$) and the greatest reductions were observed during treatment with *L. brevis* (BF). Similarly, the tannin contents get reduced significantly ($P \leq 0.05$) during all fermentation treatments. The present study, therefore, shows that fermentation could be the most effective method for improving the nutritional and bioactive components, as well as the antioxidant capacity of finger millet flour with a significant reduction in anti-nutritional components.

1. INTRODUCTION

Finger millet (*Eleusine coracana* L.) also known as ragi is one of the main millets grown in India. It is a rich source of minerals such as calcium, phosphorus, and iron contents [1]. The finger millet contains all essential amino acids such as cysteine, lysine, and methionine. Therefore, it can serve as an important source of vegetable proteins in the diet of vegetarian people. It also contains about 72% carbohydrates, including dietary fiber components and non-starchy polysaccharides which help in preventing constipation and help in decreasing the blood glucose level. It is rich in B-group vitamins such as riboflavin, thiamine, niacin, and folic acid [2]. The bran layers of finger millet comprise phenolic contents, vitamins, and minerals, which provide numerous nutritional and therapeutic benefits [3]. It has nutraceutical properties and is recognized for its antidiabetic, anti-tumorigenic, antidiarrheal, atherosclerogenic, anti-inflammatory, antimicrobial, and antioxidant characteristics [4]. Finger millet is considered as the poor man's food and can be stored for long period without being infested by insects and pests [5]. It is considered a gluten-free grain, with a lower glycemic index, and is generally used as whole grain flour for traditional food formulations, and can be utilized after processing in form of noodles, biscuits, muffins, vermicelli, pasta, and bread [6].

The prominent health benefits of fermented food products make them play a key role in a human diet. Fermentation is generally considered as one of the ancient methods of food preservation generally used in the processing of cereal and millet grains. Studies on fermented food products indicated that it helps to improve the sensory characteristics, for example, taste, flavor, and texture as well as increase the nutritional quality of fermented products. Due to these unique benefits, fermentation has become a main subject of research for the food technologists globally [7]. Fermentation has been found to significantly enhance the nutritional quality of cereal and millet grains by enhancing proteins, improving digestibility, and increasing the lysine content of grains [8]. Moreover, it has been reported to increase the availability of micronutrients such a calcium, zinc, manganese, and iron, as well

*Corresponding Author
Krishan Kumar,
Department of Food Technology, Dr. Khem Sing Gill Akal College of Agriculture, Eternal University, Sirmour, Himachal Pradesh, India.
E-mail: krishankumar02007@gmail.com

Journal of Postharvest Technology
2022, **10**(2): 35-47
www.ijpht.in

RESEARCH ARTICLE

Beneficial effect of diverse fermentation treatments on nutritional composition, bioactive components, and anti-nutritional factors of foxtail millet (*Setaria italica* L.)

Sumaira Jan[1], Krishan Kumar[1*], Naseer Ahmed[1], Priyanka Thakur[1], Divya Chauhan[1], Qurat-Ul Eain Hyder Rizvi[1], Pritesh Vyas[2]

[1] Department of Food Technology, Dr. Khem Sing Gill Akal College of Agriculture, Eternal University, Baru Sahib, Sirmour, Himachal Pradesh, India

[2] Department of Biotechnology, Dr. Khem Sing Gill Akal College of Agriculture, Eternal University, Baru Sahib, Sirmour, Himachal Pradesh, India

Received: 19.02.2022 Accepted: 16.04.2022

ABSTRACT

The foxtail millet (*Setaria italica* L.) flour was exposed to lactic acid fermentation by using two strains of *Lactobacillus* i.e. with *Lactobacillus brevis* (BF) and *Lactobacillus plantarum* (PF), yeast (*Saccharomyces cerevisiae* L.) (YF), yeast + ammonium sulfate [$(NH_4)_2SO_4$] (YAF) and combined treatment of yeast and *L. brevis* (CF) at an interval of 12, 24 and 36 h. The samples after drying were evaluated for their nutritional, anti-nutritional, minerals, and bioactive components. The total phenolics enhanced significantly ($p \leq 0.05$) during all fermentation treatments but the highest value was observed during YAF treatment. Similarly, the antioxidant activity improved significantly ($p \leq 0.05$) during all treatments but the highest values were observed during YAF treatment. The fermentation treatments increased significantly ($p \leq 0.05$) the crude protein content during all fermentation treatments. Whereas, there was a significant ($p \leq 0.05$) decrease in crude fiber and fat content. A significant ($p \leq 0.05$) increase in mineral contents such as Cu, Fe, Mn, and Zn was observed after all fermentation treatments. Anti-nutrients such as phytic acid declined significantly ($p \leq 0.05$) during all fermentation treatments but the highest reductions were observed during treatment with *L. brevis* (BF) and with yeast + (NH4)2SO4 (YAF). Similarly, the tannin contents reduced significantly ($p \leq 0.05$) during all fermentation treatments. The results concluded that fermentation could be the most efficient technique of improving the bioactive compounds, nutritional components, and antioxidant activity of foxtail millet flour with a significant reduction in anti-nutritional components.

Keywords: Anti-nutrients, fermentation, *Lactobacillus brevis*, *Lactobacillus plantarum*, *Saccharomyces cerevisiae*

Citation: Jan, S., Kumar, K., Ahmed, N., Thakur, P., Chauhan, D., Rizvi, Q. E. H., and Vyas, P. 2022. Beneficial effect of diverse fermentation treatments on nutritional composition, bioactive components, and anti-nutritional factors of foxtail millet (*Setaria italica* L.). *Journal of Postharvest Technology*, **10**(2): 35-47.

INTRODUCTION

Foxtail millet (*Setaria italica* L.), an individual from the grass family Poaceae, is one of the world's most nutritious millets and is an important food in Asia and Africa. It remained an underutilized crop like different millets but, and its cultivation is easy

* *For correspondence*: K. Kumar (Email: krishankumar02007@gmail.com)

ISSN: 2348-4330

Received: 24 September 2019 | Revised: 16 May 2020 | Accepted: 2 June 2020
DOI: 10.1111/jfpp.14672

ORIGINAL ARTICLE

Journal of Food Processing and Preservation ifst WILEY

Physico-chemical characterization and utilization of finger millet (*Eleusine coracana* L.) cultivars for the preparation of biscuits

Arshdeep Kaur[1] | Krishan Kumar[1] | Harcharan Singh Dhaliwal[2]

[1]Department of Food Technology, Akal College of Agriculture, Eternal University, Baru Sahib, India
[2]Department of Biotechnology, Akal College of Agriculture, Eternal University, Baru Sahib,, India

Correspondence
Krishan Kumar, Department of Food Technology, Akal College of Agriculture, Eternal University, Baru Sahib, Sirmour, HP 173101, India.
Email: krishankumar02007@gmail.com

Abstract

Finger millet being underutilized but highly nutritious millet was explored for nutritional characteristics. Twelve cultivars of finger millet were found to be a potential source of proteins (7.19%–12.56%), crude fibers (3.17%–5.83%), crude fat (1.07%–1.87%), and ash or mineral content (2.81%–3.61%) as well as a rich source of minerals such as Cu (0.61–1.62 mg/100 g), Mn (4.01–7.44 mg/100 g), Fe (3.97–8.04 mg/100 g), Zn (2.08–4.50 mg/100 g), and Ca (318–659 mg/100 g). Cultivars were screened out for the highest content of calcium and the cultivar GPHCPB-149 richest in calcium (659 mg/100 g) was utilized for supplementation in biscuits at different proportions, that is, 0, 25, 50, and 75%. A significant ($p \leq .05$) increase in the calcium and crude fiber contents was reported with increased incorporation of finger millet in biscuits. Sensory evaluation studies concluded that finger millet flour was successfully incorporated up to 50% in wheat flour for the preparation of biscuits.

Practical applications

The study showed that finger millet is a rich source of nutrients and has great potential to be utilized for the development of functional bakery products. It can be successfully incorporated up to 50% with wheat flour for the preparation of functional bakery products. Finger millet incorporated biscuits were found to contain higher levels of crude fiber, calcium, iron, and zinc contents than control biscuits and may offer the inherent health benefits of finger millet to the consumers by alleviating the deficiency of calcium and prevention of other lifestyle diseases.

1 | INTRODUCTION

Finger millet (*Eleusine coracana* L.) is an annual robust grass, mainly grown as a cereal grain in the semi-arid tropics and subtropics of the world under rainfed conditions. It ranks fourth in importance among millets in the world after sorghum, pearl millet, and foxtail millet (Upadhyaya, Gowda, & Reddy, 2007). It has carbohydrate contents of 81.5%, protein 9.8%, crude fiber 4.3%, and minerals 2.7% which is much higher as compared to other cereals and millets. Its crude fiber and mineral contents are markedly higher than those of wheat (1.2% fiber, 1.5% minerals) and rice (0.2% fiber, 0.6% minerals) (Saleh, Zhang, Chen, & Shen, 2013). The high proportion of carbohydrates is in the form of non-starchy polysaccharides and dietary fiber, which helps to relieve constipation and lowering of glucose in the blood. It has a well-balanced amino acid profile and is a good source of methionine, cystine, and lysine. It is also a rich source of vitamins, namely, thiamine, riboflavin, folic acid, and niacin (Vidyavati, Begum, Vijayakumari, Gokavi, & Begum, 2004). Belton and Taylor (2013) reported that finger millet has mineral contents in the range of 1.58%–2.80% with a higher content of calcium (Ca) and about half of the Ca is present in the outer husk.

Finger millet is considered as an important nutraceutical grain due to the presence of a high amount of calcium (0.38%), dietary

NUTRACEUTICAL POTENTIAL AND PROCESSING ASPECTS OF MILLETS

Krishan Kumar*, Harish Kumar and Shiv Kumar

Department of Food Technology, Akal College of Agriculture, Eternal University, Baru Sahib, Sirmour-173101 (HP)
**Email*: krishankumar02007@gmail.com

Abstract

Millets are one of the most important drought-resistant crops widely grown in the semi-arid tropics of Africa and Asia. These are highly valuable for presence of various nutraceuticals components which are helpful in prevention of various lifestyle diseases such as cancer, cardiovascular diseases, low and high blood pressure, diabetes etc.Because of their important contribution in food security and potential health benefits, millet grains are now main topic of research for food scientists. Various processing techniques are being developed to enhance nutritional quality, improving the digestibility and bioavailability of nutrients with reduction in anti-nutrient contents. Value added products from millets could be helpful in prevention and treatment of nutritional deficiency disorders. Promotion of these value added products can improve the socio-economic status and also health status of the consumers. To promote their utilization as food in developing countries, major attention should be given towards encouragement of research works and projects for studying the processing aspects, product development and nutritional enrichment of processed products. This review discusses the nutraceutical potential, health benefits and techniques used in processing of millets for fulfilment of the dietary need of global population and alleviation of malnutrition in developing countries.

Keywords: Phytochemicals; Anti-nutrients; Antioxidants; Nutraceuticals; Value addition

Introduction

Millets are one of the drought-resistant crops having short growing season and tolerant to various diseases and pests (Devi et al., 2014). These are considered as ancient grains, cultivated thousands of years ago at the creation of human civilization. Cultivation of millets started about 4000 years before as supported by various evidences (Shahidi and Chandrasekara, 2013). These are small-seeded grains with different varieties such as pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), kodo millet (*Paspalum setaceum*), proso millet (*Penicum miliaceum*), foxtail millet (*Setaria italic*), little millet (*Panicum sumatrense*), and barnyard millet (*Echinochloa utilis*) cultivated throughout the world (Bouis, 2000). Being rich in antioxidants, millets are being used as nutraceuticals. They are reported to be helpful in treatment of migraine, asthma, blood pressure, diabetes, heart

CHAPTER- III

MATERIALS AND METHODS

3.1 ISOLATION AND CHARACTERIZATION OF ENDOPHYTIC MICROBES FROM CEREAL CROPS

3.1.1 Sample Collection

The Divine Valley of Peace, Baru Sahib situated at 30.7537° N, 77.2965° E, in Sirmour district, Himachal Pradesh, India and is spread over 400 acres. A total of 27 plant samples comprising cereal crops (wheat, oat, barley, and maize), millets (pearl millet, foxtail millet, and finger millet), and pseudo cereal crops (buckwheat and amaranth) were collected from Agricultural farm and different sites of Baru Sahib in sterile polythene bags and stored at 4°C for further use (Fig. 3.1).

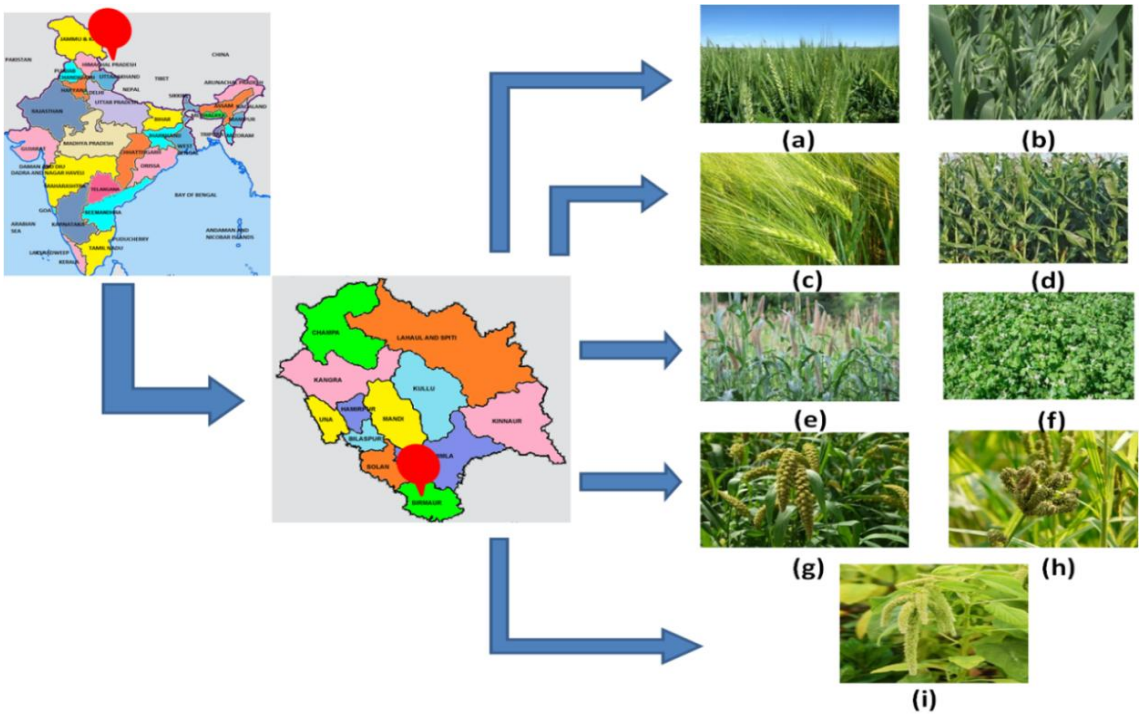

Fig. 3.1 A schematic representation of the isolation of endophytic microbes from different crops a) Wheat (b) Oat (c) Barley (d) Maize (e) **Pearl millet (f) Buck wheat (g) Foxtail millet (h) Finger millet and (i) Amaranth**

Environmental Sustainability
https://doi.org/10.1007/s42398-020-00094-1

ORIGINAL ARTICLE

Amelioration of drought stress in Foxtail millet (*Setaria italica* L.) by P-solubilizing drought-tolerant microbes with multifarious plant growth promoting attributes

Divjot Kour[1] · Kusam Lata Rana[1] · Ajar Nath Yadav[1] · Imran Sheikh[1] · Vinod Kumar[2] · Harcharan Singh Dhaliwal[1] · Anil Kumar Saxena[3]

Received: 19 September 2019 / Revised: 1 January 2020 / Accepted: 4 January 2020

Abstract
Drought is the most limiting factors affecting plant development. It severely affects the crops and leads to serious reductions in yield. There are certain nutrients which also act as limiting factor for plants such as phosphorus and nitrogen. Under the conditions of nutrient limitations, growth is greatly reduced. Plant associated microbiome are gaining attention as they help the host (plant) to combat stress conditions. In the present study, stress-adaptive and phosphorus-solubilizing microbes were isolated from rhizosphere of different crops such as wheat, maize, foxtail millet, and finger millet growing in NW Indian Himalayas. A total of 70 microbes were isolated using different defined and selective growth media. The isolated microbes were screened for plant growth promoting (PGP) ability of phosphate solubilization using three different insoluble phosphorus (P) substrates (apatite, tricalcium phosphate and rock phosphate) under the drought stress conditions (5–8% PEG-8000). Among isolated microbes 27 isolates exhibited P-solubilizing attribute under the water deficient conditions. The two efficient drought-adaptive and P-solubilizing isolates were identified as *Acinetobacter calcoaceticus* EU- LRNA-72 and *Penicillium* sp. EU-FTF-6, respectively, by 16S rRNA and 18S rRNA gene sequencing. The isolates EU- LRNA-72 and EU-FTF-6 were evaluated for plant growth promoting (PGP) traits and mitigation of drought stress in foxtail millet under the controlled and natural conditions. The isolates *A. calcoaceticus* EU- LRNA-72 and *Penicillium* sp. EU-FTF-6 efficiently mitigated the adverse effects of drought in foxtail millet by enhancing the accumulation of glycine betaine, proline, sugars, and decreasing lipid peroxidation. The drought tolerant P-solubilizing microbes could be useful for plant growth promotion and mitigation of drought stress for crops growing under the water deficient conditions.

Keywords Agricultural sustainability · Drought · Foxtail millet · PGPMs · Phosphorus solubilization

Introduction

Drought is a very complex phenomenon which affects different parts of the world and causes negative impacts on social, economic and environmental aspects. Global warming and extreme dry conditions are ultimately going to hinder food productions (Niu et al. 2018). Drought stress causes devastating effects on different growth stages of plants. All the physiological processes are completely disturbed during drought due to disruption of membrane structure, enzyme activities, and ultra structural cellular components (Hasanuzzaman et al. 2018). Drought, thus, is one of the most critical expression of environmental stress which affects plant's biochemistry and physiology. On the other hand, phosphorus (P), essential macronutrient for metabolic activities, is the major growth limiting nutrient. It is often required in

Divjot Kour and Kusam Lata Rana contributed equally to present work.

✉ Ajar Nath Yadav
ajar@eternaluniversity.edu.in; ajarbiotech@gmail.com

[1] Department of Biotechnology, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib, Sirmour, Himachal Pradesh 173101, India

[2] Quality Analysis Lab, Forage Section, College of Agriculture, CCS, Haryana Agricultural University, Hisar, Haryana 125004, India

[3] ICAR-National Bureau of Agriculturally Important Microorganisms, Kusmaur, Mau 275103, India

Published online: 31 January 2020

Biologia
https://doi.org/10.1007/s11756-022-01291-5

ORIGINAL ARTICLE

Plant growth promotion of pearl millet (*Pennisetum glaucum* L.) by novel bacterial consortium with multifunctional attributes

Tanvir Kaur[1] · Rubee Devi[1] · Sunil Kumar[1] · Divjot Kour[2] · Ajar Nath Yadav[1]

Received: 31 August 2022 / Accepted: 5 December 2022

Abstract

Intensive agricultural practices with chemical fertilizers are becoming the reason of environmental deterioration. To feed the ever increasing worldwide population with sustainability goals is a one major challenge and biostimulants developed from the beneficial soil and plant microbiome is a better approach for farming practices to increase the crop productivity. In agricultural fields various categories of biostimulants are utilized that contains one microbial culture and multiple strains of microbes in single formulation as microbial consortium. The mixture of microbial species in a formulation is an emerging technology in the present era because of its multiple benefits for plant growth and plant protection for agro-environment sustainability. The present study deals with the isolation of rhizospheric and endophytic bacteria from different cereal and pseudocereal crops and development of a single inoculum as well as consortium for the cereal crops growth. A total of 147 bacteria (rhizospheric and endophytic) were sorted out and were screened for plant growth promoting attributes of nitrogen fixation, phosphorus and potassium solubilization. Among all the bacterial isolates, three potential strains EU-PEN-6, EU-PRP-12 and EU-PRK-4 exhibiting N-fixing, P and K-solubilizing attributes were identified using 16S rRNA gene sequencing as *Pseudomonas extremorientalis*, *Bacillus subtilis*, and *Bacillus amyloliquefaciens*, respectively. In best of our knowledge, the present investigation has firstly reported *P. extremorientalis, B. subtilis* and *B. amyloliquefaciens* associated with the endophytic region of wheat and rhizosphere of pearl millet. The strains inoculation on pearl millet as single culture and as bacterial consortium improved the parameters like length and biomass of root/shoot, chlorophyll, carotenoids, total soluble sugar content, phenolics, and flavonoids over untreated control. The bacterial consortium was found to have more potential over single culture inoculation. A bacterial consortium could be used as bioinoculants for cereal crops growing in hilly regions.

Keywords Agricultural sustainability · Biostimulants · Bacterial Consortium · Pearl millet · Plant growth promotion

Abbreviations

BLAST	Basic Local Alignment Search Tool
CFU	Colony forming unit
gDNA	Genomic DNA
K	Potassium
LSD	Least significant difference
N	Nitrogen
NA	Nutrient agar
NCBI	National Center for Biotechnology Information
OD	Optical density
P	Phosphorus
PGP	Plant growth promoting

✉ Ajar Nath Yadav
ajarbiotech@gmail.com; ajar@eternaluniversity.edu.in

[1] Microbial Biotechnology Laboratory, Department of Biotechnology, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib, Sirmour 173101, Himachal Pradesh, India

[2] Department of Microbiology, Akal College of Basic Sciences, Eternal University,, Baru Sahib, Sirmour, 173101, Himachal Pradesh, India

Introduction

Cereals crops are the staple food for the worldwide population and they cultivated in more than 734.32 million ha of area. Globally, 2980.2 million tonnes of cereal crops

Published online: 09 December 2022

Natl. Acad. Sci. Lett.
https://doi.org/10.1007/s40009-022-01190-y

SHORT COMMUNICATION

Synergistic Effect of Endophytic and Rhizospheric Microbes for Plant Growth Promotion of Foxtail Millet (*Setaria italica* L.)

Tanvir Kaur[1] · Rubee Devi[1] · Sunil Kumar[1] · Divjot Kour[2] · Ajar Nath Yadav[1]

Received: 22 June 2022 / Revised: 12 September 2022 / Accepted: 12 October 2022

Abstract Microbial bioformulations in agriculture is vastly known and accepted for the sustainable agriculture and most of the bioformulation applied in the agricultural fields are developed from a single strain which have displayed inconsistent results. Microbial consortium is one new and promising bioformulation that could be used for growth and development of the crops. In the present investigation, isolation of plant (cereal and pseudocereal)-associated rhizospheric and endophytic microbes exhibiting nitrogen fixation, phosphorus and potassium solubilization capability was carried out. Afterward, the microbial mixture was developed for the growth promotion of foxtail millet crop. A total of 163 bacteria were sorted out and they were screened for nitrogen fixation, P- and K-solubilization attributes. Potent NPK strains were identified as *Stenotrophomonas rhizophila* EU-FEN-32 (N-fixer), *Pseudomonas marginalis* EU-FRP-16 (P-solubilizer) and *Bacillus* sp. strain EU-FRK-38 (K-solubilizer) using 16S rRNA gene sequencing. These strains inoculation on foxtail millet as microbial consortium improved the growth and physiological parameters in comparison with respect to chemical fertilizer and untreated control. The compatible mixture of microbes was found to have more potential and it could be used as bioinoculants for cereal crops growing in hilly regions.

Keywords Bioformulations · Foxtail millet · Microbial consortium · Sustainable agriculture

Globally, agricultural practices are not uniform, but the utilization of agrochemicals is common. Total 890 man-made agrochemicals are known which plays crucial role in enhancing the crop yield. The utilization of agrochemicals on the other hand leaves the hazardous effect on the environment and humans (mostly farmers). Formulation based on the microbes (bacteria, and fungi) are the finest substitute of agrochemical which sustains the agriculture as well as environment. Microbe's exhibits diverse indirect and indirect plant growth promoting (PGP) attributes, such as fixation and nutrients (nitrogen, phosphorus, potassium, zinc, and selenium) solubilization; production of growth hormones, antibiotics, nutrient chelator (siderophores) which benefits in the plant growth development [1]. Beneficial microbes exhibiting multifarious PGP traits as bioinoculants could be used as singly or as consortium (mixture of two or more microbes). The majority of available bioformulations developed ever since are derived from single species. Particularly from the last decade, microbial bioformulations were also developed containing two or more microbial species as combining the microbes gives combined benefits. Thus, the conglomeration of beneficial microbes is an efficient bioinoculants over the single microbe containing bioformulations [2].

The rhizospheric soil and samples of different cereal crops (maize, wheat) and pesudocereal crops (millets and amaranth) were collected from the green slopes of the Shivaliks, Himachal Pradesh. The samples were placed in the sterilized plastic bags and stored at 4 °C until the isolation of endophytic and rhizospheric bacteria. The isolation of cultural endophytic and rhizospheric bacteria were performed using serial dilution plating method on different

✉ Ajar Nath Yadav
ajarbiotech@gmail.com; ajar@eternaluniversity.edu.in

[1] Microbial Biotechnology Laboratory, Department of Biotechnology, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib, Sirmour, Himachal Pradesh 173101, India

[2] Department of Microbiology, Akal College of Basic Sciences, Eternal University, Baru Sahib, Sirmour 173101, India

Published online: 07 December 2022

Current Microbiology (2023) 80:186
https://doi.org/10.1007/s00284-023-03255-7

SHORT COMMUNICATION

Mutualistic Effect of Macronutrients Availing Microbes on the Plant Growth Promotion of Finger Millet (*Eleusine coracana* L.)

Tanvir Kaur[1] · Rubee Devi[1] · Rajeshwari Negi[1] · Divjot Kour[2] · Ajar Nath Yadav[1]

Received: 28 November 2022 / Accepted: 4 March 2023

Abstract
Globally, man-made agrochemicals plays crucial role in plant growth promotion and boost crop yield. The agrochemicals overuse leaves the detrimental damage on the environment and humans. Biostimulants developed from single or multiple microbes (archaea, bacteria, and fungi) could be the appropriate alternative of agrochemical which sustains the agriculture as well as environment. In the present investigation, 93 beneficial bacteria associated with rhizospheric and endophytic region were isolated using diverse growth media. The isolated bacteria were screened for macronutrients availing traits including dinitrogen fixation, phosphorus and potassium solubilization. The bacterial consortium was developed using selected bacteria with multifunctional attributes and evaluated for the growth promotion of finger millet crop. Three potent NPK strains were identified as *Erwinia rhapontici* EU-FMEN-9 (N-fixer), *Paenibacillus tylopili* EU-FMRP-14 (P-solubilizer) and *Serratia marcescens* EU-FMRK-41 (K-solubilizer) using 16S rRNA gene sequencing and BLAST analysis. The developed bacterial consortium inoculation on finger millet resulted in the improvement of growth and physiological parameters with respect to chemical fertilizer and control. The compatible mixture of bacteria was found to have more ability to increase the growth of finger millet and it might be utilized as biostimulants for nutri-cereal crops growing in hilly regions.

Introduction

The cereals of the future, millets are increasingly gaining attention because of their health benefits across the globe. Apart from health benefits millets are sustainable crop alternatives to other crops with respect to water scarcity. The small seeded nutri-cereals comprises of seven different types of millets such as pearl millet, foxtail millet, finger millet, barnyard millet, kodo millet, proso millet, and little millet [1]. Finger millet (ragi) is a minor millet cereal which is solely consumed by the humans and it provides different health benefits due to high content of dietary fibre, phenolic compounds, and calcium. This nutri cereal is also antitumorigenic, atherosclerogenic and antidiabetic, along with antimicrobial and antioxidant properties [2]. Finger millet is widely practiced across the Asia and different types of agrochemicals mainly consisting of macronutrients are being applied to the increase productivity. The utilization of agrochemicals such as urea, diammonium phosphate and muriate of potash benefits the optimal growth and productivity of crop but on the other hand these chemicals utilization for extended period could cause severe damage to the environment, humans and microflora of soil. In environment, conventional agrochemicals could cause contamination in groundwater, eutrophication, degradation of the soil quality and pollution in air. Moreover, the chemical fertilizers use could also reduce the profit margin of the growers as nutrients utilization efficiency is limited. The less or no use of chemical fertilizer is not possible as growing population demand of the food couldn't be fulfilled [3].

As an alternative, biostimulants developed from microbes could be utilized for the growth and production of the crops. Microbial-based biofertilizers is one of the safe and finest substitutes of agrochemical fertilizers which also promote the agricultural and environmental sustainability. The use of biostimulants offers multiple benefits such as quality grain production, soil fertility improvement and plant protection from abiotic and biotic factors. The production and

✉ Ajar Nath Yadav
ajarbiotech@gmail.com; ajar@eternaluniversity.edu.in

[1] Department of Biotechnology, Microbial Biotechnology Laboratory, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib, Sirmour 173101, Himachal Pradesh, India

[2] Department of Microbiology, Akal College of Basic Sciences, Eternal University, Baru Sahib, Sirmour 173101, Himachal Pradesh, India

Published online: 18 April 2023