MANIPAL UNIVERSITY
JAIPUR

INSPIRED BY LIFE

SDG 2

SUSTAINABLE DEVELOPMENT GOALS

REPORT 2023

2 ZERO HUNGER

MANIPAL UNIVERSITY
JAIPUR

SDG 2 focuses on ensuring adequate healthy food access while supporting resilient agriculture techniques that respect workers and the land. The implementation of SDG 2 at Manipal University Jaipur is evident in academic effort to create Sustainable agricultural and food distribution systems, as well as providing access to healthy and sustainable food options for individuals on campus.

Contents

MANIPAL UNIVERSITY
JAIPUR

INSPIRED BY LIFE

2 ZERO HUNGER

ACADEMICS

Program/Courses offered in

Course Code	Course Name	L	T	P	C	Semester
HA1101	Food Production Foundation - I	4	0	0	4	I
HA1102	Food & Beverage Service Foundation - I	4	0	0	4	I
HA1131	Food Production Lab - I	0	0	4	2	I
HA1132	Food & Beverage Service Lab - I	0	0	2	1	I
HA1201	Food Production Foundation - II	4	0	0	4	II
HA1202	Food & Beverage Service Foundation - II	4	0	0	4	II
HA1231	Food Production Lab - II	0	0	4	2	II
HA1232	Food & Beverage Service Lab - II	0	0	2	1	II
HA2101	Introduction to Indian Cuisine	4	0	0	4	III
HA2131	Indian Cuisine Lab	0	0	4	2	III
HA2132	Food & Beverage Service Lab - III	0	0	2	1	III
HA2201	Global Cuisine & Patisserie	3	0	0	3	IV
HA2202	Food & Beverage Management	3	0	0	3	IV
HA2231	Global Cuisine Lab	0	0	4	2	IV
HA2232	Advanced Food and Beverage Service Lab	0	0	2	1	IV
HA2233	Bakery & Confectionery Lab	0	0	4	2	IV
HA3241	Culinary Management - I	0	2	4	4	VI
HA4141	Culinary Management - II	0	2	4	4	VII
BT6202	Plant Biotechnology	3	0	1	4	II
BT1201	Mycology, and Plant Pathology	2	1	0	3	II
BT1101	Diversity of Lower Plants	2	1	0	3	I

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MUJ/Q&C/22/F/1.01

MANIPAL UNIVERSITY
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FACULTY OF SCIENCE

SCHOOL OF BASIC SCIENCES

DEPARTMENT OF BIOSCIENCES

INDUSTRIAL WORKSHOP ON THE OPERATIONS AND HANDLING OF BIOREACTOR

Date of Event (11.09.2023-12.09.2023)

1. **Introduction of the Event-** In this workshop, we get the essential knowledge and practical skills about the bioreactor. A bioreactor is a specialized device used in biotechnology and microbiology to create controlled environments for the growth and cultivation of various biological organisms, primarily microorganisms such as bacteria, yeast, and fungi, as well as cells and tissues. These versatile devices play a pivotal role in various scientific and industrial applications, including pharmaceuticals, biopharmaceuticals, agriculture, environmental remediation, and biofuel production.

2. **Objective of the Event**

   - ***Understanding Bioreactor Principles*:** Fundamental understanding of bioreactor principles, including how they work, their components, and their role in industrial processes.

   - ***Bioreactor setup and monitoring*:** Bioreactor setup and monitoring are crucial aspects of bioprocess management, ensuring the controlled cultivation of microorganisms, cells, or tissues for various applications.

   - ***Safe Handling and Operation*:** Safe handling of bioreactors, emphasizing the importance of following safety protocols to prevent accidents and ensure the well-being of personnel and the environment.

   - ***Process Optimization*:** Optimizing bioprocesses within bioreactors, including parameters like temperature, pH, agitation, and aeration, to maximize productivity and yield.

3. **Beneficiaries of the Event:** Gain in-depth knowledge and practical skills related to bioreactor setup, operation, and monitoring. This knowledge is beneficial in many food industries. with a better understanding of bioreactor monitoring and control, we can maintain consistent product quality, a crucial factor in industries such as biopharmaceuticals where product safety is paramount.

4. **Details of the Guests**

   Mr. Abhishek Thakur is an engineer at PRS BIO

5. **Brief Description of the event:**

   The "Industrial Workshop on the Operations and Handling of Bioreactor" is a specialize ed event designed to provide comprehensive knowledge and practical insights into the setup, operation, and management of bioreactors in industrial settings. This workshop

aims to cater to professionals, scientists, researchers, engineers, and individuals across various industries and sectors where bioreactor technology plays a crucial role.

Key elements of this workshop typically include:

In-Depth Learning: The event offers participants a deep dive into the principles, components, and operational aspects of bioreactors. Attendees will gain a thorough understanding of how bioreactors work and their importance in various industries.

Safety and Regulatory Compliance: Safety is a paramount concern when working with bioreactors. The workshop provides guidance on safe handling practices and emphasizes compliance with industry regulations and standards.

Hands-On Experience: The workshop focuses on the opportunity for practical, hands-on experience with bioreactor equipment, allowing them to apply their knowledge in a real-world setting.

Process Optimization: The workshop focuses on strategies and techniques for optimizing bioreactor processes, including monitoring and controlling critical parameters like temperature, pH, agitation, and aeration.

Quality Assurance: Quality control and assurance are essential in industries like pharmaceuticals and biopharmaceuticals. The workshop covers methods for ensuring product quality and consistency.

Industry Insights: The workshop features presentations, case studies, and discussions on current industry trends, innovations, and best practices related to bioreactor technology.

Practical Applications: The knowledge gained from the workshop can be directly applied to various sectors, including pharmaceuticals, biotechnology, environmental science, agriculture, and food production.

Career Development: Individuals attending the workshop can enhance their skills and knowledge, potentially opening up new career opportunities and advancement prospects in their respective fields.

Overall, the "Industrial Workshop on the Operations and Handling of Bioreactor" is a valuable educational and networking event that equips participants with the expertise and confidence to operate bioreactor systems effectively, driving advancements in biotechnology, pharmaceuticals, environmental science, and related fields.

6. Photographs

Dr. Sandeep Srivastava and Dr. Rakesh Kumar Sharma introduced our guest and briefed the workshop.

Our Guest Mr. Abhishek Rathore demonstrated the bioreactor controls

7.Brochure of the event:

8. Schedule of the event

DATE	TIMINGS	TOPIC
11/09/2023	10:00 AM	Inauguration
	10:30 AM	High Tea
	10:45 AM	Basics of Bioreactor
	11:30 AM	Reactor components
	1:00 PM	Lunch Break
	2:30 PM	Reactor setup
12/09/2023	9:30 AM	Bioreactor and data acquisition
	1:30 PM	Lunch Break
	2:30 PM	Q&A Session

MANIPAL UNIVERSITY
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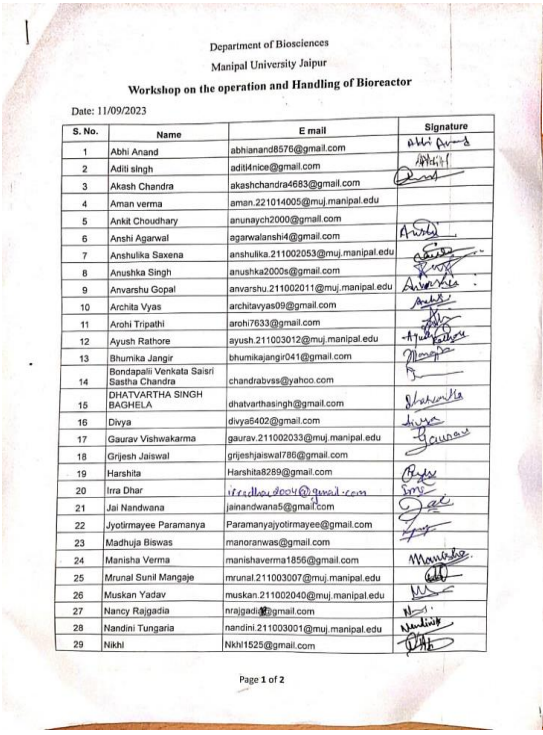
Attendance of the Event

Total attendee-71



Department of Biosciences
Manipal University Jaipur

Workshop on the operation and Handling of Bioreactor

Date: 11/09/2023

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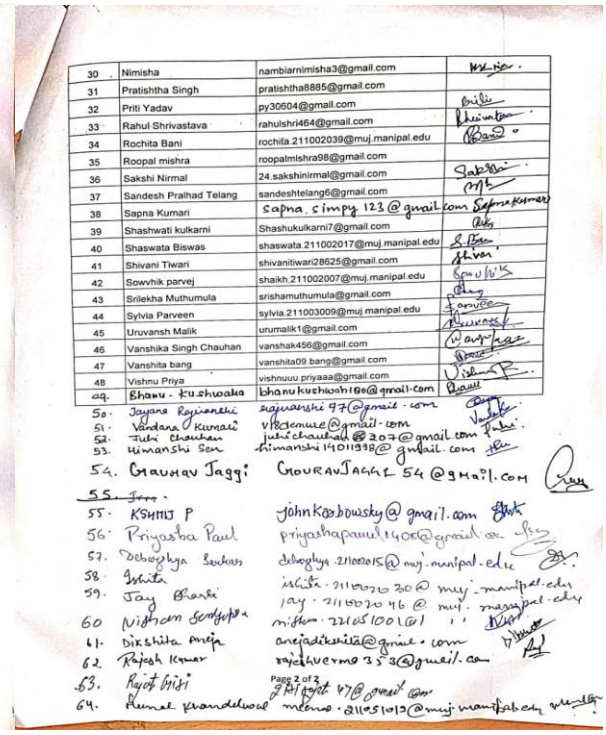
Page 1 of 2



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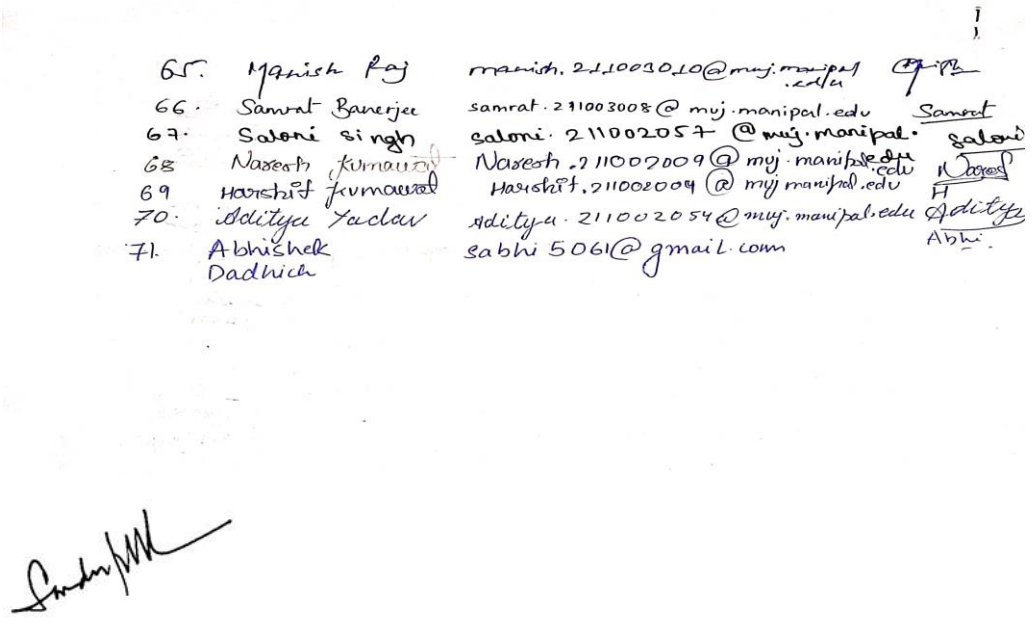
63.	Rajat Bisi	Page 2 of 2	
64.	Kunal Khandelwal	kunal.211051012@muj.manipal.edu	



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70.	Aditya Yadav	Aditya.211002054@muj.manipal.edu
71.	Abhishek Dadhich	sabhi5061@gmail.com

Seal and Signature of Head with date

MUJ/Q&C/FoMC/SHTM/2023/International Workshop – IAESTE

MANIPAL UNIVERSITY JAIPUR

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FACULTY OF MANAGEMENT & COMMERCE

SCHOOL OF HOSPITALITY AND TOURISM MANAGEMENT

&

Directorate of International Collaboration, MUJ

in collaboration with

I·A·E·S·T·E

IAESTE

LC MUJ

along with

JoJo Internationals

has organized a

CULTURAL CULINARY WORKSHOP

(SDG: Zero Hunger & Sustainable Consumption)

11/08/2023

(9:00 – 14:00)

AMIT DATTA

Digitally signed by AMIT DATTA
Date: 2024.01.11 11:36:03 +05'30'

Content of Report

1. Introduction

Goal 12 is about ensuring sustainable consumption and production patterns, which is key to sustain the livelihoods of current and future generations. Our planet is running out of resources, but populations are continuing to grow. The workshop also aims to generate awareness of it. Goal 2 is about Zero Hunger, which is a key to sustain humanity and provide nutritious food for all human being.

The International Association for the Exchange of Students for Technical Experience, Association, commonly known as IAESTE, is an association of national committees representing academic, industrial and student interests. The main aim is to help the members realise their dreams and to facilitate the exchange of ideas both technical as well as, cultural, by connecting students from various cultures and countries.

2. Objective of the Event

- To promote and strengthen international collaborations at MUJ
- To provide a learning opportunity for the SHTM students
- Spread SDG Awareness related to Responsible Consumption & Production and Zero Hunger

3. Brief Description of the event

On 11th August 2023, a Cultural Culinary Workshop was organized in association with IAESTE-MUJ and JoJo International. The DoIC, MUJ supported the event. IAESTE interns from 22 different countries and 25 BHM students participated in preparing their local delicacies. The workshop was organized at SHTM lab. A session on sustainable development

goals 12 and 2, i.e on Sustainable Consumption & Production and Zero Hunger was conducted by the resource person and SHTM faculty members. Further the career scope of culinary professional was shared with the students. Thereafter the participants prepared different dishes. The food was presented and the leadership team of MUJ tasted and applauded the efforts of the participants. Later certificate was awarded to all the participants.

4. Photographs of the event

Glimpses of the event

Certificate distribution to the foreign IAESTE interns

3. SDG Presentation by the resource person foreign interns

5. Brochure

MANIPAL UNIVERSITY JAIPUR

IAESTE LC MUJ

SCHOOL OF HOSPITALITY AND TOURISM MANAGEMENT

&

Directorate of International Collaboration, MUJ

Has organized a

Cross -Cultural Culinary Workshop

On 11th August 2023 (SHTM Lab)

For Registration Contact IAESTE coordinators:
Yahya Aseerullah (9573642592) or Aditya Patil (9421524060)

3 Brochure

MANIPAL UNIVERSITY JAIPUR

6. Schedule of the event

Resource Person: Mr Ankit Adhikari, Recruitment Supervisor, JoJo International. Email: cv8@jojointernational.co.in. www.jojo-international.com.au (+61470234428)

Date	Time	Duration	Venue
11th August, 2023	9:00 am – 14:00 pm	05 hours	#325, 1AB HM Lab
Introduction, Culinary Session on Responsible Consumption & Production and Zero Hunger, Food Presentation, Certificate Distribution, Lunch, Vote of thanks.			

7. Attendance of the Event Total attendee – 47 (22 Foreign + 25 Indian [MUJ])

Sr	Participant's Name	Country	University
1	Aaron John Goff	United Kingdom	University of Edinburgh
2	Marlene Elisabeth Metz	Germany	Heidelberg University
3	Benedikt Lohnes	Germany	Technical University of Darmstadt
4	Nina Lauks	Poland	Uniwersytet Medyczny w Lodzi
5	Yaba Rosette Tanoé	Germany	Friedrich-Alexander-Universitat Erlangen-Nurnberg
6	Suwapat Thongyoun	Thailand	Chulalongkorn University, Bangkok
7	Blanca Prior Palomero	Spain	Universidad Politecnica de Madrid
8	Valentín Gregorio Galindo Benéitez	Spain	Universidad Politecnica de Madrid
9	Friedrich Albrecht Dang	Germany	Technische Universitat Munchen
10	Mustafa Aidini Abala	Turkey	Erciyes University
11	Tristan Robert A. Toye	Belgium	Katholieke Universiteit Leuven
12	Laura Maria Estrada D'Amado	Sweden	Chalmers University of Technology
13	Pablo Rodriguez Sanchez	Spain	University of Málaga,
14	Arshia Vali Pour	Iran	Iran University of Science and Technology
15	Oscar Monje Lola	Spain	Universidad Politecnica de Madrid
16	Mohamed Haroun Boutaieb	Tunisia	National School of Architecture and Urbanism
17	Khadijeh Ahmadi Zamani	Iran	K.N. Toosi University of Technology
18	Amine Zribi	Hungary	Eotvos Lorand University
19	Eya YAHYAOUI	Tunisia	National Engineering School of Tunis (ENIT)
20	Muhammed Yasir Yılmaz	Turkey	Istanbul Technical University
21	Eren Asci	Turkey	Kocaeli University
22	Daniel Manuel Allan Werner-Meier	Germany	Technical University of Cologne
23	VANSHIKA	India	Manipal University Jaipur
24	MEHMA SINGH	India	Manipal University Jaipur
25	HARSH ADITYA SINGH RATHORE	India	Manipal University Jaipur
26	SHIVAM JAISWAL	India	Manipal University Jaipur
27	ABHIJEET ARORA	India	Manipal University Jaipur
28	AJAY AHIR	India	Manipal University Jaipur
29	SARTHAK GAUTAM	India	Manipal University Jaipur
30	RITU RAJPUROHIT	India	Manipal University Jaipur
31	ALAM HUSSAIN	India	Manipal University Jaipur
32	GARIMA PANDEY	India	Manipal University Jaipur
33	RUDR SIKARIA	India	Manipal University Jaipur
34	VAIBHAV ENDORIA	India	Manipal University Jaipur

35	DHANUSHWEE L	India	Manipal University Jaipur
36	DIVESH NIMAWAT	India	Manipal University Jaipur
37	PREKSHA MAHESHWARI	India	Manipal University Jaipur
38	ARUSHI RATHORE	India	Manipal University Jaipur
39	PAWAN	India	Manipal University Jaipur
40	HIMANSHU SAINI	India	Manipal University Jaipur
41	ANSHUMAN CHETIA	India	Manipal University Jaipur
42	RUDRARAJ SINGH SISODIA	India	Manipal University Jaipur
43	RANJEET SINGH CHUNDAWAT	India	Manipal University Jaipur
44	ANKIT MANKANI	India	Manipal University Jaipur
45	PRAKASH MANKANI	India	Manipal University Jaipur
46	RITWIK GUPTA	India	Manipal University Jaipur
47	KULDEEP SINGH	India	Manipal University Jaipur

8. Feedback of the Event

The session was interesting and will benefit the student's learnings about the different culinary products and about SDG goals of responsible Production and Consumption and Zero Hunger. Similar views were also expressed by the delegates, IAESTE members, and SHTM students after the session was completed.

9. Letter of Correspondence and Certificates

From: Team Incoming IAESTE LC MUJ <head.incoming@iaestemuj.in>
Sent: Monday, August 7, 2023 5:38:53 PM
To: Dr. Amit Datta [MU - Jaipur] <amit.datta@jaipur.manipal.edu>
Cc: President <president@iaestemuj.in>; Dr. Arun Kumar Poonia [MU - Jaipur] <arunkumar.poonia@jaipur.manipal.edu>
Subject: 4th Edition of International Cross-Cultural Culinary Workshop

Dear Sir,

Please find the details of the International Cross-Cultural Culinary Workshop below:

Date: 11 August 2023
Time: 10:00 AM-2:00 PM
Total guests: 30 (including leadership, faculty, foreign interns and team members)

Certificates will be issued to 25 Hotel Management students and 15 foreign interns as discussed.

Thank you.
--
Warm Regards,

IAESTE LC MUJ

Team Incoming
IAESTE India, LC
MUJ Website:
www.iaestemuj.in

Yahya Aseerullah
Head, Incoming
Mobile: (+91) 9573642592

Aditya Patil
Head, Incoming
Mobile: (+91) 9421524060

IAESTE Office, 1st Floor, Administrative Block
Dome Building, Manipal University Jaipur

From: cv8@jojointernational.co.in <cv8@jojointernational.co.in>
Sent: Tuesday, August 4, 2023 2:15 PM
To: Dr. Amit Datta [MU - Jaipur] <amit.datta@jaipur.manipal.edu> Dr. Aravind Kumar Rai [MU - Jaipur] <aravindkumar.rai@jaipur.manipal.edu>
Subject: FW: Proposal for Meeting

Respected Sir,

Greetings from JOJO International!!

Hope this email finds you in good health.

Noted and also discuss the benefits and advantages associated with the programs.

Feel free to keep in touch with us about any of your queries.

NOT HAPPY** with Our Services, **then Write** your **CONCERN at** **care@jojointernational.org

Best Regards,

Ankish Adhikari,
Recruitment Supervisor.
Contact:+91-70030-10217
Skype: live:54bf85b47b529fc1

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Think Green Before You Print This Page!!!

From: Dr. Aravind Kumar Rai [MU - Jaipur] <aravindkumar.rai@jaipur.manipal.edu>
Sent: Wednesday, July 28, 2023 5:21 PM
To: cv8@jojointernational.co.in

CERTIFICATES :

MUJ/Q&C/FoMC/SHTM/2023/International Workshop – IAESTE

MANIPAL UNIVERSITY JAIPUR

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Glimpses of the event

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10	Mustafa Aidini Abala	Turkey	Erciyes University
11	Tristan Robert A. Toye	Belgium	Katholieke Universiteit Leuven
12	Laura Maria Estrada D'Amado	Sweden	Chalmers University of Technology
13	Pablo Rodriguez Sanchez	Spain	University of Málaga,
14	Arshia Vali Pour	Iran	Iran University of Science and Technology
15	Oscar Monje Lola	Spain	Universidad Politecnica de Madrid
16	Mohamed Haroun Boutaieb	Tunisia	National School of Architecture and Urbanism
17	Khadijeh Ahmadi Zamani	Iran	K.N. Toosi University of Technology
18	Amine Zribi	Hungary	Eotvos Lorand University
19	Eya YAHYAOUI	Tunisia	National Engineering School of Tunis (ENIT)
20	Muhammed Yasir Yılmaz	Turkey	Istanbul Technical University
21	Eren Asci	Turkey	Kocaeli University
22	Daniel Manuel Allan Werner-Meier	Germany	Technical University of Cologne
23	VANSHIKA	India	Manipal University Jaipur
24	MEHMA SINGH	India	Manipal University Jaipur
25	HARSH ADITYA SINGH RATHORE	India	Manipal University Jaipur
26	SHIVAM JAISWAL	India	Manipal University Jaipur
27	ABHIJEET ARORA	India	Manipal University Jaipur
28	AJAY AHIR	India	Manipal University Jaipur
29	SARTHAK GAUTAM	India	Manipal University Jaipur
30	RITU RAJPUROHIT	India	Manipal University Jaipur
31	ALAM HUSSAIN	India	Manipal University Jaipur
32	GARIMA PANDEY	India	Manipal University Jaipur
33	RUDR SIKARIA	India	Manipal University Jaipur
34	VAIBHAV ENDORIA	India	Manipal University Jaipur

35	DHANUSHWEE L	India	Manipal University Jaipur
36	DIVESH NIMAWAT	India	Manipal University Jaipur
37	PREKSHA MAHESHWARI	India	Manipal University Jaipur
38	ARUSHI RATHORE	India	Manipal University Jaipur
39	PAWAN	India	Manipal University Jaipur
40	HIMANSHU SAINI	India	Manipal University Jaipur
41	ANSHUMAN CHETIA	India	Manipal University Jaipur
42	RUDRARAJ SINGH SISODIA	India	Manipal University Jaipur
43	RANJEET SINGH CHUNDAWAT	India	Manipal University Jaipur
44	ANKIT MANKANI	India	Manipal University Jaipur
45	PRAKASH MANKANI	India	Manipal University Jaipur
46	RITWIK GUPTA	India	Manipal University Jaipur
47	KULDEEP SINGH	India	Manipal University Jaipur

8. Feedback of the Event

The session was interesting and will benefit the student's learnings about the different culinary products and about SDG goals of responsible Production and Consumption and Zero Hunger. Similar views were also expressed by the delegates, IAESTE members, and SHTM students after the session was completed.

9. Letter of Correspondence and Certificates

From: Team Incoming IAESTE LC MUJ <head.incoming@iaestemuj.in>
Sent: Monday, August 7, 2023 5:38:53 PM
To: Dr. Amit Datta [MU - Jaipur] <amit.datta@jaipur.manipal.edu>
Cc: President <president@iaestemuj.in>; Dr. Arun Kumar Poonia [MU - Jaipur] <arunkumar.poonia@jaipur.manipal.edu>
Subject: 4th Edition of International Cross-Cultural Culinary Workshop

Dear Sir,

Please find the details of the International Cross-Cultural Culinary Workshop below:

Date: 11 August 2023
Time: 10:00 AM-2:00 PM
Total guests: 30 (including leadership, faculty, foreign interns and team members)

Certificates will be issued to 25 Hotel Management students and 15 foreign interns as discussed.

Thank you.
--
Warm Regards,

IAESTE LC MUJ

Team Incoming
IAESTE India, LC
MUJ Website:
www.iaestemuj.in

Yahya Aseerullah
Head, Incoming
Mobile: (+91) 9573642592

Aditya Patil
Head, Incoming
Mobile: (+91) 9421524060

IAESTE Office, 1st Floor, Administrative Block
Dome Building, Manipal University Jaipur

From: cv8@jojointernational.co.in <cv8@jojointernational.co.in>
Sent: Tuesday, August 4, 2023 2:15 PM
To: Dr. Amit Datta [MU - Jaipur] <amit.datta@jaipur.manipal.edu> Dr. Aravind Kumar Rai [MU - Jaipur] <aravindkumar.rai@jaipur.manipal.edu>
Subject: FW: Proposal for Meeting

Respected Sir,

Greetings from JOJO International!!

Hope this email finds you in good health.

Noted and also discuss the benefits and advantages associated with the programs.

Feel free to keep in touch with us about any of your queries.

NOT HAPPY** with Our Services, **then Write** your **CONCERN at** **care@jojointernational.org

Best Regards,

Ankish Adhikari,
Recruitment Supervisor.
Contact:+91-70030-10217
Skype: live:54bf85b47b529fc1

INDIA HEAD OFFICE: | MUMBAI-INDIA |
JOJO INTERNATIONAL PVT. LTD.
Contact: +91-22-28577040
www.jojointernational.com

AUSTRALIA OFFICE: | SYDNEY-NSW |
JOJO INTERNATIONAL (AUS) PTY LTD.
Contact: +61470234428
www.jojo-international.com.au

BRANCH OFFICES IN INDIA:
| KOLKATA+913340319494 | | BANGALORE+918777851669 | | NAVIMUMBAI+918976226899 |
| PUNE+917715020459 | | DARJEELING+916296399980 | | VARANASI+916389739003 |
Think Green Before You Print This Page!!!

From: Dr. Aravind Kumar Rai [MU - Jaipur] <aravindkumar.rai@jaipur.manipal.edu>
Sent: Wednesday, July 28, 2023 5:21 PM
To: cv8@jojointernational.co.in

CERTIFICATES :

RESEARCH

Summary for Manipal University Jaipur 2

Manipal University Jaipur 2021 to 2023

Research performance within SDG 1: No Poverty (2023)

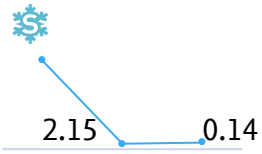
Entity: Manipal University Jaipur · Within: All subject areas (ASJC) · Year range: 2021 to 2023 · Data source: Scopus, up to 30 Oct 2024

10

Scholarly Output

0.53

Field-Weighted Citation Impact



1

International Collaboration

147

Views Count

15

Citation Count

Collaboration summary within SDG 1: No Poverty (2023)

Entity: Manipal University Jaipur · Within: All subject areas (ASJC) · Year range: 2021 to 2023 · Data source: Scopus, up to 30 Oct 2024

International Collaboration

Publications co-authored with Institutions in other countries/regions

Manipal University Jaipur
10.0%

Academic-Corporate Collaboration

Publications with both academic and corporate affiliations

Manipal University Jaipur
0.0%

Top keyphrases within SDG 1: No Poverty (2023)

Entity: Manipal University Jaipur · Within: All subject areas (ASJC) · Year range: 2021 to 2023 · Data source: Scopus, up to 30 Oct 2024

Top keyphrases by relevance

- India
- Urban Water
- Developing Countries
- Developing Country
- Volunteer Service
- Water Management
- Participant Observer
- Welfare Program
- Legislative Body
- Rural Management
- Mode Supply
- Survey Area
- Level Sentiment Analysis
- Foreign Assets
- Individual Company

MANIPAL UNIVERSITY
JAIPUR

EVENTS

MUJ/DSW/Student Clubs/2023/Biotech Club MUJ/9th September'23

MANIPAL UNIVERSITY
JAIPUR

DIRECTORATE OF STUDENTS' WELFARE

IMPORTANCE OF GUT MICROBE IN HUMAN HEALTH AND DISEASE

Biotech Club, Manipal University Jaipur

Date of Event (9th September 2023)

(Platform: Google Meet)

Index

1. Introduction of the Event

The Biotech Club, Manipal University Jaipur organized an online Bio wellness session on 9th September'23. The convenor – Dr. Mousumi Debnath, Faculty Coordinator, Biotech Club, invited: Mr. Surendra K Chikara, founder and CEO of Bione Ventures Pvt. Ltd., Bengaluru, Mr. Prabhat Nath Jha, professor, BITS Pilani.

This Bio wellness session was organised for students to understand the importance of gut microbes in human health and diseases caused by them. Measures for keeping the body healthy and be deprived of diseases were discussed in meeting.

2. Objectives of the Event

- To increase the awareness about the various microbes found inside the human body, especially the gut and their roles in human health and how can they affect humans due to poor and malnourished diet.
- To discover how minor dietary adjustments can elevate the quality of these microorganisms serves as a catalyst, inspiring students to embrace healthier dietary choices and cultivate a wholesome lifestyle
- To understand the measures implemented to maintain body and keep state of mind healthy
- Understanding the wellness of gut and its environment and with help of an online test called "MyMicroBiome Test"

3. Beneficiaries of the Event

- MUJ students
- BITS PILANI students

4. Brief Description of the event

The Biotech Club at Manipal University Jaipur successfully hosted an enlightening online webinar titled "Importance Of Gut Microbes in Human Health and Diseases," skillfully guided by our esteemed faculty coordinator, Dr. Mousumi Debnath, from the Department of Biosciences. We were honored to welcome the distinguished guest, Mr. Surendra K Chikara, who graced the event with his expertise. The session commenced with an insightful opening address by Dr. Mousumi, setting the stage for an engaging and informative gathering. Dr. Surendra then assumed the role of guest lecturer, sharing his expertise and knowledge with our students.

He delivered a comprehensive presentation, elucidating the pivotal role of gut microbes in human health and disease. Dr. Surendra delved into the diverse array of microbes residing within the human body and the intricate relationship they share with our dietary choices. He expounded on the profound connections between gut microbes, diabetes, and obesity, emphasizing the transformative potential of personalized dietary recommendations in rejuvenating gut health. Dr. Surendra also introduced us to the innovative concept of the MyMicroBiome Test, a tool for analyzing gut health and tailoring balanced diets to maintain its well-being.

The session culminated in an engaging Q&A session, where Dr. Surendra K Chikara addressed students' inquiries, covering topics such as nutrition, gut health-related health issues, and dietary recommendations for nurturing and sustaining a healthy gut. In

closing, heartfelt gratitude was extended to all participants, speakers, and organizers for their invaluable contributions.

The online webinar proved to be an enriching and informative guide to holistic health, leaving a lasting impact on all those who attended.

5. Photographs

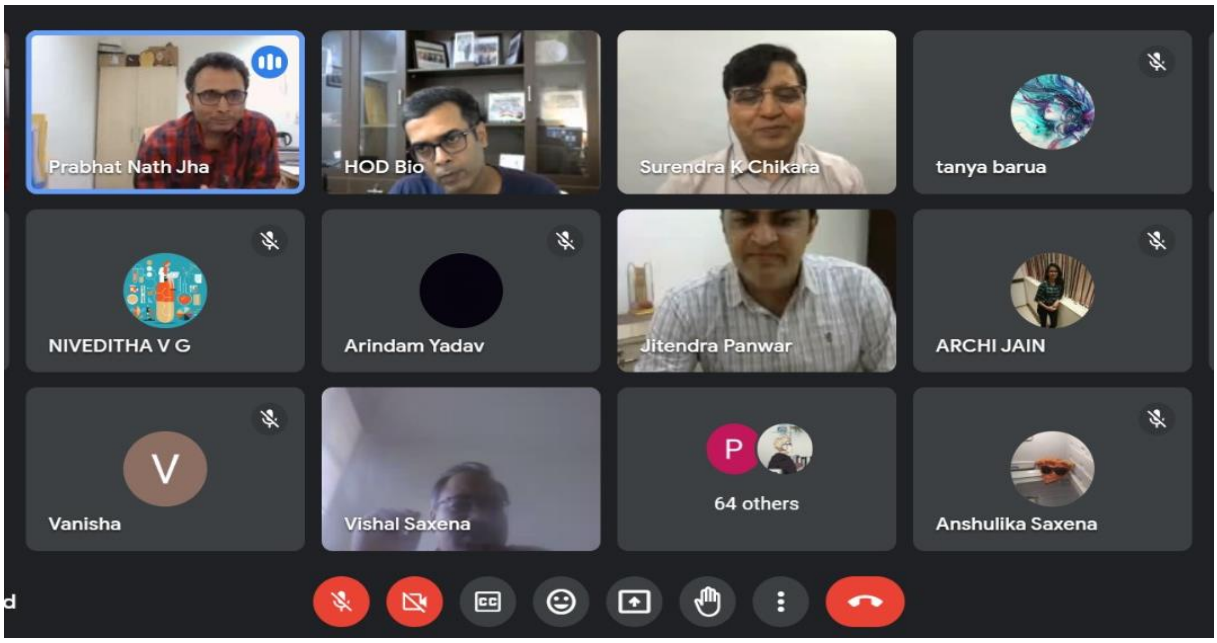


Figure 1 Introduction to Speakers

Figure 2 Explanation of topic by Dr. Surendra K Chikara

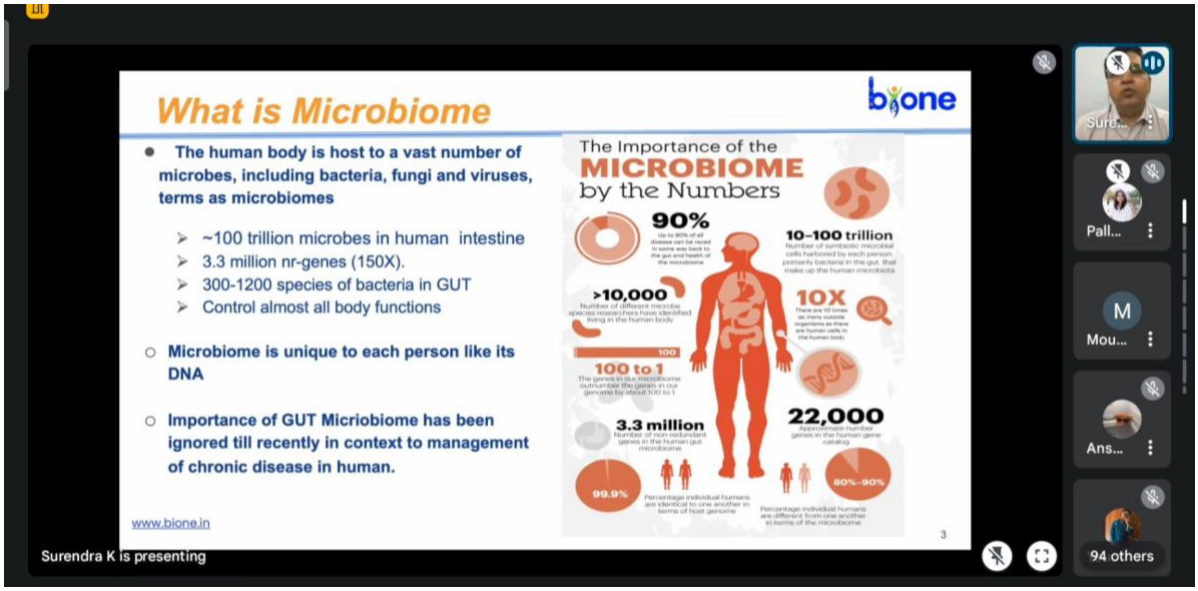


Figure 3 Presentation by Mr. Chikara

Figure 4 Final address/ Vote of thanks

6. Brochure or Creative of the Event

7. SCHEDULE OF THE EVENT:

The event was on the 9th September 2023 from 4:00 AM- 5:30 PM on Google Meet.

8. ATTENDANCE OF THE EVENT:

S.No.	Name	Registration No.
1.	Anshulika Saxena	211002053
2.	Prachi Jain	221002016
3.	Anvarshu Gopal	211002011
4.	Anuj Kumar	221002063
5.	Divyanshu Joshi	221002056
6.	Arindam Yadav	221003015
7.	Anshi Agarwal	211002008
8.	Yashvardhan Gupta	221002012
9.	Tanya Barua	221002065
10.	Mohammad Aman	221003012
11.	Poorvi Sharma	221002074
12.	Vaishali Shahi	23FS10BIO00056
13.	Tushar Pareek	23FS10BIO00040
14.	Aishwarya Jaiswal	23FS20MBO00014
15.	Pari Tayal	23FS10BIO00049
16.	Simran maharshi	23FS20MBO00022
17.	Garima	23FS20MBO00011
18.	Nikita	23FS20MBO00018
19.	Prashant pradhan	23FS20MBO00015
20.	Tanishka	23FS10BIO00048

21.	Riya ranjan	23FS10MIC00009
22.	Akshara Alex	23FS10BIO00022
23.	Priya Agarwal	23FS10BIO00042
24.	Pragya Chauhan	23FS10BIO00006
25.	Kanushree Rathore	23FS10BIO00055
26.	Juhi Garg	23FS10BIO00036
27.	Aishwarya Rai Saxena	23FS10BIO00065
28.	Radhika Rathore	23FS20MBO00008
29.	Lavanya	23FS20MBO00002
30.	Faizan Khan	23FS10BIO00009
31.	Shreyas M Iyer	2020PHXF0005P
32.	Simran Khushwaha	2018PHXF0406P
33.	Muskan Yadav	211002040
34.	Rochita Bani	211002039
35.	Samrat Banerjee	211003008
36.	Priya sharma	2023PHXP0001P
37.	Abhimanyu kumar	2023PHXP0002P
38.	Shivani Tiwari	211002002
39.	Sakshi Gupta	2023H1290008P
40.	Dikshita Aneja	231051005
41.	Siddharth	2020B1A31392P
42.	Yasaswini Reddy S	2020B1A71892P
43.	Harsh khandan	2020B1A40601P
44.	Anisha Saini	f2021B1TS2072P

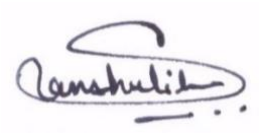
45.	Ayush	2020B1A70623P
46.	Archi Jain	2020B1A71380P
47.	Ameya Aglawe	2020B1A41913P
48.	Suhani Gupta	23FE10CSB00027
49.	Adya	23FS10BIO00067
50.	Sahil Kumar	23FS10BIO00046
51.	Namrata Yadav	23FS10BIO00032
52.	Anukriti sharma	23FS10BIO00052
53.	Ragini Singh Thakur	23FS10BIO00051
54.	Akash Chandra	211002036
55.	Avyakt Garg	2020B1A71902P
56.	Sahaj Tandi	2020B1A31904P
57.	Sylvia Parveen	211003009
58.	Anushka Singh	211002003
59.	Divya	211002056
60.	Gourav verma	2FS10BIO00017
61.	Kashish jain	230115700
62.	Gaurav Jetlie	23FS10MIC00003
93.	Thati Ameta	23FS10BIO00031
64.	Abhishek	2020B1A81914P
65.	Saksham Kumar	23FS10BIO00059
66.	Rohan Sharda	2020B1A31610P
67.	Nitya gupta	23FS10BIO00039
68.	Jaspreet Marwaha	23FS10MIC00011

69.	Tejas Sangale	23FE10BTE00034
70.	Aditi Mukherjee	230106036
71.	Garima	230111382
72.	Asmi Dhadiwal	23FE10BTE00013
73.	Sheryl	23FS10BIO00021
74.	Krishnendra Singh	23FS10BIO00014
75.	Soumya	23FS10BIO00002
76.	Sakshi Nirmal	211002060
77.	Stephenie Namchyo	230108439
78.	Bhumika Agarwal	23FS10MIC00010
79.	Arun Ramanathan	2020B1A41907P
80.	Ishpreet Singh	2020B1A40651P
81.	Nihal Panchal	23FS10BIO00010
82.	Shivali Sharma	23FS10MIC00012
83.	Jayraj Kuntal	23FS10BIO00018
84.	Samarth Trivedi	2020B1A71605P
85.	Gautam chikkara	MT230007
86.	Vanisha Sharma	230201821
87.	Harshita	211003011
88.	Smita Dey	2019PHXF0419P
89.	Sanyam Gupta	2020B1A31910P
90.	Mona singh	23FS10BIO00035
91.	Avinash Gautam	RU2119424
92.	Jyoti yadav	BU0210257546

93.	Gargi	23FS20MBO00026
94.	Anirudha Kumar Sahu	2018PHXF0408P
95.	Deeya Pradhan	23FS10BIO00023
96.	Jigyasha Rishu	23FS10BIO00012
97.	Mariyam khan	23FS10BIO00027
98.	Soubhik Ghosh	221002009
99.	Aditi Rathore	221002036
100.	Tanisha Singh	221002003

9.POST EVENT LINK:

https://meet.google.com/okc-uans-dpd



Anshulika Saxena

President, Biotech Club MUJ

Signature of the Student Coordinator

Dr. Mousumi Debnath

School of Basic Sciences

Signature of the Faculty Coordinator

MANIPAL UNIVERSITY
JAIPUR

FACULTY OF DESIGN

School of Design & Art

Department of Fashion Design

National Event

Department of Fashion Design, "D" Club & DSW, in collaboration with Maybelline, called the "Brave Together India Initiative by Maybelline"

20th October 2023

MANIPAL UNIVERSITY
JAIPUR

Index

MANIPAL UNIVERSITY
JAIPUR

1. **Introduction of the Event**

   The Department of Fashion Design, "D" Club & DSW, in collaboration with Maybelline, is organizing the "Brave Together India Initiative by Maybelline" for MUJ students. This initiative is in partnership with "Yuvaa."

2. **Objective of the Event**

   The "Brave Together" initiative is a global campaign aligned with Sustainable Development Goal 3: Good Health and Well-being, addressing anxiety and depression by offering support tools to navigate various emotions, including stress, anxiety, depression, or any other feelings that make you uncomfortable. The objective of the "Brave Together" initiative is to globally address and combat anxiety and depression by providing a comprehensive support system and tools to navigate a range of emotions, including stress, anxiety, and discomfort. This campaign aims to create a community-driven approach that fosters open conversations around mental health, reduces stigma, and encourages individuals to seek help when needed. By offering accessible resources and support tools, "Brave Together" seeks to empower people to better understand and manage their mental well-being, ultimately promoting a more compassionate and supportive environment for individuals facing challenges related to anxiety and depression, thereby contributing significantly to the attainment of global health and well-being goals.

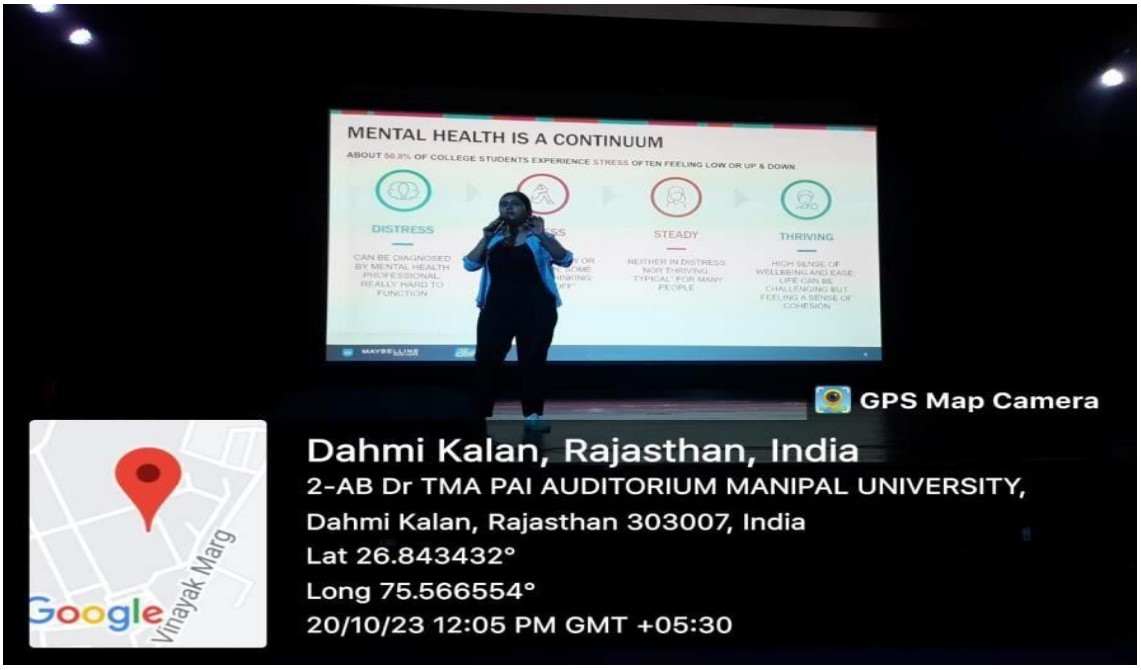
   Beneficiaries of the Event:

   Students of Faculty of Design, Manipal University Jaipur

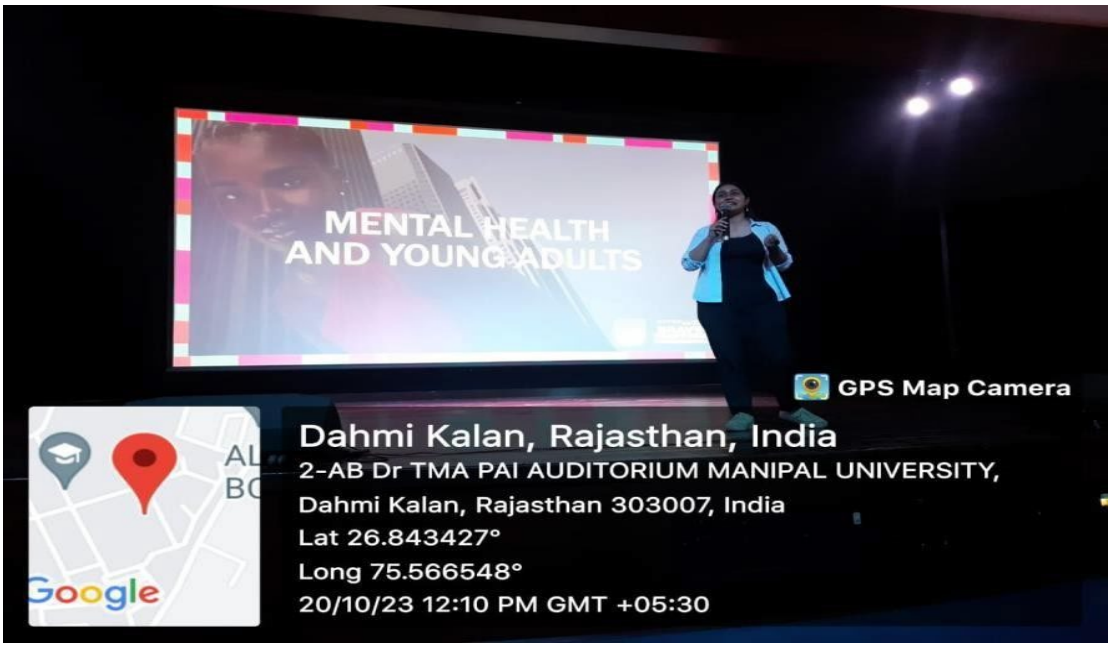
3. **Brief Description of the event: -**

   This initiative, conducted in collaboration with a community of mental health experts, is aligned with Sustainable Development Goal 3: Good Health and Well-being. Maybelline launched "Brave Together India" in India, with brand ambassador and Indian Badminton Star P.V. Sindhu, to raise awareness about mental health and its importance in the country. Yuvaa aims to engage with college students under the "Brave Together India" initiative to discuss mental health, anxiety, and stress, and to understand the challenges faced by the youth of our country. Through these initiatives, they aim to interact with and listen to over 50,000 students from 14 major cities in India, including Mumbai, Delhi, Bangalore, Pune, Kolkata, Ahmedabad, Jaipur, Hyderabad, Surat, Vadodara, Indore, Ranchi, Manipal, and Kota. This campaign is dedicated to helping students overcome stress, anxiety, and depression, thus enhancing their overall well-being and contributing to the global goal of promoting good health.

4. **Photographs of the event**



Speaker Vaibhavi addressing students



Speaker Vaibhavi addressing students

5. Schedule of the event

The lecture was conducted on 17th March 2023, from 11:30 AM - 12:30 PM and 2:00 PM - 3:00 PM, at TMA PAI Auditorium at Manipal University Jaipur.

6. Total attendee of the Event – 352

Timestamp	Email Address	Name :
10-20-2023 9:46:04	shubhii.tambi@gmail.com	Shubhi Tambi
10-20-2023 9:46:58	harsh9octvardhan@gmail.com	Harshvardhan singh
10-20-2023 9:47:03	navyavidyarthi@gmail.com	Navya vidyarthi
10-20-2023 9:47:06	pabuwalbhavika.bp@gmail.com	Bhavika Pabuwal
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10-20-2023 10:39:21	verma.shruti1109@gmail.com	Shruti verma
10-20-2023 10:40:26	tiwaridrishti328@gmail.com	Drishti Tiwari

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10-20-2023 11:18:51	sharma.uday.2312@gmail.com	Uday Sharma
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10-20-2023 11:19:24	tanishqchoudhary007@gmail.com	Tanishq Choudhary
10-20-2023 11:19:43	jhaanuragkumar05@gmail.com	Anurag kumar jha
10-20-2023 11:19:45	jaink5623@gmail.com	Khushi Jain
10-20-2023 11:19:52	drishti222004@gmail.com	Drishti
10-20-2023 11:20:25	raginiladha2004@gmail.com	Ragini Ladha
10-20-2023 11:20:26	umeshchaharjaat@gmail.com	UMESH Singh Chahar
10-20-2023 11:20:30	apoorvkrishanverma@gmail.com	Apoorv Krishan Verma
10-20-2023 11:20:44	maithree.g@gmail.com	Maithree
10-20-2023 11:20:46	kashishdogra2037@gmail.com	Kashish
10-20-2023 11:20:49	jahanvijaishree00@gmail.com	jahanvi jai shri
10-20-2023 11:20:51	mathurshreya0819@gmail.com	Shreya Mathur
10-20-2023 11:20:58	gauravvijay471@gmail.com	Mahima vijayvargiya
10-20-2023 11:21:00	ishikajangid09@gmail.com	Ishika jangid
10-20-2023 11:21:13	deepaligupta.23dg@gmail.com	Deepali Gupta
10-20-2023 11:21:20	prakriti573@gmail.com	Prakriti Chhabra
10-20-2023 11:21:24	sethivibhorbest@gmail.com	Vibhor Sethi
10-20-2023 11:21:28	ankitasinghjunu3011@gmail.com	Ankita Singh
10-20-2023 11:21:53	mandeepkang.1992@gmail.com	Mandeep kaur
10-20-2023 11:21:57	jainvrishti.04@gmail.com	Vrishti jain
10-20-2023 11:22:03	andreaaji02@gmail.com	Andrea
10-20-2023 11:22:10	mibhumittal1602@gmail.com	Bhumi mittal
10-20-2023 11:22:27	ishashekhawat10@gmail.com	Isha shekhawat
10-20-2023 11:22:28	tanu89473@gmail.com	Tanu Sharma
10-20-2023 11:22:35	charlesjustin2124@gmail.com	Justin
10-20-2023 11:23:22	dechenamo25@gmail.com	Dechen Angmo
10-20-2023 11:23:25	disasarkar1234@gmail.com	Disha Sarkar

10-20-2023 11:23:41	agarwalarshiya05@gmail.com	Arshiya Agarwal
10-20-2023 11:23:43	tikshasukhija9024977749@gmail.com	Tiksha Sukhija
10-20-2023 11:23:59	agarwalsim1394@gmail.com	Simran Agarwal
10-20-2023 11:24:00	ishitajhunjhunwala1@gmail.com	Ishita jhunjhunwala
10-20-2023 11:24:10	kushicool2417@gmail.com	Prachi Jain
10-20-2023 11:24:14	mehul21756@gmail.com	Mehul garg
10-20-2023 11:24:23	tanmaysehgal100@gmail.com	Tanmay Sehgal
10-20-2023 11:24:26	nikitarawatniki1234@gmail.com	nikitarawatniki1234@gmail.com
10-20-2023 11:24:27	padmjadodiya2005@gmail.com	Padmja Dodiya
10-20-2023 11:24:28	bsr0980@gmail.com	Bhagirath Singh Rathore
10-20-2023 11:24:38	sanjanau412@gmail.com	SANJANA UPADHYAY
10-20-2023 11:25:02	mehrauliagaurav@gmail.com	Gaurav mehraulia
10-20-2023 11:25:07	faaizmallick23@gmail.com	Faaiz haisb mallick
10-20-2023 11:25:09	rishu.rishabh029@gmail.com	Rishabh Mishra
10-20-2023 11:25:18	jalanjayash@gmail.com	Jayash Jalan
10-20-2023 11:25:47	prasadmanish303@gmail.com	Manish Prasad
10-20-2023 11:25:56	saracandraw1@gmail.com	Saransh sharma
10-20-2023 11:26:03	sim.arora2005@gmail.com	Simran
10-20-2023 11:26:11	mohitrajp466@gmail.com	Mohit Rajpurohit
10-20-2023 11:26:27	g.sugyani5@gmail.com	Sugyani P. Gouda
10-20-2023 11:26:27	divyanshibhargava3@gmail.com	Divyanshi Bhargava
10-20-2023 11:26:35	jshandilya2224@gmail.com	Jayesh Shandilya
10-20-2023 11:26:44	mehrashambhavi123@gmail.com	Shambhavi mehra
10-20-2023 11:26:47	arpitsoni546@gmail.com	Arpit Soni
10-20-2023 11:27:03	abhisheksainpaintingart@gmail.com	Abhishek Sain
10-20-2023 11:27:28	priyaprajapat9090@gmail.com	Priya Prajapat
10-20-2023 11:27:50	nikhil12nikhil12@gmail.com	Nikhil choudhary
10-20-2023 11:28:46	tanushekhawatjp@gmail.com	Tanushree Shekhawat
10-20-2023 11:28:58	goutampatil3335@gmail.com	Goutam patil
10-20-2023 11:29:02	nk7422116@gmail.com	Nisha
10-20-2023 11:29:59	mudityadav19@gmail.com	Mudit Yadav
10-20-2023 11:30:01	muskanyadav0304@gmail.com	Muskan yadav
10-20-2023 11:30:15	manvikeshwani6114@gmail.com	Manvi Keshwani
10-20-2023 11:30:22	geetikarai1016@gmail.com	Geetika Rai
10-20-2023 11:30:31	krittikasaini5@gmail.com	Krittika Saini
10-20-2023 11:30:41	adrija@ghantel.com	Adrija Rathore
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10-20-2023 11:31:09	berioussama6789@gmail.com	PREM PRAKASH
10-20-2023 11:31:10	kartiktotla2009@gmail.com	Kartik Totla
10-20-2023 11:31:25	chowdhrylakshya@gmail.com	Lakshya Chowdhry
10-20-2023 11:31:31	fernandesfloy73@gmail.com	Floy Fernandes
10-20-2023 11:31:38	mariyabaiwala11@gmail.com	Mariya
10-20-2023 11:32:32	vanshikamalik0390@gmail.com	vanshika
10-20-2023 11:33:22	kavyakalra005@gmail.com	Kavya Kalra
10-20-2023 11:33:22	lipika.dudeja14@gmail.com	Lipika Dudeja
10-20-2023 11:33:33	gungundagdi@gmail.com	Neha dagdi
10-20-2023 11:33:38	ishanisantuka@gmail.com	Ishani Santuka
10-20-2023 11:33:39	lavanya.aggarwal.57@gmail.com	Lavanya Aggarwal
10-20-2023 11:33:59	anand.shreya32@gmail.com	Shreya Anand
10-20-2023 11:34:54	linkjokerx150@gmail.com	Shrestha
10-20-2023 11:35:09	vedikakiishore@gmail.com	Vedika
10-20-2023 11:35:17	kovvurugeetika284@gmail.com	Kovvuru Geetika
10-20-2023 11:36:08	samarpreetsinghpasrija@gmail.com	Samarpreet Singh Pasrija
10-20-2023 11:36:19	ankitakumawat0801@gmail.com	Ankita kumawat
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10-20-2023 11:36:56	shreyansh777784@gmail.com	Shreyansh saini
10-20-2023 11:37:00	aashijain5707@gmail.com	Aashi jain
10-20-2023 11:37:00	bhuyangayatri01@gmail.com	Gayatri B
10-20-2023 11:37:01	harmandeep0405@gmail.com	Harman deep
10-20-2023 11:37:08	aanchalbachwani831@gmail.com	Aanchal bachwani
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10-20-2023 11:37:35	singhgaurang32@gmail.com	Gaurang Ashawat
10-20-2023 11:37:42	soumimajumder2005@gmail.com	Soumi Majumder
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10-20-2023 11:45:28	sonibhavya283@gmail.com	Bhavya Soni
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10-20-2023 11:51:34	shreshtha.gaur.16@gmail.com	Shreshtha gaur
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10-20-2023 12:16:54	ishitapadha3@gmail.com	Ishita
10-20-2023 12:31:39	kaushikisharma438@gmail.com	Kaushiki Sharma
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10-20-2023 12:32:42	shinjini27@yahoo.com	Shinjini Bansal
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10-20-2023 12:39:35	anshtrivedi14feb@gmail.com	Ansh Trivedi
10-20-2023 13:16:39	deepitmathur99@gmail.com	Deepit Mathur
10-20-2023 14:00:39	rishabhrao256@gmail.com	Rishabh
10-20-2023 14:01:22	edom.mx541513@gmail.com	Megha sharma
10-20-2023 14:01:39	malekaniksha@gmail.com	Kaniksha male
10-20-2023 14:01:42	vanshikasharma262005@gmail.com	Vanshika

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10-20-2023 14:09:58	adarshpan11052002@gmail.com	Adarsh Panchal
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10-20-2023 14:10:44	d19934198@gmail.com	Drishti bhansali
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10-20-2023 14:11:08	nikitabswl13@gmail.com	Nikita Biswal
10-20-2023 14:11:15	ridhiarora017@gmail.com	Ridhi Arora
10-20-2023 14:11:23	akshatyojit6@gmail.com	Akshat Sharma
10-20-2023 14:11:25	manishdendor66@gmail.com	Manish Dendor
10-20-2023 14:11:30	pratikshashekhawat0210@gmail.com	Pratiksha Shekhawat
10-20-2023 14:12:04	varshitha05x@gmail.com	Varshitha
10-20-2023 14:12:19	rs0810944@gmail.com	Ishika saini
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10-20-2023 14:12:48	purvaisinghal@gmail.com	PURVAI SINGHAL
10-20-2023 14:15:37	guneetpahwa1@gmail.com	Guneet Pahwa
10-20-2023 14:16:34	riyaguptasas2013@gmail.com	Riya Gupta
10-20-2023 14:16:49	chandrikastar1@gmail.com	Chandrika Verma
10-20-2023 14:16:52	pyneaditi05@gmail.com	Aditi Pyne
10-20-2023 14:18:21	priyamvadatiwari924@gmail.com	Priyamvada Tiwari
10-20-2023 14:18:32	shantanuchauhan915@gmail.com	Shantanu Singh Chauhan
10-20-2023 14:18:38	jazzzz.xo2004@gmail.com	Jasmine Kaur
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10-20-2023 14:21:05	kantrishika0@gmail.com	Rishika
10-20-2023 14:21:13	tanwarmadhu97@gmail.com	Madhu Tanwar
10-20-2023 14:21:18	kashish964800@gmail.com	Kashish Kriplani

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10-20-2023 14:22:41	boomhackstar@gmail.com	Lekshmi narayanan aji
10-20-2023 14:23:52	raianushka983@gmail.com	Anushka rai
10-20-2023 14:24:25	vedangsoni1512@gmail.com	Vedang soni
10-20-2023 14:25:15	narelanamrata@gmail.com	Namrata Narela
10-20-2023 14:25:22	suhaniverma945@gmail.com	Suhani verma
10-20-2023 14:25:35	sonisatvik911@gmail.com	Satvik Soni
10-20-2023 14:25:47	clasher.in2005@gmail.com	Kathryn Binuraj
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10-20-2023 14:30:40	ram.krc3388@gmail.com	Ram
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10-20-2023 14:36:14	shrija.suman1@gmail.com	Shrija Suman
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10-20-2023 14:53:04	rojanfrancis0@gmail.com	Rojan Francis R
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10-20-2023 15:43:47	abhijithsurabhi3@gmail.com	Abhijith babu
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Mahboob Anwer
Event Coordinator

Signature of HOD

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Department of Fashion Design

School of Design & Art

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EVENT REPORT

MANIPAL UNIVERSITY
JAIPUR

FACULTY OF DESIGN

HERITAGE CLUB

School of Architecture and Design

FOOD WALK

Walled City, Jaipur

18th FEBRUARY 2023

Contents

1. Introduction of the Event:

Heritage Club, School of Architecture and Design conducted a Food walk through a well curated route in the walled city of Jaipur for the students of MUJ, where students got to explore the Heritage City of Jaipur through its tasty delicacies while also enjoying the religious vibe in the walled city on the occasion of Mahashivratri.

2. Objective of the Event:

The curated route of Food Walk took the participants to the pink city in order to help them appreciate and admire the following –

- The scrumptious local delicacies along with their specific history.
- The streets featuring continuous small scaled shops and local vendors that thrive upon the city's heart.
- The built heritage of walled city, as the route also covered prominent architectural structures such as Hawa Mahal, Tripolia Gate and Tarkeshwar temple(one of the most prominent shiva temple in Jaipur) etc.

3. Beneficiaries of the Event:

- Students from all faculties of MUJ.
- Faculty members of MUJ

4. Brief Description of the event:

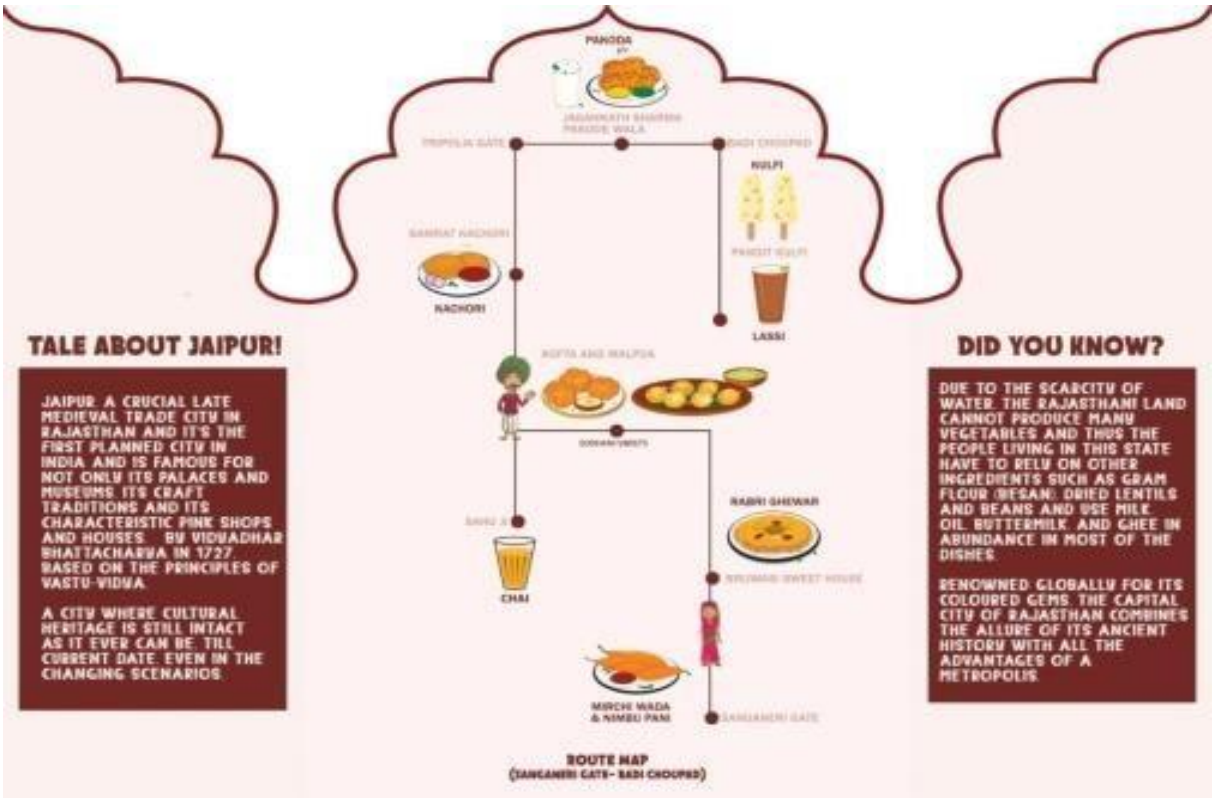
Heritage Club (School of Architecture and Design) conducted a Food Walk in the Walled City of Jaipur to acquaint the student fraternity of MUJ with the food delicacies and heritage beauty of Jaipur, on 18th February 2023. The food walk included several food items which offered different tastes of local Rajasthani cuisines where students could appreciate and admire the taste.

This Food Walk was the third physical event of the Heritage Club, but first of its kind ever. The walk began from Sanganeri Gate and terminated at Zaleb Chowk (route details as per brochure on the following page). Besides briefing about the history of the traditional bazaars, participants were also enlightened about the legacy of diverse cuisines by the enthusiastic food vendors themselves who showed utmost hospitality to the group of students and faculties.

The food menu provided a variety of items ranging from local drinks like nimbu pani to snacks like mirchi bada, kachoris & pakoras to sweets like ghewar and kulfi. The portions of all food items were specially made uniquely after requesting the vendors so that the portions then become easily consumable by a single person. Hence, everyone got an opportunity to taste all items (and the walk made it easy to digest them and create an appetite for the next item).

The walk ended with a positive feedback and contentment by all the participants. Mementos (key chains) created in-house by the club and school were distributed to everyone as a token of memory and gratitude. E-certificates were also given to all participants and volunteers of the event.

5. Brochure of the event



6. Photographs of the event.

Picture 1- Participants of the Food Walk

Picture 2-Sodhani Sweets (2nd stop)
Food vendors presenting the importance and making of malpua and aloo vada along with the narrative on when the shop was opened.

Picture 3- Sahoo Restaurant (3rdstop)
Participants having a break with Tea.

Picture 4 – Jagannath Pakode Wale (4th stop).

Picture 5- Pandit Kulfi (last stop).

7. Attendance of the Event:

ID	Name2	Registration Number	Course & Branch	h/d	Contact	Signature
1	Divyesh Shankla	210501003	Barch	Day scholar	9894699992	
2	Mansi	200501024	B.arch	Day scholar	7877991098	
3	Ria Rattan Kotwal	210501028	B.Arch	Hosteler	7406524738	
4	Jai	200901001	BBA	Hosteler	969093693	
5	Sonali	211002041	Bio science	Hosteler	8770273605	
6	Sanchoita	200606015	B.ARCH	Hosteler	8408803378	
7	Hrishita Kesarwani	229303266	Cse ai ml	Hosteler	9922490410	
8	Anjali Adhikari	210501025	B Arch	Hosteler	9733182131	
9	Priya Agarwal	211002006	Bsc biotechnology (biosciences)	Hosteler	7061587976	
10	Bhavesh Khemka	210501009	Architecture	Day scholar	9116006663	
11	Athrav	219301466	Btech cse	Hosteler	9833094011	
12	Shashank Goyal	211002043	Bio science	Hosteler	9024935154	
13	Naman Agrawal	219303093	B.Tech CCE	Hosteler	7013464852	
14	Riddhi Daga	211201064	BJMC	Hosteler	9331214622	
15	Vivek Anand	210901312	Business Administration	Hosteler	8610310054	
16	Yashi Shree	229301030	Btech	Hosteler	9599147349	
17	Dr. Subhash Devrath	-	-	Day scholar	9571188767	
18	Mrs. Suman Devrath	-	-	Day scholar	9571188767	
19	Tejashwini joshi	210901112	BBA marketing	Hosteler	6309335977	
20	Harshita mandhra	220501018	Architecture	Hosteler	9610814620	
21	Vaishnavi shukla	210501022	Barch	Hosteler	7607694292	
22	Anaya	221151002	1 year phd	Hosteler	7889559667	
23	Abhik	220502004	M.arch	Day scholar	7873726178	
24	Ankita Shrivastava	220501012	B. arch	Day scholar	8839638509	
25	PRACHITA BHIWAPURKAR	200501001	B.ARCH	Hosteler	9898711500	
26	Aarshia Chauhan	229302370	BTech IT	Hosteler	9710000136	
27	Vaidehi Agarwal	229302245	Btech IT	Hosteler	9999367467	
28	Arpita garg	229303156	Btech with cce	Hosteler	7983182007	
29	Shriya	220501014	B.arch	Hosteler	9599571767	
30	Kasvi Soni	229311033	Btech cse with iot	Hosteler	9650848355	
31	MOULESH MR	220501005	B arch	Hosteler	9087023888	
32	Rudr Sikaria	220801018	BHM	Hosteler	8638136126	

33	Ahaana Verma	221015001	BCA	Hosteler	9315421451	
34	Mehma singh	220801003	Bhm management	Hosteler	7267984000	
35	Yash bhargava	221201025	BAJMC	Hosteler	8458922968	
36	Divyansh	229310407	CSE(AI&ML)	Hosteler	7082947781	
37	Anjali choudhary	211002005	Bsc biotechnology	Hosteler	6367051288	
38	Ikshita Bagla	220501021	B.Arch	Hosteler	9336057274	
39	Sajal panwar	220501002	B.arch	Hosteler	9667899121	
40	Mustansir kanchwala	220903021	B.com honours	Hosteler	8871600661	
41	Rijul Chaudhary	220501003	B.arch	Hosteler	8433130649	
42	Aarya Chandiramani	220501010	B.arch	Day scholar	8852953085	
43	Arghya Bhagwat	220501022	B.Arch	Hosteler	8219847663	
44	Pranjal Puri	220606004	B.des interior design	Hosteler	7727031282	
45	Vedika Gupta	221007014	BSc psychology	Hosteler	9310489974	
46	Shinaya Badgujar	221105022	BA Liberal Arts	Day scholar	8209657590	
47	Ayamullah Khan	229309022	B.Tech	hosteler	8530044774	

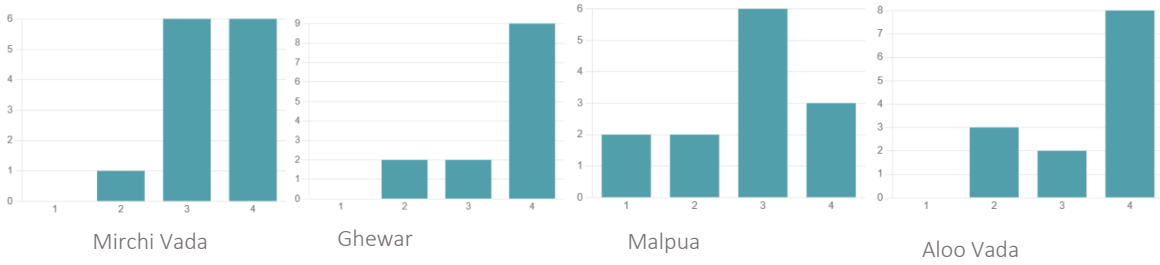
8. Feedback:

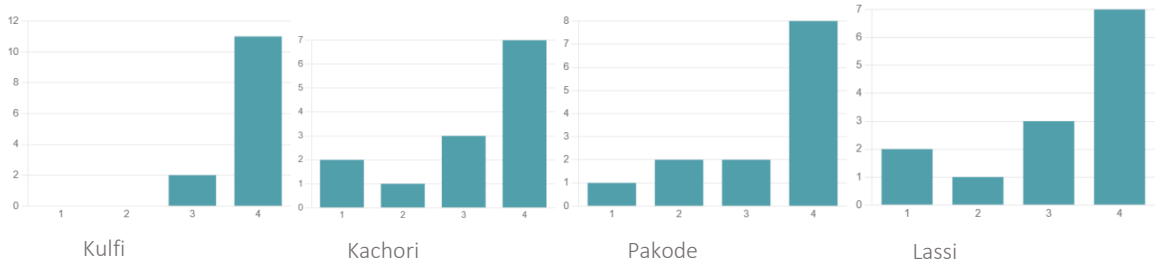
Students were amazed by the flavor of cuisines and had a boundless experience while exploring local markets and historical sites through the organized route. They cherished and gave a positive response towards organizing such walks and events in future.

Following is the feedback collected through Google Forms-

Response to each food items by students-

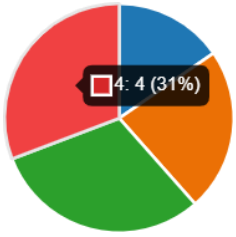
1-Not Bad; 2-Good; 3-Very Good; 4-Delicious



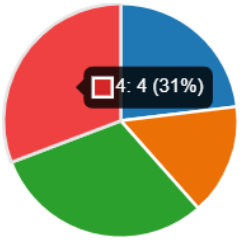


- Route curated for the walk-

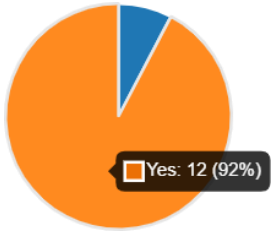
  1-Very Satisfied; 2-Satisfied; 3-Neutral; 4-Unsatisfied



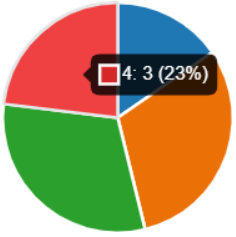
- Walk to be informative-



- Order of the Food Items-



- Overall Experience-



- Feedbacks from Students through forms-

  "Walk was well organized". – Bhavesh Khemka

"Good event... Enjoyed very much". – Rudr Sikaria

"It was a very great experience. Tasting different food items I have never heard of was superb". - Mansi

9. Post event link-

10. Faculty Coordinator:

Signature of Faculty Coordinator
Ar. Ayushi Sharma
Assistant Professor, SA&D
9660311113

Signature of Faculty Coordinator
Ar. Neha Saxena
Associate Professor, SA&D
9950158160

Assistant Director, DSW

DIRECTOR STUDENT WELFARE & PROCTOR
MANIPAL UNIVERSITY, JAIPUR

SHTM/School Connect Event-SDG/2023/02

MANIPAL UNIVERSITY JAIPUR

SCHOOL OF HOSPITALITY & TOURISM MANAGEMENT

&

DIRECTORATE OF ADMISSIONS

In Collaboration with

HERITAGE GIRLS SCHOOL, EKLINGI, UDAIPUR

organized

MUJ Career Counselling Session – Quality Education

(SCHOOL CONNECT PROGRAM)

(2nd December 2023)

10:00-13:00

Content of Report

1. Introduction of the Event

The educational confluence at Heritage Girls School, Eklingiri, Udaipur, served as an enlightening rendezvous aimed at introducing students to the diverse academic realm offered by Manipal University Jaipur. This event was designed to bridge the gap between the aspirations of Class XI and XII students and the plethora of opportunities available at the university.

2. Objective of the Event

2.2. Showcasing Manipal University Jaipur: The primary objective was to showcase the array of quality education, quality academic programs, facilities, and career prospects that Manipal University Jaipur offers.

2.3. Informative Engagement: To engage students actively and provide comprehensive insights into the educational landscape, enabling them to make informed decisions regarding their future academic pursuits.

3. Beneficiaries of the Event:

Class XI and XII students from Heritage Girls School, Eklingiri.

4. Brief Description of the event:

The educational rendezvous at Heritage Girls School, Eklingiri, Udaipur, was a dynamic and illuminating affair. Students from Class XI and XII were invited to explore the rich tapestry of academic possibilities offered by Manipal University Jaipur. The session was conducted by **Mr Abhay Kashyap, Assistant Professor, School of Hospitality & Tourism Management, Manipal University Jaipur.**

The event unfolded as an immersive experience, featuring engaging sessions and interactive presentations. Students were introduced to the diverse spectrum of academic programs, state-of-the-art facilities, and promising career pathways available at Manipal University Jaipur. Representative from the university curated insightful discussions, providing a glimpse into the university's esteemed faculty, campus life, and the holistic educational environment fostered at the institution. This event was an empowering platform that aimed to equip students with comprehensive knowledge, enabling them to make informed decisions about their future academic endeavors post-Class XII. It encouraged active participation, ignited aspirations, and paved the way for students to envision a fulfilling educational journey at Manipal University Jaipur.

5. Corresponding Mail

Abhay Kashyap [MU - Jaipur]

From: Bishwanath Chaudhary [MU - Jaipur]
Sent: 01 December 2023 23:58
To: Abhay Kashyap [MU - Jaipur]
Subject: FW: Career Fair Confirmation: Heritage Girls School Udaipur

FYI,please.

From: Pratibha Rohit <pratibha@mindler.com>
Sent: Monday, November 27, 2023 5:21 PM
To: Pratibha Rohit <pratibha@mindler.com>
Cc: care@heritagegirlsschool.com; viceprincipal@heritagegirlsschool.com; mamta@heritagegirlsschool.com; shalini@heritagegirlsschool.com; Prateek Bhargava <prateek@mindler.com>; Prikshit Dhanda <pd@mindler.com>; Urvi Shah <urvi.shah@mindler.com>
Subject: Career Fair Confirmation : Heritage Girls School Udaipur

Dear University Delegates,

I hope this email finds you well. **On behalf of the Mindler Team & Heritage Girls School Udaipur,** I'm delighted to inform you that your esteemed university's participation at our upcoming Career Fair has been confirmed.

Venue : **Heritage Girls School, NH-8, Eklingji, Rajasthan - 313202**
Date : **December 2' 2023**
Timings : **10:00 am to 1:00 pm**

At the venue
- School shall setup the stall for each university
- Each stall space will have a table with chairs for the university representatives
- Universities can bring in their collaterals (standee, table runners/cover & brochure)

On November 30' 2023,you will receive a reminder email for the aforementioned event.
Please Note: 1. All the cost of travel and stay is borne directly by the University
2. School is making arrangements according to the list, so we request that any changes be communicated to us in advance

If you require any further information or assistance, please do not hesitate to contact us.
Thank you for being a part of this event, and we eagerly await your participation!

Best,

6. Schedule of event

Date: 02/12/2023 Timing: 10.00 AM- 1:00 PM

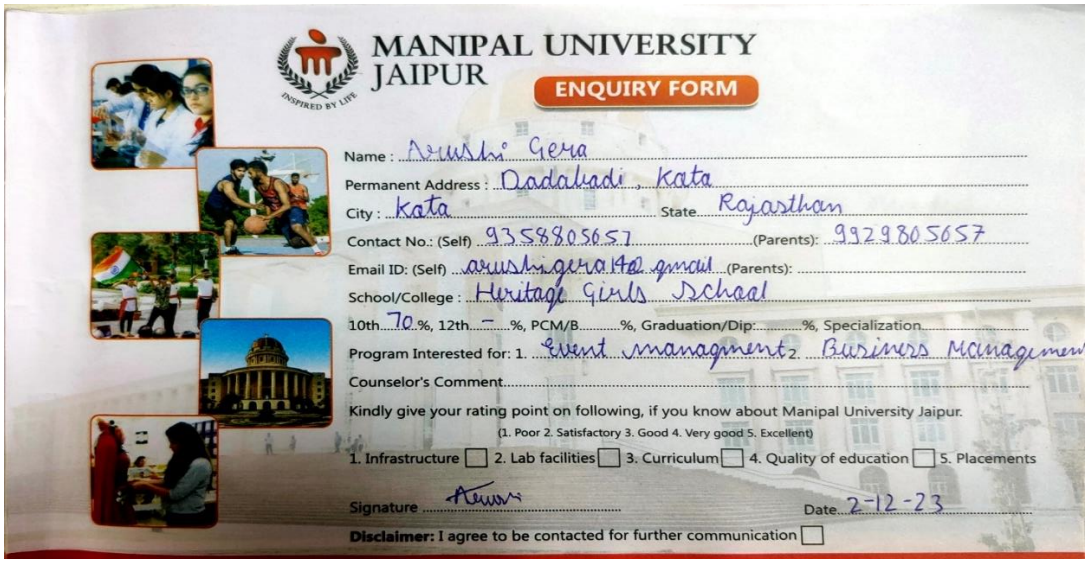
7. Photographs of the event

Figure 1: Resource Person at the Venue

Figure 3: Career Counselling of School Students

9. **Participants:** 20 attendees

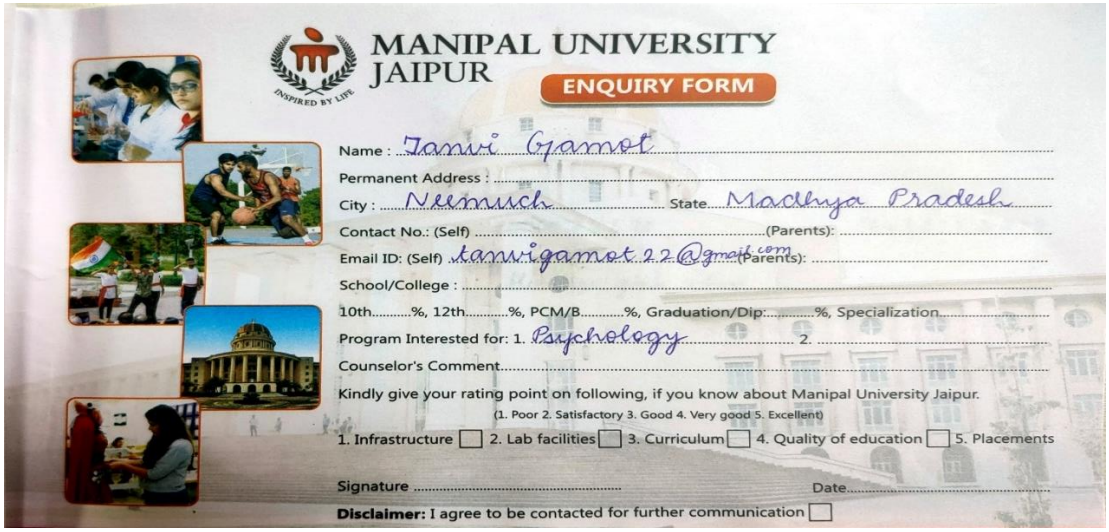
Sr	Name	Contact
1	Arushi Gera	9358805657
2	Tanvi Gamot	Not Shared
3	Yashika Jajodia	6000973688
4	Arista Singh	Not Shared
5	Bharti Panwar	Not Shared
6	Vishva Meghani	Not Shared
7	Bhavika Bohra	7803022471
8	Yajal Jain	9079335192
9	Nimisha Soni	8160358474
10	Kaashvi Shukla	Not Shared
11	Avani Kalal	Not Shared
12	Vani Patel	Not Shared
13	Charvi Padiyar	Not Shared
14	Nidhi Jain	Not Shared
15	Aryan Dagar	8839664443
16	Janvi Singh	9336140128
17	Riya Kapoor	Not Shared
18	Kavya Sharma	Not Shared
19	Esha Mehta	Not Shared
20	Arna Malhotra	Not Shared



MANIPAL UNIVERSITY
JAIPUR
INSPIRED BY LIFE

ENQUIRY FORM

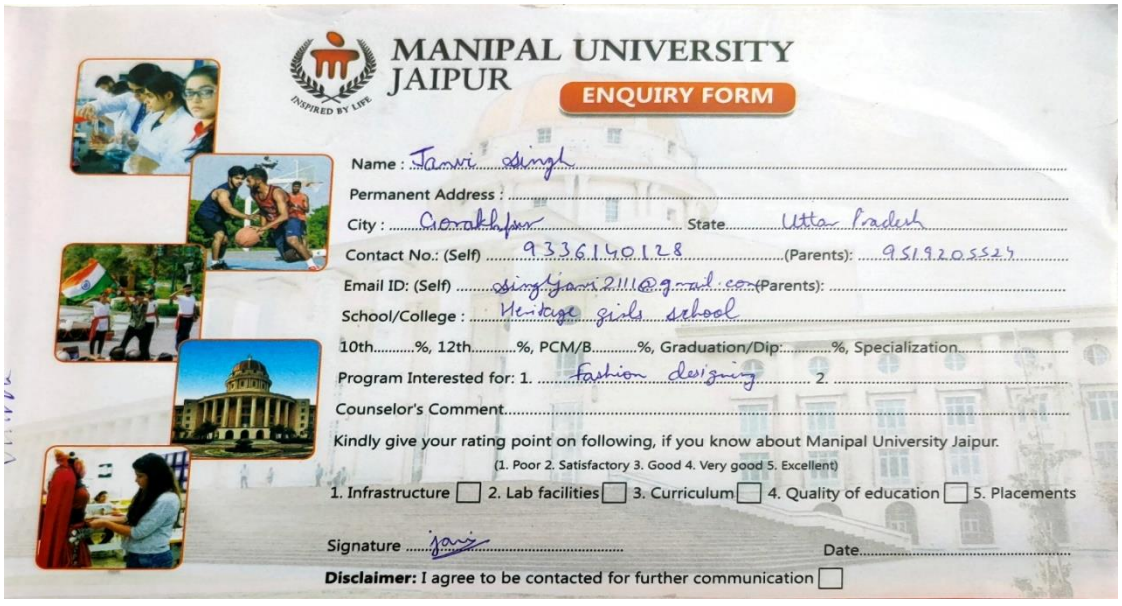
Name : Anushi Gera
Permanent Address : Dadabadi, Kata
City : Kata State Rajasthan
Contact No.: (Self) 9358805657 (Parents): 9929805657
Email ID: (Self) anushigera10@gmail (Parents):
School/College : Heritage Girls School
10th 70 %, 12th – %, PCM/B %, Graduation/Dip: %, Specialization
Program Interested for: 1. Event managment 2. Business Management
Counselor's Comment
Kindly give your rating point on following, if you know about Manipal University Jaipur.
(1. Poor 2. Satisfactory 3. Good 4. Very good 5. Excellent)
1. Infrastructure ☐ 2. Lab facilities ☐ 3. Curriculum ☐ 4. Quality of education ☐ 5. Placements
Signature Anushi Date 2-12-23
Disclaimer: I agree to be contacted for further communication ☐



MANIPAL UNIVERSITY
JAIPUR
INSPIRED BY LIFE

ENQUIRY FORM

Name : Tanvi Gamot
Permanent Address :
City : Neemuch State Madhya Pradesh
Contact No.: (Self) (Parents):
Email ID: (Self) tanvigamot22@gmail.com (Parents):
School/College :
10th %, 12th %, PCM/B %, Graduation/Dip: %, Specialization
Program Interested for: 1. Psychology 2.
Counselor's Comment
Kindly give your rating point on following, if you know about Manipal University Jaipur.
(1. Poor 2. Satisfactory 3. Good 4. Very good 5. Excellent)
1. Infrastructure ☐ 2. Lab facilities ☐ 3. Curriculum ☐ 4. Quality of education ☐ 5. Placements
Signature Date
Disclaimer: I agree to be contacted for further communication ☐



MANIPAL UNIVERSITY
JAIPUR
INSPIRED BY LIFE

ENQUIRY FORM

Name : Tanvi singh
Permanent Address :
City : Gorakhpur State Uttar Pradesh
Contact No.: (Self) 9336140128 (Parents): 9519205524
Email ID: (Self) singhtanvi2111@gmail.com (Parents):
School/College : Heritage girls school
10th %, 12th %, PCM/B %, Graduation/Dip: %, Specialization
Program Interested for: 1. Fashion designing 2.
Counselor's Comment
Kindly give your rating point on following, if you know about Manipal University Jaipur.
(1. Poor 2. Satisfactory 3. Good 4. Very good 5. Excellent)
1. Infrastructure ☐ 2. Lab facilities ☐ 3. Curriculum ☐ 4. Quality of education ☐ 5. Placements
Signature Tanvi Date
Disclaimer: I agree to be contacted for further communication ☐

Sample forms

MUJ/Q&C/FoMC/SHTM/2023/Outreach Program – 1

MANIPAL UNIVERSITY JAIPUR

FACULTY OF MANAGEMENT & COMMERCE

SCHOOL OF HOSPITALITY AND TOURISM MANAGEMENT

&

EPICUREAN CLUB

In association with

DIRECTORATE OF STUDENT WELFARE, MUJ

Conducted an

OUTREACH ACTIVITY - ZERO HUNGER

at

NGO

JANKALA SAHITYA MANCH SANSTHAN, JAIPUR

27TH December 2023

1. Introduction of the Event

SHTM & Epicurean club in association with Directorate of Student Welfare organized an outreach program of SDG's mission of ZERO HUNGER at NGO - Jan Kala Sahitya Manch Sansthan, Jaipur MATRA CHAYA BAL GRAH, A-17, Ashok Vihar, Mansarovar, Jaipur - 302020 on 27th Dec 2023.

2. Objective of the Event

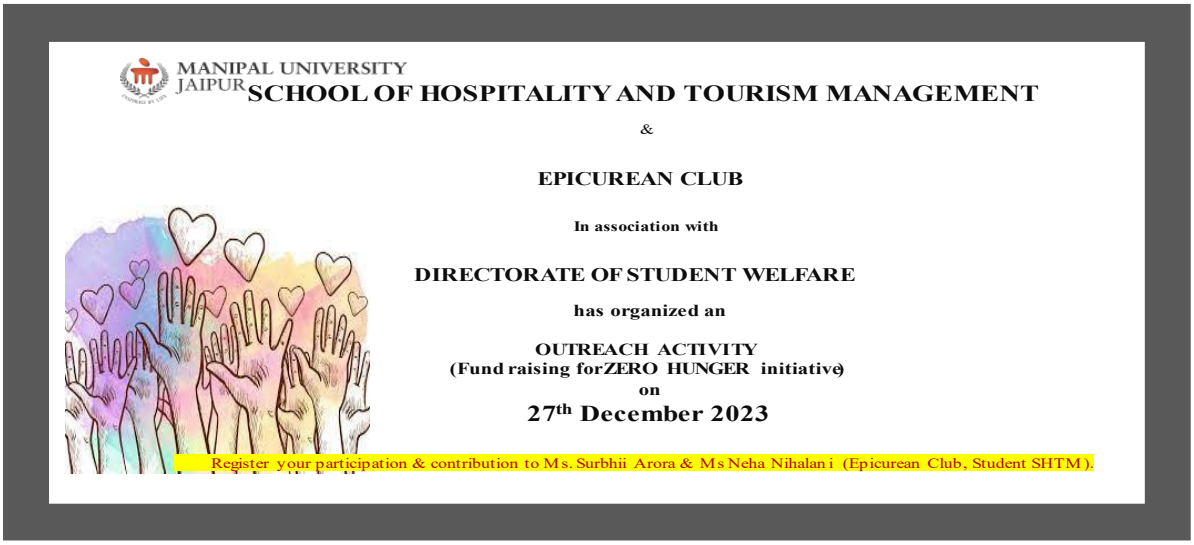
- Organizing an outreach activity
- Develop value ethics among the SHTM students
- Spread awareness of SDG initiatives

3. Beneficiaries of the Event

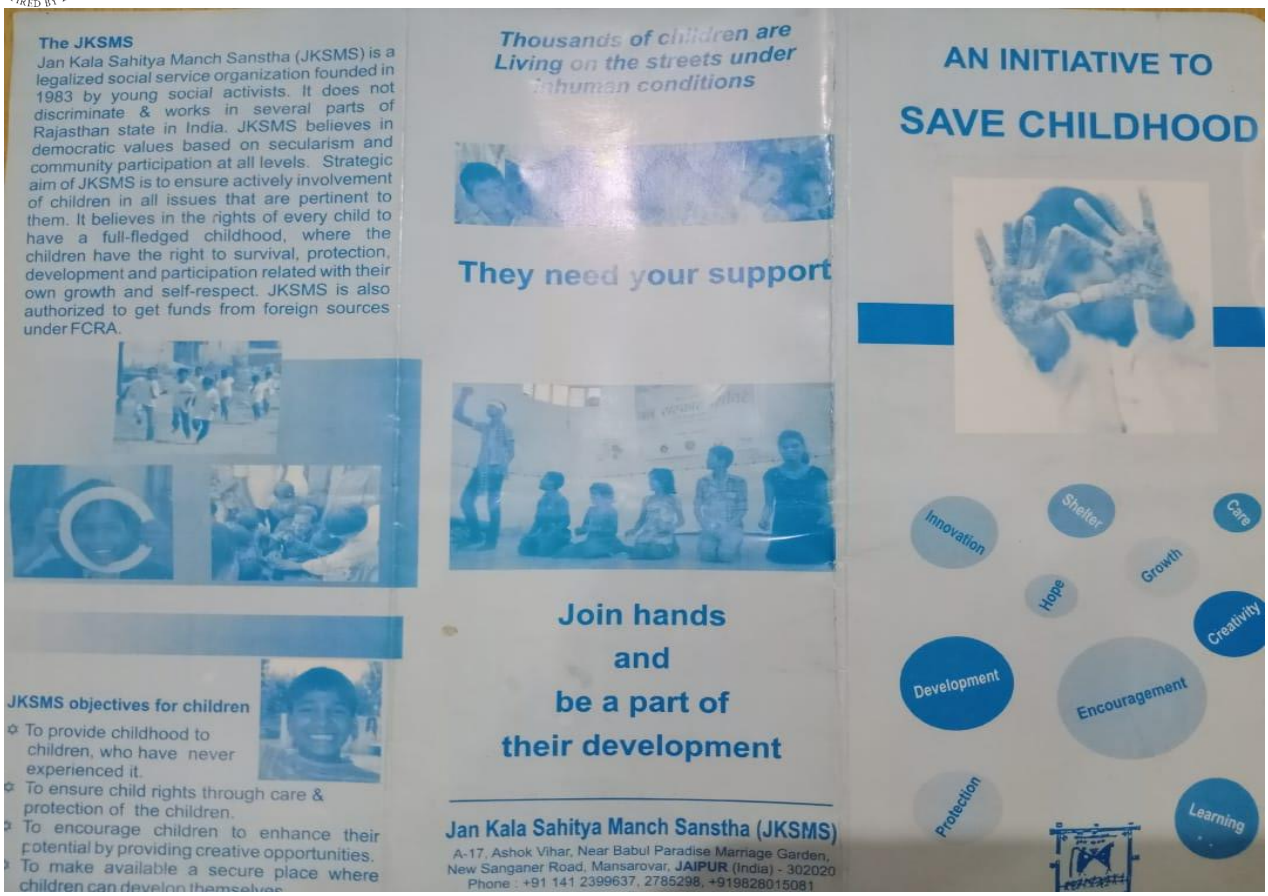
NGO - Jan Kala Sahitya Manch Sansthan, Jaipur is an orphanage which provides education, shelter and other basic needs to the homeless, and abandoned children. It is a safe place for children who are looking for shelter and food. They take education seriously and provide the same to the children.

4. Brief Description of the event

The motive to inculcate corporate social responsibility among the students, Epicurean club run by School of Hospitality & Tourism Management came up with the idea of raising funds for the children of the orphanage. A core team of students initiated the outreach drive and collected donations from the students and faculty members of MUJ. The team was led by the students of Hotel Management and the members of Epicurean Club under the guidance of the faculty members of SHTM, showing great leadership skills and teamwork. On 27th Dec 2023, the students and faculty members went to the NGO and donated the collected fund, stationery items and foods to the orphanage representatives.



Brochure



NGO - Pamphlet

5. Photographs

Students of SHTM and Epicurean Club are serving food items to the children's of ***NGO.***

Students & faculty members of SHTM are serving food items to the children's of ***NGO.***

Ms. Surbhii Arora – listing the items for donation at the ***NGO.***

HOD of SHTM, Dr. Amit Datta, along with faculty members and students donating the collected fund, stationery items and food to the Manager of the NGO - Jan Kala Sahitya Manch Sansthan, Jaipur.

6. Attendance detail: - 54 students and 3 Faculty members Faculty members: Dr Aravind Kumar Rai, Dr Amit Datta, & Dr Mukesh Shekhar

S. No.	Registration No	Student Name
1	200801027	SURBHII ARORA
2	220801002	VANSHIKA
3	220801003	MEHMA SINGH
4	220801005	RAKSHITA VERMA
5	220801008	SHIVAM JAISWAL
6	220801009	ABHIJEET ARORA
7	220801012	AJAY AHIR
8	220801013	SARTHAK GAUTAM
9	220801014	NITIN KUMAR
10	220801015	RITU RAJPUROHIT
11	220801016	ALAM HUSSAIN
12	220801017	GARIMA PANDEY
13	220801018	RUDR SIKARIA
14	220801019	VAIBHAV ENDORIA
15	220801020	DHANUSHWEE L
16	220801021	DIVESH NIMAWAT

17	220801022	PREKSHA MAHESHWARI
18	220801025	ARUSHI RATHORE
19	220801027	PAWAN
20	220803003	DIVYANSH YADAV
21	220803006	ANIE ASHOK VASWANI
22	220803008	LAKSHYARAJ SINGH CHAUHAN
23	220803009	KIRTI JAIN
24	220803010	DIYANSHI GOYAL
25	220803011	TANISHK SAINI
26	210801001	GAURAV AJMERA
27	210801003	HARDIK CHACHAN
28	210801004	TAKSHLIKA SHARMA
29	210801005	GAUTAM PRATAP SINGH
30	210801007	KHUSHI BAJORIA
31	210801008	AKHYA UPADHYAY
32	210801009	SHUBHAM KOCHAR
33	210801011	RITURAJ SINGH BHATI
34	210801012	PALAK JAISWAL
35	210801015	ARVIND SINGH RATHORE
36	210801016	VIKAS MAHAWAR
37	210801017	RITESH MAHAWAR
38	210801018	SHANTANU BANERJEE
39	210801019	ARNNIE KHANNA
40	210801023	NEHA NIHALANI
41	210801025	KHUSHI BHATIA
42	210801027	SIDDHI CHAUHAN
43	210801028	ALVIN K PAPPACHAN
44	200801021	JATIN PODDAR
45	210801030	MANAV SHARMA
46	200801011	BHAVIKA CHANGULANI
47	210801032	HARMAN SINGH
48	210801034	NITIN KUDI
49	210803001	YASODHA SUNDARARAMAN
50	210803003	ARPIT GUPTA
51	210803004	RADHIKA SHARMA
52	210803006	TEENAM ROY
53	210803008	AKSHAT JAIN
54	210803010	ROHAN SINGH

7. Acknowledgement Letter: -

जन कला साहित्य मंच संस्था
JAN KALA SAHITYA MANCH SANSTHA
JKSMS

22 A, Metro City Colony, Near Choudhary Ramchandra Circle, Behind UTSAV Apparment, Mangyavass, Mansarover, Jaipur,
Phones : 9828015081, 9694087999, 7240011105 • E-mail : jksmsjaipur@gmail.com • Web : www.jksms.org

Ref. No.

Date. 21-12-2023

Dear Sir,

School of Hospitality and Tourism Management and Directorate of Student Welfare, Manipal University Jaipur.

We hope this letter finds you well. On behalf of everyone at Apna Ghar Orphanage, we want to express our deepest gratitude for your generous donation of Rs 5000.

Your support means a lot to us and plays a crucial role in helping us provide a nurturing and caring environment for the children at our orphanage. With your contribution, we can continue to meet their basic needs, offer educational opportunities, and create a loving atmosphere that fosters their growth and well-being.

Your kindness and compassion are making a real difference in the lives of these children, giving them a chance for a brighter future. We are truly grateful for your commitment to our cause.

Thank you once again for your generosity. Your support is invaluable, and we look forward to keeping you updated on the positive impact it has on the lives of the children in our care.

Warm regards,

SECRETARY
JAN KALA SAHITYA MANCH SANSTHA
JAIPUR

Kamal Kishor

(Secretar)

MUJ/DSW/Society Connect/Oct 2023/04

MANIPAL UNIVERSITY
JAIPUR

DIRECTORATE OF STUDENT'S WELFARE

(SOCIETY CONNECT)

#DAANUTSAV 2023

Orphanage Visit

(Naya Savera, Nirman Nagar)

4th October 2023

Index

1. Introduction of the Event

Rotaract Club, Manipal University Jaipur has conducted a social connect event by visiting the children of the Naya Sawera NGO with club students and faculty Mr Hemant Kumar, This visit has given these children of the NGO a great experience.
.

2. Objective of the Event

The objective of this event is to help the under privileged kids of society, by organizing creative Visit , by this we are encouraging their inner creative sides and providing them with an uplifting environment.

3. Beneficiaries of the Event

Community, students of MUJ

4. Details of the Guests

NAYA SAVERA NGO

Naya Sawera' is one of the leading Youth Base, registered Non-Government & Not-For-Profit Charitable Organization registered under Societies Registration Act working for the welfare of the people of different underprivileged sections of society by various means. The aim is to see that no human being is deprived of his basic needs because of poverty. The organization also seeks to support and nurture the talents who cannot avail proper facilities due to their harsh conditions.

Our organization is distinct in terms of volunteers as our organization is a youth-run NGO. Most of the volunteers and core-team members of our NGO comprise young people. This promotes leadership skills as we give complete independence in decision making to our volunteers, which is not catered by any other organization. We try to inculcate a sense of purpose and insight in the young minds and this gives them a head start in facing the turmoil of tomorrow.

The idea behind our every project is given by the youth and also executed by them. To encourage more youth participation, we organize various campaigns and take part in youth friendly events. Our motive behind this effort is to form a committed team of young individuals who can together mitigate all the problems of tomorrow.

5. Brief Description of the event

The event was conducted by the Rotaract Club Members and Directorate of Students Welfare for the children of Naya Sawera. This visit took place on 4th October, on the Occasion of DAANUTSAV 2023. On the account of DAAN UTSAV 2023, Rotaract Club

organized this event in NAYA SAVERA NGO. Students participated with enthusiasm throughout the drive. Everyone gathered at 9 a.m. to depart for the drive.

The drive helped MUJ Students to understand the State of the NGO Childrens and how we, as regular people, can help maintain it.

6. Photographs of the event

Image 1 Rotaract Club students with NGO Childerens

Image 2 MUJ Students interacting with NGO Childeren

Image 3 Rotaract Club Srtucents participating in the drive

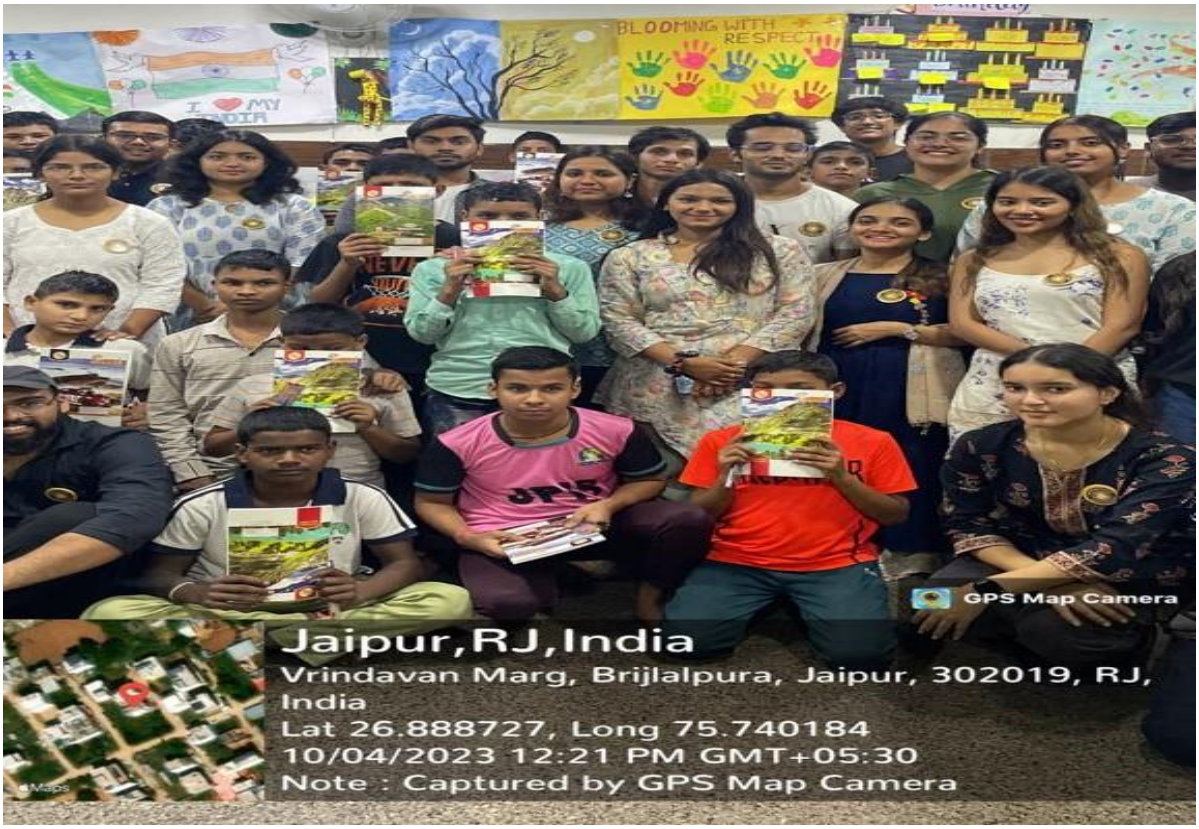


Image 4 Students participating in the drive.

7. Brochure or creative of the event

#DAANUTSAV 2023- Orphanage Visit(Naya Savera)

8. Schedule of the event

S.NO.	Name of the Event	Time	Place
1.	Orphanage Visit- Naya Savera	10:00 AM	Naya Savera Nirman Nagar Jaipur

9. Attendance of the Event (insert in the document only)

Total attendee- 90

S.NO.	Registration Number	Name	Institute Name
1	219402024	Puneet Sharma	Manipal University Jaipur
2	220606004	Pranjal Puri	Manipal University Jaipur
3	220606020	Chaarvi Kumar	Manipal University Jaipur
4	220901002	Anshu jangir	Manipal University Jaipur
5	220901073	Diya Mittal	Manipal University Jaipur
6	220901322	Divyanshi Singh	Manipal University Jaipur
7	220901391	Dipika Agarwal	Manipal University Jaipur
8	220903033	Suhani Jain	Manipal University Jaipur
9	221002064	shweta mishra	Manipal University Jaipur
10	221002065	Tanya Barua	Manipal University Jaipur
11	221003007	Yachna Jain	Manipal University Jaipur

12	221007004	Urvi Thakare	Manipal University Jaipur
13	221007020	Ayushi Mittal	Manipal University Jaipur
14	221007021	Arshi Jain	Manipal University Jaipur
15	221007075	Preetika Sharma	Manipal University Jaipur
16	221015007	Mehul Kumar	Manipal University Jaipur
17	221015026	Rohit Arora	Manipal University Jaipur
18	221015074	Rupal Sharma	Manipal University Jaipur
19	221015107	Munesh	Manipal University Jaipur
20	221105005	Dhruv Nair	Manipal University Jaipur
21	229301094	Yashovardhan Pratap Singh	Manipal University Jaipur
22	229301095	Shaurya Singh	Manipal University Jaipur
23	229301221	Rubhav Bahirwani	Manipal University Jaipur
24	229302051	Prince jindal	Manipal University Jaipur
25	229302160	Parth johar	Manipal University Jaipur
26	229302266	Utkarsh	Manipal University Jaipur
27	229302571	Shreya Kumari	Manipal University Jaipur
28	229302644	Ankur kumar	Manipal University Jaipur
29	229303005	Nidhi Verma	Manipal University Jaipur
30	229303207	Ritik Laxwani	Manipal University Jaipur
31	229309083	Raghav Gupta	Manipal University Jaipur
32	229310012	Pragati Pandey	Manipal University Jaipur
33	229310059	Aditya Yadav	Manipal University Jaipur
34	229310222	Aayush Sharma	Manipal University Jaipur
35	229310269	Sneha Bhatia	Manipal University Jaipur
36	229310321	Shiv Rajput	Manipal University Jaipur
37	229310412	Jatin Verma	Manipal University Jaipur
38	229311075	Aarna Tyagi	Manipal University Jaipur
39	229311104	Shashwat Kumar	Manipal University Jaipur
40	23FA10BAP00002	Tanisha Mathur	Manipal University Jaipur
41	23FA10BAP00027	Natasha Joan Menezes	Manipal University Jaipur
42	23FA10BAP00033	Dipal gupta	Manipal University Jaipur
43	23FA10BHE00012	Nausheen broca	Manipal University Jaipur
44	23FA10BHE00035	Taneesha puri	Manipal University Jaipur
45	23FA10BLE00004	Tanisha chaturvedi	Manipal University Jaipur
46	23FA10BSP00004	Aarya Mahale	Manipal University Jaipur
47	23FA10BSP00005	Teshant arora	Manipal University Jaipur
48	23FA10BSP00017	Megha Sharma	Manipal University Jaipur
49	23FA10BSP00024	Lavanya Choudhary	Manipal University Jaipur
50	23fa10bsp00025	Jasleen kaur	Manipal University Jaipur
51	23FA10BSP00028	Anupama Rustagi	Manipal University Jaipur
52	23FA10BSP00039	Jiya Kumar	Manipal University Jaipur
53	23FA10BSP00041	Kali Vithlani	Manipal University Jaipur
54	23FA10BSP00046	Rafia	Manipal University Jaipur
55	23fa10bsp00047	Vartika Agarwal	Manipal University Jaipur
56	23FA10BSP00049	Aarushi Thora	Manipal University Jaipur

57	23fa10bsp00058	Kashvi Mahajan	Manipal University Jaipur
58	23FA20MCP00005	Ayushi Pushkarna	Manipal University Jaipur
59	23fd10bar00004	Aadhya mahajan	Manipal University Jaipur
60	23FD10BFD00009	Mariya Shabbir Baiwala	Manipal University Jaipur
61	23FE10AEE00008	Kisna Rana	Manipal University Jaipur
62	23fe10bte00029	Saloni kamal	Manipal University Jaipur
63	23FE10CAI00028	VALLURI SRI AASRITHA	Manipal University Jaipur
64	23FE10CAI00105	Mritunjay Singh	Manipal University Jaipur
65	23FE10CAI00282	isha nagpal	Manipal University Jaipur
66	23FE10CAI00352	Maanyata Aul	Manipal University Jaipur
67	23FE10CAI00360	shaivi adesh	Manipal University Jaipur
68	23FE10CAI00360	shaivi adesh	Manipal University Jaipur
69	23FE10CAI00485	Kakul Rawat	Manipal University Jaipur
70	23FE10CAI00487	Dev Sharma	Manipal University Jaipur
71	23FE10CAI00548	Poorti Swarup	Manipal University Jaipur
72	23fe10cai00579	Arjun Malhotra	Manipal University Jaipur
73	23FE10CCE00034	KRISHNA GOEL	Manipal University Jaipur
74	23FE10CCE00057	Mohit kumhar	Manipal University Jaipur
75	23FE10CCE00079	Lakshya Verma	Manipal University Jaipur
76	23FE10CCE00085	Siddhartha tiwari	Manipal University Jaipur
77	23fe10cds00125	Suryanshi Singh	Manipal University Jaipur
78	23FE10CDS00177	Manas Mathur	Manipal University Jaipur
79	23FE10CDS00208	Ananya Srivastava	Manipal University Jaipur
80	23FE10CDS00224	Harsh Ajmera	Manipal University Jaipur
81	23FE10CDS00235	Anika sharma	Manipal University Jaipur
82	23FE10CDS00241	Armaan Setia	Manipal University Jaipur
83	23FE10CDS00284	Anant Barjatya	Manipal University Jaipur
84	23FE10CDS00397	Hrishita Singh Timaney	Manipal University Jaipur
85	23FE10CDS00423	Purvi Sharma	Manipal University Jaipur
86	23FE10CDS00483	Kritika Magnani	Manipal University Jaipur
87	23FE10CDS00528	VANSHIKA VISHNAWAT	Manipal University Jaipur
88	23fe10cii00012	Nishant Prasad	Manipal University Jaipur
89	23FE10CII00034	Trisha shanvi	Manipal University Jaipur
90	23fe10cii00035	Bhargavi Anand	Manipal University Jaipur

10. Feedback of the Event

The students participated enthusiastically and helped to spread message for cleanliness.

(Hemant Kumar)

Assistant Director, Society Connect

Directorate of Student's Welfare

DIRECTOR STUDENT WELFARE & PROCTOR
MANIPAL UNIVERSITY, JAIPUR

(Prof. AD Vyas)

Director, Directorate of Student's Welfare

MUJ/DSW/Society Connect/ 18 Oct 2023

MANIPAL UNIVERSITY
JAIPUR

DIRECTORATE OF STUDENT'S WELFARE

(SOCIETY CONNECT)

FACULTY OF DESIGN

SCHOOL OF DESIGN & ART

DEPARTMENT OF FASHION DESIGN

Social Outreach Activity in collaboration with NSS

at

Aashray Care Home, Jaipur

Dated: 18th October 2023

Index

Content of Report

1. Introduction of the Event

Department of fashion design organized Social Outreach Activity in collaboration with Directorate of Student's welfare MUJ and NSS – National Service Scheme at NGO named "Aashray Care Home" for HIV infected and affected Children (Girls) in Nirmaan nagar, Jaipur on 18th October 2023. where faculties of fashion design and students conducted a skill development & training session on Crocia & origami with NGO kids under SDG's.

About the NGO :-
Aashray Care Home is a sanctuary dedicated to nurturing 37 remarkable children aged 3 to 18 years with special needs, primarily those affected by HIV acquired from their mothers. We believe in providing a loving environment where these children receive essential care, education, and opportunities for a brighter future. As we embark on constructing a purpose-built home designed for their needs, join us in our mission to empower these resilient young souls and create a better tomorrow.

Link of webpage for Aashrey Care Home : https://aashraycare.org/

2. Objective of the Activity

The main objective of the event was to interact with NGO Girls and conduct training for some craft based hands on skills under SDG's and donate some nutritious food items to them. All these activities were conducted by students from fashion design department along with faculty.

Another objective was to provide these girls of NGO, some information about Manipal University Jaipur in relation to education and further societal activities.

3. Beneficiaries of the Event:-

Girls of Aashrey Care Home were the beneficiaries of this activity as they got something for their use and our students as well who spent some quality time with the kids and got to chance to understand their social and moral responsibility as a responsible citizen.

4. Brief Description of the Event:- The Department of Fashion Design, in collaboration with the Directorate of Student's Welfare MUJ and NSS (National Service Scheme), organized a Social Outreach Activity at the NGO "Aashray Care Home" for HIV infected and affected girls in Nirmaan Nagar, Jaipur on 18th October 2023. Faculty members and students from the fashion design program actively participated in this initiative, conducting a skill development and training session on Crocia and origami with the NGO kids, aligning with the Sustainable Development Goals (SDGs).

Mr. Harshwardhan Soni, Prof. Pratibha Mishra, and the students carried out the activity at the NGO premises. The primary objective was to engage with the girls from the NGO, providing them training in craft-based hands-on skills under SDGs, and also donating nutritious food items. The

students from the fashion design department actively led and participated in these activities, working alongside the faculty.

In addition to the skill development aspect, the event aimed to familiarize the girls from Aashray Care Home with information about Manipal University Jaipur, encompassing educational opportunities and societal activities. The beneficiaries of this outreach were not only the girls

from the NGO, who received practical items for their use, but also the participating students. The latter had the opportunity to spend quality time with the children, gaining a deeper understanding of their social and moral responsibilities as responsible citizens.

5. Photographs of the event with captions

Image 1 Student Engaging the NGO children

Image 2 Student making children to learn Art and Craft

Image 3 Workshop with NGO Kids

Image 4 Workshop with NGO Kids

Image 5 Workshop MUJ Team FOD

6. Brochure or creative of the event:

7. **Schedule of the event: The activity was conducted on 18/12/2023 from 1 pm till 4:30pm.**

8. **Total attendees of the Event …55**

S.NO.	Reg. No.	Student Name	Year
1.	23FD10BFD00001	MANYA SRIVASTAVA	Manipal University Jaipur
2.	23FD10BFD00002	PRAGATI RATHORE	Manipal University Jaipur
3.	23FD10BFD00003	SHAILJA SINGH	Manipal University Jaipur
4.	23FD10BFD00004	ANYA AMITKUMARSURANA	Manipal University Jaipur
5.	23FD10BFD00005	NISHTHA BANSAL	Manipal University Jaipur
6.	23FD10BFD00006	SHALIMA M	Manipal University Jaipur
7.	23FD10BFD00007	REVA SHARMA	Manipal University Jaipur
8.	23FD10BFD00008	TAMANNA GRACYSINGH	Manipal University Jaipur
9.	23FD10BFD00009	MARIYA SHABBIRBAIWALA	Manipal University Jaipur
10.	23FD10BFD00010	KRITTIKA SAINI	Manipal University Jaipur
11.	23FD10BFD00011	GURMEHAR KAURCHAHAL	Manipal University Jaipur
12.	23FD10BFD00012	KUNAL VERMA	Manipal University Jaipur
13.	23FD10BFD00013	PARTH BADAYA	Manipal University Jaipur
14.	23FD10BFD00014	CHINDIRALA VARSHITHA	Manipal University Jaipur
15.	23FD10BFD00015	SAMARTH SHANGARI	Manipal University Jaipur
16.	23FD10BFD00016	KRITIKKA CHIRANIA	Manipal University Jaipur
17.	220601001	ANUSHKA	Manipal University Jaipur
18.	220601003	SHRUTI VERMA	Manipal University Jaipur
19.	220601004	NAVDHA MISHRA	Manipal University Jaipur
20.	220601005	SUMERA PARVEEN	Manipal University Jaipur
21.	220601006	HIMANSHI SAMPAT JANGID	Manipal University Jaipur
22.	220601007	VIDISHA BAJAJ	Manipal University Jaipur
23.	220601008	JANVEE SONI	Manipal University Jaipur
24.	220601009	ADRIJA RATHORE	Manipal University Jaipur
25.	220601010	ABHAMAYI SHRESTHA	Manipal University Jaipur
26.	220601011	PIYUSH RAJ	Manipal University Jaipur
27.	220601013	VRINDA MAHESHWARI	Manipal University Jaipur
28.	220601015	DRISHTI TIWARI	Manipal University Jaipur
29.	220601016	NAVYA GUPTA	Manipal University Jaipur
30.	220601017	SAKSHI AGRAWAL	Manipal University Jaipur
31.	220601018	GARIMA HOTWANI	Manipal University Jaipur
32.	220601019	MINI GAUTAM	Manipal University Jaipur
33.	220601020	KHUSHI MEHTA	Manipal University Jaipur
34.	220601021	NEHA DAGDI	Manipal University Jaipur
35.	220601022	PREKSHA BAPLAWAT	Manipal University Jaipur
36.	220601023	RAKHI VERMA	Manipal University Jaipur
37.	220601024	KHUSHI PORWAL	Manipal University Jaipur
38.	220601025	SNEHA KHANDELWAL	Manipal University Jaipur
39.	210601001	TANUSHREE SHEKHAWAT	Manipal University Jaipur
40.	210601003	JAGRATI JAIN	Manipal University Jaipur
41.	210601007	AYUSH SAINI	Manipal University Jaipur
42.	210601008	PRIYA LODHI	Manipal University Jaipur
43.	210601009	BHUMIKA SINGH RATHORE	Manipal University Jaipur
44.	210601011	NAVYA VIDYARTHI	Manipal University Jaipur

45.	210601013	GEETIKA RAI	Manipal University Jaipur
46.	210601014	KOVVURU GEETIKA	Manipal University Jaipur
47.	210601015	DEVIKA SONI	Manipal University Jaipur
48.	210601016	SAMYA GUPTA	Manipal University Jaipur
49.	210601017	KAVYA KALRA	Manipal University Jaipur
50.	210601018	SNEHA SARKAR	Manipal University Jaipur
51.	210601019	SIMRAN PARAG PATIL	Manipal University Jaipur
52.	210601020	HARSHVARDHAN SINGH	Manipal University Jaipur
53.	210601023	RAJNISH KUMAR	Manipal University Jaipur
54.	210601024	SHUBHI TAMBI	Manipal University Jaipur
55.	210601025	BHAVIKA PABUWAL	Manipal University Jaipur
56	23FA10BSP00049	Aarushi Thora	Manipal University Jaipur
57	23fa10bsp00058	Kashvi Mahajan	Manipal University Jaipur
58	23FA20MCP00005	Ayushi Pushkarna	Manipal University Jaipur
59	23fd10bar00004	Aadhya mahajan	Manipal University Jaipur
60	23FD10BFD00009	Mariya Shabbir Baiwala	Manipal University Jaipur
61	23FE10AEE00008	Kisna Rana	Manipal University Jaipur
62	23fe10bte00029	Saloni kamal	Manipal University Jaipur
63	23FE10CAI00028	VALLURI SRI AASRITHA	Manipal University Jaipur
64	23FE10CAI00105	Mritunjay Singh	Manipal University Jaipur
65	23FE10CAI00282	isha nagpal	Manipal University Jaipur
66	23FE10CAI00352	Maanyata Aul	Manipal University Jaipur
67	23FE10CAI00360	shaivi adesh	Manipal University Jaipur
68	23FE10CAI00360	shaivi adesh	Manipal University Jaipur
69	23FE10CAI00485	Kakul Rawat	Manipal University Jaipur
70	23FE10CAI00487	Dev Sharma	Manipal University Jaipur
71	23FE10CAI00548	Poorti Swarup	Manipal University Jaipur
72	23fe10cai00579	Arjun Malhotra	Manipal University Jaipur
73	23FE10CCE00034	KRISHNA GOEL	Manipal University Jaipur
74	23FE10CCE00057	Mohit kumhar	Manipal University Jaipur
75	23FE10CCE00079	Lakshya Verma	Manipal University Jaipur
76	23FE10CCE00085	Siddhartha tiwari	Manipal University Jaipur
77	23fe10cds00125	Suryanshi Singh	Manipal University Jaipur
78	23FE10CDS00177	Manas Mathur	Manipal University Jaipur
79	23FE10CDS00208	Ananya Srivastava	Manipal University Jaipur
80	23FE10CDS00224	Harsh Ajmera	Manipal University Jaipur

9. Letter of Appreciation from sAASHREY CARE HOME

Positive Women Network of Rajasthan

Exempted from Taxes under Section 80G of Income Tax Act.

Dated : 28/10/2023

L. Sr. No Aashray/2023/305

To

Department of Fashion Design &

Directorate of Student's Welfare,

Manipal University Jaipur

Subject: Letter of appreciation and gratitude for workshop

Respected Sir/Madam,

I am writing on behalf of Aashray Care Home, Jaipur, to express our deepest gratitude to the Department of Fashion Design and the Directorate of Student's Welfare at Manipal University Jaipur, in collaboration with the National Service Scheme (NSS), for conducting a remarkable workshop on crochette and paper origami on 18th October 2023.

The workshop, led by the dedicated faculty coordinators, Mr. Harshwardhan Soni and Ms. Pratibha Mishra, was a beacon of hope and inspiration for the 30 girls at Aashray Care Home who are affected by HIV. The initiative not only provided them with valuable craft skills but also instilled a sense of self-dependence and purpose in their lives. Your team's commitment to addressing Sustainable Development Goals (SDG's) 1, 2, 3, and 4 through this workshop is truly commendable.

The collaborative effort demonstrated by your institution and the NSS showcased a profound understanding of the importance of education and skill development, particularly for individuals facing challenging circumstances. Through your workshop, these young girls were empowered with creative skills that will undoubtedly contribute to their livelihoods and personal growth.

We appreciate the thoughtfulness and expertise your team brought to the workshop, making it a meaningful and enriching experience for the participants. Your dedication to social causes and community development is evident through your actions, and we are truly honored to have been a part of this initiative.

Once again, thank you for your valuable contribution to our cause. We look forward to the possibility of collaborating on similar projects in the future and continuing our joint efforts to make a positive impact on the lives of those in need.

Warm regards,

Aashray Care Home, Jaipur

aashray.care@gmail.com

Aashray Care Home

Registered Office : Plot No. 49,50,63, Gandhigram, Jaisinghpura, Newata, Jaipur
Project Office (Aashray Care Home) : 423, Rani Sati Nagar, Nirman Nagar, Jaipur-302019
Project Office (Care & Support Centre) : Hall No. 2, Modi Dharamsala in front of SMS Hospital, Jaipur
P : 0141 2812419, 9314610141, 9549958111 **E :** aashraycare@gmail.com **W :** aashraycare.org

Harshwardhan Soni

Event Coordinator

Dr. Deepshikha Sharma

HoD Fashion Design

(Hemant Kumar)

Assistant Director, Society Connect

Directorate of Student's Welfare

DIRECTOR STUDENT WELFARE & PROCTOR
MANIPAL UNIVERSITY, JAIPUR

(Prof. AD Vyas)

Director, Directorate of Student's Welfare

FACULTY OF DESIGN

SCHOOL OF DESIGN & ART

DEPARTMENT OF FINE ARTS

Social Connect Outreach Program

at

NAYA SAVERA NGO, Shyam Nagar Jaipur

7th November 2023

Introduction of the Event

The Department of Fine Arts at the School of Design and Art, Manipal University Jaipur, recently conducted a **Social Connect Outreach Program** in collaboration with the **National Service Scheme (NSS)** at the **NGO Naya Savera in Shyam Nagar, Jaipur**. Approximately **26 students** from the Department of Fine Arts actively participated in this initiative, engaging with the children of the NGO under the coordination of Dr. Kusum Kanwar. The collaborative effort centered around a craft activity, during which both students and children created vibrant flowers using felt cloth. This event aligns with several United Nations Sustainable Development Goals (SDGs), notably Goal 2: Zero Hunger, Goal 4: Quality Education, and Goal 16: Peace, Justice, and Strong Institutions. Moreover, Mr. Akhilesh, the founder of the NGO, addressed the participating students, providing insights into the organization's functioning and emphasizing the importance of their collective contribution towards these SDGs.

Objective of the Event

- To student participation in collaborative fun and learning activity.
- To encourage students for creative thinking.

Beneficiaries of the Event

Children of Naya Savera NGO.

Photographs of the Event

(Dept. students and children making flowers of Felt fabric)


GPS Map Camera
Jaipur,RJ,India
Vrindavan Marg, Brijlalpura, Jaipur, 302019, RJ, India
Lat 26.888724, Long 75.740216
11/07/2023 12:24 PM GMT+05:30
Note : Captured by GPS Map Camera

(The NGO's owner addresses the students, explaining the organization's functioning to them.)

(Group photo of all the people after the activity)

(Group photo of all the people after the activity)

Attendance of the Event

Total Attendee – 25

S. No.	Full Name	MUJ ID/Registration
1	**Faculty**	**Dr. Kusum Kanwar**
2	23FD10BFA00001	AADITRI SHARMA
3	23FD10BFA00002	SANYA GUPTA
4	23FD10BFA00003	HIMANSHI GURJAR
5	23FD10BFA00004	ARPIT SONI
6	23FD10BFA00005	PADMJA DODIYA
7	23FD10BFA00007	MANISH PRASAD
8	23FD10BFA00008	ARSHIYA AGARWAL
9	23FD10BFA00009	PRACHI JAIN
10	23FD10BFA00010	PREMPRAKASH SINGHRAWAT
11	23FD10BFA00011	ISHA SHEKHAWAT
12	23FD10BFA00012	GAURAV MEHRAULIA
13	23FD10BFA00013	BHAGIRATH SINGHRATHORE
14	23FD10BFA00014	SANJANA UPADHYAY
15	23FD10BFA00015	SIMRAN SIMRAN
16	23FD10BFA00001	AADITRI SHARMA
17	23FD10BFA00003	HIMANSHI GURJAR
18	210603005	PRAKRITI CHABRA
19	210603019	RUT BADAYA
20	210603033	TANU SHARMA
21	210603013	RISHABH MISHRA
22	210603026	ISHIKA JANGID
23	210603042	MOHIT RAJPUROHIT
24	210603006	DRISHTI
25	210603041	NIKEETA
26	210603029	DEEPALI GUPTA
27	210603017	APOORV KRISHNA

Dr Kusum Kanwar
Coordinator

Prof. (Dr) Anantkumar Ozarkar
Head of the Department

Regd. No.: 922/Jaipur/2008-09

NAYA SAWERA

Let's Wake-up for Better Tomorrow...

Dr. Kusum Kanwar

Assistant Professor

Department of Fine Arts

School of Design and Art

Manipal University Jaipur

Subject: Appreciation for Social Connect Outreach Program

Dear Dr. Kusum Kanwar,

I wanted to express my sincere appreciation for the recent Social Connect Outreach Program organized by the Department of Fine Arts in collaboration with NSS at Naya Sawera NGO. The initiative, which involved 25 enthusiastic students crafting flowers with children under your guidance, reflects a commendable commitment to community engagement.

The choice to align this activity with SDGs, specifically Goals 2, 4, and 16, showcases a purposeful contribution to broader societal goals.

Congratulations on this impactful initiative. I look forward to more such endeavors from the Department of Fine Arts and Directorate of Student Welfare, Manipal University Jaipur.

Best regards,

NAYA SAWERA SOCIETY

Akhilesh Maheshwari

Director & Founder

Naya Sawera NGO

Email: naya.sawera2020@gmail.com

Contact no: +91 9649020121

MANIPAL UNIVERSITY
JAIPUR

MUJ/Q&C/22/F/1.01

MANIPAL UNIVERSITY
JAIPUR

FACULTY OF SCIENCE

SCHOOL OF BASIC SCIENCES

DEPARTMENT OF BIOSCIENCES

INDUSTRIAL WORKSHOP ON THE OPERATIONS AND HANDLING OF BIOREACTOR

Date of Event (11.09.2023-12.09.2023)

1. **Introduction of the Event-** In this workshop, we get the essential knowledge and practical skills about the bioreactor. A bioreactor is a specialized device used in biotechnology and microbiology to create controlled environments for the growth and cultivation of various biological organisms, primarily microorganisms such as bacteria, yeast, and fungi, as well as cells and tissues. These versatile devices play a pivotal role in various scientific and industrial applications, including pharmaceuticals, biopharmaceuticals, agriculture, environmental remediation, and biofuel production.

2. **Objective of the Event**

   - ***Understanding Bioreactor Principles*:** Fundamental understanding of bioreactor principles, including how they work, their components, and their role in industrial processes.

   - ***Bioreactor setup and monitoring*:** Bioreactor setup and monitoring are crucial aspects of bioprocess management, ensuring the controlled cultivation of microorganisms, cells, or tissues for various applications.

   - ***Safe Handling and Operation*:** Safe handling of bioreactors, emphasizing the importance of following safety protocols to prevent accidents and ensure the well-being of personnel and the environment.

   - ***Process Optimization*:** Optimizing bioprocesses within bioreactors, including parameters like temperature, pH, agitation, and aeration, to maximize productivity and yield.

3. **Beneficiaries of the Event:** Gain in-depth knowledge and practical skills related to bioreactor setup, operation, and monitoring. This knowledge is beneficial in many food industries. with a better understanding of bioreactor monitoring and control, we can maintain consistent product quality, a crucial factor in industries such as biopharmaceuticals where product safety is paramount.

4. **Details of the Guests**

   Mr. Abhishek Thakur is an engineer at PRS BIO

5. **Brief Description of the event:**

   The "Industrial Workshop on the Operations and Handling of Bioreactor" is a specialize ed event designed to provide comprehensive knowledge and practical insights into the setup, operation, and management of bioreactors in industrial settings. This workshop

aims to cater to professionals, scientists, researchers, engineers, and individuals across various industries and sectors where bioreactor technology plays a crucial role.

Key elements of this workshop typically include:

In-Depth Learning: The event offers participants a deep dive into the principles, components, and operational aspects of bioreactors. Attendees will gain a thorough understanding of how bioreactors work and their importance in various industries.

Safety and Regulatory Compliance: Safety is a paramount concern when working with bioreactors. The workshop provides guidance on safe handling practices and emphasizes compliance with industry regulations and standards.

Hands-On Experience: The workshop focuses on the opportunity for practical, hands-on experience with bioreactor equipment, allowing them to apply their knowledge in a real-world setting.

Process Optimization: The workshop focuses on strategies and techniques for optimizing bioreactor processes, including monitoring and controlling critical parameters like temperature, pH, agitation, and aeration.

Quality Assurance: Quality control and assurance are essential in industries like pharmaceuticals and biopharmaceuticals. The workshop covers methods for ensuring product quality and consistency.

Industry Insights: The workshop features presentations, case studies, and discussions on current industry trends, innovations, and best practices related to bioreactor technology.

Practical Applications: The knowledge gained from the workshop can be directly applied to various sectors, including pharmaceuticals, biotechnology, environmental science, agriculture, and food production.

Career Development: Individuals attending the workshop can enhance their skills and knowledge, potentially opening up new career opportunities and advancement prospects in their respective fields.

Overall, the "Industrial Workshop on the Operations and Handling of Bioreactor" is a valuable educational and networking event that equips participants with the expertise and confidence to operate bioreactor systems effectively, driving advancements in biotechnology, pharmaceuticals, environmental science, and related fields.

6. Photographs

Dr. Sandeep Srivastava and Dr. Rakesh Kumar Sharma introduced our guest and briefed the workshop.

Our Guest Mr. Abhishek Rathore demonstrated the bioreactor controls

7.Brochure of the event:

8. Schedule of the event

DATE	TIMINGS	TOPIC
11/09/2023	10:00 AM	Inauguration
	10:30 AM	High Tea
	10:45 AM	Basics of Bioreactor
	11:30 AM	Reactor components
	1:00 PM	Lunch Break
	2:30 PM	Reactor setup
12/09/2023	9:30 AM	Bioreactor and data acquisition
	1:30 PM	Lunch Break
	2:30 PM	Q&A Session

MANIPAL UNIVERSITY JAIPUR

INSPIRED BY LIFE

Attendance of the Event

Total attendee-71

Department of Biosciences

Manipal University Jaipur

Workshop on the operation and Handling of Bioreactor

Date: 11/09/2023

S. No.	Name	E mail	Signature
1	Abhi Anand	abhianand8576@gmail.com	
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~~55. Irra.~~			
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64.	Kunal Khandelwal	meena.211051012@muj.manipal.edu	
65.	Manish Raj	manish.211003010@muj.manipal.edu	
66.	Samrat Banerjee	samrat.211003008@muj.manipal.edu	Samrat
67.	Saloni singh	saloni.211002057@muj.manipal.	Saloni
68	Naresh Kumawat	Naresh.211002009@muj.manipal.edu	Naresh
69	Harshit Kumawat	Harshit.211002004@muj.manipal.edu	H
70.	Aditya Yadav	aditya.211002054@muj.manipal.edu	Aditya
71.	Abhishek Dadhich	sabhi5061@gmail.com	Abhi.

Page 1 of 2

Page 2 of 2

Seal and Signature of Head with date

MUJ/Q&C/FoMC/SHTM/2023/International Workshop – IAESTE

MANIPAL UNIVERSITY
JAIPUR

FACULTY OF MANAGEMENT & COMMERCE

SCHOOL OF HOSPITALITY AND TOURISM MANAGEMENT

&

Directorate of International Collaboration, MUJ

in collaboration with

IAESTE
LC MUJ

along with

JoJo Internationals

has organized a

CULTURAL CULINARY WORKSHOP

(SDG: Zero Hunger & Sustainable Consumption)

11/08/2023
(9:00 – 14:00)

AMIT DATTA
Digitally signed by AMIT DATTA
Date: 2024.01.11 11:36:03 +05'30'

Content of Report

1. Introduction

Goal 12 is about ensuring sustainable consumption and production patterns, which is key to sustain the livelihoods of current and future generations. Our planet is running out of resources, but populations are continuing to grow. The workshop also aims to generate awareness of it. Goal 2 is about Zero Hunger, which is a key to sustain humanity and provide nutritious food for all human being.

The International Association for the Exchange of Students for Technical Experience, Association, commonly known as IAESTE, is an association of national committees representing academic, industrial and student interests. The main aim is to help the members realise their dreams and to facilitate the exchange of ideas both technical as well as, cultural, by connecting students from various cultures and countries.

2. Objective of the Event

- To promote and strengthen international collaborations at MUJ
- To provide a learning opportunity for the SHTM students
- Spread SDG Awareness related to Responsible Consumption & Production and Zero Hunger

3. Brief Description of the event

On 11th August 2023, a Cultural Culinary Workshop was organized in association with IAESTE-MUJ and JoJo International. The DoIC, MUJ supported the event. IAESTE interns from 22 different countries and 25 BHM students participated in preparing their local delicacies. The workshop was organized at SHTM lab. A session on sustainable development

goals 12 and 2, i.e on Sustainable Consumption & Production and Zero Hunger was conducted by the resource person and SHTM faculty members. Further the career scope of culinary professional was shared with the students. Thereafter the participants prepared different dishes. The food was presented and the leadership team of MUJ tasted and applauded the efforts of the participants. Later certificate was awarded to all the participants.

4. Photographs of the event

Glimpses of the event

Certificate distribution to the foreign IAESTE interns

3. SDG Presentation by the resource person foreign interns

5. Brochure

3 Brochure

MANIPAL UNIVERSITY JAIPUR

6. Schedule of the event

Resource Person: Mr Ankit Adhikari, Recruitment Supervisor, JoJo International. Email: cv8@jojointernational.co.in. www.jojo-international.com.au (+61470234428)

Date	Time	Duration	Venue
11th August, 2023	9:00 am – 14:00 pm	05 hours	#325, 1AB HM Lab
Introduction, Culinary Session on Responsible Consumption & Production and Zero Hunger, Food Presentation, Certificate Distribution, Lunch, Vote of thanks.			

7. Attendance of the Event Total attendee – 47 (22 Foreign + 25 Indian [MUJ])

Sr	Participant's Name	Country	University
1	Aaron John Goff	United Kingdom	University of Edinburgh
2	Marlene Elisabeth Metz	Germany	Heidelberg University
3	Benedikt Lohnes	Germany	Technical University of Darmstadt
4	Nina Lauks	Poland	Uniwersytet Medyczny w Lodzi
5	Yaba Rosette Tanoé	Germany	Friedrich-Alexander-Universitat Erlangen-Nurnberg
6	Suwapat Thongyoun	Thailand	Chulalongkorn University, Bangkok
7	Blanca Prior Palomero	Spain	Universidad Politecnica de Madrid
8	Valentín Gregorio Galindo Benéitez	Spain	Universidad Politecnica de Madrid
9	Friedrich Albrecht Dang	Germany	Technische Universitat Munchen
10	Mustafa Aidini Abala	Turkey	Erciyes University
11	Tristan Robert A. Toye	Belgium	Katholieke Universiteit Leuven
12	Laura Maria Estrada D'Amado	Sweden	Chalmers University of Technology
13	Pablo Rodriguez Sanchez	Spain	University of Málaga,
14	Arshia Vali Pour	Iran	Iran University of Science and Technology
15	Oscar Monje Lola	Spain	Universidad Politecnica de Madrid
16	Mohamed Haroun Boutaieb	Tunisia	National School of Architecture and Urbanism
17	Khadijeh Ahmadi Zamani	Iran	K.N. Toosi University of Technology
18	Amine Zribi	Hungary	Eotvos Lorand University
19	Eya YAHYAOUI	Tunisia	National Engineering School of Tunis (ENIT)
20	Muhammed Yasir Yılmaz	Turkey	Istanbul Technical University
21	Eren Asci	Turkey	Kocaeli University
22	Daniel Manuel Allan Werner-Meier	Germany	Technical University of Cologne
23	VANSHIKA	India	Manipal University Jaipur
24	MEHMA SINGH	India	Manipal University Jaipur
25	HARSH ADITYA SINGH RATHORE	India	Manipal University Jaipur
26	SHIVAM JAISWAL	India	Manipal University Jaipur
27	ABHIJEET ARORA	India	Manipal University Jaipur
28	AJAY AHIR	India	Manipal University Jaipur
29	SARTHAK GAUTAM	India	Manipal University Jaipur
30	RITU RAJPUROHIT	India	Manipal University Jaipur
31	ALAM HUSSAIN	India	Manipal University Jaipur
32	GARIMA PANDEY	India	Manipal University Jaipur
33	RUDR SIKARIA	India	Manipal University Jaipur
34	VAIBHAV ENDORIA	India	Manipal University Jaipur

35	DHANUSHWEE L	India	Manipal University Jaipur
36	DIVESH NIMAWAT	India	Manipal University Jaipur
37	PREKSHA MAHESHWARI	India	Manipal University Jaipur
38	ARUSHI RATHORE	India	Manipal University Jaipur
39	PAWAN	India	Manipal University Jaipur
40	HIMANSHU SAINI	India	Manipal University Jaipur
41	ANSHUMAN CHETIA	India	Manipal University Jaipur
42	RUDRARAJ SINGH SISODIA	India	Manipal University Jaipur
43	RANJEET SINGH CHUNDAWAT	India	Manipal University Jaipur
44	ANKIT MANKANI	India	Manipal University Jaipur
45	PRAKASH MANKANI	India	Manipal University Jaipur
46	RITWIK GUPTA	India	Manipal University Jaipur
47	KULDEEP SINGH	India	Manipal University Jaipur

8. Feedback of the Event

The session was interesting and will benefit the student's learnings about the different culinary products and about SDG goals of responsible Production and Consumption and Zero Hunger. Similar views were also expressed by the delegates, IAESTE members, and SHTM students after the session was completed.

9. Letter of Correspondence and Certificates

From: Team Incoming IAESTE LC MUJ <head.incoming@iaestemuj.in>
Sent: Monday, August 7, 2023 5:38:53 PM
To: Dr. Amit Datta [MU - Jaipur] <amit.datta@jaipur.manipal.edu>
Cc: President <president@iaestemuj.in>; Dr. Arun Kumar Poonia [MU - Jaipur] <arunkumar.poonia@jaipur.manipal.edu>
Subject: 4th Edition of International Cross-Cultural Culinary Workshop

Dear Sir,

Please find the details of the International Cross-Cultural Culinary Workshop below:

Date: 11 August 2023
Time: 10:00 AM-2:00 PM
Total guests: 30 (including leadership, faculty, foreign interns and team members)

Certificates will be issued to 25 Hotel Management students and 15 foreign interns as discussed.

Thank you.
--
Warm Regards,

IAESTE LC MUJ

Team Incoming
IAESTE India, LC
MUJ Website:
www.iaestemuj.in

Yahya Aseerullah
Head, Incoming
Mobile: (+91) 9573642592

Aditya Patil
Head, Incoming
Mobile: (+91) 9421524060

IAESTE Office, 1st Floor, Administrative Block
Dome Building, Manipal University Jaipur

From: cv8@jojointernational.co.in <cv8@jojointernational.co.in>
Sent: Tuesday, August 4, 2023 2:15 PM
To: Dr. Amit Datta [MU - Jaipur] <amit.datta@jaipur.manipal.edu> Dr. Aravind Kumar Rai [MU - Jaipur] <aravindkumar.rai@jaipur.manipal.edu>
Subject: FW: Proposal for Meeting

Respected Sir,

Greetings from JOJO International!!

Hope this email finds you in good health.

Noted and also discuss the benefits and advantages associated with the programs.

Feel free to keep in touch with us about any of your queries.

NOT HAPPY** with Our Services, **then Write** your **CONCERN at** **care@jojointernational.org

Best Regards,

Ankish Adhikari,
Recruitment Supervisor.
Contact:+91-70030-10217
Skype: live:54bf85b47b529fc1

INTERNATIONAL

INDIA HEAD OFFICE: | MUMBAI-INDIA |
JOJO INTERNATIONAL PVT. LTD.
Contact: +91-22-28577040
www.jojointernational.com

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Think Green Before You Print This Page!!!

From: Dr. Aravind Kumar Rai [MU - Jaipur] <aravindkumar.rai@jaipur.manipal.edu>
Sent: Wednesday, July 28, 2023 5:21 PM
To: cv8@jojointernational.co.in

CERTIFICATES :

MANIPAL UNIVERSITY
JAIPUR

COLLABORATIONS

9. Letter of Appreciation from sAASHREY CARE HOME

Positive Women Network of Rajasthan

Exempted from Taxes under Section 80G of Income Tax Act.

Dated : 28/10/2023

L. Sr. No Aashray/2023/305

To

Department of Fashion Design &

Directorate of Student's Welfare,

Manipal University Jaipur

Subject: Letter of appreciation and gratitude for workshop

Respected Sir/Madam,

I am writing on behalf of Aashray Care Home, Jaipur, to express our deepest gratitude to the Department of Fashion Design and the Directorate of Student's Welfare at Manipal University Jaipur, in collaboration with the National Service Scheme (NSS), for conducting a remarkable workshop on crochette and paper origami on 18th October 2023.

The workshop, led by the dedicated faculty coordinators, Mr. Harshwardhan Soni and Ms. Pratibha Mishra, was a beacon of hope and inspiration for the 30 girls at Aashray Care Home who are affected by HIV. The initiative not only provided them with valuable craft skills but also instilled a sense of self-dependence and purpose in their lives. Your team's commitment to addressing Sustainable Development Goals (SDG's) 1, 2, 3, and 4 through this workshop is truly commendable.

The collaborative effort demonstrated by your institution and the NSS showcased a profound understanding of the importance of education and skill development, particularly for individuals facing challenging circumstances. Through your workshop, these young girls were empowered with creative skills that will undoubtedly contribute to their livelihoods and personal growth.

We appreciate the thoughtfulness and expertise your team brought to the workshop, making it a meaningful and enriching experience for the participants. Your dedication to social causes and community development is evident through your actions, and we are truly honored to have been a part of this initiative.

Once again, thank you for your valuable contribution to our cause. We look forward to the possibility of collaborating on similar projects in the future and continuing our joint efforts to make a positive impact on the lives of those in need.

Warm regards,

Aashray Care Home, Jaipur

aashray.care@gmail.com

Aashray Care Home

Registered Office : Plot No. 49,50,63, Gandhigram, Jaisinghpura, Newata, Jaipur
Project Office (Aashray Care Home) : 423, Rani Sati Nagar, Nirman Nagar, Jaipur-302019
Project Office (Care & Support Centre) : Hall No. 2, Modi Dharamsala in front of SMS Hospital, Jaipur
P : 0141 2812419, 9314610141, 9549958111 **E :** aashraycare@gmail.com **W :** aashraycare.org

बाल अधिकारिता विभाग, राजस्थान सरकार द्वारा मान्यता प्राप्त
FAITH NARAYANI DEVI SOCIAL WELFARE, HEALTH CARE
RESEARCH AND EDUCATIONAL SOCIETY (Regd.)
के द्वारा संचालित Regd. No.: 344 Jaipur 2012/2013
मातृ छाया बाल गृह
विश्वास के साथ..... आपका हाथ.....
Branch Office :- 134-B, Govind Vihar Colony, Gandhi Path West, Vaishali Nagar, Jaipur
E-mail : matrachayabalgrah@gmail.com | Mob No. 9829118962, 9079021478

Sr. No.....

Date. 16/08/23

To Whom It May Concern

Department of Physics, School of Basic Sciences in Association with Directorate of Student Welfare, NCC, NSS and COSMOS-THE SCIENCE CLUB of Manipal University Jaipur, has organised a Social Connect Event **"Donation Drive at Matra Chaya Baal Grah"** on 16th August 2023.

The event was well coordinated by the students of COSMOS-THE SCIENCE CLUB of MUJ.

It was a societal-connect activity where students of Manipal University Jaipur interacted with children of Matra Chaya Baal Grah and donated clothes and stationery to the orphanage.

Dr. Ashima Bagana, Dr. Rashi Nathawat, Dr. Debanjan Bhattacharjee and Mr. Hemant Kumar played an important role in the success of the event.

President
Niranjan Kumar Dadhich

Chetna

Chetna

Head Office :- 38-A, Raman Vatika, Khirni Phatak Road, Kanta, Jhotwara, Jaipur-302012 (Rajasthan)

JEEVAN JYOTI OLD AGE HO
Prajna Pratishthan
Pashu Hatwara, Ramgarh Road,
Jaipur (Rajasthan) Pin Code - 302027

आपका
अपना सा घर....

DATE 29/09/2023

LETTER OF APPRECIATION

We would like to express our appreciation for conducting many fun activities and counselling sessions by students of manipal university jaipur. accept our mirthful thanks once again and please do spare time for visiting our NGO once again because we always need your support for our worthy cause.
We wish them much luck in their future endeavors.

Abhimanyu Kothari
CEO

jeevanjyotijaipur@gmail.com
jeevanjyoti.co.in
+91-8890366112

Regd. No. 922/Jaipur/2008-09

NAYA SAWERA
Let's Wake-up for Better Tomorrow...

To,

Directorate of Student's Welfare
Manipal University Jaipur
Jaipur – 303007

Date: **30-12-2023**

Subject: Letter of Appreciation.

Respected Sir,

We appreciate students from Rotaract Club MUJ and The Directorate of Student's Welfare for organizing the drive at our Child Shelter Home. In that time students and staff from your university stepped up and conducted a Donation Drive on 4 October 2023 where they distributed stationery items to children and spent time with them. We look forward to more such events in future.

Thank you.

Regards,

NAYA SAWERA SOCIETY

Akhilesh Maheshwari
(Director)
Naya Sawera Society

Registered Office: A - 18, Classic Residency, Hem Marg, Swage Farm, Sodala, Jaipur – 302019
Shelter Home Address: E -64, Nirman Nagar E West, Aj mer Road, Jaipur - 302019
Mobile: +91 9649020121, +91 9587018121, +91 9928400229 E-mail: naya.sawera2020@gmail.com
Web: www.nayasawera.org, www.facebook.com/nayasawera

9. Letter of Appreciation from sAASHREY CARE HOME

Positive Women Network of Rajasthan

Exempted from Taxes under Section 80G of Income Tax Act.

Dated : 28/10/2023

L. Sr. No Aashray/2023/305

To

Department of Fashion Design &

Directorate of Student's Welfare,

Manipal University Jaipur

Subject: Letter of appreciation and gratitude for workshop

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Warm regards,

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Pashu Hatwara, Ramgarh Road,
Jaipur (Rajasthan) Pin Code - 302027

आपका
अपना सा घर....

Date 5/10/2023

LETTER OF APPRECIATION

We would like to express our appreciation for conducting many fun activities and counselling sessions by students of manipal university jaipur. accept our mirthful thanks once again and please do spare time for visiting our NGO once again because we always need your support for our worthy cause.
We wish them much luck in their future endeavors.

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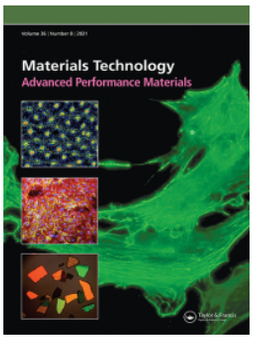

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Grain boundary segregation in a high entropy alloy

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ABSTRACT

Grain boundary (GB) segregation was experimentally studied in a bulk high entropy Cantor alloy, which indicated for the first time that Cr strongly segregates to the GBs along with the weak segregation of Mn, implying co-segregation of Cr and Mn to the GBs. The strong segregation of Cr and weak segregation of Mn are explained in terms of the driving forces for GB segregation, where alloy interaction is favourable and stronger in the case of Cr, while elastic strain energy governs Mn segregation.

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KEYWORDS
Alloy; segregation; grain boundaries

Introduction

High entropy alloys (HEA) and their coatings are of significant interest because of their unique mechanical and high temperature properties [1]. They consist of five or more elements with identical atomic percentages [1–6]. The high entropy term [4,6] comes from their configurational entropy, which is maximum when all elements have identical atomic percentage. In these multi-component HEA systems, grain boundary (GB) segregation can occur, which is important for high-temperature applications. Depletion of elements from bulk can lead to nucleation of stable phases [4]. Multicomponent systems are used for structural components, for instance, in aircraft engines and power-plant turbines. Previous studies on ternary and quaternary systems, CrMoV-, NiCrMoV-power plants steels, conducted by Misra's group, indicated GB segregation of alloying and trace elements involving co-operative and site-competitive interaction processes with impact on mechanical properties [7–15]. The degree of GB segregation and the nature of GB interaction processes were governed by applied stress and rate of cooling after heat treatment.

Based on the above discussion, the objective of the study is to explore GB segregation phenomena in Cantor alloy, Co20Ni20Cr20Fe20Mn20 because it is extensively studied [4,16–21]. To the best of our understanding, we report 'first experimental study' demonstrating GB segregation in bulk HEA. The study will lead to ab-initio design of complex multicomponent systems for high-temperature applications. Furthermore, segregation or depletion of elements at the grain boundary has an important effect in determining if GBs are in equilibrium with minimum GB energy.

Experimental

Cantor alloy was melted using high purity elements in a vacuum induction melting (VIM) furnace and cast in a preheated mould. Prior to segregation experiments, small samples cut from the ingot were homogenized at 1273K for 24 h. An electron backscatter diffraction (EBSD) image of homogenized alloy showing large grain size is presented in Figure 1. Subsequently, they were heated at three different temperatures of 773K, 823K, 873K for 6 h and rapidly cooled to room temperature. We heat treated them for several hours to enhance GB segregation for easy elemental mapping by energy dispersive x-ray spectroscopy (EDS) in scanning electron microscopy (SEM). These temperatures were selected because at low temperatures the face centred cubic (FCC) phase in the Cantor alloy may be unstable [4,22,23]. The polished samples were examined using SEM equipped with EDS. Elemental maps with GB point analysis were obtained to study GB segregation.

Results and discussion

It is pertinent to mention that after homogenization at 1000K for 24 h the grain size was large approaching 1 mm and no segregation of any element was observed. Thus, the data presented below is a true representative of GB phenomena. Figures 2–4 summarize the results

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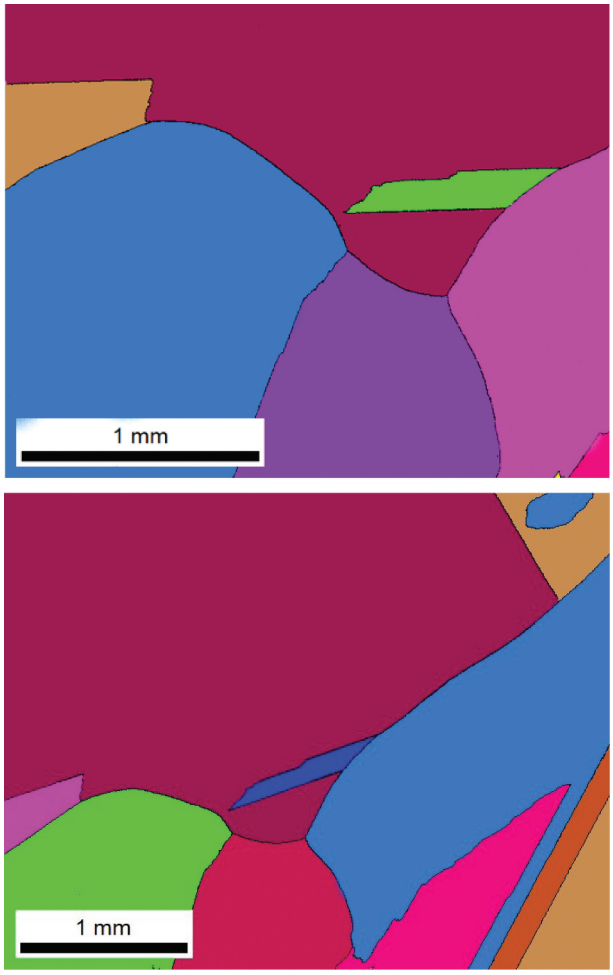

Figure 1. EBSD images of experimental alloy homogenized at 1273K for 24 h.

of three experimental temperatures. Cr segregated strongly to the GBs, while segregation of Mn was weak, and nicely decorated along the GBs with a necklace-type appearance (Figure 2). In Figure 3, an illustration of point analysis at GB is presented. At the GB regions there was a clear depletion of Co, Fe and Ni. To delineate the change in Cr and Mn concentration as a function of temperature, we have plotted Cr/Mn ratio. Cr/Mn ratio at 773K and 823K was similar, but significantly greater at 873K because of greater diffusion at 873K. The data in Figures 2–4 indicate that significant degree of segregation (several monolayers) occurred at the GBs.

The driving force for GB or interface segregation consists of three aspects [4,24]: (a) interfacial energy term, (b) alloy interaction term [4,25] and (c) elastic solute strain energy McLean [4,26]. In a two-component system, the relationship between the atomic fraction of segregant at the GB, x^{gb}, and its bulk atom fraction, x^{b}, is given by [4,24,27]:

$$x^{gb}/\left(1-x^{gb}\right) = x^{b}/\left(1-x^{b}\right)exp\left(-\Delta G_{seg}/RT\right) \quad (1)$$

where ΔG_{seg} is enthalpy of segregation and is driving force for segregation to the GB, R is gas constant and T is absolute temperature. Equation 1 is a relationship between GB segregation and bulk composition and does not take into consideration the mass balance constraint [4,24,27]. Based on three terms of driving force for GB segregation, ΔG_{seg}, segregation can be expressed by [4,24,27]:

$$\begin{aligned}\Delta\ G_{seg} = &\left(\gamma_B - \gamma_A\right)\lambda \\ &+ 2w_{AB}\left[z^{l}\left(x^{b} - x^{gb}\right) + z^{v}\left(x^{b} - 0.5\right)\right] \\ &- F(M)\Delta\ r^{2}\end{aligned} \quad (2)$$

In equation 2, GB or interfacial energy is the first term, where γ_i are the interfacial energies of ith component and λ is molar area. The alloy interaction term is the second term consisting of regular solution constant w_{AB} and is related to the enthalpy of mixing of a binary alloy, z^{l} and z^{v} are the number of bonds of an atom to neighbours that are present either within the same atom plane or in adjacent planes, respectively. The elastic strain energy is the third term comprising elastic moduli function, $F(M)$ and Δr is the difference in atomic radii between the GB segregating element and bulk component [4,24,27].

Our previous studies focused on multicomponent systems consisting of three or more components and indicated that co-operative (co-segregation) and site-competitive processes occur at the GBs [7–15]. Here, site-competitive process occurs between two elements when both have affinity towards the GB but have a mutually repulsive interaction. Under such circumstances, the element with stronger affinity to the GB substitutes or replaces the other. Cooperative process occurs when both the segregating species have different degrees of attraction to the GB such that both the elements are attracted. Thus, in our case, it can be implied that Cr has stronger interaction with the GB, while Mn is weakly attracted to the GB. Considering that Cr was strongly segregated to the GB in comparison to Mn (Figures 2–4), the addition of three terms in equation 2 (ΔG_{seg}) should be more negative for Cr in comparison to Mn, favouring stronger GB segregation of Cr and weaker segregation of Mn.

However, the values reported in the literature for surface energy (Cr = 2006 mJ/m^2, Mn = 1298 mJ/m^2) [4,28] suggest that Mn has lower surface energy. Thus, elastic strain energy in equation 2 depends on the square of the difference in atomic radii between the segregating element and the bulk alloy (r_{Cr}-r_{Cantor} = 0.0019 nm; r_{Mn}-r_{Cantor} = 0.0032 nm, when r_{Cr} = 0.1290 nm; r_{Mn} = 0.1303 nm; r_{Cantor} = 0.1271 nm) [4]. A higher value of r_{Mn}-r_{Cantor} suggests that elastic strain energy favours GB segregation of Mn, followed by Cr [4]. Thus, the two driving forces in equation 2 are expected to favour segregation of Mn rather than Cr. This is contrary to the

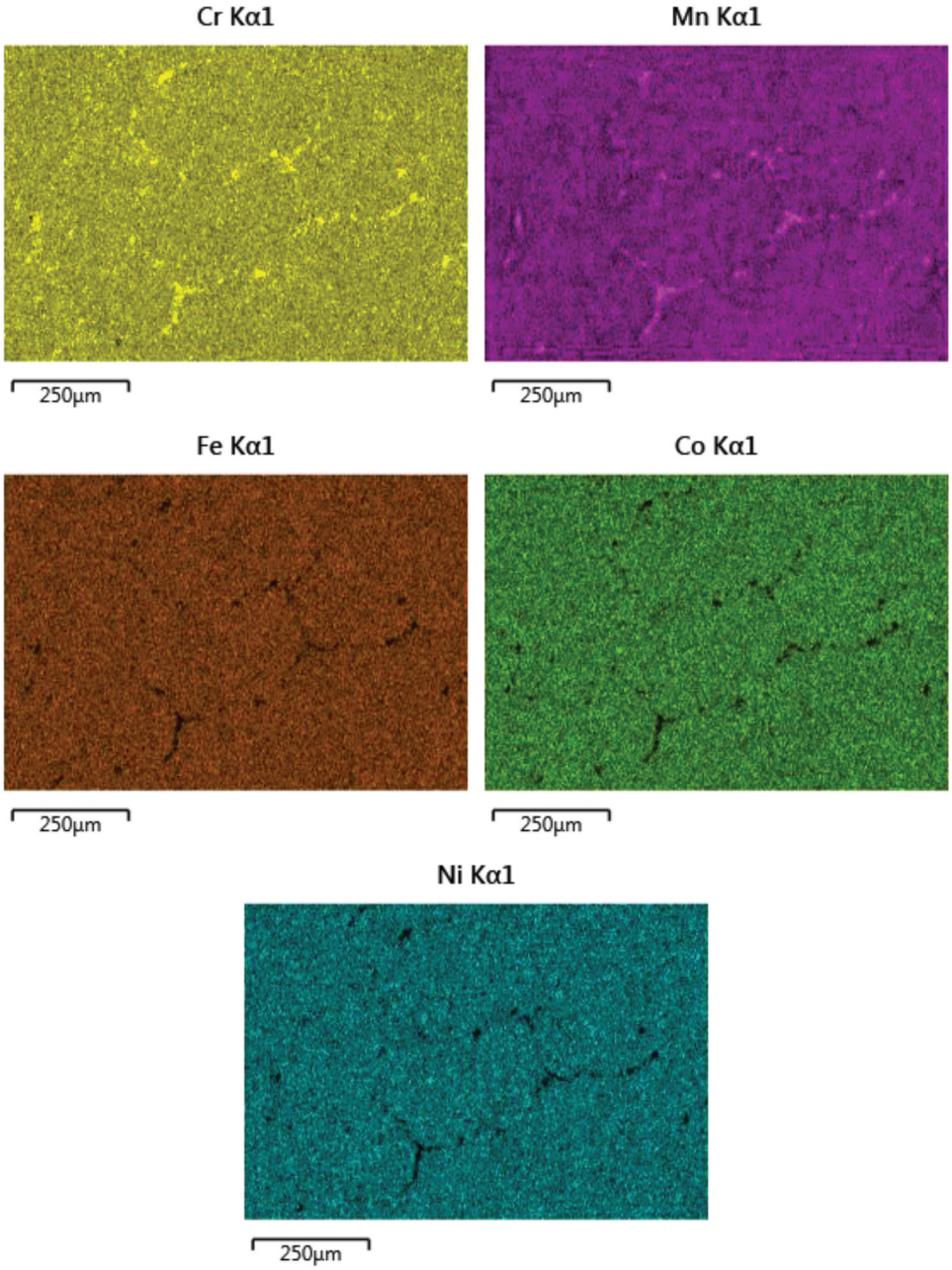

Figure 2. An example of EDS elemental mapping showing stronger GB segregation of Cr, weaker segregation of Mn and depletion of Fe, Co and Ni at the GBs.

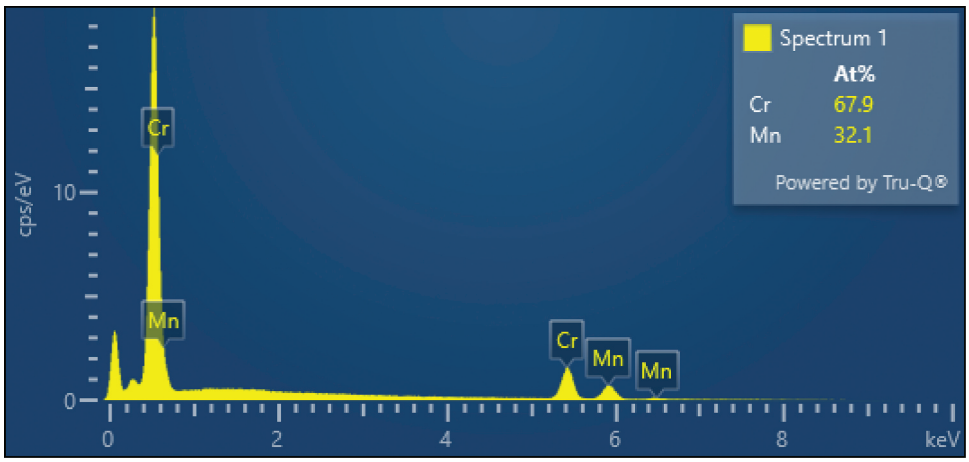

Figure 3. An example of EDS point analysis at the GB showing stronger segregation of Cr and weaker segregation of Mn at the GBs and depletion of Fe, Co and Ni at the GBs in the alloy.

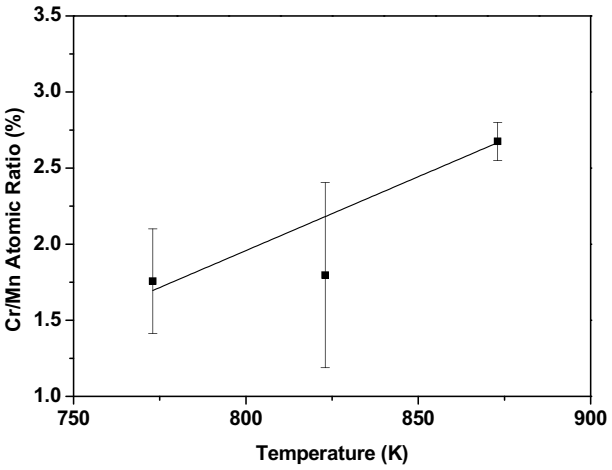

Figure 4. Cr/Mn atomic% ratio as a function of temperature demonstrating stronger GB segregation of Cr and weaker GB segregation of Mn. Bars indicate the range over which the values were observed.

experimental observations. We therefore conclude that greater driving force for GB segregation of Cr must come from the alloy interaction term in equation 2. This is difficult to evaluate because it is governed by the regular solution constant (and bond energy) in equation 2, which is a cumulative contribution of five different elements in the Cantor alloy. Recently, the affinity between Cr-Cr and Mn-Mn atoms was studied in terms of Cr-Cr and Mn-Mn bonds and it was concluded that Cr-atoms are more likely to exhibit GB segregation compared to Mn-atoms, implying that Cr-atoms are expected to segregate where Cr-atoms previously segregated [4]. Based on the above discussion, we conclude that the segregation of Mn is favoured by the GB energy (term 1 in equation 1) and the elastic strain energy (term 3) terms of driving force for segregation, but the observation of stronger GB segregation of Cr is related to greater and dominant interaction energy term 2 in equation 2 of the driving force for segregation. Our observations of segregation of Cr and Mn agree with similar observation on thin film of Cantor alloy deposited on Si tips, followed by the study with atom probe tomography [16].

It is important to mention the consequence of GB segregation on the stability of high HEA and nucleation of phase at the GB. GB segregation of Cr and consequent depletion of Cr in the bulk alloy are envisaged to render the FCC alloy stable and the Cr-rich GB region may act as a potential site for nucleation of Cr-containing phase on heat treatment for extended period [4,22,23].

Conclusions

Stronger GB segregation of Cr and weak segregation of Mn were experimentally observed in the bulk Cantor alloy, i.e. co-operative segregation of Cr and Mn. The differences in the behaviour of Cr and Mn segregation were explained in terms of three constituents of driving force for GB, where strong alloy interaction dominated and favoured GB segregation of Cr, while Mn segregation was favoured by GB energy and elastic strain energy terms of driving force that were less dominant. GB segregation is envisaged to positively impact the stability of the FCC alloy of Cantor alloy, and the GB Cr-rich region may act as a nucleation site for precipitation of Cr-containing phase.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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RESEARCH ARTICLE

Comparative evaluation of native *Trichoderma* species from groundnut rhizosphere against stem rot caused by *Sclerotium rolfsii* Sacc.

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Abstract

Sclerotium rolfsii Sacc. is one of the important soil borne pathogen causing stem rot of groundnut prevalent in all growing area worldwide. The present study aimed on the identification of native *Trichoderma* isolates, and its efficacy against the stem rot pathogen in groundnut at field level. Thirty-five isolates of *Trichoderma* spp. isolated from the groundnut rhizosphere were comparatively evaluated for their biocontrol potential against *S. rolfsii* Sacc. and growth promoting traits in groundnut. The morphological studies of the 35 isolates were supported molecularly by amplifying of ITS region and classified into four species namely, *T. asperellum*, *T. citrinoviride, T. longibrachiatum* and *T. harzianum* which were further subjected to biocontrol efficacy tests. The highly efficient representative isolates namely, *T. harzianum* Thar23, *T. asperellum* Tasp49, *T. longibrachiatum* Tlongi5 and *T. citrinoviride* Tcitri2 were evaluated to produce lytic enzymes and growth promoting traits. The comparative study of these isolates revealed that, *T. harzianum* Thar23 produced significant ($P < 0.05$) amount of lytic enzymes viz., chitinase (31.36 U/ml), β 1, 3 glucanase (4.1 U/ml) and protease (2.76 U/ml). *T. harzianum* Thar23 promotes plant growth traits namely germination efficacy (31.48%), increase in the shoot length (42%) and root length (42.43%), improved vigor index, and increased relative water content (25.56%). Soil application, seed treatment and drenching with the powder formulation of Thar23 in field for the years 2019 and 2020 significantly ($P < 0.05$) reduced stem rot disease incidence to 59.45% and 53.79% and increased pod yield to 2.85 t/ha and 2.68 t/ha respectively. *T. harzianum* isolate Thar23 will help the groundnut growers for eco-friendly management of stem rot disease and increased yield.

Keywords Groundnut · Lytic enzymes · *S. rolfsii* · Stem rot · *Trichoderma* spp.

Introduction

Groundnut (*Arachis hypogaea* L.) is an important food and oil seed crop due to its high protein and oil content. Several biotic and abiotic factors are responsible for dismal productivity. Diseases like stem rot, collar rot, root rot, leaf spot, bud necrosis, etc., are critical. Stem rot is also known as sclerotium blight caused by soil borne fungi *S. rolfsii* causes yield loss over 20–25 percent (Annual Report 2015–16). Under warm and high moisture conditions, white mycelium spread over the plant debris, soil and infect the host. The dark brown sclerotia of the pathogen are hard, spherical and 0.5–1.5 mm in size often found in the infected are of host and soil (Aycock 1966). Though fungicides are effective against pathogens, but they cause adverse effect on the environment thus can be replaced by biocontrol agents.

Trichoderma spp. (Teleomorph: *Hypocrea*) is an omnipresent ascomycetous fungus known for its biocontrol and industrial properties. This fungi were named *Trichoderma* in 1794 (Persoon 1794) and years later in 1865, the sexual stage Hypocrea species was suggested (Tulasne and Tulasne 1865). Diverse species of *Trichoderma* namely, *T. harzianum, T. asperellum, T. viride, T. virens, T. hamatum*

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and *T. atroviride* have been reported as biocontrol agents. *T. reesei, T. parareesei* and *T. longibracheatum* are known for industrial enzyme production. *Trichoderma* species are widely present in the soil rhizosphere and documented for symbiotic relationship with the host roots. Due to the importance of the application of *Trichoderma* spp. as biocontrol agent in field condition, it is necessary to explore its biogeography. There are different studies conducted by the researchers to decipher the diversity of the native *Trichoderma* spp. and its application against major plant pathogens at national (Kumar et al. 2012; Agrawal and Kotasthane 2012; Devi et al. 2021; Manzar et al. 2021; Jambhulkar et al. 2022) and global (Li et al. 2016; Boat et al. 2020; Ma et al. 2020; Nofal et al. 2021). However, there is a need to explore the diversity of the native species at groundnut growing area of Jaipur, a semi-arid eastern plain zone of Rajasthan (Agro-climatic Zone- III-A), India.

There are various biocontrol mechanisms viz., mycoparasitism, antibiosis, induced systemic resistance in *Trichoderma* spp. and also known for production of many lytic enzymes viz., chitinases, glucanases, xylanase and proteases etc., as their primary weapons against the fungal pathogens (Sharma et al. 2014) and induce the systemic defence response by activating defence enzymes like peroxidases (PODs), polyphenol oxidases (PPO) and phenylalanine ammonia lyase (PAL) (Malolepsza et al. 2017). Plant growth promotion is crucial component of *Trichoderma* spp. which helps in improvement of plant growth in terms of increased plant biomass, root and shoot length and grain yield. *Trichoderma* colonizes fully on root tissues and triggers various mechanisms which induce plant growth promotion, facilitate nutrient uptake, induce plant defence mechanisms, helps in rhizosphere construction, increase carbohydrate metabolism, induce of phytohormones, root exudates and photosynthesis in host (Sallam et al. 2019). Among the genus of *Trichoderma* spp., *T. harzianum* is the most researched biocontrol species followed by others such as *T. viride*, *T. asperellum*, *T. hamatum*, *T. virens* and *T. koningii* (Keswani et al. 2014). Species like *T. longibrachiatum* and *T. citrinoviride* needs to be studied for its biocontrol and plant growth promoting capabilities. Therefore, the comparative evaluation of biocontrol efficacy and plant growth promoting traits of native isolates of *Trichoderma* spp. will be helpful in the characterization of biocontrol control agents and potential strains can be utilized at field conditions.

In the present study, we have isolated and characterized native isolates of *Trichoderma* from groundnut rhizosphere and potent isolates were comparatively evaluated to assess biocontrol and plant growth promoting potential against groundnut stem rot pathogen *S. rolfsii* under field conditions.

Materials and methods

Collection and isolation of *Trichoderma* isolates

The 60 rhizospheric soil samples were collected from groundnut growing areas of Jaipur (Agro-climatic Zone- III-A), a semi-arid eastern plain zone of Rajasthan, India. The longitude and latitude of collection locations were recorded and are given Table 1. For the isolation of *Trichoderma* spp., the rhizospheric soil samples were serially diluted on *Trichoderma* selective medium (TSM) (Elad et al. 1981) and incubated at 28 °C ± 1 °C for 4 days. The newly emerging mycelia of fungal colonies were subcultured to fresh potato dextrose agar (PDA) plates and incubated at 28 °C ± 1 °C for 7 days and maintained in potato dextrose agar (PDA) slants at 4 °C for further use in experiment. Culture of *S. rolfsii* was available at Department of Plant Pathology, SKN Agriculture University, Jobner- Jaipur.

Identification of *Trichoderma* isolates

Morphological identification

The purified 35 isolates were identified based on the different morphological characters viz., cultural characters like colour, growth and texture, microscopic features branching of conidiophores, phialides disposition, size and shape of conidia were identified based on the Rifai (1969), Bissett (1984) and Samuels et al. (1999).

Molecular identification

Actively growing *Trichoderma* isolates (5 mm disc) were inoculated into 50 mL potato dextrose broth (PDB) (HIMEDIA Labs, India) and incubated at 28 ± 2 °C for 5–6 days at 180 rpm. The fungal mycelia were harvested using Whatman No. 1 filter paper and washed three times with sterile distilled water. Collected mycelium was grounded finely with liquid nitrogen and stored at − 80 °C till further use. Cetyltrimethyl ammonium bromide (CTAB) method was followed for total fungal DNA extraction (Culling 1992). The internal transcribed spacer (ITS) region was amplified by using universal primers ITS1 (5′-TCCGTAGGTGAACCTGCGG-3′)/ITS4 (5′-TCCTCCGCTTATTGATATGC3′) (White et al. 1990).

PCR reaction mixture was prepared in the final volume of 25 µl containing 2.5 µl of 10X PCR buffer with $MgCl_2$, 1 µl of forward and reverse primer each (10 pM), 0.5 µl of 10 mM dNTP's, 0.5 µl of DyNAzyme II DNA Polymerase (2 U/µl), 2 µl of genomic DNA (50 ng/µl) and 17.5 µl of Molecular biology grade water and amplified by following

Table 1 List of *Trichoderma* isolates along with NCBI accession numbers and morphological specifications

S. no.	Isolate code	Location	Latitude and longitude	NCBI accession number	*Trichoderma* spp.	Morphological characteristics
1	Tasp1	Jobner, Jaipur	26° 58′ 33.6″ N 75° 22′ 10.7″ E	KT426888	Group I—*Trichoderma asperellum*	Colony: dark green Conidiophores: regularly branched, with lateral branches and paired Phialides: whorls of 2–4 phialides, straight, slightly wider in middle than base and ampulliform Conidia: globose to subglobose
2	Tasp2	Durgapura, Jaipur	26° 50′ 41.0″ N 75° 46′ 52.5″ E	KT426889		
3	Tasp3	Bagru, Jaipur	26° 49′ 02.3″ N 75° 33′ 09.8″ E	KT426890		
4	Tasp4	Samod Jaipur	27° 14′ 01.5″ N 75° 46′ 53.1″ E	KT426891		
5	Tasp5	Sambhar, Jaipur	27° 00′ 12.3″ N 75° 11′ 24.7″ E	KT426892		
6	Tasp6	Chaksu Jaipur	26° 35′ 55.6″ N 75° 56′ 27.1″ E	KU170973		
7	Tasp46	Jobner, Jaipur	26° 58′ 59.3″ N 75° 32′ 35.1″ E	MT065825		
8	Tasp47	Chaksu Jaipur	26° 36′ 14.7″ N 75° 55′ 33.1″ E	MT065826		
9	Tasp48	Durgapura, Jaipur	26° 55′ 51.8″ N 75° 45′ 14.2″ E	MT065827		
10	Tasp49	Samod Jaipur	27° 12′ 32.6″ N 75° 46′ 57.5″ E	MT065828		
11	Tasp50	Jobner, Jaipur	26° 59′ 54.9″ N 75° 22′ 06.5″ E	MT065829		
12	Tasp51	Bagru, Jaipur	26° 50′ 08.7″ N 75° 33′ 19.1″ E	MT065830		
13	Thar1	Durgapura, Jaipur	26° 55′ 35.0″ N 75° 42′ 06.1″ E	KT426893	Group II—*Trichoderma harzianum*	Colony: whitish green to pale green Conidiophores: flexuous, branches almost right angled Phialides: whorls of 2–6, ampulliform to laginiform, subulate, short, skittle-shaped, narrower at the base Conidia: globose to subglobose to short obovoid
14	Thar2	Samod Jaipur	27° 11′ 08.5″ N 75° 46′ 59.9″ E	KT426894		
15	Thar3	Jobner, Jaipur	26° 57′ 56.3″ N 75° 22′ 35.9″ E	KT426895		
16	Thar4	Durgapura, Jaipur	26° 50′ 30.0″ N 75° 47′ 00.2″ E	KT426896		
17	Thar5	Jobner, Jaipur	26° 58′ 46.2″ N 75° 22′ 21.1″ E	KT426897		
18	Thar20	Samod Jaipur	27° 11′ 08.5″ N 75° 46′ 59.9″ E	MT065754		
19	Thar21	Durgapura, Jaipur	26° 50′ 46.1″ N 75° 46′ 46.4″ E	MT065755		
20	Thar22	Bagru, Jaipur	26° 50′ 08.7″ N 75° 33′ 19.1″ E	MT065756		
21	Thar23	Jobner, Jaipur	26° 58′ 33.6″ N 75° 22′ 10.7″ E	MT065757		
22	Thar24	Sambhar, Jaipur	26° 52′ 26.2″ N 75° 07′ 38.4″ E	MT065758		
23	Thar25	Chaksu Jaipur	26° 35′ 55.6″ N 75° 56′ 27.1″ E	MT065759		

Table 1 (continued)

S. no.	Isolate code	Location	Latitude and longitude	NCBI accession number	*Trichoderma* spp.	Morphological characteristics
24	Tlongi1	Jobner, Jaipur	26° 93′ 21.6″ N75° 37′ 73.1″ E	KT426898	Group III—*Trichoderma longibrachiatum*	Colony: dark olive green with yellow tinge Conidiophores: long main branches produce only a few side short branches Phialides: laginiform or bottle shaped Conidia: sub-cylindrical with distinct truncate base
25	Tlongi2	Bagru, Jaipur	26° 49′ 02.3″ N 75° 33′ 09.8″ E	KT426899		
26	Tlongi3	Chaksu Jaipur	26° 36′ 14.7″ N 75° 55′ 33.1″ E	KT426900		
27	Tlongi4	Samod Jaipur	27° 12′ 32.7″ N 75° 51′ 31.3″ E	KT426901		
28	Tlongi5	Sambhar, Jaipur	27° 00′ 12.3″ N 75° 11′ 24.7″ E	KT426902		
29	Tlongi25	Durgapura, Jaipur	26° 55′ 35.0″ N 75° 42′ 06.1″ E	MT052706		
30	Tcitri1	Bagru, Jaipur	26° 48′ 20.4″ N 75° 33′ 05.6″ E	MT065795	Group IV—*Trichoderma citrinoviride*	Colony: dusky yellowish green Conidiophores: main branches long and relatively straight Phialides: more elongate, lageniform or narrowly shaped Conidia: less ellipsoidal, apex broadly rounded
31	Tcitri2	Chaksu Jaipur	26° 34′ 58.2″ N 75° 59′ 48.2″ E	MT065796		
32	Tcitri3	Samod Jaipur	27° 12′ 32.7″ N 75° 51′ 31.3″ E	MT065797		
33	Tcitri4	Sambhar, Jaipur	27° 01′ 58.6″ N 75° 18′ 48.0″ E	MT065798		
34	Tcitri5	Jobner, Jaipur	26° 59′ 40.4″ N 75° 20′ 49.4″ E	MT065799		
35	Tcitri6	Durgapura, Jaipur	26° 50′ 24.1″ N 75° 46′ 51.2″ E	MT065800		

protocol: initial denaturation for 1 min at 95 °C, 30 cycles of denaturation for 30 s at 95 °C, primer annealing for 1 min at 60 °C, extension at 72 °C for 1 min and a final extension period for 7 min at 72 °C. The amplified PCR products were electrophoretically separated using 1.2% agarose gel in 1X TAE buffer at 80 V for 1 h. Amplified PCR fragments were visualized in UV light and gel documented. The desired amplified products were gel eluted (GeneJET Gel Extraction Kit, Thermo Scientific™, USA) and sequenced through the Sanger sequencing method (Eurofins Pvt. Ltd). The sequence contig was prepared using CAP3 sequence assembly program and aligned sequence were confirmed with nBLAST (www.ncbi.nlm.nih.gov/BLAST) and submitted to NCBI (http://www.ncbi.nlm.nih.gov/).

Phylogenetic analysis

The phylogenetic tree was constructed by aligning the generated sequences using ClustalW multiple sequence alignment program (Thompson et al. 1994) and MEGA7 software program (Kumar et al. 2016). Maximum Composite Likelihood (MCL) method was used to estimate the pairwise distances and bootstrap method was used to study the nodal robustness with a replication of 1000. The Kimura 2-parameter distance model (Kimura 1980) was used for the construction of maximum-likelihood (ML) tree (Kumar et al. 2016).

Screening for antagonistic activity of *Trichoderma* isolates

Antagonistic activity of different 35*Trichoderma* isolates against groundnut stem rot pathogen *S. rolfsii* was done by dual culture plate method (Dennis and Webster 1971). Seven days old actively growing mycelial disc (5 mm) of *Trichoderma* isolates and *S. rolfsii* were placed on PDA plates opposite from the periphery and plates without *Trichoderma* served as a control and plates were incubated at 28 ± 2 °C for 5–7 days. The percentage of inhibition was calculated by following formula

$$\text{Percentage of inhibition (PI)} = \frac{C-T}{C} \times 100$$

where 'C' is the radial growth of pathogen in the control PDA plate in cm and 'T' is the radial growth pathogen in test plate in cm.

The antagonism level of these isolates was evaluated according to Bell et al. (1982). *Trichoderma* isolates with significant antagonistic potential against *S. rolfsii* were

evaluated for production of lytic enzymes and plant growth promoting traits in groundnut.

Lytic enzymes assay of selected isolates of four *Trichoderma* spp.

Preparation of cell-free culture filtrate

The cell-free culture filtrate from selected isolates *T. harzianum* Thar23, *T. asperellum* Tasp49, *T. longibrachiatum* Tlongi5 and *T. citrinoviride* Tcitri2were prepared using freeze-dried mycelia of *S. rolfsii* as a sole carbon source. Actively grown mycelial mat of *S. rolfsii* was harvested from 7 days old PDB broth and homogenized by using liquid nitrogen. The freeze dried pathogen mycelial powder was stored at − 20 °C. A 5 mm mycelial disc of actively growing selected *Trichoderma* isolates was inoculated in autoclaved 250 ml of minimal synthetic broth (MSB) containing (g/l) $FeSO_4$-0.01, $MnSO_4$-0.01, $ZnSO_4$- 0.01, KCl-0.5, $MgSO_4$-0.5, K_2HPO_4-1.0, $NaNO_3$-3.0; pH 5.5 amended with 1% freeze dried mycelia of *S. rolfsii* and flasks were kept at 28 ± 2 °C at 180 rpm and filtered through Whatman no. 1 filter paper at different time interval from day 1 to 10.

Estimation of chitinase (EC 3.2.1.14)

Dinitrosalicylic acid (DNSA) method was used to estimate the chitinase production from *Trichoderma* isolates. One millilitre of culture filtrate with 0.5 ml of colloidal chitin and 0.5 ml of 1 M sodium acetate buffer was mixed and incubated at 40 °C for 6 h and centrifuged at 12,000 rpm for 5 min at 4 °C. One millilitre of supernatant was mixed with 0.5 ml of DNSA in 1 M NaOH and 0.1 ml of 10 M NaOH and kept at 100 °C for 5 min. The assay mixture was recorded spectrophotometrically at 582 nm and N-acetylglucosamine (GlcNAc) was used as standard. Specific chitinolytic activity was defined as unit of GlcNAc released by 1 ml of enzyme solution under assay conditions.

Estimation of β-1,3-glucanase (EC 3.2.1.39)

β-1,3-Glucanase activity was determined using laminarin as a substrate. The assay mixture contains 0.5 ml of culture filtrate with 1 ml of laminarin in 50 mM acetate buffer (pH 4.8) and was incubated at 50 °C for 10 min. One ml of dinitrosalicylic acid was added to the reaction mixture and kept at 95 °C for 5 min and total amount of reducing sugar was recorded at 540 nm. One unit of β-1,3-glucanase activity was defined as the amount of enzyme required to release one µmol of reducing sugar per minute.

Estimation of protease (EC 3.4.21.4)

Protease activity was determined using 1% casein as substrate in 50 mM phosphate buffer (pH 7.0) was denatured at 100 °C for 15 min in the water bath. The reaction mixture containing 1 ml of casein substrate was added with 3 ml of 10% tricholoroacetic acid (TCA) and kept at 4 °C for 1 h. This mixture was centrifuged at 8000 rpm for 15 min at 4 °C, and supernatant was recorded at 280 nm. One unit of protease activity was defined as the amount of enzyme solution equivalent to release 1 µmol of tyrosine under assay conditions.

Plant growth promoting traits of selected isolates of four *Trichoderma* spp. in groundnut

The plant growth promoting ability of the selected *Trichoderma* isolates in groundnut (RG-510 Spreading variety) was studied under pot conditions. Groundnut seeds were treated with spore suspensions of each selected *Trichoderma* isolates containing 2×10^8spores $ml^{-1}$and were soaked for one hour. Spore suspensions from selected isolates were prepared from PDA plates containing 7 days old cultures of *Trichoderma* by scraping gently on the surface of the plates with sterile distilled water containing 0.01% Tween 20 and filtered through two layers of sterile muslin cloth. The spore concentration was adjusted with the aid of haemocytometer.

Efficacy on seed germination, root, and shoot length and relative water content (RWC)

The germination efficacy of selected *Trichoderma* isolates in groundnut seeds was studied by treating with *Trichoderma* spore suspension (2×10^8 spores ml^{-1}) and transferred to respective pots containing sterile soil along with farm yard manure (FYM) in 10:1 ratio. Seeds treated with sterile water served as control. After 10 days, the number of germinated seedlings in each replication was counted and the germination was calculated and expressed by using the following formula

$$\text{Germination percentage (\%)} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100$$

Groundnut plants (30 days old) were harvested from each treatment and washed three times with sterile distilled water. The root and shoot length were observed and based on the root and shoot length with germination percentage, the vigour index was calculated by using formula given by Abdul Baki and Anderson (1973).

$$\text{Vigour Index (VI)} = (\text{Mean shoot length} + \text{Mean root length}) \times \text{Germination (\%)}$$

To determine relative water content, the harvested plants were air dried and weighed (fresh weight). For dry weight, the plants were kept in hot air oven at 100 °C for 20 min, and then kept at 80 °C for 24 h at oven then weighed and recorded (Tian et al. 2015). Each control and treatment were repeated three times. The following formula was used to determine RWC of shoots and roots.

$$\text{RWC (\%)} = \frac{\text{FW - DW}}{\text{FW}} \times 100$$

where, RWC is relative water content, FW: fresh weight, and DW: dry weight.

Groundnut stem rot management by application of selected isolates of four *Trichoderma* spp. under field conditions

The field experiment was conducted in the randomized block design with three replications in the kharif season of 2019 and 2020 at Agronomy Farm, S.K.N. College of Agriculture, Jobner situated 260 05′ N-latitude and 750 28′ E-longitudes and at an altitude of 427 m above mean sea level in Jaipur district of Rajasthan. The region falls in agroclimatic zone III-a (semi-arid eastern plain), and variety RG 510 was used for both experimental years. The seeds were treated with talc-based bioformulation of different *Trichoderma* isolates at 8 g/kg. The spore concentration of the bioformulation was maintained 2×10^8 CFU/g. The treatment schedule is as follows.

T1—Soil application with *T. asperellum* Tasp49 enriched FYM (10: 200) + seed treatment with *T. asperellum* Tasp49 at 8 g/kg seeds + drenching with *T. asperellum* Tasp49 at 8 ml/l at 40 days after sowing.

T2—Soil application with *T. harzianum* Thar23 enriched FYM (10: 200) + seed treatment with *T. harzianum* Thar23 at 8 g/kg seeds + drenching with *T. harzianum* Thar23 at 8 ml/l at 40 days after sowing.

T3—Soil application with *T. longibrachiatum* Tlongi5 enriched FYM (10: 200) + seed treatment with *T. longibrachiatum* Tlongi5 at 8 g/kg seeds + drenching with *T. longibrachiatum* Tlongi5 at 8 ml/l at 40 days after sowing.

T4—Soil application with *T. citrinoviride* Tcitri2 enriched FYM (10: 200) + seed treatment with *T. citrinoviride* Tcitri2 at 8 g/kg seeds + drenching with *T. citrinoviride* Tcitri2 at 8 ml/l at 40 days after sowing.

T5—Untreated control.

Disease incidence was monitored on a weekly basis by observation of symptoms and was calculated by the following formula

$$\text{Disease incidence (DI) (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

Shelling of the well dried 100 g pods from each treatment was done and recorded weight of kernels and the shelling percentage was calculated by following formula

$$\text{Shelling percentage} = \frac{\text{Kernel weight}}{\text{Pod weight}} \times 100$$

The pod yield was calculated from each treatment separately after threshing, winnowing, and cleaning the produce was weighed and converted in terms of Tones/ha.

Statistical analysis

The normality of the data was checked and found that data are treatment-wise normally distributed. All the treatments replicated thrice in a completely randomized design and the descriptive statistics of the data are presented as mean value ± SD. Significance of mycelial growth inhibition, enzyme production and growth promotion were tested by a one-way analysis of variance (ANOVA). The data were analysed by ANOVA using R-programming language and treatment means were compared using Fisher's Protected LSD test at p = 0.05 (Gomez and Gomez 1984).

Results

Morphological characteristics of *Trichoderma* isolates

Thirty-five isolates of *Trichoderma* spp. were collected from the rhizospheric soil of groundnut growing area of Jaipur District (26.9706° N, 75.3791° E) of Rajasthan, India, which were further morphologically characterized through microscopic studies. Based on morphological features the isolates were classified into four groups I *T. asperellum*, group II *T. harzianum*, group III *T. longibrachiatum* and group IV *T. citrinoviride* (Table 1).The group I consisted of 12 isolates of *T. asperellum* showed dark green and compact colonies on PDA medium with the typically paired and regularly branched conidiophores(Table 1). The conidia were globose to sub-globose in shape with the size of 2.5–3 µm (Fig. 1). A total of 11 isolates of *T. harzianum* in grouped exhibited whitish green to pale green on PDA surface with short branched and irregular conidiophores at right angle. The shape of conidia was globose to sub-globose to short obovoid with size of 1.5–2 µm (Fig. 1). The 6 isolates of group III were yellowish green or dark olive green on PDA plates with short, branched conidiophores, laginiform or bottle shaped conidia on long main branches with the size of

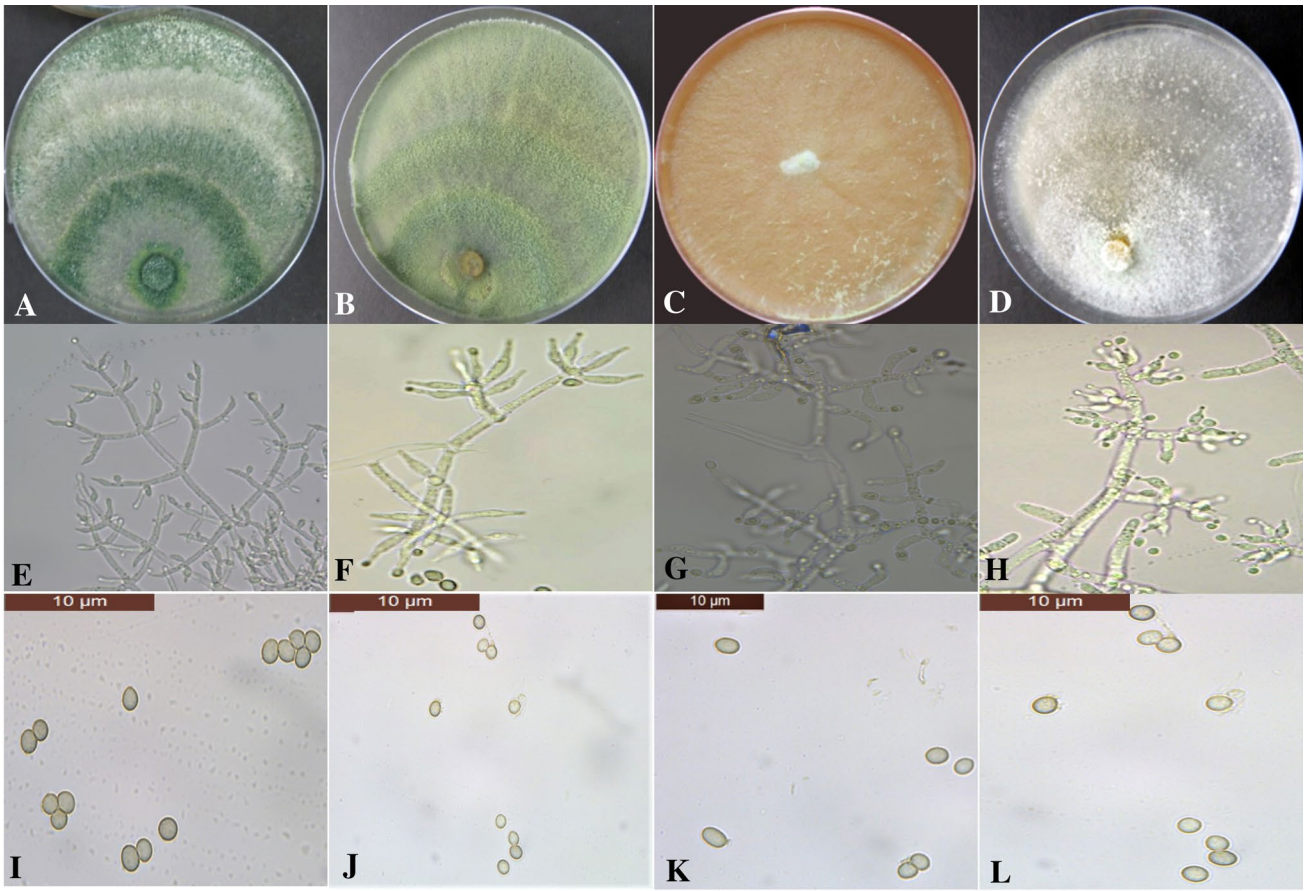

Fig. 1 PDA culture plates showing 7 days old representative isolates of *Trichoderma* spp. **a**, **e**, **i** Showing the growth on PDA, branching pattern of phialides and conidia of *T. asperellum* Tasp49. **b**, **f**, **j** Showing the growth on PDA, branching pattern of phialides and conidia of *T. harzianum* Thar23. **c, f, k** Showing growth on PDA, branching pattern of phialides and conidia of *T. longibrachiatum* Tlongi5. **d, h, l** Showing growth on PDA, branching pattern of phialides and conidia of *T. citrinoviride* Tcitri2 (scale bar 10 µm)

2–2.5 µm were classified as *T. longibrachiatum.* The group IV was classified as *T. citrinoviride* consisted of 6 isolates which showed dusky yellowish green colony on PDA with less ellipsoidal, broadly rounded apex conidia with size of 2–2.5 µm, with relatively straight long branched conidiophores, relatively elongate, lageniform or narrowly shaped phialides (Fig. 1).

Molecular characterization of *Trichoderma* isolates and phylogenetic analysis

A single amplified product around 550-650 bp of all 35 isolates of *Trichoderma* spp. were sequenced and confirmed with BLAST search tool and submitted to NCBI (Table 1). The BLAST analysis was differentiating at species level with homology percentage of 95–99%, and results obtained from phylogenetic analysis of ITS sequences showed that the 35 *Trichoderma* isolates can be separated into four different species with three distinct clades of *Trichoderma* namely (Fig. 2), the Pachybasium A clade (*T. asperellum*), the Harzianum clade (*T. harzianum*), and the Longibrachiatum clade (*T. longibrachiatum* and *T. citrinoviride*). The Pachybasium A clade consists of 12 isolates of *T. asperellum* with a bootstrap value of 98%, the clade Harzianum consisting of 11 isolates of *T. harzianum* supported by bootstrap value of 81%. The closely associated species both *T. longibrachiatum* (6 isolates) and *T. citrinoviride* (6 isolates), fall in the section Longibrachiatum clade with 96% bootstrap value indicating the close relationship of both species (Fig. 2).

Antagonistic activity of *Trichoderma* isolates against *S. rolfsii*

The antagonistic activity of 35 isolates of *Trichoderma* spp. against *S. rolfsii* was evaluated by dual culture assay. Two groups of *T. asperellum* and *T. harzianum* exhibited higher antagonistic activity with the range of 62% to 81.7% against *S. rolfsii*. Group III *T. longibrachiatum* and Group IV *T. citrinoviride* recorded moderate or lower mycelial inhibition from 51.43 to 67.5% (Fig. 3).The degree of antagonism was

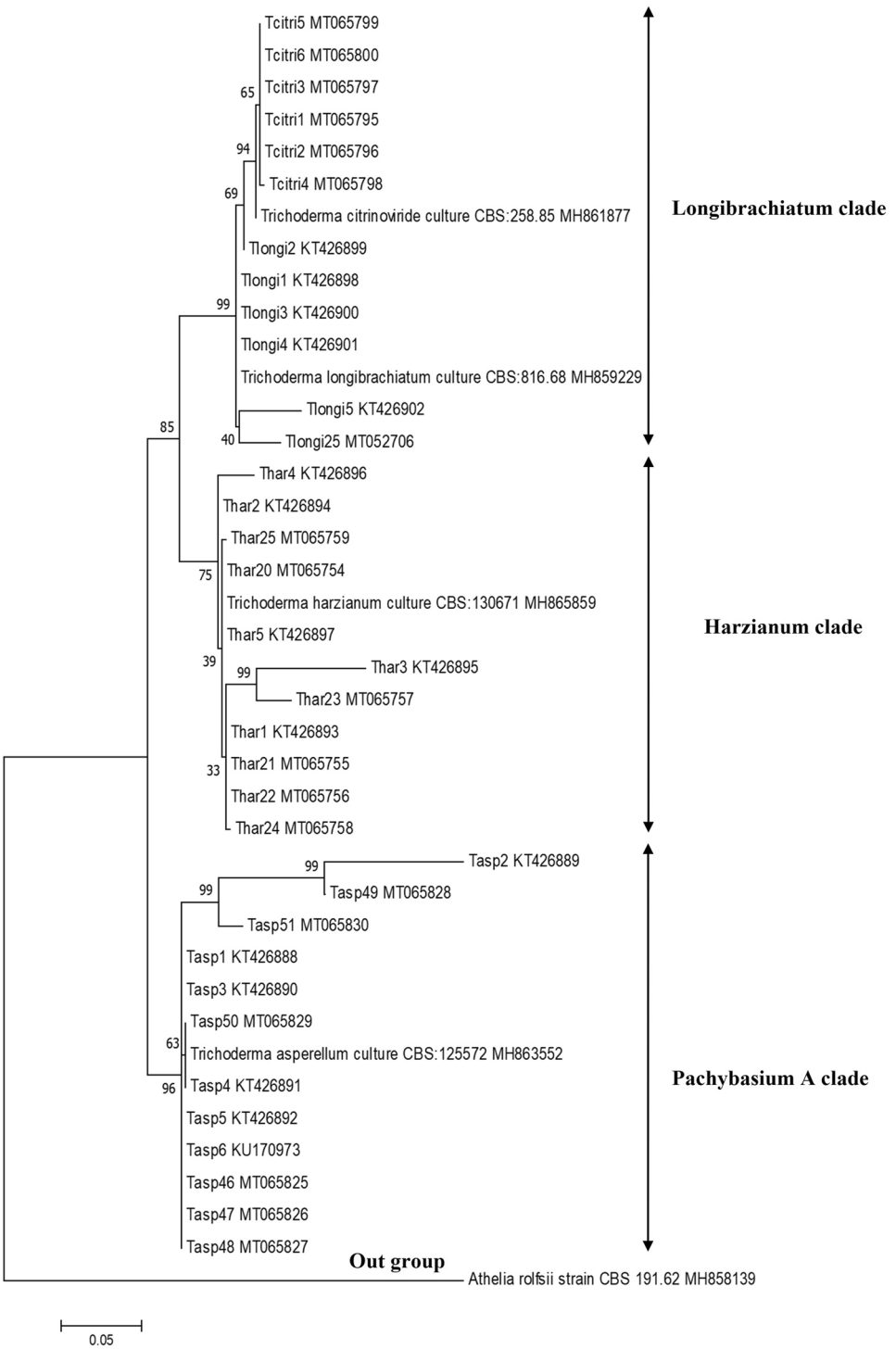

Fig. 2 Phylogenetic relationships of *Trichoderma* isolates inferred by analysis of ITS region and constructed using two parameter model implemented in the MEGA7 inferred by using the Maximum Likelihood method and Tamura-Nei model. Analysis was conducted in MEGA 7 and the percentage of replicate trees in which the associated taxa clustered together in the bootstrap test

measured by the scale described by Bell et al. (1982). Isolates from *T. asperellum* group namely Tasp1, Tasp3, Tasp6, Tasp46 and Tasp49, from *T. harzianum* group namely, Thar1, Thar3, Thar4, Thar5, Thar20, Thar21, Thar22, Thar23, Thar24 and Thar25 exhibited class 1 level of antagonism, whereas isolates like Tasp2, Tasp4, Tasp5, Tasp47, Tasp48, Tasp50 and Tasp51 from *T. asperellum* group, one isolate from *T. harzianum* Thar2, some of the isolates from *T. longibrachiatum* group namely Tlongi1, Tlongi2, Tlongi4, Tlongi5and Tcitri2, Tcitri4 and Tcitri6 from *T. citrinoviride* group expressed the class 2 level of antagonism. Class 3 level of antagonism was observed in Tlongi3 and Tlongi25 from *T. longibrachiatum* and Tcitri1, Tcitri3 and Tcitri5 from *T. citrinoviride* against *S. rolfsii*. Among 35 isolates,

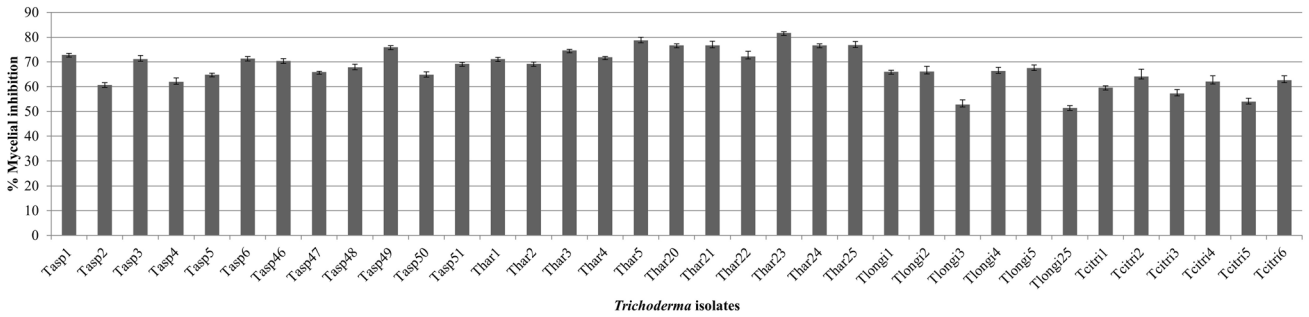

Fig. 3 Per cent mycelial inhibition of *S. rolfsi* by different *Trichoderma* isolates in dual culture assay. Treatment means were compared using Fisher's Protected LSD test (p = 0.05)

the potential isolate from each group namely *T. asperellum* Tasp49 from group I, *T. harzianum* Thar23 from group II, *T. longibrachiatum* Tlongi5 from group III and *T. citrinoviride* Tcitri2 from group IV were selected for the study of lytic enzyme production and plant growth promoting traits in groundnut.

Lytic enzymes assay of selected isolates of four *Trichoderma* spp.

The lytic enzymes like chitinase, β-1,3-glucanase and protease from selected *Trichoderma* isolates were studied by using freeze dried mycelia of *S. rolfsii* in MSB as a source of enzyme production. The enzyme activity from the isolates were gradually increased from day 1 to 7 for chitinase and day 1–6 for β-1,3-glucanase and protease and decreased after day 7. Among the selected isolates, *T. harzianum* Thar23 (31.36 U/ml) significantly produced higher amount of chitinase on day 7 followed by *T. asperellum* Tasp49 (25.26 U/ml) (Fig. 4). The other selected isolates *T. longibrachiatum* Tlongi5 (20.1 U/ml) and *T. citrinoviride* Tcitri2 (17.3 U/ml) exhibited lesser amount of chitinase enzyme activity as compared to other isolates (Fig. 4). Similarly, another lytic enzymes β -1, 3-glucanase and protease are also produced significantly higher 4.1 U/ml and 2.76 U/ml on day 6 by *T. harzianum* Thar23 followed by *T. asperellum* Tasp49 (2.6 U/ml and 2.13 U/ml). The other two selected isolates *T. longibrachiatum* Tlongi5 (1.33 U/ml and 1.16 U/ml) and *T. citrinoviride* Tcitri2 (0.8 U/ml and 0.83 U/ml) showed lesser production of these enzymes compared to other isolates (Fig. 4).

Plant growth promoting traits of selected isolates of four *Trichoderma* spp. in groundnut

The selected isolates were comparatively tested for their growth promoting ability in groundnut under greenhouse conditions. The seeds treated with *T. harzianum* Thar23 and *T. asperellum*Tasp49 significantly increased the germination efficacy to 31.48 and 24.47% and increased the shoot length by 42 and 21.44% and root length by 73.72 and 62.76% compared to control with vigour index of 3598.25 and 3030.65

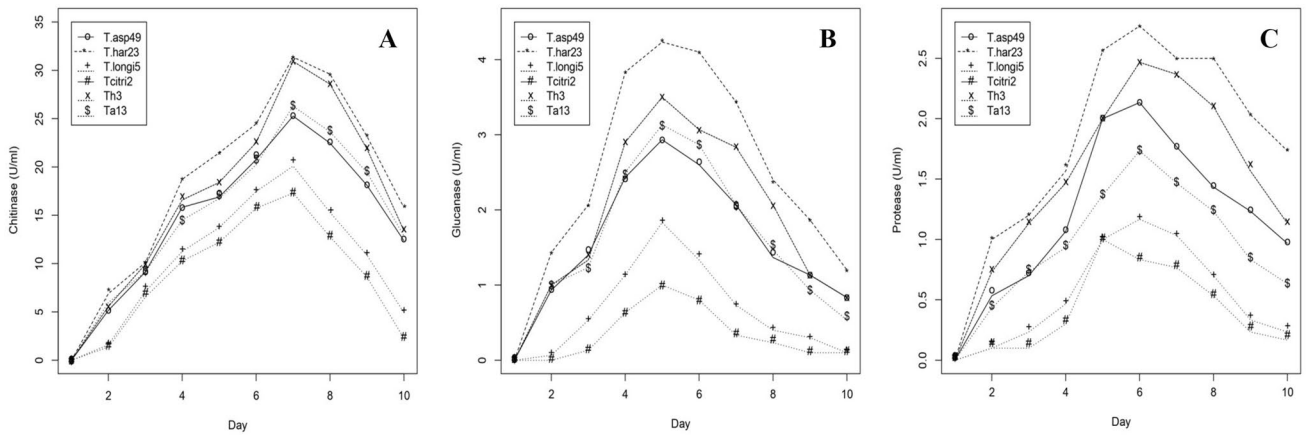

Fig. 4 Lytic enzymes **a** chitinase, **b** β-1,3-glucanase and **c** protease secretion (U/ml) from selected *Trichoderma* isolates at different time intervals

Table 2 Plant growth promoting efficacy of selected *Trichoderma* isolates in groundnut under glasshouse conditions

Trichoderma isolates	Shoot length (in cm)	Root length (in cm)	Germination (%)	Plant vigour index	Relative water content of shoot (%)	Relative water content of root (%)
Tasp49	22.27 ± 1.36^{c}	15.3 ± 0.1^{c}	80.67 ± 0.29^{d}	3030.65 ± 128.31^{d}	75.77 ± 0.02^{d}	77.73 ± 2.38^{d}
Thar23	26.03 ± 0.71^{d}	16.33 ± 0.23^{d}	85.2 ± 0.2^{e}	3598.25 ± 58.05^{e}	78.36 ± 0.27^{e}	81.23 ± 0.59^{e}
Tlongi5	20.36 ± 0.47^{b}	10.8 ± 0.26^{b}	70.33 ± 0.42^{c}	2191.98 ± 35.51^{c}	71.40 ± 0.84^{c}	70.47 ± 0.82^{c}
Tcitri2	19.4 ± 0.46^{ab}	9.37 ± 0.15^{a}	68.23 ± 0.25^{b}	1962.78 ± 20.64^{b}	67.55 ± 0.77^{b}	67.25 ± 1.02^{b}
Control	18.33 ± 0.21^{a}	9.4 ± 0.17^{a}	64.8 ± 0.529^{a}	1797.17 ± 26.98^{a}	66.46 ± 0.64^{a}	60.65 ± 2.71^{a}

Values given in the column are the average of three replications followed by standard deviation. The different small letters (a–e) superscripts within the column are significantly difference at $P \leq 0.05$

(Table 2) and increase in plant biomass in terms of the fresh and dry weight of shoot and root. The RWC of shoot and root treated with Thar23 shown higher (81.23%) than control (60.65%) (Table 2). However, the moderate effect on germination efficacy and plant growth promoting traits was observed in seed treatment with *T. citrinoviride* Tcitri2 as compared to other selected isolates (Table 2).

Groundnut stem rot management by application of selected isolates of four *Trichoderma* spp. under field conditions

Field experiments were conducted to evaluate the efficacy of native *Trichoderma* isolates on stem rot disease incidence, shelling percent and pod yield for the year of 2019 and 2020 kharif season. Soil application, seed treatment and drenching with *T. harzianum* Thar23 and *T. asperellum* Tasp49 significantly ($P < 0.05$) reduced stem rot disease incidence up to 59.45%, 52.01% in 2019 and 53.79%, 48.74% for the year of 2020 and increased pod yield in *T. harzianum* Thar23 (2.85 t/ha and 2.68 t/ha) and *T. asperellum* Tasp49 (2.62 t/ha and 2.55 t/ha) treated plots with increased shelling per cent (Table 3). However, treatment with *T. longibrachiatum* Tlongi5 and *T. citrinoviride* Tcitri2 shows moderate reduction in disease incidence up to 35.11%, 34.16% in 2019 and 34.16%, 33.21% in 2020 with pod yield of 2.13 t/ha, 2.05 t/ha in 2019 and 2.05 t/ha and 1.95 t/ha in 2020 (Table 3). The results obtained from field experiments that indicate the effect of application of *T. harzianum* Thar23 in improvement of the pod yield up to 51.59% and 38.58% during 2019 and 2020 kharif seasons, respectively.

Discussion

The present study was focused on morphological and molecular characterization, antagonistic ability, and plant growth promoting traits in the potential native *Trichoderma* isolates tested against stem rot pathogen *S. rolfsii* of groundnut. The isolates from rhizosphere soil of groundnut were collected and characterized based on the morphological characteristics to identify the species level by using the reference of Rifai (1969), Bissett (1984) and Samuels et al. (1999) and classified in to four groups, namely *T. asperellum* (12), *T. harzianum* (11), *T. longibrachiatum* (6) and *T. citrinoviride* (6). Morphological characterization of native *Trichoderma* isolates has earlier been taken up by several researchers (Rifai 1969; Bissett 1984; Pandian et al. 2016; Devi et al. 2021; Jambhulkar et al. 2022). In addition to supporting the reliability of morphological identification, isolates were further characterized molecularly by amplifying ITS region. Kullnig-Gradinger et al. (2002) described the multigene phylogeny approaches for the evolution of *Trichoderma* spp. by using the ITS1 and ITS2, 28S rDNA, mitSSU, *tef* 1 and ech42 genes. Indian researchers have widely surveyed in different locations of the country and have reported from the different geographical locations like New Delhi (Muthu and Sharma 2011), South Andaman Island (Kumar et al. 2012), Chhattisgarh (Agrawal and Kotasthane 2012), Manipur (Kamala et al. 2015) and Uttarakhand (Manzar et al. 2021), different states of India (Devi et al. 2021). The present study revealed the presence of diverse *Trichoderma* spp. in the rhizosphere of groundnut growing area of Jaipur District of Rajasthan. Mainly *T. asperellum* and *T. harzianum* were found to be dominant species with greater antagonistic potential against a wide range of phytopathogens. Till now, 375 species of *Trichoderma* spp. have been identified and their DNA barcoding information was deposited in the International Subcommission on Taxonomy of *Trichoderma* (ICTT) (http://www.trichoderma.info). The modern *Trichoderma* taxonomy methods help in the precise identification and reorganization of 50 new species of *Trichoderma* per year (Cai and Druzhinina 2021). Similar studies by Manzar et al. (2021) highlighted the phylogenetic relationship among the *Trichoderma* spp. based on the ITS and *tef-1α* sequences. Out of 20 isolates, nineteen isolates belonged to *T. asperellum* as compared to *T. harzianum* (one isolate). With the upcoming trend of development of potential native strains of *Trichoderma* spp. characterization

Table 3 Effect of soil application, seed treatment and drenching with selected *Trichoderma* isolates against *S. rolfsii* in groundnut under field conditions during 2019 and 2020 kharif season

Trichoderma isolates	Per cent disease incidence (PDI)		Reduction over control		Pods per plant		Shelling per cent		Pod yield (t/ha)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Tasp49	18.66 ± 0.50^{c}	20.66 ± 0.66^{c}	52.01^{b}	48.74^{b}	25.33 ± 0.57^{b}	29.00 ± 1.00^{a}	61.43 ± 0.37^{b}	58.76 ± 0.51^{b}	2.62 ± 0.03^{b}	2.55 ± 0.04^{a}
Thar23	15.76 ± 0.66^{d}	18.63 ± 0.51^{d}	59.45^{a}	53.79^{a}	31.00 ± 1.00^{a}	22.33 ± 1.15^{b}	66.06 ± 0.15^{a}	62.16 ± 0.25^{a}	2.85 ± 0.04^{a}	2.68 ± 0.02^{a}
Tlongi5	25.23 ± 0.20^{b}	26.46 ± 0.45^{b}	35.11^{c}	34.37^{c}	20.00 ± 1.00^{c}	15.66 ± 0.05^{c}	54.93 ± 0.56^{c}	51.00 ± 0.20^{c}	2.13 ± 0.03^{c}	2.07 ± 0.05^{b}
Tcitri2	25.6 ± 0.43^{b}	26.93 ± 0.47^{b}	34.16^{c}	33.21^{c}	19.33 ± 1.15^{c}	16.00 ± 0.00^{c}	54.66 ± 0.23^{c}	50.50 ± 0.45^{c}	2.05 ± 0.03^{c}	$1.95 \pm 0.03b^{c}$
Control	38.9 ± 0.65^{a}	40.33 ± 0.41^{a}	–	–	18.66 ± 0.57^{c}	15.33 ± 0.57^{c}	50.7 ± 0.41^{d}	48.76 ± 0.23^{d}	1.88 ± 0.03^{d}	1.84 ± 0.43^{c}

Values given in the column are the average of three replications followed by standard deviation. The different small letters (a–e) superscripts within the column are significantly difference at $P \leq 0.05$

through molecular and morphological tools have become very important step in research.

To further utilize the native strains for biological control, antagonism tests are required to understand the mechanism under in vitro and in vivo conditions. The antagonistic ability of the *Trichoderma* isolates was tested against *S. rolfsii* showed significant reduction in the mycelial growth of pathogen. Significant variation was observed in the isolates from *T. asperellum* and *T. harzianum* while *T. longibrachiatum* and *T. citrinoviride* exhibited moderate efficacy. The CWDEs are specialized group (glycosyl-hydrolases, oxidoreductases, lyases, and esterases) of enzymes produced by *Trichoderma* spp. which are key component against wide range of phytopathogens. Recently Kaur et al. 2021 reported purified proteins both endochitinase and β-1,3-glucanase from *T. viride* isolate T1#3 degrade the hyphae of *R. solani* causing sheath blight in rice. Several research findings stated that the genus of *Trichoderma* is known to produce CDWs like chitinase, β-1,3-glucanase and protease are playing key role in the suppression of the growth of major soil borne pathogens (Guigon-Lopez et al. 2015; Li et al. 2016; Elamathi et al. 2018; Boat et al. 2020; Macena et al.2020). In recent years, green synthesis of nanoparticles by these species made an impact in the agricultural and food sector due to the secretion of bioactive enzymes, metabolites and accumulation of metals are responsible for reduction of metal ions and helping in the formation nanoparticles. Raja et al. 2021 reported that biologically synthesized nanoparticles by using cell free culture filtrate of *T. harzianum* Th3 inhibits the mycelial growth of groundnut root rot complex pathogens by 60–65%. Production of secondary metabolites during mycoparasitism also a pivotal key of *Trichoderma* spp. in the antagonistic mechanism. For example, secondary metabolites like harzianic acid (HA), 6-pentyl-α-pyrone (6PP), koninginin, harzianopyridone and etc. can be correlated with biocontrol mechanisms (Vinale and Sivasithamparam 2020).

Plant growth promoting fungi (PGPF) are majorly associated with wide range of hosts and helps in transformation of soil nutrients, alter the niche of rhizosphere, elucidate the systemic resistance, and improve the plant growth. *Trichoderma* spp. are one of major beneficial fungal community present in the soil environment which directly create an impact on plants such as increased in number lateral roots and length, cumulative root length and root tips, germination efficacy and seeding growth, improved surface area of roots and leaves, wet and dry weight of plant biomass, and positive effect on flowering. And also responsible for elucidation of plant immunity through increasing jasmonic acid (JA), salicylic acid (SA), ethylene (ET), phytoalexin levels and root exudates in plants, soil nutrients solubilization, and nutrient uptake. Some of the *Trichoderma* spp. are rhizospheric competent in nature that can be able to colonize the plant

roots and enter the epidermis and outer cortex of root system (Harman et al. 2004). Recently Nofal et al. (2021) reported that seedling treatment with 10% cell free culture filtrate of *T. atroviride* from rhizosphere of tomato could improve the plant growth and decreased wilt incidence percentage (8%) caused by *Fusarium oxysporum* f. sp. *lycopersici*. The current study also revealed the impact of seed inoculation with selected native *Trichoderma* isolates which helps in improvement of germination efficacy, root, and shoot length in groundnut. The RWC of the root and shoot in treated plants has been increased which indicates the acceleration in the plant growth. Based on the obtained results, the highly efficient strain *T. harzianum* Thar23 exhibits excellent mycelial growth inhibition of pathogen, lytic enzymes production and improve the plant growth could be used against biotic and abiotic stress at greenhouse and field level in pest management practices.

Performance of microbial antagonistic under field condition is one of the important key factors in commercialization of the product at market level. The present findings were in accordance with several research findings stated that the importance of performance of *Trichoderma* spp. against reduction of different pathogen population at field level (Sharma et al. 2012; Jambhulkar et al. 2022). In this present study, there are differences in performance of *Trichoderma* isolates, however treatment with *T. harzianum* Thar23 enhanced groundnut growth, reduction in *S. rolfsii* disease incidence, significant increase in shelling percentage and pod yield among other isolates.

Conclusion

Based on morpho and molecular characterization 35 native *Trichoderma* isolates were grouped into four different *Trichoderma* spp. namely, *T. asperellum* (12), *T. harzianum* (11), *T. Longibrachiatum* (6) and *T. citrinoviride* (6) from rhizosphere of groundnut and screened based on the antagonistic activity against *S. rolfsii.* The potential isolates from each group viz*., T. harzianum* Thar23, *T. asperellum* Tasp49, *T. longibrachiatum* Tlongi5 and *T. citrinoviride* Tcitri2 were selected for lytic enzyme production and plant growth promoting studies in groundnut. The highly efficient isolate *T. harzianum* Thar23 exhibits excellent mycelial growth inhibition of pathogen, lytic enzymes production and improves the plant growth which could be used in biotic and abiotic stress management in groundnut at both green house and field level.

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Declarations

Conflict of interest The authors declare no competing of interest.

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Climate trends and maize production nexus in Mississippi: empirical evidence from ARDL modelling

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Climate change poses a significant threat to agriculture. However, climatic trends and their impact on Mississippi (MS) maize (*Zea mays* L.) are unknown. The objectives were to: (i) analyze trends in climatic variables (1970 to 2020) using Mann–Kendall and Sen slope method, (ii) quantify the impact of climate change on maize yield in short and long run using the auto-regressive distributive lag (ARDL) model, and (iii) categorize the critical months for maize-climate link using Pearson's correlation matrix. The climatic variables considered were maximum temperature (Tmax), minimum temperature (Tmin), diurnal temperature range (DTR), precipitation (PT), relative humidity (RH), and carbon emissions (CO_2). The pre-analysis, post-analysis, and model robustness statistical tests were verified, and all conditions were met. A significant upward trend in Tmax (0.13 °C/decade), Tmin (0.27 °C/decade), and CO_2 (5.1 units/decade), and a downward trend in DTR (− 0.15 °C/decade) were noted. The PT and RH insignificantly increased by 4.32 mm and 0.11% per decade, respectively. The ARDL model explained 76.6% of the total variations in maize yield. Notably, the maize yield had a negative correlation with Tmax for June, and July, with PT in August, and with DTR for June, July, and August, whereas a positive correlation was noted with Tmin in June, July, and August. Overall, a unit change in Tmax reduced the maize yield by 7.39% and 26.33%, and a unit change in PT reduced it by 0.65% and 2.69% in the short and long run, respectively. However, a unit change in Tmin, and CO_2 emissions increased maize yield by 20.68% and 0.63% in the long run with no short run effect. Overall, it is imperative to reassess the agronomic management strategies, developing and testing cultivars adaptable to the revealed climatic trend, with ability to withstand severe weather conditions in ensuring sustainable maize production.

Maize is the most important cereal, known as the "queen of cereals[1]." The United States (US) is the leading producer, followed by China, Brazil, and Argentina[2]. The US contributes 32% to global production, and 60% of total production is exported[2]. Within the US, Mississippi (MS) is the state that contributes 748.3 million USD annually to national maize revenue[3]. Mississippi has 0.64 million acres under maize cultivation[4]. Mississippi has eight of the total twelve soil types, 60% of cropland is irrigated (by center pivot and furrow), and maize is grown on raised beds[5,6]. Mississippi has registered its maize yield progressing at a faster annual growth rate than the US for the past two decades[7]. As a result, MS actual maize yield surpassed the US in 2000; the current yields for MS and the US are 12.51 and 11.87 Mg ha^{-1}, respectively[4]. Over the past half-century, MS has experienced a rapid increase (173%) in the harvested acres for maize compared to the US average (47%)[4]. More intriguingly, MS maize still has a considerable yield gap of 2 to 5.6 Mg ha^{-1}, or 14 to 31%, at the state level when compared to the highest achievable yield under best management practices[7]. Closing these yield gaps is critical for economic benefits, reducing food prices, and consequently improving food security[8]. Strategies to close existing yield gaps via research necessitate a broader understanding of the causal factors and their extent on variations in crop yield[9].

The factors that govern crop production and its variability include genetics, environment, and management such as soil properties, and agronomic management for instance fertilization, irrigation, tillage, planting dates,

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row-to-row width, planting population, planting time, depth, etc.,[10,11]. However, amongst all, the climate is noted to be the major uncontrollable contributor affecting crop production, with the proven potential to explain up to or even greater than 60% of the global crop yield variations[12]. Numerous studies on wheat (*Triticum aestivum* L.)[13–16], maize[17–19] and rice (*Oryza sativa* L.)[20,21] has demonstrated a consensus on crop-climate link in cereals. Based on region-specific studies, the crop-climate association was found to be strong, ranging 22–60%, 40–71.3%, and 67–92% in wheat, maize, and rice, respectively. The same has been confirmed by global studies for other crops as well[22–25]. Specifically, in maize, Rizzo et al.[26] attempted to separate climate, management, and genetic factors and deduced that climate change (48%) explained most of the yield variation, followed by management (39%), and genetics (13%). Given the alarming rate of future climate warming, almost 1.5 °C upsurge, precipitation (PT) irregularities (24–40%) combined with increased carbon emissions, the coefficient of yield dependability on climate is expected to rise further by 47% in 2050[27].

Climatic trends induce biotic and abiotic stresses in plants by controlling microclimates around them, and influence evapotranspiration, gas exchange, resource use efficiency, plant-microbe relations, phenological processes, crop performance, and finally yield[28]. The severity of crop-climate links is determined by the magnitude and trend of change of climatic variables, which vary by region, and such estimates for MS are lacking[29]. Mississippi is in a climatically vulnerable southeastern region of the US, and has a significant agroeconomic impact[30,31]. Also, Mississippi agriculture relies on reduced capital investments and infrastructural inputs, removing several choices for combating climate-related negative consequences[32,33]. Even so, only a few climate-crop studies were conducted so far for MS[34–37], and even fewer on maize[21,38,39]. Therefore, the current study is aimed at calculating (i) the trend in climatic variables, namely, daily maximum temperature (Tmax), daily minimum temperature (Tmin), diurnal temperature range (DTR), precipitation (PT), carbon emissions (CO_2), and relative humidity (RH) in MS during 1970–2020, and (ii) impact of change in these variables on MS maize yield. The novelty of this study lies in investigating climatic variables other than just temperatures and PT, monthly investigations of trends in climatic variables, pinpointing crucial months impacting maize and employing econometric method for the first time to explore crop-climate link in MS.

Methodology

A detailed step-by-step outline of the various methodologies used to accomplish the study's objectives is displayed in Fig. 1. The sections below provide a detailed discussion on the various methodology components, including data, study model specifications, and the estimation procedures involved.

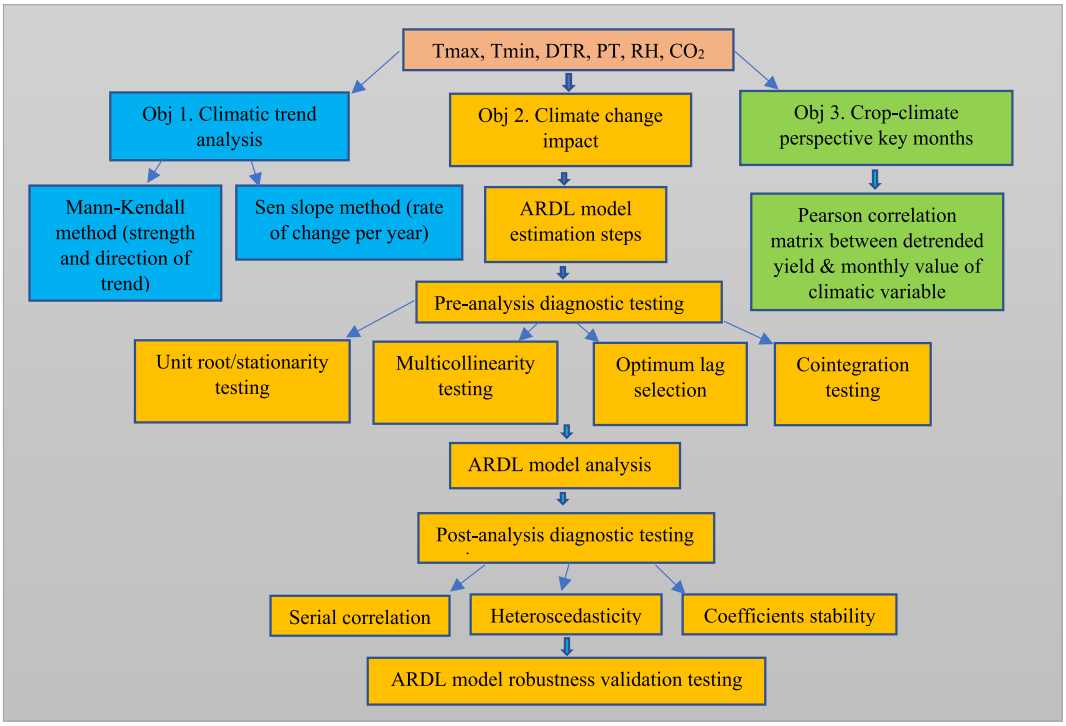

Figure 1. A step-by-step flowchart outlining the detailed methodology for the three different objectives. The first objective—estimating the trend for each of the six climatic variables—maximum temperature (Tmax), minimum temperature (Tmin), diurnal range (DTR), precipitation (PT), relative humidity (RH), and carbon dioxide emissions (CO_2)—is shown in blue boxes on the left, the second objective—quantifying the overall impact of climatic variables on maize yield—are shown in yellow boxes in the middle, and the third objective workflow—identifying the key months for crop-climate linkage—are shown in green boxes on the right.

Data

The present study utilized the past 50 years of time-series dataset for MS (Fig. 2), from 1970 to 2020 similarly to previous studies[12,40–42].

As per World Meteorological Organization guidelines, 30 years (at minimum) dataset is recommended for climatic trend computations[43]. The response variable was maize yield, and the explanatory variables were Tmax, Tmin, DTR, PT, RH and CO_2 (Fig. 1). Harvested area (HA) was included as an input control variable as suggested by Jan et al.[44]. Moreover, following Chandio et al.[40], the Tmax, Tmin, DTR, and RH were averaged, and PT was totaled to maize growing season (MGS) for analyzing the impact of growing season anomalies. Also, the monthly averaged data of each variable was utilized to compute the month-wise climatic impact on maize. The MGS (March-September) was taken as per the USDA harvesting and planting dates handbook. The data on CO_2 was available on a yearly average basis. The data were gathered from the USDA-NASS repository (https://www.nass.usda.gov/) for yield, National Oceanic and Atmospheric Administration (NOAA) database (https://www.noaa.gov/) for Tmax, Tmin, DTR, and PT, PRISM database (https://prism.oregonstate.edu/comparisons/) for RH, and US energy information administration (https://www.eia.gov/environment/emissions/state/) for CO_2. There is a vast literature authenticating the use of time series data and the aforesaid data sources for crop-climate estimations[45–48].

Econometric model specification

The two-dimensional effects of climate change on crops include a short-term effect that is directly impacting the yield in the current and subsequent (residual effect) years[49,50]. This immediate effect accumulates to build the foundation for permanent effects, referred to as long-term effects, that ultimately influence the soil-forming processes, soil properties, microbial buildups in the soil, and nutrient-use abilities[51–53]. Therefore, the study evaluated both the short and long-term relationships between the variables using the widely used auto-regressive distributive lag (ARDL) bound-testing method[44,54–58]. The ARDL model is preferred over other statistical methods because it can efficiently run the analysis for both short-term and long-term relationships simultaneously at ceteris paribus keeping all other variables unchanged[55]. Moreover, the ARDL model accounts for previous year inputs/factors influencing the current year yield, by incorporating the "lag length" component in its functionality[59]. These factors could be residual effects of previous year fertilization especially if a granular form is applied, late season excessive rainfall, or maybe rollover effects of previous crop rotation[60,61]. By regressing the lag values of the regressors against the regressand, the lag length feature statistically advises the ARDL model on how far back in time it needs to go to capture the residual effect[62,63]. The ARDL model works well regardless of the integration level of the time series data *i.e.,* level (I = 0), at first difference (I = 1), or combination of I (0), and I (1)[56]. The ARDL approach is robust against endogeneity issues, which arises when the dependent variable tends to correlate with the error term in the regression model[64], reducing residual correlation, and small sample sizes[54]. The ARDL has an intrinsic feature of error correction model (ECM) that estimates the pace (% per year) with which the short-term effects transfer cumulatively to form permanent basis for the long-term effects[54]. The following linear equation was used to evaluate short-term and long-term association of mentioned variables:

$$Y = f(Tmax, Tmin, DTR, Prec, RH, CO_2, HA) \tag{1}$$

The natural log form variables are suggested for time series data to smoothen multicollinearity and instability issues if any[56].

$$\begin{aligned} lnY_t =& \beta_0 + \beta_1 \ln(Tmax)_t + \beta_2 \ln(Tmin)_t + \beta_3 \ln(DTR)_t + \beta_4 \ln(PT)_t \\ &+ \beta_5 \ln(RH)_t + \beta_6 \ln(CO_2)_t + \beta_7 \ln(HA)_t + \varepsilon_t \end{aligned} \tag{2}$$

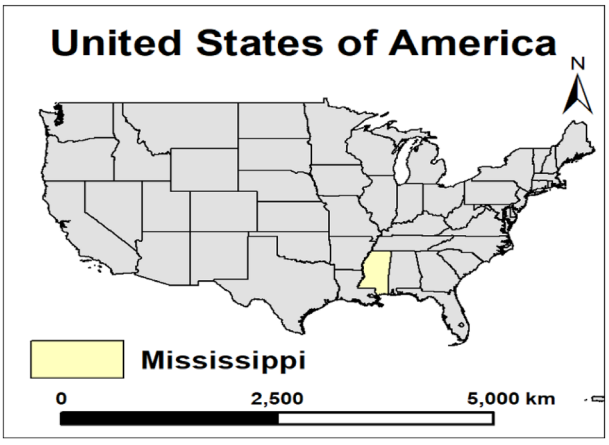

Figure 2. The study area (Mississippi state) highlighted on the USA map.

where, Y_t is maize yield (Mg ha^{-1}) in year ***t***. Tmax, Tmin, and DTR are in (°C), PT in (mm), RH in (%), CO_2 in metric ton, HA is maize harvested in hectares, β_0 is intercept, and $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$ are coefficients of slopes in the function, and ε_t is error term in time *t*.

Auto-regressive distributive lag (ARDL) bound test approach
The ARDL model equation adopted in similar previous studies[44,55,57], is used here as follow:

$$\begin{aligned}\Delta lnY_{it} =& \alpha_0 + \sum_{i=1}^{n} \alpha_1 \Delta \ln(Y)_{t-i} + \sum_{i=1}^{n} \alpha_2 \Delta ln(Tmax)_{t-i} \\ &+ \sum_{i=1}^{n} \alpha_3 \Delta ln(Tmin)_{t-i} + \sum_{i=1}^{n} \alpha_4 \Delta ln(DTR)_{t-i} + \sum_{i=1}^{n} \alpha_5 \Delta ln(PT)_{t-i} \\ &+ \sum_{i=1}^{n} \alpha_6 \Delta \ln(CO_2)_{t-i} + \sum_{i=1}^{n} \alpha_7 \Delta ln(RH)_{t-i} + \sum_{i=1}^{n} \alpha_8 \Delta ln(HA)_{t-i} \\ &+ \sum_{i=1}^{n} \gamma_1 \Delta ln(Y)_{t-i} + \sum_{i=1}^{n} \gamma_2 \Delta \ln(Tmax)_{t-i} + \sum_{i=1}^{n} \gamma_3 \Delta ln(Tmin)_{t-i} \\ &+ \sum_{i=1}^{n} \gamma_4 \Delta ln(DTR)_{t-i} + \sum_{i=1}^{n} \gamma_5 \Delta ln(PT)_{t-i} + \sum_{i=1}^{n} \delta_6 \Delta ln(CO_2)_{t-i} \\ &+ \sum_{i=1}^{n} \gamma_7 \Delta ln(RH)_{t-i} + \sum_{i=1}^{n} \gamma_8 \Delta \ln(HA)_{t-i} + \emptyset(ECT)_{t-i} + \varepsilon_t \end{aligned} \quad (3)$$

where *Y* is maize yield, *t* is the time in year, *i* is the lag order with n is the highest lag value, α_0 is the intercept, Δ denotes the first differencing, ε_t is the error term, α_1 to α_8 represents coefficients of long term cointegration for different variables, γ_1 to γ_8 are short term coefficients for different variables, ECT is the error correction term and $\varnothing$ is its coefficient which determines the pace (% per year) by which short term climatic impacts cumulatively transfer to form basis for permanent long term effects.

The first differencing, as suggested in previous studies[23,65], was applied as a technique to detrend the maize yield to account for the other yield impacting unobserved factors such as advancement in agricultural technology, progression of the adjustments in growers according to the management recommendations, and the infrastructural developments. The data on aforesaid factors was not available. Detrending is widely used in literature to exclude (minimize) the impact of such unobserved variables and to capture the sole impact of climate variables on crop yields[23,65].

Climatic trend analysis

The Mann-Kendall test[66,67] and Sen slope method[68] were employed to time series (1970–2020) data for all study variables to establish the trend on both monthly and growing seasonal timescale (Mar-Sep). Both these non-parametric tests are recommended by the World Meteorological Organization for climatic trend estimation[69]. The Kendall tau computes the direction and strength of the trend where positive sign of the coefficient indicates increasing (upward), negative sign signifies decreasing (downward) trend, and the magnitude of 0–0.25 (weak), 0.26–0.50 (fair), 0.51–0.75 (moderate), and values above 0.76 (strong) signifies the strength of the trend[70–72]. However, the Sen slope coefficient indicates the rate of change per year. For more detailed understanding on methodology of both these tests, readers are suggested to read Gocic and Trajkovic[73] or Gujree et al.[74] procedures.

Estimation procedures

Unit tests
Units root problem arise when the mean, variances, and co-variances are time dependent or non-constant during the study timeframe[75]. Usually, unit root problems (non-stationarity) exist with time series data, if it exists, can cause spurious regression[76]. When a single coefficient fails to accurately reflect the true relationship between the study variables, false regression occurs, and the conclusions drawn may be untrue[76]. Hence, the Augmented Dickey-Fuller (ADF)[77] and the Phillips–Perron tests (PP)[78] unit root tests were performed. The results revealed that all the variables were stationary at level or first differencing, fulfilling the assumption of ARDL bound testing model (Table 1A).

Multicollinearity testing
Analyses involving multiple variables may be susceptible to multicollinearity due to the propensity of variables to become correlated with one another[79]. To avoid overfitting in a regression model caused by multicollinearity, either the variables exhibiting it should be eliminated, or it needs to be verified that the data is free of multicollinearity, using tests such as the variance inflation factor (VIF) test and tolerance test[80]. The present study performed both these tests and found that the VIF value (3.45) and tolerance value (0.30) were within the permissible limits (Table 1B); VIF < 10 and tolerance value (TOV) > 0.1[42,79,80], confirmed that multicollinearity was not an issue with the dataset (Table 1B).

Variables	ADF		PP		
	Level	First difference	Level	First difference	
(A) Unit root test results following Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests of variables including maximum temperature (Tmax), minimum temperature (Tmin), carbon dioxide emission (CO_2), harvested area (HA), precipitation (PT), and maize grain yield (Y)					
Tmax	−6.276***		−10.036***		
Tmin	−6.340***		−10.580***		
CO_2	−2.256	−8.400***	−2.264	−8.357***	
HA	−3.237	−8.323***	−3.170	−10.284***	
PT	−6.317***		−6.287***		
Y	−7.058***		−7.054***		
Variable	**Variance inflation factor (VIF)**	**Tolerance value (TOV)**			
(B) Multicollinearity test results based on variance inflation factor (VIF) and tolerance value (TOV) tests of variables including maximum temperature (Tmax), minimum temperature (Tmin), carbon dioxide emission (CO_2), harvested area (HA), and precipitation (PT)					
Tmax	4.512	0.221			
Tmin	4.126	0.242			
CO_2	3.207	0.312			
PT	2.475	0.404			
HA	2.937	0.340			
Mean value	3.451	0.304			
Lag	**SMLR**	**FPE**	**AIC**	**SIC**	**HQ**
(C) Model's lag selection criterion using sequential modified statistics test (SMLR), final prediction error (FPE) test, Akaike information criterion (AIC) method, Schwarz information criterion (SIC) method, and Hannan-Quinn information criterion (HQ) method					
0	NA	8.36e-13	−10.783	−10.544	−10.693
1	177.455	4.28e-14	−13.768	−12.099*	−13.142*
2	37.853	7.06e-14	−13.350	−10.249	−12.188
3	26.476*	3.42e-14*	−14.295*	−9.7631	−12.597
4	67.775	7.43e-14	−13.990	−8.0276	−11.756
Test Statistic	**Value**	**Significance (%)**	**Level I (0)**	**First difference I (1)**	
(D) The ARDL bounds cointegration test results					
F-statistic	7.228	10	2.08	3	
		5	2.39	3.38	
		1	3.06	4.15	

Table 1. Pre-analysis diagnostic testing. "***"shows the significance level at 1%. *Indicates lag order selected by the criterion, SMLR: sequential modified likelihood ratio test statistic, FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion, and each test at 5% level of significance.

Optimum lag selection

The ARDL model can determine the number of prior years to include in the model for regressing the explanatory variables (including their lag values) against the regressand (current year yield) by using the optimal lag number, to incorporate the previous years' residual effects on current year maize yield[55]. The study used statistical tests such as Sequential modified likelihood ratio (SMLR) test, final prediction error (FPE) test, Akaike information criterion (AIC) method, Schwarz information criterion (SIC) method, and Hannan-Quinn information criterion (HQ) method, as guided by Agbenyo et al.[57], and Warsame et al.[55], to select optimum lag length for the model.

The appropriate lag length for the ARDL model was determined to be three (Table 1C), based on the minimum value generated by majority of the tests (SMLR, FPE, and AIC) utilized. The lag length of three signifies that the previous three years data needs to be considered to regress against the regressand for capturing residual effects.

Cointegration testing

The Wald F-test was used for the null and alternative hypotheses testing after running a regression to check for the existence of cointegration between regressors and regressand[44]. The two types of threshold values were produced, the upper bound threshold values were termed I (1), and the lower bound threshold values were termed I (0). The null hypothesis is accepted if the Wald F-statistics value is less than the lower bound (at I = 0) threshold value, indicating no relationship present between the regressand and regressors[41]. However, the null hypothesis is rejected if the Wald F-statistics value is higher than the upper bound (at I = 1) threshold value, indicating the presence of a relationship between the regressand and regressors[41]. The Wald F-test value (Table 1D) was estimated as 7.228, which, at the 1% significance level, was higher than the upper critical limit (4.15). The absence

of cointegration was thus ruled out as the null hypothesis, and the presence of cointegration was determined at a 1% level of significance.

Post analysis diagnostic tests, and sensitivity/robustness check of ARDL model

After the ARDL model estimation, the study performed Breusch-Godfrey LM test (for serial correlation check), Breusch–Pagan–Godfrey test (for heteroscedasticity check), and cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) of recursive residuals tests (for stability check of the model coefficients), as suggested by the previous studies[58].

The results confirmed that the functional model was free from serial correlation and heteroskedasticity (mis-specifications) issues (Table 2A). The CUSUM and CUSUMSQ test graphs found that the parameter plot lines were consistent, stable, and stayed within critical bounds at the 5% level of significance (Figs. 3 and 4). Hence, confirming the accuracy and stability of short and long run model coefficients that affected the MS maize yield from 1970 to 2020. The CUSUM test can identify systematic, whereas the CUSUMSQ test identifies rapid and drastic variations from the constancy of the model coefficients[81].

After confirming the ARDL model's goodness of fit and predictive effectiveness by running post-analysis diagnostic tests, the sensitivity analysis was carried out using the fully modified ordinary least square (FMOLS) model to examine the robustness of the ARDL model functionality in long run. The FMOLS model showed that Tmax and PT had a negative impact on maize yield while Tmin and CO_2 had a positive impact (Table 2B). These results are consistent with the long-run coefficients of the ARDL model, further validating the robustness of the model recommendations.

Test	Statistics	Probability		
(A) Diagnostic test results following Breusch–Pagan–Godfrey test, Breusch-Godfrey LM test, cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) of recursive residuals tests, for the error terms of the regression equation obtained based on the ARDL model output				
BPG test for Heteroskedasticity	0.532	0.919		
BG LM test for Serial Correlation	0.841	0.443		
CUSUM	Stable	Figure 3		
CUSUM Squares	Stable	Figure 4		
Variable	**Coefficient**	**Std. error**	**t-Statistic**	**Prob**
(B) Results of fully modified ordinary least square (FMOLS) model for confirming the robustness and validation of the study model				
Tmax	−14.133	4.073	−3.469***	0.001
Tmin	7.735	2.524	3.064***	0.004
CO_2	1.374	0.574	2.396**	0.021
HA	0.252	0.115	2.180**	0.035
PT	−1.253	0.438	−2.858***	0.007
C	26.614	10.959	2.429**	0.019
R-square	0.828			
Adjusted R-square	0.808			

Table 2. Post analysis diagnostic testing. Tmax represents maximum temperature, Tmin: minimum temperature, CO_2: carbon emissions, HA: harvested acres for maize, and PT: precipitation.

Figure 3. Cumulative sum (CUSUM) plot of recursive residuals of ARDL model with 95% confidence interval around the null.

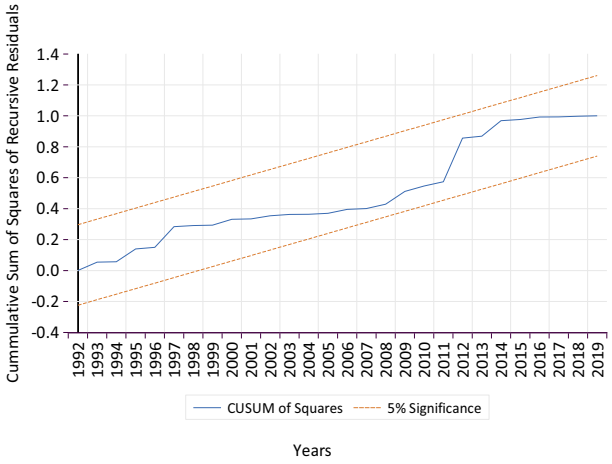

Figure 4. Cumulative sum (CUSUM) of squares Plot for recursive residuals of ARDL model with 95% confidence interval around the null.

Pearson's coefficient of correlation matrix

Pearson's coefficient of correlation between detrended (first differenced) yield and monthly averaged value of each climatic variable, as suggested by Eck et al.[82], was calculated. Based on the strength of correlation, the months that had the greatest impact on maize yield were pinpointed.

Results and discussions

The final regression fit equation used by the ARDL was a reduced model, which excluded DTR and RH since they were found to be non-significant and reducing the overall predictive efficiency of the model. Hence, the pre and post diagnostic tests (Tables 1, 2)—all of which were based on the ARDL model's assumptions—were only carried out for the variables that were part of the ARDL model. However, all variables were included for climatic trend analysis, and for calculating the Pearson's correlation between detrended (first differenced) yield and monthly averaged values of climatic variables (Tables 3 and 4B).

Climatic trend analysis

Tmax increased by 0.13 °C per decade in MGS, while Tmin increased by 0.27 °C per decade, which is 107.67% faster than Tmax (Table 3). Other studies have found similar unsymmetric Tmin-Tmax warming rates[83–86].

	Tmax		Tmin		DTR		PT		RH		CO_2	
Series\test	Kendall tau	Sen slope	Kendall tau	Sen slope	Kendall tau	Sen slope	Kendall tau	Sen slope	Kendall tau	Sen slope	Kendall tau	Sen slope
March	0.139	0.032	0.146	0.030	0.012	0.001	−0.095	−0.193	0.047	0.021	–	–
April	0.014	0.003	0.101	0.015	−0.078	−0.008	0.090	0.194	0.157	0.060	–	–
May	0.103	0.012	0.178	0.022	−0.092	−0.009	−0.087	−0.183	0.003	0.000	–	–
June	0.051*	0.007*	0.373***	0.035***	−0.261**	−0.028**	0.095	0.163	0.125	0.036	–	–
July	−0.006	−0.001	0.262**	0.024**	−0.401***	−0.031***	0.119	0.147	0.068	0.022	–	–
August	0.066*	0.009*	0.299**	0.027**	−0.201*	−0.019*	0.158	0.269	−0.009	−0.004	–	–
September	0.143	0.021	0.183	0.027	0.006	0.001	−0.063	−0.112	−0.110	−0.060	–	–
MGS	0.176*	0.013*	0.422***	0.027***	−0.252**	−0.015**	0.057	0.432	0.027	0.011	0.669***	0.514***
Mean	28.56 °C		16.02 °C		12.54 °C		48.49 mm		66.73%		53.58 million metric tons (Mmt)	

Table 3. The summarized results of the Mann–Kendall test and the Sen slope method for trend estimation of variables including maximum temperature (Tmax), minimum temperature (Tmin), diurnal temperature range (DTR), precipitation (PT), relative humidity (RH), and carbon dioxide emission (CO_2) in Mississippi from 1970 to 2020. Kendall tau negative (−) value signifies downward (decreasing) trend, and positive (+) value indicates upward (increasing) trend with its value ranging between -1 and 1, and its absolute value signifies the strength of the trend. As the absolute value of Kendall tau approach 1, the strength of the trend becomes strong. The Sen slope value represents the rate of change (of variable) per year. Kendall tau is a pure number (unitless) as it is a correlation coefficient and Sen slope units are °C/year (for Tmax, Tmin, and DTR), mm/year (for PT), percentage/year (for RH), and Mmt/year (for CO_2). The negative (−) value of Sen slope means the rate of decrease per year while the positive (+) value represents the rate of increase per year. Significance: "*" $p < 0.05$, "**" $p < 0.01$, and "***" $p < 0.001$.

Variable	Coefficient	Std. Error	t-Statistic	Prob	
(A) Calculated ARDL model estimates for short and long run effects of Tmax, Tmin, CO_2, HA, and PT on maize yield (dependent variable)					
ARDL model long run effects					
Tmax	−26.330	9.169	−2.872***	0.008	
Tmin	20.684	6.731	3.073***	0.005	
CO_2	0.629	0.976	0.644**	0.032	
HA	0.155	0.154	1.007	0.323	
PT	−2.696	0.983	−2.742**	0.011	
ARDL model short run effects					
Tmax	−7.392	2.074	−3.563***	0.001	
Tmin	2.361	1.340	1.760	0.091	
CO_2	−0.061	0.623	-0.098	0.922	
HA	0.018	0.093	0.198	0.844	
PT	−0.645	0.249	−2.587**	0.016	
C	44.329	25.660	1.728**	0.096	
ECM	−0.302	0.038	−7.892***	0.000	
R square	0.834				
Adjusted R square	0.766				
	Climatic variables				
Growing season months	**Tmax**	**Tmin**	**DTR**	**PT**	**RH**
(B) Pearson's correlation matrix between the first differenced (detrended) yield and climatic variables (Tmax, Tmin, DTR, PT, RH) based on each month of MGS					
March	0.248	0.228	0.013	−0.251	0.103
April	0.062	0.129	−0.107	0.024	0.248
May	0.173	0.240	−0.123	−0.143	−0.024
June	−0.001**	0.485***	−0.420**	0.267	0.226
July	−0.159***	0.314*	−0.472***	0.132	0.190
August	−0.000	0.354**	−0.319*	−0.323*	0.022
September	0.213	0.231	−0.019	−0.098	−0.126

Table 4. Impact of climate change on maize yield. "*" $p < 0.05$, "**" $p < 0.01$, and "***" $p < 0.001$. Tmax represents maximum temperature, Tmin: minimum temperature, DTR: diurnal temperature range, CO_2: carbon emissions, HA: harvested acres for maize, PT: precipitation, and ECM: error correction model. Significance codes: "*" $p < 0.05$, "**" $p < 0.01$, and "***" $p < 0.001$.

There was an upward trend for Tmax for MGS, specifically for June and August, but it was weak, as magnitude of correlation strength was less than 0.25 (Fig. 5A; Table 3). July was the only month that experienced a Tmax decreasing trend (Fig. 5A), yet non-significant (Table 3).

In contrast, MGS shows an upward trend for Tmin, increasing by 0.27 °C per decade in the last five decades (Fig. 5B; Table 3). Tmin warming rates ranged between 0.24 and 0.35 °C per decade in June, July, and August of MGS (Table 3). June, Tmin had the greatest rise, adding 0.35 °C per decade to global warming (Table 3). The equivalent rising trends were seen by Eck et al.[82] and Sharma et al.[87] in MGSs in the southeastern part of the US.

In recent years, the DTR (Tmax-Tmin) has been recognized as another climatic variable that is essential for diagnosis, particularly under rising unsymmetrical warming scenarios[88,89]. There was a downward trend for DTR in June, July, and MGS, and a weak trend for August (Fig. 5C). In MGS, the DTR decreased by 0.15 °C per decade, but in June, July, and August, it decreased by 0.19–0.31 °C per decade (Table 3). These rates are comparable with the computations of Sun et al.[90] for the other maize-growing regions.

Precipitation and RH, neither for MGS nor for any other month were found to indicate a significant trend line (Figs. 5D, 6A), although numerically, a negative trend was noted in March, May, and September for PT and August and September for RH (Table 3).

A moderately strong and significant upward trend and an annual increase rate of 0.51 units was noted for CO_2 (Fig. 6B; Table 3). The same is corroborated by Rahman[91] and Wu et al.[92] previously in the context of direction and strength, and by Ainsworth et al.[93] in the context of rate of increase.

The climatic impact on maize

The Tmax was found to have a significant negative effect on maize yield in both the short and long run (Table 4A). More specifically, every 1 °C rise in Tmax reduced the maize yield by 7.39% and 26.33% in the short and long run, respectively (Table 4A).

On further downscaling the analysis to monthly basis to capture the effect of within season variability, it was noted that the monthly averaged Tmax of June and July had a significantly negative correlation with maize yield (Table 4B). This indicates that Tmax in June and July (reproductive-early grain filling stages) contributed the

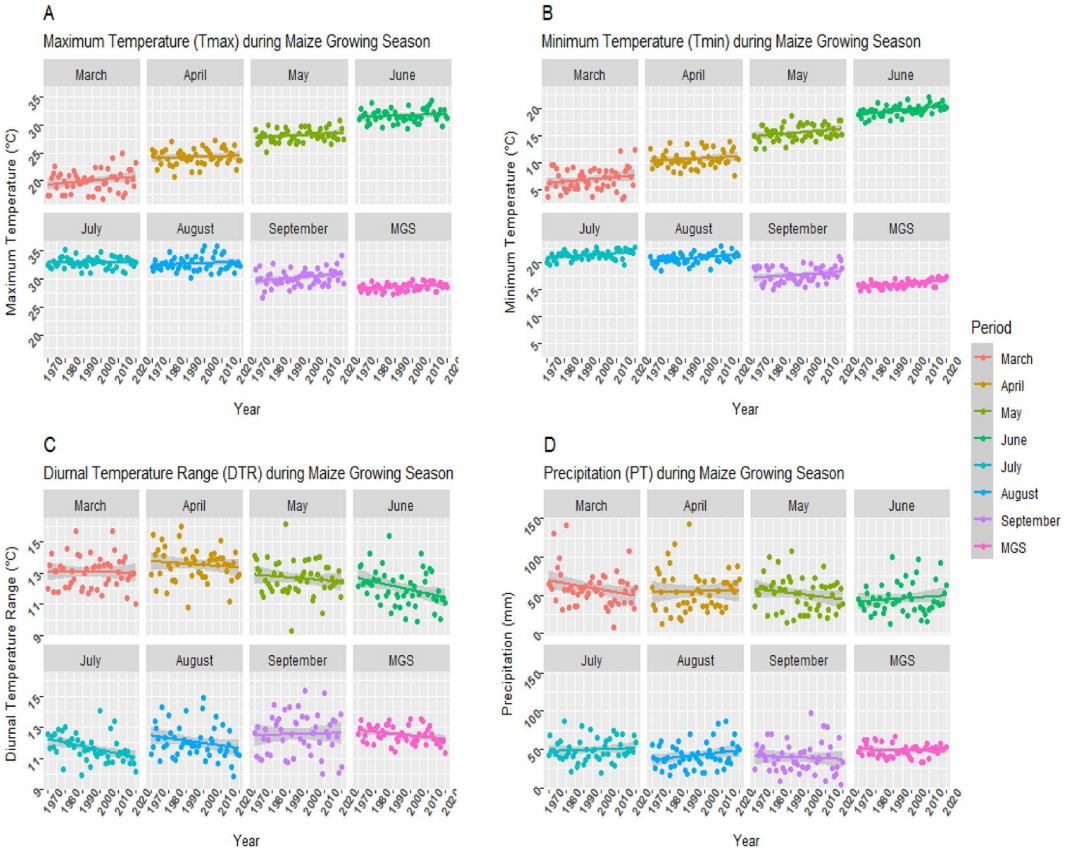

Figure 5. Trend lines for Tmax (**A**), Tmin (**B**), DTR (**C**), and precipitation (**D**) for maize growing season (MGS) and its individual months from 1970 to 2020 in Mississippi. Each figure is faceted by months from March to September and average of all months all together in MGS.

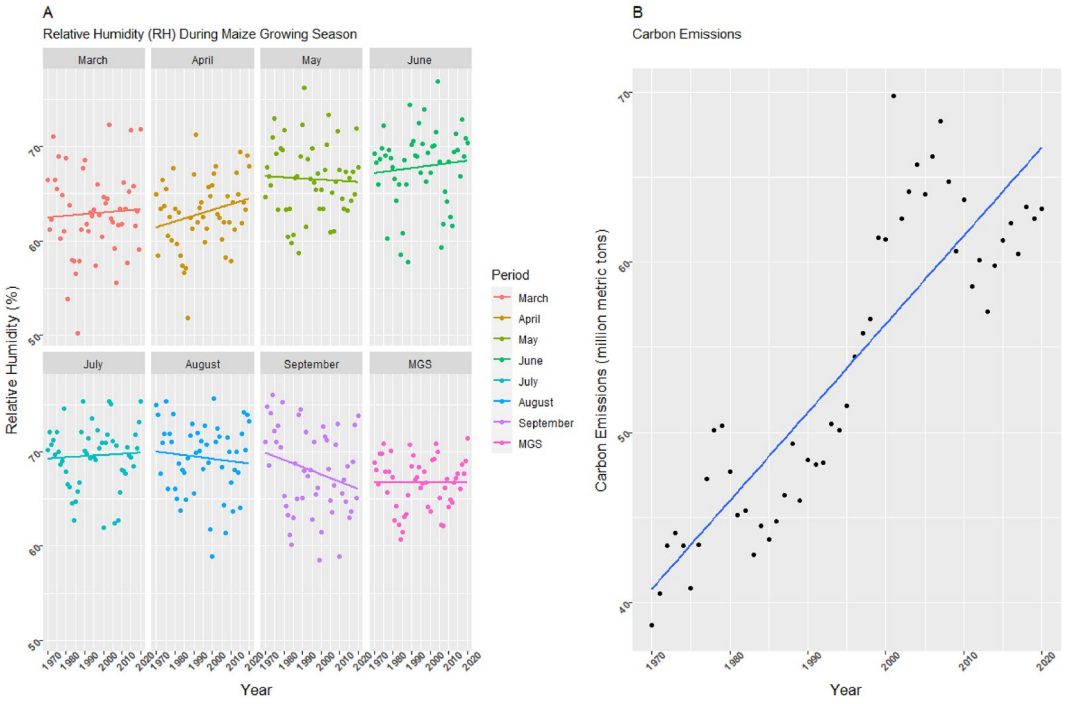

Figure 6. (**A**) Trend lines for relative humidity for maize growing season (MGS) and its individual months from 1970 to 2020 in Mississippi. (**B**)Trend line for CO_2 emissions for years from 1970 to 2020 in Mississippi. Figure A is faceted by months from March to September and average of all months all together in MGS.

most to yield loss in MS. This is because in reproductive stage, stress-induced plant dysfunction has irreparable harm on kernel development and yield which is not the case with the vegetative phase[94,95]. These findings are consistent with those of Kucharik and Serbin[17] in the context of highly correlated months with respect to maize growing season and to those of Lobell and Field[23], and Wu et al.[92] in the context of Tmax's adverse effects. Hu and Buyanovsky[96] reported that maize needs both a warming trend with temperatures higher than average in April and May to provide better conditions for germination and emergence and a cooling trend with temperatures lower than average in June-August to promote reproductive success and, consequently, yield. This statement is largely agreed with by Lobell and Asner[97] as well. However, MS had not seen any significant warming trend in April and May; instead, it showed an unfavorable significant warming trend in June and August (Table 3). Contrary to favorable conditions, MS was observed to have temperatures that were below average (28.56 °C) in April (24.24 °C) and May (28.13 °C) and above average in June (31.66 °C) and August (32.78 °C) (Table 3). The Mid-MGS (*i.e.*, the beginning reproductive stage) coincides with June and July (hotter climate), which affects tasseling and grain filling, thereby yield, and is sensitive to additional warming[98,99]. Furthermore, the average Tmax (28.56 °C) noted in MS for MGS (Table 3) has already surpassed the optimal temperature (26.40 °C) for maize[100], and is rapidly approaching 29 °C, which is damaging to maize[101]. The main reason is that after surpassing 29 °C[101,102] or 30 °C[103], processes such as anthesis-silking, assimilates production, translocation of resources during reproductive and grain filling are hampered. Temperature beyond this range has been linked to impaired pollen structure, decreased sugar (energy) levels upon anthesis, and retarded pollen shedding, all of which negatively affect pollen germination ability and fertilization[104]. More recent studies found that short duration of Tmax episodes during anthesis can cause significant reduction in pollen germination (30%), kernel number (72%), kernel weight (10%), and stomatal conductivity (52%) in maize[105,106]. Further at the biochemical level, the activity of the enzymes involved in converting atmospheric CO_2 to glucose or other key photosynthesis-related molecules were found to be disrupted by elevated temperatures[107]. In worst case scenario at higher temperatures, a yield loss could reach 34–80%[87,108].

A 1°C rise in Tmin increased maize productivity by 20.68% over the long run, indicating a significant and positive effect on maize yield in MS (Table 4A). Several other maize-growing regions have shown that yields respond to Tmin[87,109–111]. Tmin warming was also shown to be advantageous to maize yield in the short run, while the impact was not significant (Table 4A). Although there has not yet been an agreement regarding the physiological effects of Tmin on plants as there is an inclination of the crop-climate research towards the Tmax or Tavg and overlooking the Tmin[112,113]. The current study's findings on the positive association of Tmin and maize yield were supported by evidence from the literature, which included studies using statistical modeling[87,114–121] as well as simulation-based studies[122,123]. This is attributable to the fact that the increased Tmin speeds up night-time respiration, resulting in carbohydrates losses[124]. However, this carbon starvation enhances the following day photosynthetic rate to more than make up for the losses brought on by the accelerated night-time respiration, increasing overall plant productivity[125,126]. Consequently, the amassed dry matter from various plant tissues starts remobilizing toward grain, increasing maize kernel weight, and hence, the yield[127]. Also, the increased Tmin is believed to impart conducive conditions for germination, emergence, seedling growth, grain filling (during night-time), and milk-maturity stage in maize[110]. More importantly, according to Badu-Apraku et al.[127], Cairns et al.[128], and Sanchez et al.[100], all the beneficial mechanisms of Tmin mentioned above only prevail when the Tavg is below 25 °C or 26.40 °C. The Tavg for the current study was found to be 22.29 °C (Table 3). Furthermore, a similar case of Tavg of less than 25 °C was observed in all studies that supported the current findings, specifically at 21.2 °C and 24.4 °C in Liu et al.[116] and Shammi and Meng[36]. Contrarily, the studies that found negative effects of Tmin on maize yield were all found to have been carried out at Tavg of more than 25 °C[129]. For example, Wang et al.[130] tested at Tavg (27-31 °C), Liu et al.[131] tested at Tavg (25–35 °C), Suwa et al.[132] at Tavg (31 °C), and Wilhelm et al.[133] at 29.5 °C and observed negative Tmin-yield impact in maize. Furthermore, it was noted that June, July, and August demonstrated a significant and positive correlation between Tmin and detrended yield (Table 4B). This suggests that warmer nights in June, July, and August are beneficial for maize yields in MS, but there is no evidence that this beneficial effect offsets the detrimental effect of Tmax during the same months. Chen et al.[110] also noted 1 °C Tmin warming during May/September improved maize yield by 303/284 kg ha^{-1}. Reilly[134], Izaurralde et al.[135], and Reilly et al.[136] also realized the positive effects of warming on maize yield. Also, according to Schlenker and Roberts[137], Lobell et al.[138], and Lobell et al.[139], yield reductions are expected when temperature surpasses 30 °C, which was not the case with this study (Table 3). So far, the curve of Tmin has never reached the point at which it can cause the Tavg to pass above the optimal range and negatively affect maize yield.

According to the model's long-run estimation, the rising trend in CO_2 emissions had a positive and significant impact on maize yield (Table 4A). Ahsan et al.[140] and Chandio et al.[40] also realized similar yield improvements due to CO_2 emissions. However, it was discovered that the impact of CO_2 emissions on maize yield in the short run was not significant (Table 4A), and this is consistent with Warsame et al.[55] and Anapalli et al.[38] studies, focused on MS. Specifically, every unit increase in CO_2 emissions resulted in a long-term improvement in maize yield of 0.62% (Table 4A). Similar reports of 0.23% and 0.70% yield increases were noted by Asfew and Bedemo[56] and Mahrous[141] where they quantified the positive effects of increased CO_2 emissions. However, Islam et al.[142] estimated that under current climate change scenarios, these CO_2 emissions-driven yield increments might reach 3.5 to 12.8% at the rate of 1.80% every decade[143]. The upsides of elevated CO_2 on maize yield are due to its effects on plant physiology, growth, and biochemistry, through diminished stomatal conductivity and enhanced photosynthetic rates[144–147]. The decreased stomatal conductance reduces water loss thereby increasing water use efficiency, especially in drought-stress conditions[148,149]. The rise in atmospheric CO_2 levels increases the intercellular CO_2 concentration (Ci) and thus, photosynthetic rate (A)[150]. However, maize has a lower carbon saturation point than C3 plants like soybean[151] due to the high affinity (to CO_2) of the key enzyme, phosphoenolpyruvate carboxylase[152,153]. These physiological and biochemical responses of maize to CO_2 indicated that further increases in CO_2 levels may not increase assimilation production[150,151]. Increased CO_2 level have been shown

to benefit other crops[154–157]. However, the response of C4 plants (maize) to elevated CO_2 levels is complex, as it is influenced by various factors such as air temperature, water availability, light intensity, vapor pressures, and nitrogen availability[158,159]. Nevertheless, predicted rise in CO_2 levels by the years 2050 and 2100 may diminish the beneficial effect of CO_2 in row crops, like maize[150,151]. Further research is therefore required to determine the influence of elevated CO_2 in C4 plants at different growth stages[150,152,160,161]

Even though PT is a crucial crop growth factor, the current findings revealed that, at a 1% level of significance, PT patterns were determined to pose a negative and significant effect on maize yields in both the short- and long-term (Table 4A). More specifically, every 1 mm change in PT had reduced maize yield in the short- and long-term, by 0.64% and 2.70%, respectively (Table 4A). These results are consistent with the observations of Rosenzweig et al.[162], Chen et al.[163], and Xiang and Solaymani[58] who also noted the negative effect of the ongoing PT trends on maize yield. A crop yield decline due to prevailing PT trends was also documented in the study by Shammi and Meng[36] in MS. These results are attributable to the excessive PT (1504.44 mm annually) in MS[164]. Excessive PT, in addition to directly or physically harming the crop, results in prolonged wet conditions that lead the soil saturation and are averse to crop development, particularly in conditions of inadequate drainage[165]. This yield-reducing effect of excess moisture is attributable to (i) root growth hindrance impairing plants ability of nutrients and water uptake[166,167], (ii) increased nitrate leaching, leading to nutrient depletion[168], (iii) anoxic conditions in soil, leading to the risk of toxic substances development, diseases, and insect infestation[169], and (iv) delayed planting or harvesting, owing to the difficulty of driving the machinery in wet fields[149,170,171]. On account of the aforementioned factors, the US as a whole suffers a 3% yield loss annually[162,172], and significant yield decline has been seen over the past two decades in various parts of the US *i.e.,* Iowa[173,174]. When the analysis was further scaled down to a monthly level, it was discovered that the most significant month correlated with the MS maize yield was August, and the association was negative (Table 4B). This indicates that the August PT had the most significant negative effect on MS maize, and Eck et al.[82] also deduced similar results documenting increased PT to be detrimental in the latter part of the MGS. This is because the uptake of nitrogen, phosphorus, and potassium in maize plants continues up until the R3-R4 stage in August, when the plant can still transpire to the extent of 0.25–0.30 inches of water, according to Lauer[175], who claimed that by this time, the two (ear and kernel number) of three key yield parameters are determined, but the kernel size/weight is still yet to be determined. Furthermore, low PT is required during the ripening period (August) of maize[96]; nonetheless, the current study found that the MGS month with the highest PT growth rate (2.69 mm/decade) was August (Table 3). However, Rosenzweig et al.[162] had a different perspective on the negative association of August-maize yield, according to them it probably has less to do with plant itself and more primarily linked with the harvesting challenges arising from overly moist conditions, for growers. Delayed harvesting degrades the quality of maize, rendering it unsalvageable, in some instances, due to rotting in the field[82]. Overall, such scenarios of delayed harvesting could lead to a yield loss to the extent of 10%[149].

Pearson's correlation matrix revealed that the RH of any month of MGS had no correlation but DTR of June, July, and August months had negative and strong correlation with the maize yield (Table 4B). These results are consistent with those of Muhammad et al.[176] who found a weak correlation of RH and HA with yields, as well as with that of Lobell[89] who examined the impact of DTR on maize yield.

The coefficient of ECM was determined to be −0.302 (Table 4A), which signifies that every year, 30.20% of the immediate climatic impact cumulatively transfers to form the permanent basis for the long-term effects. A 30.20% is equivalent to the results of Warsame et al.[55] and Jan et al.[44]. The ARDL model estimated the adjusted R^2 value of 0.766, indicating that 76.60% of the total variations in maize yield due to the studied variables are explained by the study model.

Study limitations

Each research has its unique set of limitations, which forms the base for further advancement in the research field. The factors such as maize evapotranspiration, sunshine durations/hours, irrigation intensity, and vapor pressure deficit that could interact to determine the climatic effects for better insights on crop-climate link, were not included in the present study due to data unavailability. Hence, future research is suggested incorporating the aforesaid variables along with the variables considered in the present study for more practicable and accurate estimations.

Concluding remarks

This study demonstrated a markedly rising trend in Tmax, Tmin, and CO_2, with Tmin majorly contributing to the overall warming trend in the MGS of MS. The Tmin progressed at a faster rate (0.14°C decade^{-1}) than the Tmax, causing a considerably lowering trend in the DTR. The month-wise analysis determined the most correlated month for Tmax (June and July), Tmin and DTR (June, July, and August), and PT (August) in significantly impacting maize yield in MS, indicating the varied sensitivity of maize yield to within season variability for different climatic parameters. The crop-climate link assessment revealed a significantly negative effect of Tmax and PT on maize yield in both short and long run, whereas Tmin and CO_2 emissions posed a significantly positive effect on maize yield in long run and no effect in short run. Overall, the study model explained the 76.60% variations in maize yield due to climate change in MS. As shown by the ECM coefficient of the study model, the short-term immediate climatic effects on maize progressively transfer to permanent long-term effects by 30.2% every year, making the crop-climate link more prominent in the long run than in the short run. As the water and nutrient usage efficiencies are climate driven and based on the current findings, it is suggested to reassess the agronomic optimum management strategies in the face of MS crop-climate link. Also, the research efforts need to be intensified to test crop varieties that might be more resistant to elevated Tmax, perform better under delayed planting circumstances, and continue to interact favorably with elevated CO_2 and Tmin scenarios under

the local climatic conditions of the MS. Moreover, it is recommended to test current findings at the field or in controlled settings using the locally prevalent climatic indices with a focus on agronomic optimum management strategies as they react to the climatic variations.

Data availability

The data used in this study is accessed from National Agricultural Statistics Service's repository (USDA-NASS), US Climate Divisional Database (NOAA), PRISM database, and US energy information administration. The online links for these data sources are mentioned in Section "Data" (data) of methodology chapter. However, for more information on data, rs2564@msstate.edu (Ramandeep Kumar Sharma) can be contacted. No separate field study on plants was carried out because all the data used in the study was accessible online.

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RESEARCH ARTICLE

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Efficacy evaluation of newly isolated zinc solubilizing bacteria for their potential effect on maize (*Zea mays* L.) under zinc deficient soil conditions

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Abstract

Zinc solubilizing bacteria (ZSB) induces the conversion of fixed and unavailable soil zinc to readily available zinc contributes plant zinc nutrition and fortification. The present research intended to determine the screening of plant growth-promoting (PGP) traits of potent ZSB, biochemical and molecular characterization of ZSB, and assessment of potent ZSB for crop yield at the field level. Therefore, in the present study, molecular and functional characterization of native ZSB isolates was done to examine their response to plant growth performance and yield, mobilization of zinc, and acquisition by maize plants. Zinc solubilizing bacterial isolates namely, ZSB1, and ZSB 17 were solubilized insoluble zinc namely, $ZnCO_3$, ZnO, $Zn_3(PO_4)_2$ and significantly induced growth performance of maize crop at field conditions. A biochemical study revealed that both ZSB isolates were positive for catalase and urease production. Isolates ZSB1 & ZSB17 showed different PGP attributes like production of Indole-3-acetic acid (IAA), siderophore, NH_3, and HCN. Both isolates were solubilized phosphate, potassium, and silica and showed 1-aminocyclopropane-1-carboxylate (ACC)-deaminase activity. 16S rRNA amplification and sequence study of ZSB1 and ZSB17 revealed that both the isolates were *Cupriavidus* sp. and *Pantoea agglomerans*, respectively, and novel. The results elucidated from pot studies demonstrated that both ZSB1 & ZSB17 were the more suitable isolates than other ZSB isolates, and these isolates were further tested for field studies. *Cupriavidus* sp. and *Pantoea agglomerans* strains increased Zn-translocation toward grains and yield of Maize (cv: P3441) by 19.01% and 17.64%, respectively. We conclude that the novel indigenous ZSB strains substantially heightened zinc mobilization, the yield of maize crop, restore soil health, and can be suitable for biofortification and biofertilizers technology.

KEYWORDS
16S rDNA sequencing, field experiment, PGP attributes, zinc solubilizing bacteria, zinc translocation index

1 | INTRODUCTION

The availability of plant necessary elements has a direct impact on soil fertility and agricultural crop productivity. The availability of plant essential elements may change as a result of the buildup of higher concentrations of metals and metalloids in contaminated soil (Alengebawy et al., 2021). A mediated metabolic pathway requires minimal metalloids and heavy metals at appropriate concentrations

for root microbiota, soil fertility, and plant growth (Barra & Terenzi, 2021; Upadhyay et al., 2022). Few metalloids and heavy metals, on the other hand, are even at low concentrations hazardous to plant development and soil fertility (Chibuike & Obiora, 2014). Man-made activities such as mining, developing industrial zones, chemicals and pesticides, waste disposal, and so forth are increasing the prevalence of these contaminants (Alengebawy et al., 2021; Upadhyay & Edrisi, 2021).

Essential elements such as Zn (zinc), Cu (copper), Fe (iron), Mg (magnesium), and so forth are necessary to plant growth at an optimum concentration (White & Brown, 2010). Plant growth and soil fertility are also reduced by (i) a higher concentration of essential elements, and (ii) incompatible form of essential elements in the soil (Baldantoni et al., 2019), hence optimum concentration of essential micronutrients is required for soil productivity. Microbes can mobilize or solubilize trapped essential elements in contaminated soil by releasing extra-cellular enzymes; these enzymes may be facilitated by redox reactions (Garcia-Arellano et al., 2004).

Plant growth promoting rhizobacteria (PGPR) plays remarkable and promising role in phyto-stimulation by releasing plant hormones like Indole-3-acetic acid (IAA), Gibberellins and so forth (Upadhyay & Chauhan, 2022), and other solubilized trapped essential elements of soil and increasing essential element uptake in plants (Singh et al., 2022; Upadhyay et al., 2009). These procedures are known as PGPR direct mechanisms (Mahmud et al., 2021; Singh et al., 2022). The production of exo-polysaccharides (Upadhyay et al., 2011), antibiotics, antioxidants (Upadhyay & Singh, 2015), biocontrol action to reduce phytopathogens, and so forth are indirect mechanisms of PGPRs (Mahmud et al., 2021). Mobilization and solubilization of trapped essential elements by rhizobacteria can be effective sustainable approaches to improving plant growth performance and enhancing soil fertility in zinc-contaminated soil (Bhojiya et al., 2022).

The ZSB (zinc solubilizing bacteria) are renowned for their effectiveness in the solubilization of zinc when combined with plant root exudates, which function as a chemo-attractant and improve the availability of native rhizobacteria promotes plant growth (Upadhyay et al., 2022). ZSB thus facilitate native zinc for plant assimilation, leading to plant growth promotion (Shakeel et al., 2015). Previously, studies on the utilization of ZSB to enhance the Zn acquisition in crops such as wheat, mung-bean etc. and correcting Zn deficiency in soil by increasing over 50% available Zn levels in the harvest soil samples has been reported (Dinesh et al., 2018; Mumtaz et al., 2017; Sirohi et al., 2015). In more than 300 enzymes, zinc and zinc ion plays a vital biological role by maintaining protein structure & stability and is found in many metalloenzymes as essential cofactor (Sarathambal et al., 2010).

Zinc deficiency leads to biomass and fertility reduction directly reduces crop plant yield, chlorosis in leaves which negatively impact photosynthesis, increased iron accumulation causing cellular toxicity, and increased oxidative stress with reduced Cu/Zn SOD activities (Thiébaut & Hanikenne, 2022). Zinc deficiency in maize is very likely to result in stunting, acute chlorosis, reduced pollen viability, and male sterility (Brown, 2008). Due to the selective cultivation of high-yield maize varieties with synthetic fertilizers to boost cropping and quality over the past few decades, zinc deficiency has ravaged into the soil-crop environment, making maize the most susceptible cereal crop to Zn deficiency (Fageria et al., 2002).

Fifty percent of global and Indian soils are zinc deficient which is projected to increase to an estimated 63% by 2025 leading to reductions not only in crop yield but also in food quality (Hussain et al., 2022; Shukla et al., 2021). In India, 51.2% soils from the states Andhra Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Telangana, and Uttar Pradesh were deficient in available Zn (Shukla et al., 2021). Zn solubilization and mobilization by soil microbes has sustainable perspectives in comparison to chemical fertilizers. Therefore, the intent of current investigation was focused on (i) isolation and screening of potent ZSB and its plant growth-promoting (PGP) attributes, (ii) 16SrRNA characterization of potent screened bacterial isolates, (iii) Influence of potent isolates on plant growth and soil health in zinc infested soil at field level.

2 | MATERIALS AND METHODS

2.1 | Physico-chemical properties of rhizospheric soil samples

The rhizospheric soils of chickpea plant were obtained from the Dungarpur (23.85° N; 73.68° E) and Pratapgarh (23.56° N;73.74° E) districts of Rajasthan (Figure 1), both the sites were adjacent to ZAWAR mines (Latit-24.3540034; Long-73.733064). Physico-chemical properties such as EC (Electrical conductivity), OC (Organic Carbon), Av. N (available nitrogen), Av. P (available phosphorus), Av. K (available potassium), and diethylenetriaminepentaacetic acid (DTPA) extracted zinc were analyzed as per standard procedures (Jain, Kour, et al., 2020; Vance et al., 1987).

2.2 | Isolation of ZSB and screening of its zinc solubilizing potential

The ZSB isolation was done with serial dilution plate method on specific media namely, Mineral salt media (Saravanan et al., 2007) and Bunt & Rovira medium (Bunt & Rovira, 1955) supplemented with different insoluble zinc source such as ZnO, $ZnCO_3$, and $Zn_3(PO_4)_2$ to produce a clear halo zone after 48 h incubation at 28°C ± 2°C were purified and considered as ZSB. To evaluate zinc solubilization efficiency of the isolates, the halo zone forming bacterial isolates were put on Bunt and Rovira agar and MSM media plates with a 0.1% insoluble zinc-source and at 28°C ± 2°C plates were incubated for 48 h. Zn solubilization efficiency was calculated as given equation.

$$\text{Solubilization efficiency} = \frac{\text{Zone diameter}}{\text{Diameter of colony growth}} \times 100$$

Further, for quantitative estimation (broth assay) of zinc solubilizing potential of ZSB strains were determined by following Gandhi

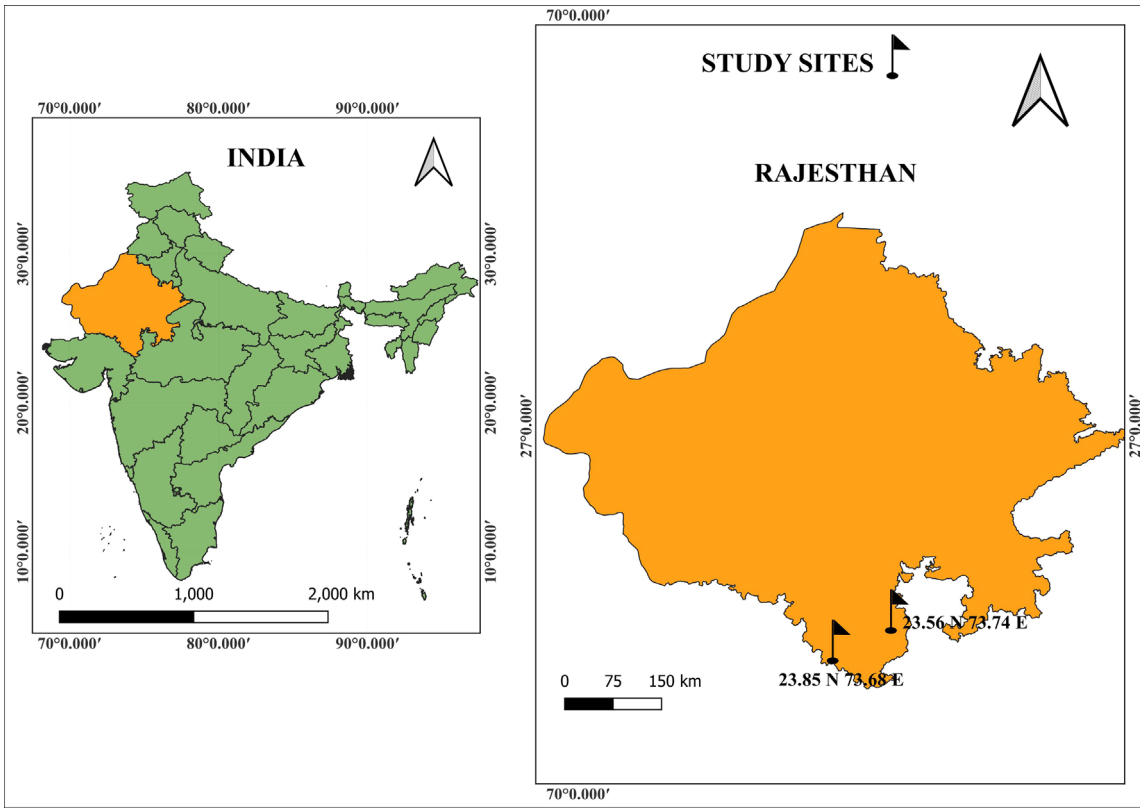

FIGURE 1 Map of the state of Rajasthan showing the geographic locations of collection of soil samples for the isolation of zinc solubilizing bacteria. [Colour figure can be viewed at wileyonlinelibrary.com]

et al. (2014). Briefly, the available zinc concentration was measured using atomic absorption spectrophotometer (AAS 4141 model, Electronics Corp. of India Ltd., India) in the culture filtrate of ZSB grown in MSM broth containing different insoluble zinc source (0.1%) at 4th, 8th, and 16th day of incubation (Gandhi et al., 2014). The pH shift of culture filtrate and uninoculated medium were also analyzed using pH meter.

2.3 | Morphological, biochemical, and molecular identification of potent ZSB

Morphological characteristics namely, form, elevation, margin, cell form, colony color, appearance colony morphology, growth, Gram staining (Gram, 1884) and basic biochemical test namely, Catalase test, Urease test, and Gelatin Liquification test were studied using the standard procedure (Blazevic & Ederer, 1975). Molecular identification of the screened ZSB isolates was carried out through 16S rRNA PCR amplification by using universal primers according to Weisburg et al. (1991) and Jain, Sanadhya, et al. (2020) and sequenced. The 16S rDNA sequences of ZSB isolates were subjected to a BLAST analysis (Altschul et al., 1990) in order to retrieve closely related sequences of type strains and further aligned using online tool CLUSTAL-W (Thompson et al., 1994). The MEGA 6.06 software was employed to construct phylogenetic tree (Tamura et al., 2013).

2.4 | HPLC and GCMS analysis for gluconic acid

The production of gluconic acid by ZSB isolates were tested by injecting the 5 days pre incubated culture filtrate in to a RP-HPLC (Agillent) having C18 column and the mobile phase acetonitrile: water (30:70 v/v) with a flow-rate @ 1.0 mL/min was used with an isocratic flow to detect gluconic acid at 210 nm through UV/Vis-detector (Jain, Kour, et al., 2020). The culture filtrates were further evaluated for the presence of various organic acids and other moieties using GCMC (GCMSQP2020, Shimadzu). Briefly, the methanol extracts (500 µL) of lyophilized culture filtrate 100 µL of N-Methyl-N-(trimethylsilyl) trifluoroacetamide and 100 µL of pyridine were added and the reactions were heated (60°C for 30 min gently) in a water bath and left 12 h for stabilization. These processed samples were analyzed through GC–MS (source temperature 200°C, ionizing voltage 70 eV) and operated with scan mode (50–700 m/z) with temperature ranged 70–260°C and data was compared with NIST library.

2.5 | Physiological and PGP attributes of potent ZSB

Physiological attributes of potent ZSB isolates such as tolerance of pH (Graham, 1992), tolerance of salinity (Upadhyay et al., 2009) tolerance of temperature (Graham, 1992), tolerance of drought (Abolhasani

et al., 2010), antibiotic resistance (Li & Ramakrishna, 2011) was performed by using standard protocols. Zinc solubilizing bacterial isolates were examined for their multiple PGP traits such as production of IAA, siderophore-production, 1-aminocyclopropane-1-carboxylate (ACC) deaminase activity, phosphate-solubilization, potassium and silica solubilization, HCN, ammonia and exopolysaccharides production with standard published methodologies (Jain, Kour, et al., 2020; Naureen et al., 2015; Siddiqui et al., 2021; Upadhyay et al., 2011; Yadav et al., 2022). Hydrolytic enzymes (αamylase, cellulase, pectinase, and protease) was measured by the method of Cappuccino and Sherman (1992) & lipase (Ertugrul et al., 2007), chitinase activity (Kumar et al., 2012), and glucanase activity (Fawzy and Monaim, 2016) were screened by using standard protocols.

2.6 | Bio efficacy evaluation of potent ZSB

2.6.1 | Pot experiment

Bio efficacy and plant growth promotion ability of selected ZSB1 and ZSB17 strains as liquid microbial inoculants was evaluated under pot culture in triplicate following complete randomized design according to our previously published research (Jain et al., 2021). The maize seeds (5–10) were treated with ZSB liquid inoculants (>8.5–$\times 10^8$ cfu mL^{-1}) and placed in 4.0–5.0 cm deep in each pot. All the pots were given uniform recommended dose of fertilizers (RDF) namely, N (@ 120 kg N: P@ 60 kg P_2O_5 and K @ 40 kg K_2Oha^{-1}; Omara et al., 2016). After 30 days of sowing, plant growth parameters namely, average shoots, root-length, root-number, leaf-number, and leaf chlorophyll content (Ronen & Galun, 1984) were analyzed using standard protocols.

2.6.2 | Field experiment

The field studies were undertaken at Krishi Vigyan Kendra, Dungarpur and Instructional farm, Rajasthan College of Agriculture (RCA), (composite soil analysis reports of both experimental fields were summarized in Supplementary data sheet Table S1.1), where the DTPA extractable zinc content is low (<0.6 PPM) in 2 years of kharif seasons to differentiate the effect of two ZSB isolates on growth and yield of Maize variety P3441. The field experiment was laid out in a RBD (randomized block design) with 15 treatments in three replications including two ZSB isolates and uninoculated control (S_1: 100% RDF, T_1: ZSB1 ONLY, T_2: ZSB1+ 100% RDF, T_3: ZSB1 + 75% RDF, T_4: ZSB1 + 50% RDF, T_5: ZSB1 + 100% RDF + $ZnSO_4$, T_6: ZSB1 + 75% RDF + $ZnSO_4$, T_7: ZSB1 + 50% RDF + $ZnSO_4$, T_8: ZSB17 ONLY, T_9: ZSB17 + 100% RDF, T_{10}: ZSB17 + 75% RDF, T_{11}: ZSB17 + 50% RDF, T_{12}: ZSB17 + 100% RDF + $ZnSO_4$, T_{13}: ZSB17 + 75% RDF + $ZnSO_4$, T_{14}: ZSB17 + 50% RDF + $ZnSO_4$) as similar approach was adopted by earlier reported work of Upadhyay et al. (2019). The sowing was done by manual dibbling the seeds at a distance of 60 cm × 40 cm row to plant (Fahad et al., 2016).

ZSB liquid biofertilizer @ 5 mL kg^{-1}treated to seed before sowing. To enhance the health of cropping over the crop season, all recommended agronomical practices namely, sowing, weeding, manuring, harvesting, and so forth were taken. Ten plants were randomly selected from every plot at physiological maturity of the crop (106–110 days from sowing), the parameters of yield and harvest including cob length (cm); number of grains per row; number of rows per cob; weight of cobs per plot; weight of grain (g); thousand grain weight (g); biological yield per plot (g); harvest index (%) were evaluated manually (Supplementary data sheet: experimental details) (Gheith et al., 2022). Data analysis was accomplished by using the analysis of variance determining levels of significance.

2.7 | Analysis of Zn-content and Zn-translocation index (ZTI)

The powdered sample (shoot and grain) from all 15 treatments were digested using a triacid mixture (HNO_3: H_2SO_4: $HClO_3$ in the ratio of 9:2:1) and the Zn-content were measured using AAS to quantify the Zn translocation index (ZTI) (Rengel & Graham, 1996).

$$\mathrm{ZTI} = \frac{\text{Zn concentration in grains}}{\text{Zn concentration in shoot}} \times 100$$

3 | RESULTS

In the present study, the physico-chemical characteristics of Dungarpur and Pratapgarh soil samples are described in Table S1.2. The soil samples textured with clay loam and sandy loam, while the soil pH ranged from acidic to neutral. The rhizospheric soils contains moderate to high range of ECe, OC, Av. N, Av. P, and Av. K. The DTPA extractable concentrations of Zn-soil (available Zn) were observed as 0.572 and 0.686 ppm.

3.1 | Isolation and assay (qualitative and quantitative) for zinc solubilization by ZSB

Microorganisms have varied solubilization response with different insoluble form of zinc hence, in the present study, ZSB isolates ZSB1 and ZSB17 were selected based on their capabilities in solubilizing multiple forms of insoluble zinc namely, ZnO, $ZnPO_4$, and $ZnCO_3$ in plate assay. Qualitative screening of zinc solubilization was carried out in MSM media and R&B media plates supplemented with different insoluble Zn compounds (Table 1). Zn solubilization zone with ZSB1 was observed in MSM media plates was 3.78 mm, 5.46 mm and 4.10 mm with $ZnCO_3$, ZnO, and $Zn_3(PO_4)_2$, respectively, and by ZSB17 was 3.09 mm, 3.79 mm, and 6.56 mm with $ZnCO_3$, ZnO, and Zn3 $(PO_4)_2$, respectively whereas in R&B media maximum zone of solubilization was observed with ZSB1 was 3.78 mm, 5.43 mm, and 4.10 mm with $ZnCO_3$, ZnO, and $Zn_3(PO_4)_2$, respectively, and by ZSB17 (3.09 mm, 2.85 mm, and 6.56 mm with $ZnCO_3$, ZnO, and $Zn_3(PO_4)_2$, respectively). Higher solubilization of Zn was observed in plates containing MSM media.

TABLE 1 Qualitative and quantitative assay for Zinc solubilization by ZSB strains on different insoluble Zn compounds.

	Qualitative assay for zinc solubilization by measuring solubilizing index (SI)					
	SI ON R&B (ZNO)	SI ON R&B (ZNC)	SI ON R&B (ZNP)	SI ON MSM (ZNO)	SI ON MSM (ZNC)	SI ON MSM (ZNP)
ZSB-1	5.43 ± 0.05	3.78 ± 0.02	4.1 ± 0.02	5.46 ± 0.05	3.78 ± 0.02	4.10 ± 0.02
ZSB-17	2.85 ± 0.04	3.09 ± 0.08	6.56 ± 0.01	3.79 ± 0.02	3.09 ± 0.08	6.56 ± 0.01

	Qualitative assay (broth assay) by measuring soluble Zinc (µg/mL) using AAS			
	4th day (µg/mL)	8th day (µg/mL)	16th day (µg/mL)	pH
ZSB-1	5.1800 ± 0.0436	14.5767 ± 0.0416	17.3033 ± 0.0603	30.2
ZSB-17	6.1100 ± 0.0201	14.2500 ± 0.0657	14.6533 ± 0.6240	40.1

Abbreviations: MSM, mineral salt media; R&B, bunt & Rovira medium; ZNO, Zinc oxide; ZNC, Zinc carbonate; ZNP, Zinc phosphate.

Both ZSB strains were further evaluated for quantitative Zn-solubilization at different time intervals in MSM broth (broth assay). The results raveled that the amount of Zn solubilized from insoluble zinc-oxide, zinc-carbonate, and zinc-phosphate by both the ZSB isolates, and Zn solubilization rate was proportional with incubation time (Table 1). Maximum available Zn registered by ZSB1 was 5.18 µg mL^{-1} on the fourth day, which peaked to 14.57 µg mL^{-1} during the eighth day, followed by 17.30 µg mL^{-1} during the 16th day whereas zinc solubilization by ZSB17 was 6.11 µg mL^{-1} on the 4th day, which peaked to 14.25 µg mL^{-1} during the eighth day, followed by 14.65 µg mL^{-1} during the 16th day. Zn solubilization and reduction in pH of the culture medium showed positive correlation for both the ZSB isolates.

3.2 | Morphological, biochemical, and molecular characterization of ZSB isolates

The shape of ZSB1 and ZSB17 isolate was rod and cocci respectively, while both were gram negative. Colony characteristics as colony color, form, elevation, margin and appearance were also noted along with key biochemical tests and described in Supplementary data sheet Table S2. Biochemical analysis revealed that both ZSB isolates were negative for gelatin liquification test, while both were positive for catalase and urease production. The 16S rRNA gene sequence of isolate ZSB1 showed 95.49% homology with 16S rRNA sequence of *Cupriavidus campinensis* strain BT HNGU56 (Accession number KY010351) already submitted to GenBank data repository of the NCBI. The sequence of 16S rRNA gene of isolate ZSB17 showed 99.68% homology with 16S rRNA sequence of *Pantoea* sp. strain AS-43 (Accession number OL604306) already submitted to GenBank data repository of the NCBI [ZSB1: *Cupriavidus* sp. (Accession number: KY244144); ZSB17: *Pantoea agglomerans* strain ZSB17 (Accession number: MK773870)]. The phylogenetic position of the species is shown in Figure 2.

3.3 | Gluconic acid production by potent ZSB isolates

The reduction of pH from in broth assays was validated by measuring gluconic acid from the chosen ZSB isolates using HPLC (Supplementary data sheet Figure S1). Both the ZSB isolates showed the secretion of gluconic acid on comparison with the standard gluconic acid and ZSB 1 and ZSB17 produced 286.14 and 102.74 mg/mL gluconic acid respectively after 5 days of incubation in Zn-supplemented MSM media. Further the culture filtrates were subjected to GCMS analysis which also revealed the secretion of different organic acids (Supplementary data sheet Figures S2 and S3).

3.4 | Physiological and PGP attributes of potent ZSB

The isolates ZSB1 and ZSB17 was screened primarily for physiological attributes that includes pH tolerance, salinity tolerance, temperature tolerance, drought tolerance, antibiotic sensitivity (Supplementary data sheet Table S3). Strain ZSB1 was able to tolerate at 1% salt concentration while ZSB17 strain were able to tolerate 2% salt concentration. Both isolates were exposed to temperature stress and ZSB1 was able to grow at various temperatures ranging from 25°C to −40°C while strain ZSB17 showed growth at temperature ranging from 20°C to −45°C. Further the drought tolerant capacities of ZSB were assessed using varying concentration of PEG on MSM-broth and ZSB1 were able to grow upto 40% PEG whereas ZSB17 were tolerated upto 10% PEG. The zinc solubilizing isolates resisted the antibiotics peniciline (µg) and ampicillin (µg) and sensitive toward kanamycin (µg), cefixime (µg), and rifampicin (µg).

Multiple PGPR activities of both ZSB isolates (Table 2) revealed that strain ZSB1 and ZSB17 were suitable plant growth promoting candidates. In the presence of L-tryptophan ZSB1 and ZSB17 produced 64.49 µg/mL IAA and 66.81 µg/mL IAA respectively. Phosphate solubilization by strain ZSB1 was 2.63 ± 0.4 and by strain ZSB17 2.97 ± 0.7 mm diameter around the colonies. Both ZSB isolates were also found positive for potassium solubilization. Both ZSB isolates were able to solubilize potash as forming clear zones in Aleksandrov agar media supplemented with mica. Zone of potash solubilization by strain ZSB1 was 2.86 ± 0.3 mm and by ZSB17 was 3.53 ± 0.02. Both isolates were also subjected for silica solubilization test. Silica solubilization by ZSB1 was 3.83 ± 0.17 and by strain ZSB17 2.64 ± 0.04 mm diameter around the colonies. These selected ZSB isolates have evaluated for different enzymes production by conducting enzyme assays. Research findings showed that both ZSB isolates

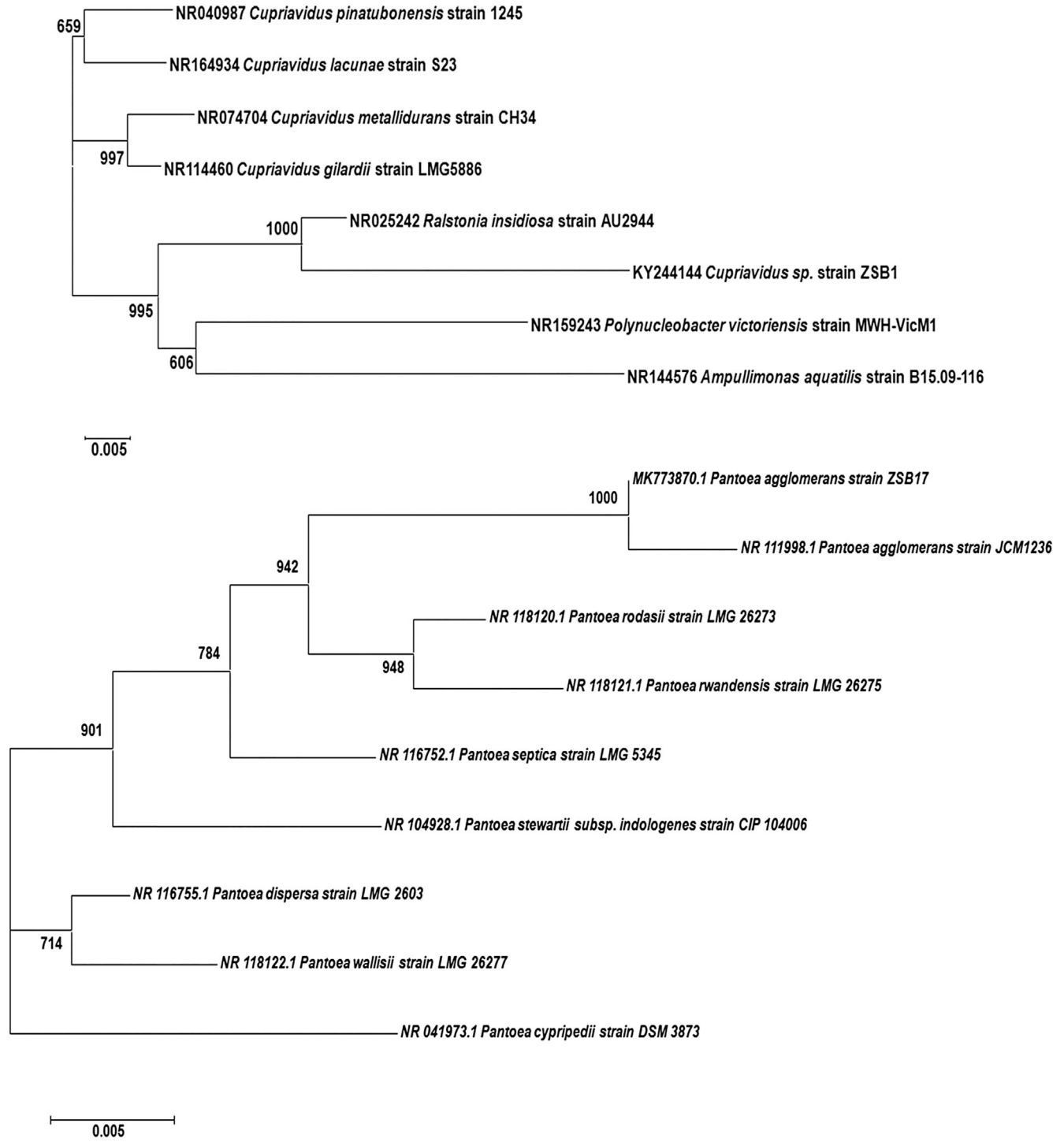

FIGURE 2 Phylogenetic analysis of potent ZSB isolates.

were positive for amylase, lipase, protease, and cellulase production and negative for chitinase and glucanase production with respect to hydrolytic enzymes.

3.5 | Bio efficacy evaluation: Pot and field study

The results from pot experiments reveled that both the ZSB isolates significantly induces maize plant growth-performance. Zinc solubilizing isolates inoculation showed substantial growth in leaf no., leaf-length, shoots-length as compared to uninoculated control and significantly enhanced the root-length, root-number, and leaf chlorophyll content (Supplementary data sheet Table S4). The untreated control showed minimum value in all studied plant growth parameters.

Field experiment was conducted following in-vitro authentication for both selected ZSB isolates ZSB1 and ZSB17 on 13 selected growth and yield related attributes were recorded in Table 3

TABLE 2 PGP and hydrolytic enzyme production traits in ZSB isolates.

Plant growth promoting traits	ZSB1	ZSB17
ACC Deaminase	+	+
Ammonia production	+	+++
Sidero-phore	+	+
HCN	+	+
EPS	−	−
IAA (μg/mL)	640.49	668.17
P solubilization index (cm)	2.63 ± 0.04	2.97 ± 0.07
K solubilization index (cm)	2.86 ± 0.03	3.53 ± 0.02
Si solubilization index (cm)	3.8367 ± 0.17	2.6467 ± 0.04
Lipase activity	+	+++
Amylase activity	+	+
Protease activity	+	+
Cellulase activity	+	+
Chitinase activity	−	−
Glucanase activity	−	−

Note: Value (mean of triplicate) ± standard deviation.

(Supplementary data sheet). In the present research, the preferred maize variety P3441 was used with implementing all favored SAP (standard-agronomic-practices). For field experiment 15 treatments along with control were designed with combination of RDF and $ZnSO_4$. Among all the treatments, the highest biological yield (q/ha) was observed in treatment T_5 (143.82 ± 5.65q/ha) which were combination of 100% RDF, ZSB1 isolates and $ZnSO_4$ followed by treatment T_{12}, T_6, T_{13}, T_2, T_{14}, T_3, T_7, T_9, T_{10}, T_4, T_{11}, T_1, T_8 over the control. The maize plant growth and production have been significantly increased through seed bacterization with ZSB isolates. The difference was significant on yield was recorded in treated than control. Table 3 presents data on the parameters of crop growth and yield trend for maize.

The impact of ZSB isolates on the maize grain Zn content & ZTI are summarized in Table 4. In treatment T_5 (ZSB1+ 100% RDF + $ZnSO_4$) highest ZTI was observed (ZTI = 55.21%) followed by the maize plants treated with treatment T_{12} (ZSB17 + 100% RDF + $ZnSO_4$; ZTI = 53.4%). This clearly illustrates the role of ZSB isolates in translocating Zn toward maize grains. Zinc translocation analysis revealed that zinc acquisition in grain and shoot was significantly enhanced with strain ZSB1 than strain ZSB17 and un-inoculated control.

4 | DISCUSSION

The growth and productivity of crops were significantly impacted by a zinc shortage in the soil ultimately lead to low zinc contents in crops (Hafeez et al., 2013; Hussain et al., 2022). Following previously published studies, the ZSB isolates were obtained from rhizospheric soil in this research (Bhatt & Maheshwari, 2020; Sunithakumari et al., 2016). *Cupriavidus* sp. and *Pantoea agglomerans* were identified as the effective ZSB strains ZSB1 and ZSB17 by 16S rRNA gene sequencing. The biochemical characterization represents the intrinsic biochemical and structural properties of the bacteria to adopt in the specific environment. In medium supplied with zinc phosphate and zinc carbonate, ZSB1 shown higher solubilization efficiency, but ZSB17 demonstrated higher solubilization in medium supplemented with zinc oxide. Ramesh et al. (2014) showed that the findings of the current investigation are supported by the ZSB strains MDSR7 and MDSR14 solubilizing all three zinc compounds (zinc, zinc-phosphate, and zinc-oxide). The current study reports that the higher Zn-solubilization zone was observed in ZnO supplemented medium compared to $ZnCO_3$ amended medium (Goteti et al., 2013; Mishra et al., 2017). In this work, a broth test was used to quantitatively evaluate the solubilization of zinc. As zinc solubilization increased over time, the highest amount of zinc was registered in ZSB17 on day 16 at 14.65 g mL^{-1}. Similar findings with isolated ZSB solubilized insoluble ZnO (40.81 $mL^{-1}$to 62.48 mL^{-1} soluble Zn) were also reported by Mishra et al. (2017). One important mechanism for the solubilization of metals and minerals is the secretion of OA (organic acids) by PGPRs, and gluconic acid is thought to be the main OA involved in the solubilization of insoluble minerals in soil (Sunithakumari et al., 2016). This will be the primary intermediary for solubilization due to the presence of 2-ketogluconic acid as a main product in cultures altered with the solubilization of insoluble zinc source (Gontia-Mishra et al., 2017) and likely as a result of increased acidity (Dinesh et al., 2018).

More or less every organism has a different active mechanism of zinc solubilization, which relies on the type of bacteria present. The ability of the ZSB strains in the current study to withstand stress, including pH, temperature, salt, and drought, is an inherent biochemical characteristic that aids in their survival in challenging rhizosphere conditions (Upadhyay et al., 2019). If a PGPR displays a variety of PGP properties, it might be a good candidate for microbial inoculants (Singh et al., 2022; Upadhyay & Chauhan, 2022). The ZSB1 and ZSB17 strains were positive for multiple PGP traits namely, ACC-deaminase-activity, siderophore-production, HCN-production, and ammonia-production. Rhizobacterial isolates are well established organisms, which may be remarkable assets for plant growth promotion through different mechanisms (Nadeem et al., 2010; Upadhyay et al., 2022; Upadhyay & Singh, 2015). ACC, a precursor for the ethylene stress hormone as the only source of nitrogen plays an important role for plant growth promotion (Mishra et al., 2017). HCN is a secondary metabolite of bacteria that inhibits growth of pathogenic microorganisms (Siddiqui, 2006). Similarly, recently Jain et al. (2020a) demonstrated that zinc tolerant PGPR produce siderophores and induced growth of plants. Ramesh et al. (2014) demonstrated that strong ammonia-producing bacterial isolates can be beneficial as a source of nitrogen for plant growth-performance.

This study, the IAA production capacities of ZSB isolates is consistent with other researchers' findings (Abaid-Ullah et al., 2015; Zhao et al., 2011). Gandhi & Muralidharan (2016) demonstrated that

TABLE 3 Effect of ZSB strains on growth and yield parameters of maize under field experiment.

Treatment	Biological yield (kg)	Cob length (cm)	Weight of cob/plot (kg)	No of cobs/ plot	No of rows/ cob	No of grains/ row	Weight of grain/plot (kg)	Grain yield (q/ha)	Weight of fodder/ plot (kg)	Stover yield (q/ha)	Biological yield (q/ha)	Harvest index (%)	1000 grain wt (g)
S_1	60.40	20.00	40.20	24.00	14.00	40.00	20.59	54.00	30.81	79.31	133.31	40.48	210.65
T_1	40.80	18.00	20.92	22.00	12.00	36.00	20.30	48.00	20.50	51.98	99.98	48.28	245.66
T_2	60.10	22.00	40.10	27.00	16.00	42.00	3.12	65.00	20.98	62.06	127.06	51.26	289.82
T_3	50.90	20.20	30.90	25.00	14.00	36.00	2.83	59.00	30.07	63.90	122.90	48.58	253.00
T_4	50.40	19.00	30.40	24.00	14.00	36.00	20.54	53.00	20.86	59.48	112.48	47.45	254.00
T_5	60.90	23.00	4.58	29.00	18.00	44.00	30.26	68.00	30.64	75.82	143.82	47.23	292.65
T_6	60.40	21.50	40.30	28.00	16.00	40.00	20.98	62.00	30.42	71.31	133.31	46.62	268.00
T_7	50.80	20.00	40.00	26.00	14.00	38.00	20.69	56.00	30.11	64.81	120.81	46.35	278.00
T_8	40.40	17.70	20.46	20.00	12.00	34.00	2.21	46.00	20.19	45.65	91.65	50.19	269.00
T_9	50.80	20.60	30.50	26.00	16.00	40.00	3.02	63.00	20.78	57.81	120.81	52.35	285.00
T_{10}	50.50	19.80	30.20	24.00	14.00	38.00	20.74	57.00	20.76	57.57	114.57	50.03	269.00
T_{11}	50.10	18.40	30.10	23.00	14.00	36.00	20.50	52.00	20.60	54.23	106.23	49.05	288.00
T_{12}	60.60	22.00	40.30	28.00	16.00	41.58	30.07	64.00	30.53	73.48	137.48	47.11	288.51
T_{13}	60.30	21.00	40.10	25.00	16.00	40.00	20.78	58.00	30.52	73.23	131.23	44.50	285.48
T_{14}	60.10	20.50	30.80	23.00	14.00	38.00	20.54	53.00	30.56	74.06	127.06	41.71	255.00
SEm±	00.270	00.937	00.169	10.160	00.638	10.632	00.113	20.362	00.286	50.962	50.602	20.794	90.111
CD at 5%	00.780	20.705	00.488	30.351	10.841	40.712	00.328	60.823	00.827	17.221	16.180	80.069	26.313
CD at 1%	10.051	30.643	00.658	40.513	20.480	60.345	00.441	90.187	10.113	23.188	21.787	10.866	35.431

Note: The data express the pooled value of the triplicate data collected in two sessions.

TABLE 4 Effect of ZSB isolates on Zinc translocation from shoot to grain; Zinc Translocation Index.

Treatment	Zn in grain	Zn in Stover	Zinc translocation index (%)
S_1	25.93	78.60	32.9
T_1	23.20	78.37	29.62
T_2	35.33	68.03	51.9
T_3	33.70	70.79	47.6
T_4	30.30	73.47	41.14
T_5	38.20	68.77	55.21
T_6	34.77	70.00	49.5
T_7	32.97	70.83	46.4
T_8	21.47	79.00	**27**
T_9	34.60	71.23	48.5
T_{10}	31.83	69.80	45.5
T_{11}	27.50	70.33	39.11
T_{12}	35.50	66.33	53.4
T_{13}	31.50	65.73	47.9
T_{14}	29.17	69.03	42.1
SEm±	0.961	1.227	
CD at 5%	2.777	3.543	
CD at 1%	3.739	4.771	

Note: The data express the pooled value of the triplicate data collected in two sessions.

phytohormone IAA (auxin) was produced by AGM3 (an isolate) at 45.61 g mL^{-1}, followed by the AGM9 37.27 g mL^{-1}in IAA broth medium. The capability of PGP isolates to solubilize insoluble P form to a plant available P form significantly improves crop production under P limiting conditions (Majeed et al., 2015).

According to the findings of an experiment performed by Dinesh et al. (2018), *B. megaterium* (Strain CDK25) is capable of soluble and mobilized phosphate, both inorganic and organic. *Bacillus licheniformis* (BHU18) and *Pseudomonas azotoformans* (BHU21), two KSB isolates, demonstrated noticeably higher K-solubilization than the results seen in the current research, according to Saha et al. (2016). According to Naureen et al. (2015), 29 out of a total of 111 bacterial isolates can dissolve mineral silicates. Zhao et al. (2011) reported on the isolation and characterization of ZSB strains with multiple PGP traits and stated that *Bacillus* spp. exhibit numerous plant growth promoting attributes that support plant growth, including Zn and P solubilization, IAA production, oxidase activity, catalase activity, and phytohormone development. The increase in plant growth could be attributed to ZSB isolates' capacity to supply nutrients through nitrogen fixation, phosphate solubilization, siderophores synthesis, and the release of phytohormones (Mumtaz et al., 2017; Jain et al., 2017). Amylase, lipase, protease, and cellulase synthesis were found in zinc solubilizing isolates, and these enzymes indirectly aid plant growth by controlling soil-borne phytopathogens (Jha et al., 2012).

Zinc solubilizing isolates inoculation under pot conditions significantly improved the root length, root no., and leaf chlorophyll content and the results were well supported by Karnwal (2021) reported zinc solubilizing *Pseudomonas* spp. isolated from vermicompost significantly improves plant growth and maximum zinc content in Okra fruit compared to uninoculated control. Application of ZSB substantially improves plant growth by increasing Zn bioavailability in soil to crop plants hence reduce the use of synthetic zinc fertilizers. The field experiment was conducted following in vitro authentication for ZSB1 and ZSB17 strains on 13 selected growth and yield-related attributes, among all the treatments, the highest biological yield (q/ha) was observed in treatment T5 (143.82 ± 5.65 q/ha) which were a mixture of 100% RDF, ZSB1 isolates and $ZnSO_4$. The maize plant growth and production have been significantly increased through seed bacterization with ZSB isolates. Hussain et al. (2015) recorded an increase in plant growth attributes primarily shoot length, root length, shoot fresh and dry biomass, and root fresh and dry biomass when Zn solubilizing *Bacillus* sp. (AZ6) was inoculated under field conditions. Sarathambal et al. (2010) have demonstrated that the dry weight of the maize is increased compared with control by the inoculation of zinc solubilizing *Gluconacetobacter diazotrophicus*. An experiment conducted by Goteti et al. (2013) in which they revealed that seed bacterization with zinc solubilizing PGP bacteria facilitates the growth of plant height (root and height of the shoot); leaf area; and dry mass.

The results of the study on the effect of ZSB isolates on zinc translocation index (ZTI) in maize plant are presented in Table 4. Zinc translocation index is used in this study as a similar notion to the translocation factor (TF) that can be viewed as the ratio of an element in a plant's shoots and roots (Upadhyay et al., 2021). The maize plant showed the highest ZTI (55.21%) in treatment T5 (ZSB1 + 100% RDF + $ZnSO_4$), followed by treatment T12 (ZSB17 + 100% RDF + $ZnSO_4$; 53.4%). This clearly shows ZSB isolates have role in translocation of Zn toward maize grains and similar finding was earlier

reported by Goteti et al. (2013) and Omara et al. (2016). In comparison to the control, the introduction of *B. aryabhattai* isolates to wheat and soybean crops dramatically boosted Zn uptake as well as shoot and seed weight (He et al., 2010). In addition to synergistic impact on plants' growth and yield, ZSBs have a strong capacity to enhance the Zn content of cereals which ultimately improves human health and immunity (Abaid-Ullah et al., 2015; Wang et al., 2014). Krithika and Balachandar (2016) reported that ZSB up-regulated the expression of Zn-regulated transporters and iron (Fe)-regulated transporter-like protein (ZIP) genes in rice suggested its important role in zinc fertilization and fortification. Uptake of micronutrients (Zn) by the plants from soil is a mutually dependent process (Bouain et al., 2014). Using microbial tools to enhance the availability of soil Zn to crop plants is one of the sustainable ways of reducing the Zn deficiency and improving Zn content of food crops grain in zinc deficient soils (Sirohi et al., 2015). Furthermore, such microbial tools will improve the zinc deficient soil and restore them to healthy soil by improving available zinc in soil. The ZSB isolates from the present study can be used for development of liquid biofertilizers to improve zinc acquisition in different crop plants cultivated in southern Rajasthan based on dedicated field studies.

5 | CONCLUSION

The primary issue that inhibits plant growth performance in degraded soil is the type of zinc that is not readily available to plants; zinc-deficient soil is frequently observed in the current research sites. Zn is a crucial micronutrient needed for healthy plant development and growth, and a deficiency does more than just harm human health and crop productivity. The findings of this research demonstrated that two distinct native bacteria, *Cupriavidus* sp. and *Pantoea agglomerans*, had the highest potential to solubilize insoluble zinc in the form of zinc that was readily available and to promote maize growth at the field level. Both isolates (*Cupriavidus* sp. and *P. agglomerans*) demonstrated a variety of PGP properties and produced catalase and urease, both of which promoted plant development. *Cupriavidus* sp. and *P. agglomerans* increased the yield of maize by 19.01% and 17.64%, respectively, and improved Zn translocation toward grains. We conclude that the *Cupriavidus* sp. and *P. agglomerans*, considerably improved soil health, maize crop production, and both unique strains could play a spectacular and promising role in bio-fertilizer technology.

AUTHOR'S CONTRIBUTION

Devendra Jain designed the research. Aradhana Sukhwal performed the experiments. Vimal Sharma interpreted the data. Gajanand Jat performed soil and AAS analysis. Aradhana Sukhwal performed HPLC and GCMS studies. Devendra Jain and Sudhir K. Udpadhay wrote the manuscript. All authors reviewed the manuscript.

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CONFLICT OF INTEREST STATEMENT

No potential conflict of interest was reported by the authors.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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