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HOST RANGE AND CROSS INFECTIVITY STUDIES OF *CORYNESPORA CASSIICOLA*

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ABSTRACT

Corynespora infecting cotton has wide host range and due to its importance in blackgram earlier in Andhra Pradesh an investigation was carried to test the ability of the pathogen, *Corynespora cassiicola* isolated from cotton could cross infect blackgram crop and *vice versa.* Isolates were collected from the major cotton and blackgram (B-1 to B-6) growing areas *viz.,* Guntur, Prakasam and Krishna districts. Experimental design was completely randomized in a factorial arrangement of 12x3x2 (12 isolates, 3 areas and 2 hosts) and replicated thrice. Cross inoculation experiments demonstrated variation in the level of latent period, infectivity and per cent disease index (PDI) among *C. cassiicola* isolates. The incubation period was 4 to 7 days in cotton for cotton isolates with highest PDI (32.94) in C-5 and lowest in C-2 isolates (20.77 PDI). It was 3 and 6 days in blackgram with blackgram isolates; the highest PDI (38.05) was recorded in B-1 and lowest in B-6 (16.06). However, C6 (8.28) and B5 (11.21) displayed the highest virulence index, respectively. Cross infectivity studies registered the highest PDI with C3 isolate (24.82) and the lowest in C5 isolate (12.48) in blackgram; whereas PDI was highest with B2 isolate (15.90) and B6 isolate (5.59) in cotton. In terms of virulence, C1 (4.50) and B4 (2.44) exhibited the highest virulence index, respectively.

Keywords: Blackgram, *Corynespora cassiicola,* Cotton, Cross infectivity

INTRODUCTION

Leaf spot disease in blackgram incited by *Corynespora cassiicola* (Berk. and Curt.) was first reported in 1959 from Bhubaneshwar, India by Addy and Mohanty (1960). Later Mallaiah *et al.* (1981) recorded the incidence of the disease on blackgram in Andhra Pradesh for the first time, and found that *C. cassiicola* isolated from blackgram was also pathogenic to greengram. Ferreira and Bentes (2017) investigated pathogenicity of *C.cassiicola on* different hosts and reported that papaya isolates caused symptoms in all the evaluated plant species, whereas egg plant and tomato isolates expressed certain degree of specificity. Studies on *Corynespora* were limited to interaction between *Alternaria* and *Corynespora* in cotton (Mahesh *et al*., 2024), progress in relation to weather (Roshan Baba *et al*., 2022) and spacing (Mounika *et al*., 2023) and in case of balckgram occurrence of *Corynespora* in relation to other diseases and weather (Sandeep Naik *et al*., 2014; Sandeep Naik *et al*., 2016), screening against

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Corynespora leaf spot under natural conditions (Gunasri *et al*., 2018) and sporulation (Madhavi and Moorthy, 2001) were studied. Since, *Corynespora* was an important leaf spot disease of blackgram earlier and now emerging as a major disease of cotton in Andhra Pradesh, to understand the cross infectivity between the isolates of cotton and blackgraman experiment was conducted in the Department of Plant Pathology, Agricultural College, Bapatla during 2022-2023 by collecting the isolates *C. cassiicola* from cotton and blackgram crops.

MATERIAL AND METHODS

Collection of *C. cassiicola* isolates

Infected samples of *Corynespora* target spot were collected by conducting roving surveyin major cotton and blackgram growing districts of Andhra Pradesh *i.e.,* Guntur, Prakasam and Krishna during *kharif* 2022-2023. Two mandals per district and three villages per mandal were surveyed. Five plants at five locations *i.e*., at four corners of each field and one at the centre were selected to carry out isolations and study the pathogenicity of *C.cassiicola* isolates (Table 1, Fig. 1 and Fig. 2).

Isolation and purification of *C. cassiicola*

Leaf bits of five mm^2 with healthy and infected leaf portion were cut, surface sterilized using 1% sodium hypochloride for a minute and rinsed with three changes of sterile distilled water to remove the disinfectant. Leaf bits were blot dried before transferring aseptically on to PDA medium in petri plates and then incubated at 27±1 ˚C in incubator.

Different isolates obtained from infected tissue were purified by single spore isolation method. Three millilitre of sterile distilled water was added to 10 days old culture tube to get spore suspension which was later diluted serially to get desired concentration and 100 ìl was aseptically transferred for single spore isolation through spread plate method using 2% solidified water agar. A well isolated, germinated spore was located after incubation of 4-5h at 27±1˚C and marked using

Table 1. *Corynespora cassiicola* isolates collected from cotton and blackgram

Crop	S. No.	Designation of the isolate	Village	Mandal	District
Cotton	1	C-1	Reddigudem	Rajupalem	Guntur
	2	C-2	Rajupalem	Rajupalem	Guntur
	3	C-3	Dachepalle	Dachepalle	Palnadu
	4	C-4	Jagarlamudi	Yeddanapudi	Prakasam
	5	C-5	Martur	Martur	Prakasam
	6	C-6	Nakkabokkalapadu	Ballikurava	Prakasam
Blackgram	1	B-1	Telagapalem	Ponnuru	Guntur
	2	B-2	Patchalatadiparru	Ponnuru	Guntur
	3	B-3	Narakoduru	Chebrolu	Guntur
	4	B-4	Vuyyuru	Vuyyuru	Krishna
	5	B-5	Yakamuru	Vuyyuru	Krishna
	6	B-6	Akunuru	Vuyyuru	Krishna

microscope. Circular disc of the medium corresponding to the marked single spore was picked up using a sterilized cork borer and was aseptically transferred to PDA medium.

Pure culture obtained was subcultured on PDA slants and incubated at 27±1 °C till the mycelium was fully grown over medium. The culture slants were then preserved in a refrigerator at 4°C for further use.

Pathogenicity studies

Pathogenicity of respective isolates was confirmed by inoculating *C. cassiicola* isolates on cotton and blackgram crops. Seed material was obtained from Regional Agricultural Research Station, Lam, Guntur. The soil was sterilized and filled in the black poly bags of 12"×12". The seeds of cotton variety L 1060 and blackgram variety PU 31 were sown and seedlings were maintained under greenhouse conditions. The bags were watered regularly. Two seedlings per bag were raised and three bags for each isolate were considered as three replications.

Cross infectivity studies among six cotton isolates and six blackgram isolates were conducted by challenge inoculation of cotton Corynespora isolates on black gram plants and the black gram corynespora isolates on cotton plants under greenhouse conditions. The seeds were sown in the black poly bags of

Descriptive scale for *Corynespora* target spot of cotton (Sheo Raj, 1988)

Scale	Leaf area infected
0	No Infection
1	A few small spots less than 2mm, scattered, brown in color, leaf area covered is less than 5%.
2	Bigger spots up to 3 mm coalescing, brown in color, 6-20% leaf area covered
3	Spots increasing in size 3-5 mm and irregular in shape tending to coalesce, 21-40% leaf area covered
4	Spots coalesce to form bigger lesions, irregular in shape and size more than 40% leaf area covered

Descriptive scale for *Corynespora* target spot of blackgram (Thakur *et al.*, 2007)

Grade	Per cent of infection
1	No infection on leaves
2	0.1% to 5% infection on the leaf surface
3	5.1% to 10% infection on the leaf surface
4	10.1% to 15% infection on the leaf surface
5	15.1% to 30% infection on the leaf surface
6	30.1% to 40% infection on the leaf surface
7	40.1% to 50% infection on the leaf surface
8	50.1% to 75% infection on the leaf surface
9	Above 75% infection on the leaf surface

12"×12", maintained two plants per bag, replicated thrice per isolate, watered regularly.

Inoculum preparation and inoculation

Pure cultures of respective isolates were grown on PDA. Conidia from 12 days old culture were dislodged by flooding the plate with distilled water followed by gentle scraping. The spore suspension was harvested into a beaker and strained through muslin cloth. The spore concentration was adjusted to 10^5 spores per ml using haemocytometer and mixed with Tween-20 @ 0.1% to ensure uniform spread of inoculums over leaves. Plants were inoculated using hand sprayer during evening hours @ 15 ml $plant^{-1}$. The plant sprayed with sterile distilled water + Tween-20 (0.1%) served as control. Immediately after spraying, the plants were covered with poly propylene covers for 24h to prevent cross contamination and to ensure humidity for pathogen establishment. Incubation period (time required for first appearance of necrotic symptoms) for each isolate was assessed by examining inoculated plants everyday for appearance of lesions. Corynespora leaf spot was scored using a four-point rating scale for cotton (Sheo Raj, 1988) and nine grade rating scale for blackgram (Thakur *et al*., 2007), respectively.

Per cent disease index (PDI) was calculated based on disease severity data (Wheeler, 1969).

$$PDI = \frac{\text{Sum of all the numerical ratings}}{\text{Total number of leaves scored X Maximum disease grade}} \times 100$$

The numerical values of percent disease index and latent period were used to calculate the Virulence index using the following formula (Thakur and Rao, 1997).

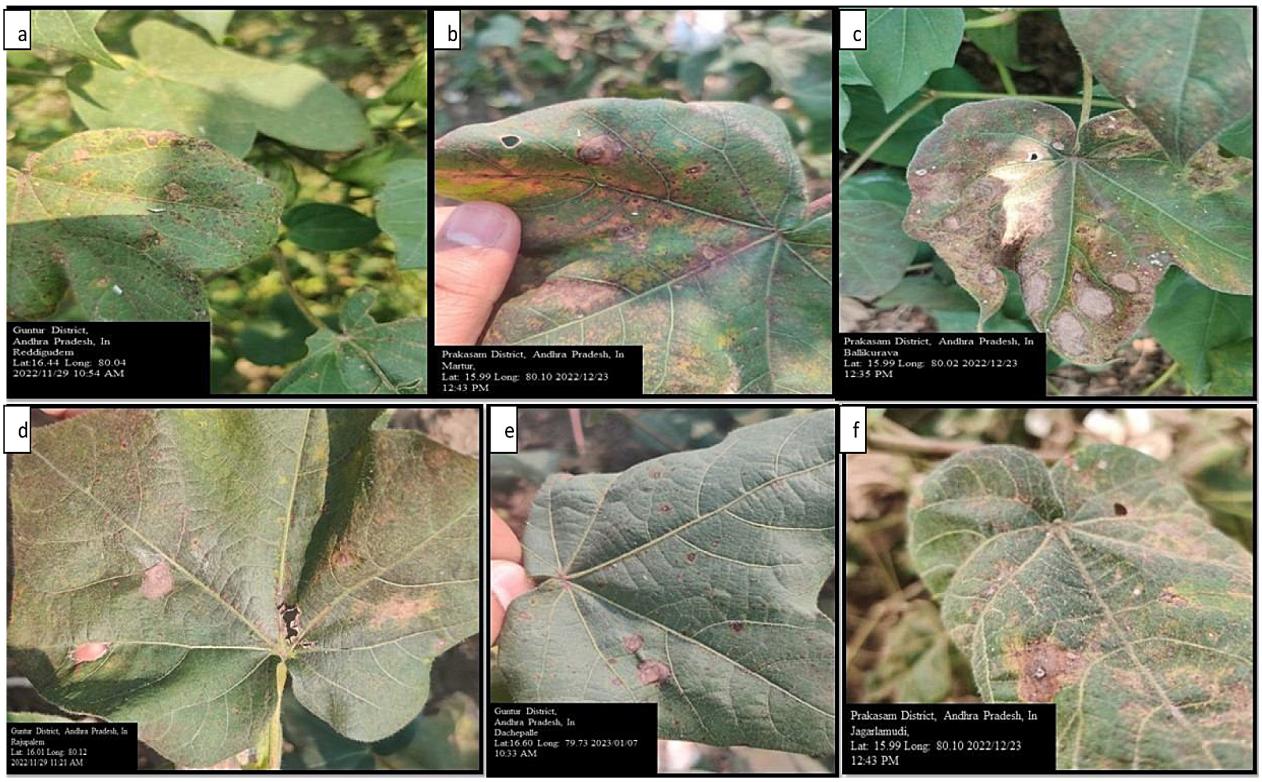
Virulence index (VI) = Per cent disease reaction (PDI) / Latent period (incubation period)

RESULTS AND DISCUSSION

C. cassiicola is a widespread cosmopolitan pathogen associated with approximately 530 different host plants in tropical and subtropical countries (Silva *et al*.,1995; Ferreira and Bentes, 2017). More than 60 genera including papaya, citrus, rubber, cassava, blackgram, cotton, cucumber etc. have been identified to harbour the pathogen, *C. cassiicola*. During the present investigation, variations in pathogenicity were shown by cross-inoculation tests between cotton isolates on blackgram and *vice versa*, and on their original host.

Pathogenicity of *C. cassiicola* isolates on their original host

Upon subjecting cotton plants to six distinct isolates of cotton, the minimal incubation period of 3.7 days was observed in the case of isolate C6, followed closely by isolates C1 and C5, both manifesting an incubation period of 4 days. Contrarily, the maximum incubation period, lasting 6.3 days, was documented for isolate C4. Concerning lesion count, isolate C6 exhibited the highest with 35.0, while C4 followed with 23.33 lesions, and the least number of lesions, numbering 18.0, was observed with C5. For assessing cotton infection by *C. cassiicola*isolates, the PDI was computed and exhibited a range from 20.77 to 32.94. The highest PDI was recorded for C5 isolate at 32.94, closely pursued by C6 isolate at 30.63, while the lowest PDI was registered for C2 isolate, standing at 20.77. In terms of virulence, C6 displayed the highest virulence index at 8.28, followed by C1 (7.20), C3 at 5.96, C5 (4.50, C4 (4.18) and the lowest virulence index was ascertained in C2, with a value of 3.64 (Table 2).



(a) Reddigudem, (b) Martur, (c) Ballikurava, (d) Rajupalem, (e) Dachepalle, (f) Jagarlamudi

Fig. 1.*Corynespora cassiicola* isolates collected from cotton

(a) Akunuru (b) Vuyyuru (c) Patchalatadiparru (d) Narakoduru (e) Telagapalem (f) Yakamuru

Fig. 2.*Corynespora cassiicola* isolates collected from Blackgram

Table 2. Reaction of cotton plants against *Corynespora cassiicola* isolates of cotton

S.No.	Isolates	Incubation period (days)	Lesion number	PDI	Virulence index
			Mean	(30 DAI)	Mean
1.	C1	4.0 (1.99)^{b}	21.0 (4.58)^{b}	28.79 (28.47)^{ab}	7.20
2.	C2	5.7 (2.37)^{a}	22.33 (4.66)^{b}	20.77 (24.1)^{b}	3.64
3.	C3	5.0 (2.24)^{ab}	19.66 (4.39)^{b}	29.80 (30.73)^{ab}	5.96
4.	C4	6.3 (2.52)^{a}	23.33 (4.83)^{b}	26.31 (27.47)^{ab}	4.18
5.	C5	4.0 (2)^{b}	18.0 (4.24)^{b}	32.94 (32.12)^{a}	4.50
6.	C6	3.7 (1.91)^{b}	35.0 (5.92)^{a}	30.63 (29.96)^{ab}	8.28
CD (@*5%*)		0.10	0.20	3.06	
SEm±		0.03	0.07	0.98	
CV (%)		2.96	4.72	4.94	

* Data represents mean of three replications
* Figures in parenthesis are square root transformed values
* Figures with the same alphabets are statistically not significant
* PDI – Per cent Disease Index

Table 3. Reaction of blackgram plants against *Corynespora cassiicola* isolates of blackgram

S.No.	Isolates	Incubation period (days)	Lesion number	PDI	Virulence index
			Mean	(30 DAI)	Mean
1.	B1	4.00 (1.99)^{bc}	5.33 (2.31)^{a}	38.00 (38.05)^{a}	9.50
2.	B2	4.66 (2.16)^{ab}	4.33 (2.06)^{a}	33.81 (35.55)^{ab}	7.26
3.	B3	3.66 (1.91)^{bc}	4.00 (1.99)^{ab}	27.80 (31.80)^{b}	7.60
4.	B4	5.66 (2.38)^{a}	5.00 (2.24)^{a}	35.81 (36.74)^{a}	6.33
5.	B5	3.33 (1.82)^{b}	5.00 (2.23)^{a}	37.33 (37.63)^{a}	11.21
6.	B6	4.33 (2.08)^{bc}	2.33 (1.47)^{b}	16.06 (23.50)^{c}	3.71
CD (@*5%*)		0.09	0.16	2.79	
SEm±		0.03	0.05	0.90	
CV (%)		2.73	5.05	4.37	

* Data represents mean of three replications
* Figures in parenthesis are square root transformed values
* Figures with the same alphabets are statistically not significant
* PDI – Per cent Disease Index

Table 4. Cross infectivity of *Corynespora cassiicola* isolates of Cotton on blackgram

S.No.	Isolates	Incubation period (days)	Lesion number	PDI	Virulence index
			Mean	(15 DAI)	Mean
1.	C1	5.33 (2.31)^{ab}	4.0 (1.99)^{a}	23.98 (29.27)^{ab}	4.50
2.	C2	5.00 (2.23)^{ab}	3.66 (1.88)^{a}	17.39 (24.63)^{c}	3.48
3.	C3	5.67 (2.38)^{a}	5.0 (2.23)^{a}	24.82 (29.85)^{a}	4.38
4.	C4	6.33 (2.52)^{a}	4.66 (2.15)^{a}	24.24 (29.49)^{a}	3.83
5.	C5	4.00 (1.99)^{b}	1.66 (1.28)^{b}	12.48 (20.68)^{d}	3.12
6.	C6	6.0 (2.44)^{a}	5.0 (2.23)^{a}	19.49 (26.19)^{bc}	3.25
CD (@5%)		0.09	0.15	1.94	
SEm±		0.03	0.05	0.62	
CV (%)		2.80	4.82	3.47	

*Data represents mean of three replications

* Figures in parenthesis are square root transformed values

* Figures with the same alphabets are statistically not significant

* PDI – Per cent Disease Index

Table 5.Cross infectivity of *Corynespora cassiicola* isolates of blackgram on Cotton

S.No.	Isolates	Incubation period (days)	Lesion number	PDI	Virulence index
			Mean	(30 DAI)	Mean
1.	B1	5.00 (2.23)^{c}	14.00 (3.73)^{a}	8.37 (16.71)^{cd}	1.67
2.	B2	7.66 (2.76)^{a}	8.00 (2.80)^{b}	15.90 (23.43)^{a}	2.08
3.	B3	5.00 (2.23)^{c}	10.66 (3.24)^{ab}	11.32 (19.65)^{bc}	2.26
4.	B4	6.00 (2.43)^{abc}	5.66 (2.37)^{b}	14.63 (22.33)^{ab}	2.44
5.	B5	5.66 (2.38)^{bc}	14.66 (3.82)^{a}	11.02 (19.22)^{bc}	1.95
6.	B6	8.00 (2.83)^{a}	6.66 (2.469)^{b}	5.59 (13.67)^{d}	0.70
CD (@5%)		0.12	0.27	3.32	
SEm±		0.04	0.09	1.06	
CV (%)		3.44	7.36	7.13	

* Data represents mean of three replications

* Figures in parenthesis are square root transformed values

* Figures with the same alphabets are statistically not significant

* PDI – Per cent Disease Index

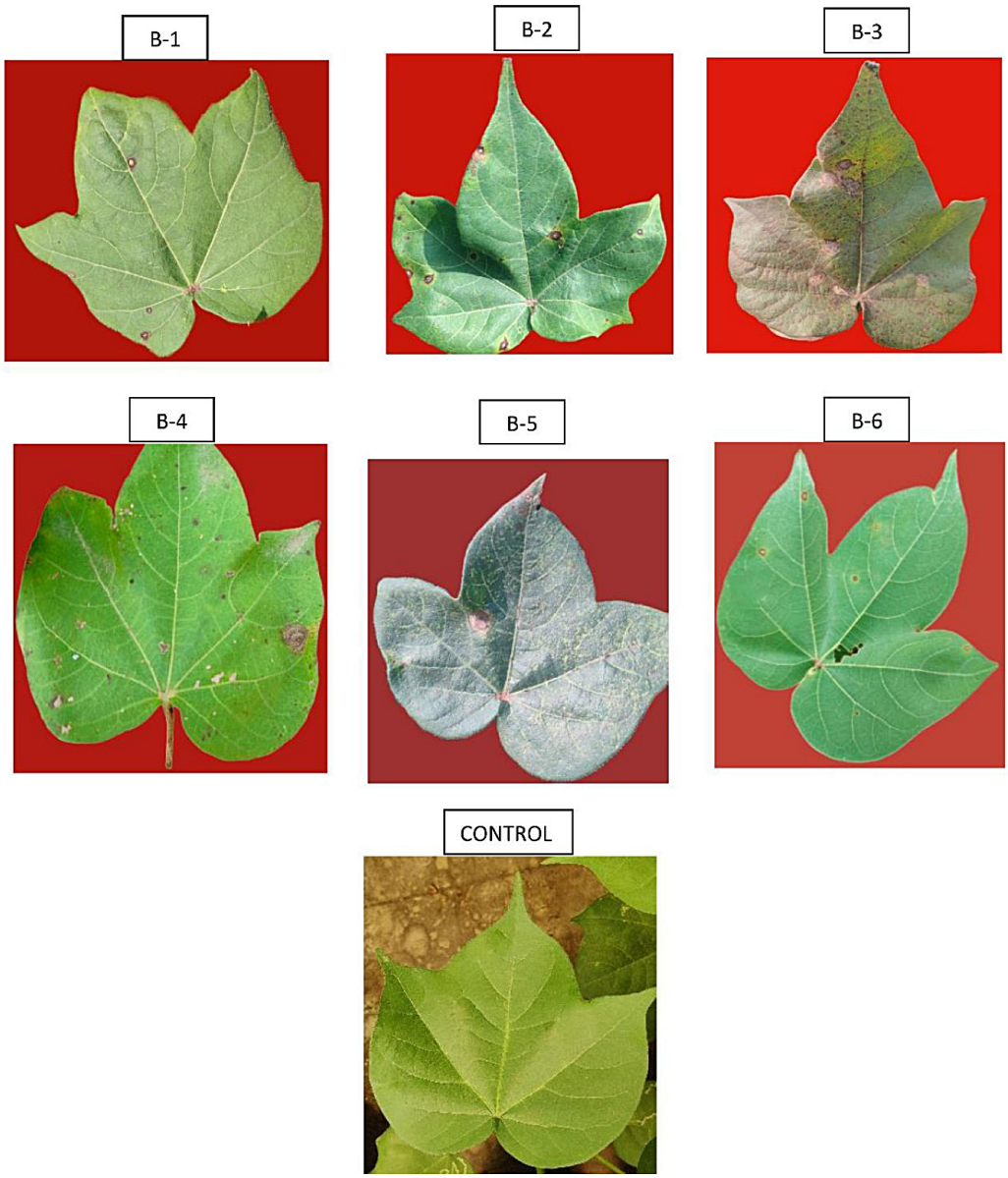


Fig. 3. Reaction of cotton inoculated with *Corynespora cassiicola* isolates of blackgram

Blackgram plants when incubated with six different isolates of blackgram, minimum incubation period of 3.33 days was observed with B5 isolate followed by B3 isolate with a period of 3.66 days and the maximum incubation period of 5.66 days was observed in B4 isolate. Maximum number of lesions were recordedin B1 isolate (5.33) followed by B4 and B5 isolates (5.00) and the minimum lesion number (2.33) was found with B6 isolate. PDI was calculated to assess the blackgram infection with *C. cassiicola* isolates and it ranged from 16.06 to 38.0. Highest PDI was found for B1 isolate with 38 followed by B5 isolates 37.33 and the minimum was found in case of B6 isolate with 16.06 PDI. Highest virulence index of 11.21 in B5 followed by B1 (9.50), B3 (7.60), B2 (7.26), B4 (6.33) and the lowest of 3.71 were recorded in B6 (Table 3).

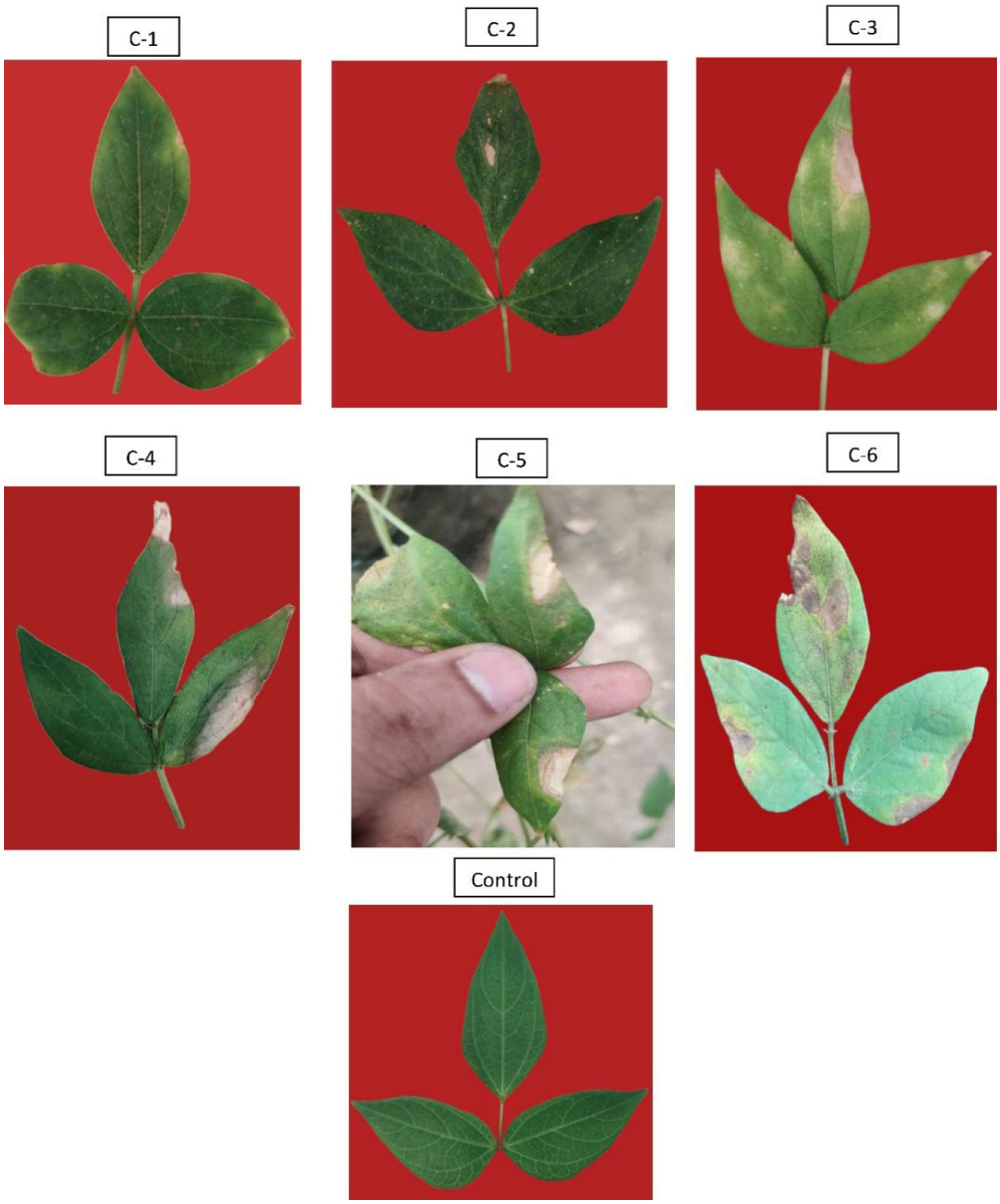


Fig. 4. Reaction of blackgram inoculated with *Corynespora cassiicola* isolates of cotton

Cross infectivity studies

Along with host range, cross infectivity studies were performed to check the effect of cotton isolates on blackgram and *vice versa*.

Cross infectivity of *C. cassiicola* isolates of cotton on blackgram

Spore suspensions from six cotton isolates when sprayed, individually, on blackgram plants the shortest incubation period was observed in C5 isolate, lasting 4 days, while the longest incubation period was recorded in C4 isolate, extending to 6.33 days. The number of lesions varied with the highest lesion count being 5.00 for both C3 and C6 isolates, and the lowest lesion count was 1.66 for C5 isolate. To assess the extent of disease, PDI was calculated, ranging from 12.48 to 24.82. The highest PDI was observed when C3 isolate was cross-inoculated onto blackgram,

Plate 1. Re isolation of *Corynespora cassiicola* from cross inoculated blackgram plants

Plate 2. Re isolation of *Corynespora cassiicola* from cross inoculated cotton plants

resulting in a PDI of 24.82, closely followed by C4 isolate with a PDI of 24.24. Conversely, the lowest PDI was found with C5 isolate, yielding a PDI of 12.48. In terms of virulence, C1 exhibited the highest virulence index at 4.50, followed by C3 (4.38), C4 (3.3) and C2 (3.48) while the least virulence index was recorded in C5 at 3.12 (Table 4, Plate 1).

Reaction of cotton to *C. cassiicola* isolates of blackgram upon cross inoculation

The spore suspension of six blackgram isolates was inoculated, individually, on cotton plants. Minimum incubation period of 5 days was observed in B1 and B3 isolates; maximum of 8 days was in B6 isolate. Number of lesions varied with each isolate when cross inoculated on cotton and the highest lesion number was found with B5 isolate (14.66) and the least number of lesions was found with B4 isolate (5.66). Per cent Disease Index ranged from 5.59 to 15.90 where the highest PDI was found when B2 isolate (15.90) was cross inoculated on cotton followed by B4 isolate with 14.63 PDI and the lowest PDI was found when blackgram plants were cross inoculated with B6 isolate (5.59). Highest virulence index was observed

in B4 (2.44) followed by B3 (2.26), B2 (2.08), B5 (1.95), B1 (1.67) and the least was observed in B6 (0.70) (Table 5, Plate 2).

Onesirosan *et al*. (1974) reported that cotton isolate of *C. cassiicola* was weakly virulent to tomato, causing few-to-many pin-point lesions, while tomato isolate was moderately virulent to cotton, causing 4 to 10 mm sized lesions on leaves. Duarte *et al.* (1983) tested two different strains of *C. cassiicola*, one from cocoa and the other from papaya and observed that the papaya strain had the ability to infect papaya plants, rubber trees, and cowpea, whereas the cocoa strain could only cause disease in its native host. Lakshmanan *et al.* (1990) reported that cotton and blackgram showed symptoms on leaf within 10 days after inoculation. Specificity in tomato isolates of *C*. *cassiicola* by not infecting papaya was observed by Cutrim and Silva (2003). They also reported non-specific nature of papaya isolate by infecting different hosts including egg plant, papaya and tomato.

Cross infectivity studies on *Phytopthora capsici* revealed pathogenicity of both isolates on chilli and black pepper, however with symptom differences (Truong *et al.*,2012). Cocoa isolate of *P. palmivora* (CPR244) and durian isolate (DSCB4) and *P. nicotianae* isolated from rubber (R2A) were found to infect oil palm buds, causing dark brown to black, necrotic lesions 5 days after inoculation. The inoculated *Phytophthora* isolates were successfully re-isolated from the infected tissues (Latifah *et al.*, 2017).

CONCLUSION

Cross infectivity of *C. cassiicola* infecting cotton and blackgram revealed non-specific nature of 12 isolates studied indicating the pathogen's ability to have wider host range and adaptability in the cropping system.

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TRAIT ASSOCIATION ANALYSIS AND DIVERSITY ASSESSMENT IN BROWN TOP MILLET (*Brachiaria ramose* L.) GERMPLASM LINES

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ABSTRACT

The experiment was conducted during the year Rabi 2022. Eight purelines developed by the SSD method have been assessed along with six lines collected from RARS, Nandyal for various phenotypic traits such as number of tillers, plant height, days to 50% flowering, flag leaf length, number of leaves per plant, primary rachis length, panicle exertion length, types of panicle, length of panicle, days to maturity, panicle weight, and 1000 grain weight were recorded. Significant variation has been observed for most of the traits such as maturity days (76-83 days), days to 50% flowering (52.6-67 days), plant height (15- 30 inch), leaves number (19-24), primary rachis length (2.7-7.1 inch), flag leaf length (4.6-7.3 inch), panicle exertion length (1.43-2.33 inch), panicle length (4.7-9.1 inch), panicle weight (0.7-2.6 gm), panicle types (open and close), number of tillers (2-4) and 1000 grain weight (0.67-2.05 gm). Path coefficient, genotypic coefficient variation, and phenotypic coefficient variation facilitate understanding the trait association influenced by genetic and environmental factors. There was a strong positive correlation between the panicle effect and the weight of 1000 grains. High heritability was observed for the trait panicle type (100%), followed by 1000 grain weight (88%), primary rachis length (80.83%), panicle weight (70.6%), panicle exertion length (63.52) and panicle length (53.48). PC score illustrated, BTM-6 with the highest PC score (3.43) followed by BTM-7 (1.95), BTM-2 (0.89, and BTM-5 (0.83). The present study signifies the genotypic and phenotypic variability in browntop millet with respect to the quantitative and qualitative traits with breeding importance.

Keywords: Browntop millet, GCV, Hierarchical Cluster Analysis, PCA, PCV

INTRODUCTION

'Milllets' are small seeded cereal crops belonging to family Poaceae are known for their cultivation across the globe in arid and semi-arid regions. They are known for their ability to grow in resource-poor soil, tolerant to a variety of stresses and produce high nutri-rich seed (Ashoka and Sunitha, 2020). Carbohydrates (60-70%) are the major compositions of millet seeds that were also loaded with higher concentrations of fibre (12-20%), protein (6-19%), fat (1.5-5%) and minerals (2-4%) with vitamins and polyphenols (Mahajan *et al*., 2021). Global millet production

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in 2023-24 is about 31.247 million metric tons. And since, 2019 onwards due to the efforts of various organizations, there is a gradual increase in millet cultivation area as well as production (FAOSTAT, 2024). While India ranked first with 38.40%, followed by Niger (11.85%) and China (8.75%) in global millet production as per the report of Processed Food Products Export Development Authority (APEDA) and Ministry of Commerce, Government of India, Agriculture , for the year 2023-24 (APEDA, 2024). They are known for their ability to grow in resource-poor soil, tolerance to a variety of stresses that includes biotic and abiotic and produce high nutri-rich seed (Ashoka and Sunitha, 2020). They require relatively less water, easy to maintain with less labour-intensive farming efforts compared to other cereals like rice, wheat etc., Depending on the cultivation, there are two groups, major millets and minor millets. First group constitutes Bajra-pearl millet (*Pennisetum glaucum* L.) and Sorghum (*Sorghum bicolor* L.). While the other group consists of Kodo millet (*Paspalum scrobiculatum* L.), barnyard millet (*Echinochloa frumentacea* L.), proso millet (*Panicum miliaceum* L.), foxtail millet (*Setaria italica* L.), finger millet (*Eleusine coracana* L.) and browntop millet (*Brachiaria ramose* L.) (Clayton *et al*., 2006).

Browntop millet (*Brachiaria ramose* L. Stapf.) is one of the minor millets that is widely grown in South India.Based on panicle morphology, there are two types of browntop millet, one is open type of panicles (2n=28) and another one is with compact panicles (2n= 38). Alternately it is also called as the illegal wife of little millet. It is also used to safeguard other crops from rodents due to its sharp leaf edge (Anuradha *et al*., 2020) and to mitigate with root-knot nematode in peppers and tomatoes (Ashoka and Sunitha, 2020). It is an annual crop, considered as domesticated in India and grown in the rainfed areas of Asia and Africa which gets matured in around 80-90 days. Vernacularly it is known as korale, karlakki, and antukorra in different parts of India. In addition to being utilized as cattle and bird fodder, browntop millet is known as a crop of nutritional rich and is being used in traditional recipes. Since it is rich in micronutrients, browntop millet has therapeutic uses. Browntop millet has 12% fiber, helps in intestinal cleaning, lowers cholesterol, and is beneficial to those with type 2 diabetes. Its anti-oxidant qualities help prevent cancer and ulcers. Because of its gluten-free nature, it is helpful in celiac disease (Ashoka and Sunitha, 2020). Under ideal conditions, it is reported to yield about 1,800 – 4,000 pounds of dry matter, however under stress conditions it also accumulates higher amounts of nitrate which is toxic (Sheahan, 2014). Browntop millet is emerging as a potent cereal mitigating climate change ensuring food security. The estimated production of browntop millet is about 730 thousand tonnes from the cultivated area of about 818.5 thousand hectares. But, on an average there are not much reports available on the browntop millet varietal development, cultivation, and production in completely in a systemic manner, except few annual reports from IIMR. To our knowledge, it is one of the first systematic study, where we are reporting development of browntop millet purelines using single seed descent method from bulk collections from farmer's fields across Rayalaseema region of Andhra Pradesh. Further, these pure lines were evaluated in greenhouse conditions and investigated for their phenotypic variability for twelve agronomic traits in comparision with the lines collected from RARS, Nandyal. The results obtained shows a substantial trait-related genetic variability in the developed lines compared to the lines collected from RARS, Nandyal.

MATERIAL AND METHODS

Plant materials

Development of Pure Lines

The 14 diverse genotypes of Browntop millet (*Brachiaria ramose* L. Stapf.), (coded name as BTM-1 to BTM-14), were collected from various parts of Rayalaseema region, Andhra Pradesh. The lines, BTM-1 to BTM-7 along with BTM-14 were collected from farmers field in different parts of Rayalaseema region of Andhra Pradesh while BTM-8 to BTM-13 were collected from RARS, Nandyal, Andhra Pradesh (Table:1, Figure:1). All collected germplasm were sown in farmers fields.

For the pure line development, single seed descent method was followed. Keeping in view of the spreading nature of the browntop millet, seeds of the individual lines were sown in the line sowing method, with each line of 1.5 mts separated by 0.25 mts to avoid the mixing of the individual lines. Randomly selected single plant germinated from a single seed was selected 25 days after sowing and tagged from individual line, and seeds of that selected plant were collected separately and used for next season. While the rest of the panicles from all other plants in the line were bulked and stored for any further use. This selection process was continued for eight seasons during 2019 to 2022, and the seed thus collected after eight seasons was bulked from the individual line and used further.

Phenotyping

The experiment was conducted in *Rabi* season (2022) in the greenhouse of the Department of Biotechnology, with a natural day/ night temperature of 30°C±1°C/35°C±1°C and with relative humidity varied from 55%–85% at Yogi Vemana University, Kadapa, Andhra Pradesh, 14.47 N 78.82 E, altitude 152.259 meters from sea level, in random block design and replicated thrice.

The field layout was in a plot of 1.5 mts and each line was separated by 0.25 mts with

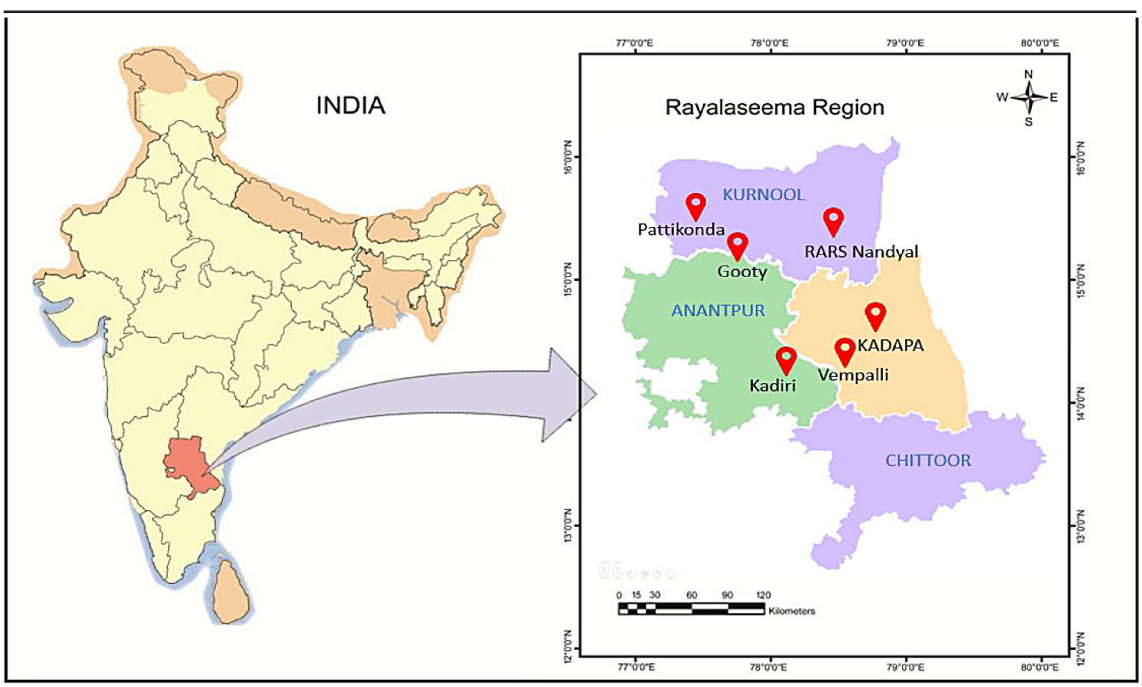

Figure 1. Collection of browntop millet germplasm from different locations of Rayalaseema region, Andhra Pradesh

basal application of 15 grams urea for each line. Fifteen days after sowing, excess number of plants were removed in order to maintain uniform number of 30 plants per line. Experimental plots were irrigated for every three days with an application of 30 grams of urea for individual line twice during the experimental period. A total 12 agronomic traits were considered for phenotypic observations that includes total number of tillers (TN), plant height (PH) (inch), number of leaves per plant (LN), days to 50% flowering (50% FD), flag leaf length (FLL) (inch), primary rachis length (PRL) (inch), panicle exertion length (PnEL) (inch), types of panicle (PnT) (open/close), length of panicle (PnL) (inch), days to maturity (MD), panicle weight (PnW), and 1000 grain weight (TGW) (gm). Number of leaves per genotypes was observed at vegetative stage (40 days after sowing). Plant height was measured from base to tip of the infloresence at the 50% flowering stage. Primary rachis length, panicle exertion, panicle type and panicle length were recorded during the 80% maturity stage of individual line. Panicle weight and 1000 grain weight of each individual line were recorded after harvesting the panicles that were kept in hot air oven maintained at 40^0C for 24 hours

Statistical Analysis

Phenotypic data was subjected to statistical analysis for descriptive statistics mean value, which were carried out using XL-STAT 2023.2.0.141. Path coefficient analysis, genotypic coefficient variance (GCV), phenotypic coefficient variance (PCV) and heretibility were carried out by Opstat software (https://opstat.pythonanywhere.com/) developed by Haryana Agricultural University, Hisar. Principal component analysis (PCA) biplot and multivariant hierarchical cluster dendrogram were analyzed by R program version 4.3.3.

RESULTS AND DISCUSSION

Phenotypic Variability

In the Study, remarkable phenotypic variation was observed among the 14 browntop millet lines. Significant variation was observed for the traits such as Days to Maturity (76-83 days), days to 50% flowering (52.6-67 days), plant height (15- 30 inch), leaves number (19-24), primary rachis length (2.7-7.1 ich), flag leaf length (4.6-7.3 inch), panicle exertion length (1.43-2.33 inch), panicle length (4.7-9.1 inch), panicle weight (0.7-2.6 gm), Type of Panicle (open or compact type, Figure:2), number of tillers (2-4) and 1000 grain weight (0.67-2.05 gm). The highest phenotypic variation was observed for primary rachis length, panicle weight and thousand grain weight. Mean values of morphological data of all 14 BTM genotypes were performed by descriptive statistical method (Table: 2). The

Figure 2. Panicle variation among all 14 lines of BTM (Open types and Close types)

Highest mean value was 80.59 for Days to Maturity and the lowest mean value was 1.24 for thousand grains weight.

Phenotypic correlation and path coefficient analysis

For the comprehensive understanding of relation among quantitative traits path coefficient analysis was performed. Phenotypic correlation found to be statistically significant at 1% and 5% level of significance (Table.3 and Figure.3). Phenotypic correlation delineates positive association of 1000 grain weight with traits such as panicle types, panicle weight and leaves number at 1% significance level. While, the traits flag leaf length, plant height and days to maturity are negatively associated with 1000 grain weight. Genotypic correlation was statistically significant at 1% and 5% level of significance (Table 4). Genotypic correlation exhibited 1000 grain weight strongly associated with panicle weight at 5% significance level. Plant maturity days was observed a strong correlation with tiller number and moderately correlated with flag leaf length, panicle exertion length and panicle length at 1% significance level. 50% flowering days, leaves number and flag leaf length were found to be highly positive corelated at 1 % significant level. Genotypic coefficient variation (GCV) and phenotypic coefficient variation (PCV) illustrate relation among genotypic and environmental factors on plant morphology. In the present investigation, some traits are shown influenced genetically and some traits were observed influenced by the environmental factors (Table 5). Highest phenotypic coefficient variation was observed for the trait panicle type followed by 1000 grain weight, panicle weight and primary rachis length. Highest ratio of PCV and GCV was observed for panicle types. Type of panicle contributed highest heritability with 100% followed by 1000 grain weight (indicated a fix trait), primary rachis length, panicle weight, panicle exertion length and panicle length

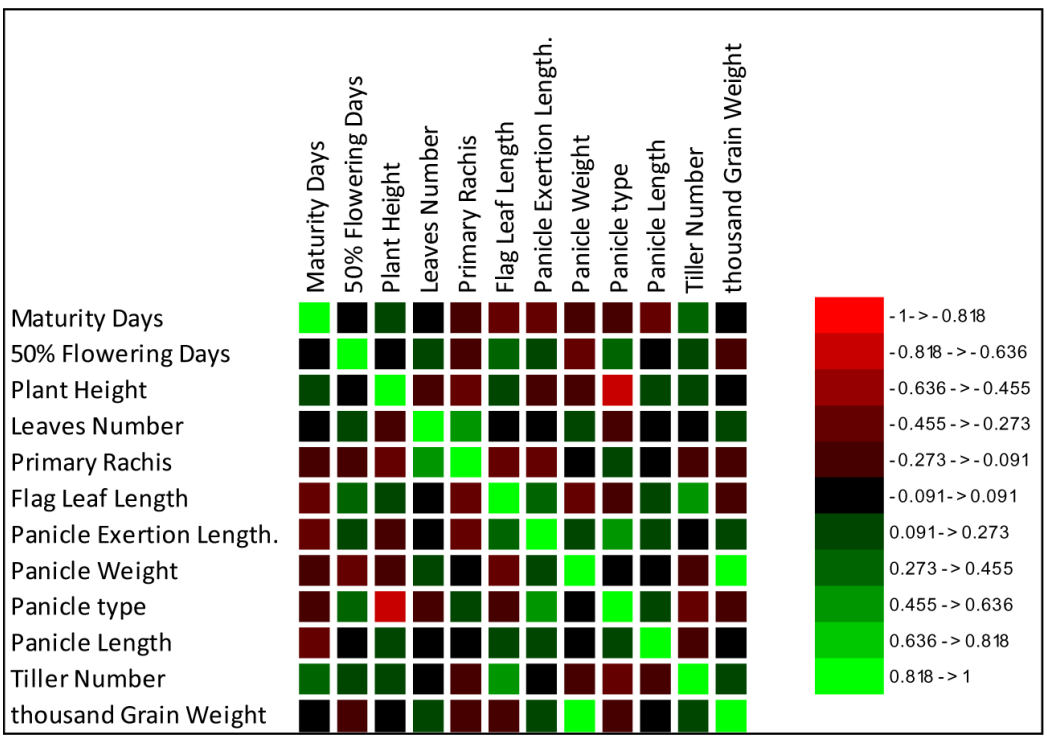

Figure 3. Image of Correlation Matrix of 12 agronomic traits of browntop millet

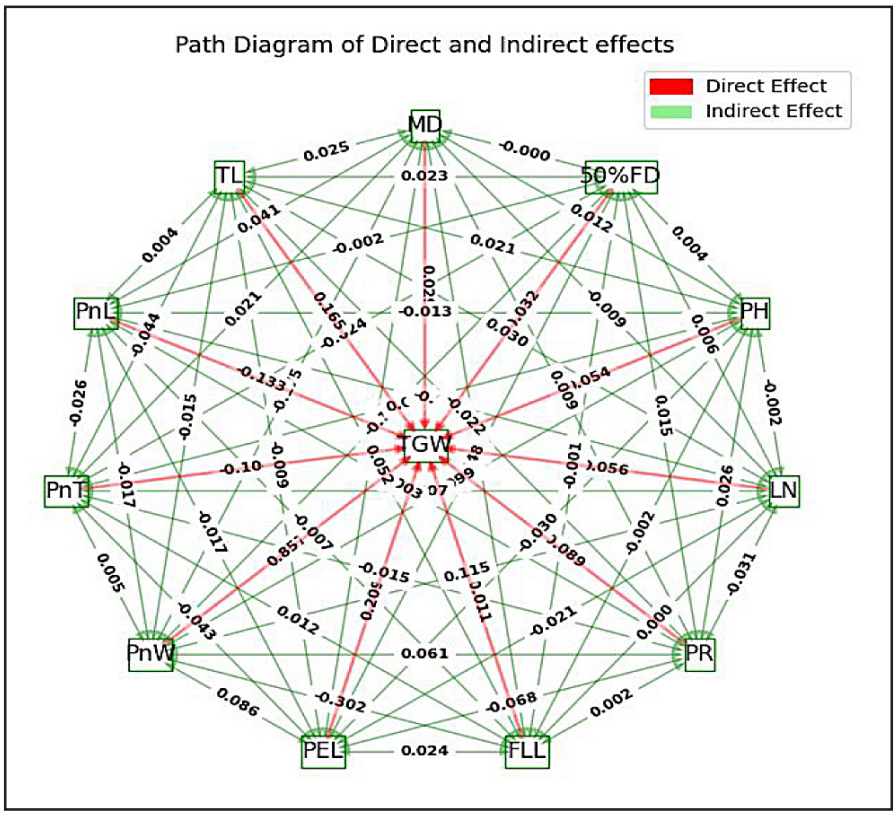

Figure 4. Path Coefficient Analysis of direct and indirect effect of selected 11 agronomic traits on 1000 Grain Weight

(Table 5). To understand the proper effect and potential, path analysis was performed with 1000 grain weight as dependent variable. Influence of other agronomic traits directly or indirectly on 1000 grain weight was as shown in Figure 4. Panicle weight represent highest positive direct effect on 1000 grain weight followed by panicle exertion length and tillers number (Figure 4). A similar pattern was observed in a study with foxtail millet landraces and released cultivars (Ramesh *et al.,* 2023).

Principal Component Analysis

Principal component analysis (PCA) method facilitates the reduction of the vast variable data set into a short dimension data set which makes it easy to understand large data sets (Singh *et al*., 2020). To obtain the mean value of phenotypic traits of all 14 browntop millet genotypes, principal component analysis was applied in the investigation. PCA illustrated the genetic diversity of all the 14 genotypes based on the different morphological characterization. Principal component analysis exhibited a total variability of 41.69%. PC1 showed 21.88% variability on X-axis and PC2 showed 19.8% variability on Y-axis, exhibiting phenotypic trait-based cluster relationship of all 14 browntop millet genotypes (Figure 5). Highest eigenvalue was recorded for PC1:2.6261 followed by PC2:2.3762, PC3:2.0268 and PC4:1.6044 respectively (Table 5). Scree plot curve line illustrated that highest variation showing PC1 followed by PC2, PC3, PC4, PC5. After PC5 straight line indicated very less variation in other PC (Figure 6). Based on PC score in PCI, BTM-6 exerted the highest PC score with 3.4271 followed by BTM-7 (1.9495), BTM-2 (0.8889) and BTM-5 (0.8308). BTM-12 exerted a

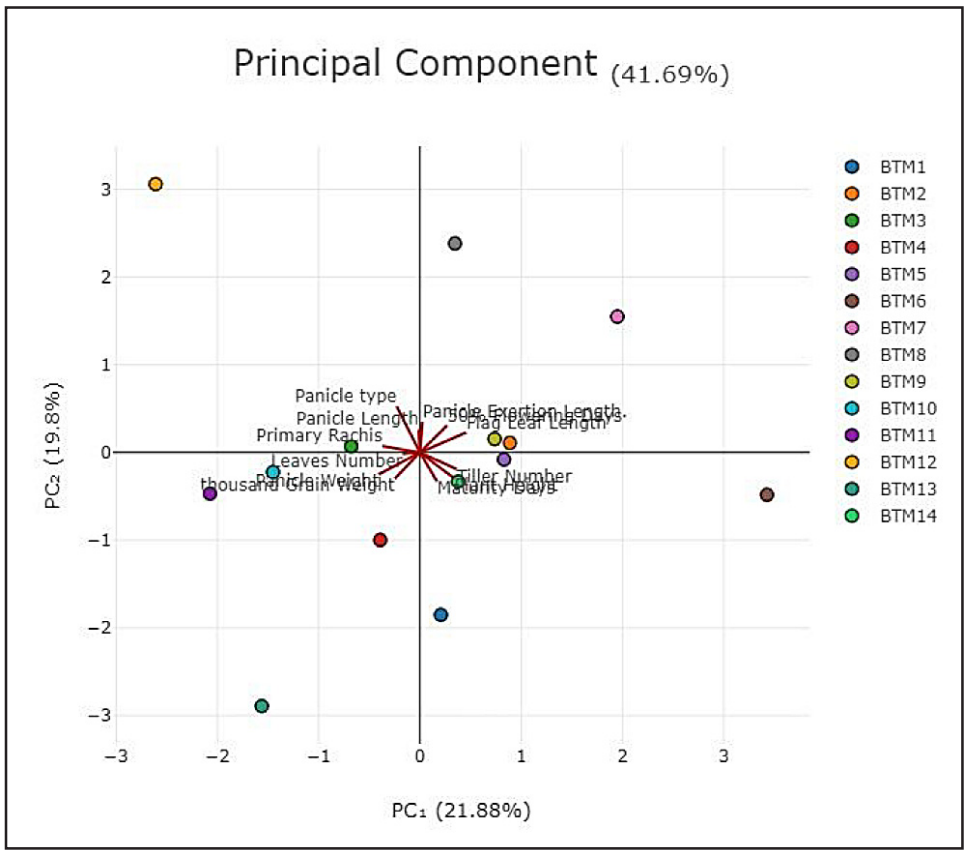

Figure 5. Principal Component biplot analysis of BTM Lines Based on their phenotypic data

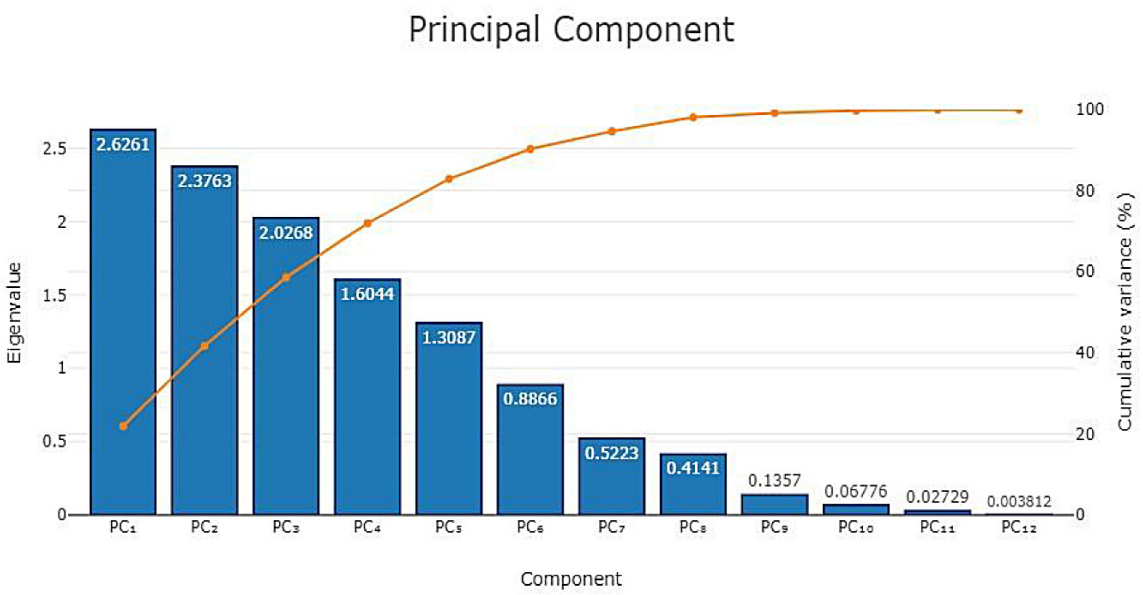

Figure 6. Scree plot Curve Depicting the variation in PC Score among the BTM lines

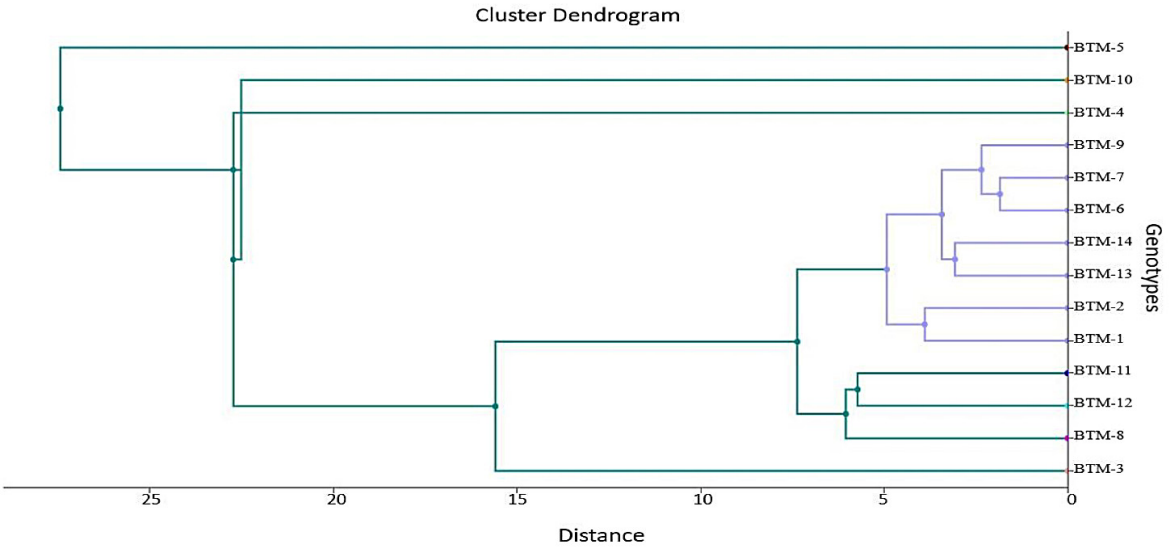

Figure 7. Hierarchical cluster dendrogram showing cluster of all 14 BTM based on their quantitative traits

minimum PC Score of -2.6094 in PC1. Highest percentage of variance was observed in PC1 (21.8843%) followed by PC2 (19.8029%), PC3 (16.8896%) and PC4 (13.3699%) (Table: 6). BTM genotypes revealed the most positive score in PC1, PC2, PC3, and PC4 related to their panicle weight and thousand-grain weight exhibited their superior yield-based trait. A similar investigation was revealed by Singh *et al.,* (2020) in chili, rice (Maji and Shaibu, 2012, Gana *et al.,* 2013), finger millet (Kandel *et al*., 2019, Babu *et al*., 2017), and pearl millet

Table 1. Collection of Browntop millet lines

S.No.	Name Given	Variety Type	Collection Area
1	BTM -1	Landraces	Kadiri, Anantapur
2	BTM-2	Landraces	Kadiri, Anantapur
3	BTM-3	Landraces	Vempalli, Kadapa
4	BTM-4	Landraces	Vempalli, Kadapa
5	BTM-5	Landraces	Gooty, Anantapur
6	BTM-6	Landraces	Pattikonda, Kurnool
7	BTM-7	Landraces	Pattikonda, Kurnool
8	BTM-8	Collection from RARS, Nandyal	RARS, Nandyal
9	BTM-9	Collection from RARS, Nandyal	RARS, Nandyal
10	BTM-10	Collection from RARS, Nandyal	RARS, Nandyal
11	BTM-11	Collection from RARS, Nandyal	RARS, Nandyal
12	BTM-12	Collection from RARS, Nandyal	RARS, Nandyal
13	BTM-13	Collection from RARS, Nandyal	RARS, Nandayal
14	BTM-14	Landraces	Local Selection Kadapa

Table 2. Analysis of variance for yield and its associated traits in browntop millet

	Tiller Number	Plant Height	Leaves Number	50% Flowering Days	Flag Leaf Length	Primary Rachis	Panicle Exertion Length	Panicle type	Panicle Length	Maturity Days	Panicle Weight	1000 Grain Weight
Minimum	2.67	15.20	19.00	52.67	4.67	2.73	1.43	1.00	4.77	76.33	0.70	0.67
Maximum	4.33	30.73	24.33	57.00	7.33	7.10	2.33	3.00	9.10	83.33	2.63	2.05
1st Quartile	3.33	20.38	20.08	53.33	5.72	3.28	1.65	1.25	6.40	79.33	1.65	1.06
Median	3.33	23.85	20.67	54.33	6.08	3.98	1.93	2.00	6.52	81.00	1.71	1.17
3rd Quartile	3.67	26.80	21.25	55.67	6.69	4.47	2.18	2.00	6.73	82.00	2.10	1.40
Mean	3.41	23.47	20.88	54.62	6.11	4.23	1.91	1.86	6.77	80.60	1.74	1.24
Variance (n-1)	0.24	25.25	1.75	2.34	0.63	1.68	0.09	0.44	1.20	4.84	0.26	0.16
Standard deviation (n-1)	0.49	5.03	1.32	1.53	0.79	1.29	0.30	0.66	1.10	2.20	0.51	0.39
SS	9.45	984.9	68.40	91.23	24.61	65.34	3.54	17.14	46.73	188.78	10.16	6.04
MS	0.72	75.76	5.26	7.01	1.89	5.02	0.27	1.31	3.59	14.52	0.78	0.46
F	1.19	4.21	1.11	3.19	2.44	13.65	6.22	NA	4.44	3.30	8.20	24.01
P	0.03	0.001	0.03	0.006	0.02	0.0001	0.0001	0.000	0.001	0.005	0.000	0.000
CD1%	NA	9.617	NA	3.36	NA	1.376	0.47	0.000	2.03	4.76	0.700	0.316
CD5%	NA	7.11	NA	2.48	1.47	1.01	0.35	0.000	1.15	3.521	0.518	0.233

Table 3. Phenotypic Correlation of 12 agronomic traits in browntop millet genotypes

	Tiller Number	Plant Height	Leaves Number	50% Flowering Days	Flag Leaf Length	Primary Rachis	Panicle Exertion Length	Panicle type	Panicle Length	Maturity Days	Panicle Weight	1000 Grain Weight
Tiller Number	1.000	0.129	0.182	0.139	0.316*	-0.134	-0.055	-0.268	0.026	0.154	-0.092	0.124
Plant Height	0.129	1.000	-0.042	0.075	0.164	-0.289	-0.141	-0.535**	0.101	0.226	-0.115	0.015
Leaves Number	0.182	-0.042	1.000	0.100	-0.014	0.346*	-0.098	-0.065	0.168	-0.156	0.134	0.124
50% Flowering Days	0.139	0.075	0.100	1.000	0.052	-0.169	0.229	0.232	0.016	0.010	-0.212	-0.145
Flag Leaf Length	0.316*	0.164	-0.014	0.052	1.000	-0.201	0.115	-0.117	0.049	-0.310*	-0.352*	-0.215
Primary Rachis	-0.134	-0.289	0.346*	-0.169	-0.201	1.000	-0.323*	0.141	0.019	-0.100	0.072	-0.126
Panicle Exertion Length	-0.055	-0.141	-0.098	0.229	0.115	-0.323*	1.000	0.411**	0.129	-0.228	0.100	0.227
Panicle type	-0.268	-0.535**	-0.065	0.232	-0.117	0.141	0.411**	1.000	0.194	-0.200	-0.049	-0.187
Panicle Length	0.026	0.101	0.168	0.016	0.049	0.019	0.129	0.194	1.000	-0.306*	0.131	-0.006
Maturity Days	0.154	0.226	-0.156	0.010	-0.310*	-0.100	-0.228	-0.200	-0.306*	1.000	-0.204	-0.091
Panicle Weight	-0.092	-0.115	0.134	-0.212	-0.352*	0.072	0.100	-0.049	0.131	-0.204	1.000	0.850**
1000 Grain Weight	0.124	0.015	0.124	-0.145	-0.215	-0.126	0.227	-0.187	-0.006	-0.091	0.850**	1.000

** = Significant at 1 % and * = Significant at 5 % level of significance

Table 4. Genotypic Correlation of 12 agronomic traits in browntop millet genotype

	Tiller Number	Plant Height	Leaves Number	50% Flowering Days	Flag Leaf Length	Primary Rachis	Panicle Exertion Length	Panicle type	Panicle Length	Maturity Days	Panicle Weight	1000 Grain Weight
Tiller Number	1.000	0.240	-0.991**	0.702**	1.419	-0.652**	0.321*	-1.073	-1.013	0.874**	-0.145	0.329*
Plant Height	0.240	1.000	-0.503**	-0.106	0.311*	-0.567**	-0.170	-0.743**	0.291	0.183	-0.113	0.058
Leaves Number	-0.991**	-0.503**	1.000	0.796**	-0.333*	2.005	0.187	-0.339*	-1.076	0.339*	0.297	0.092
50% Flowering Days	0.702**	-0.106	0.796**	1.000	0.937**	-0.073	0.284	0.357*	0.113	0.167	-0.489**	-0.254
Flag Leaf Length	1.419	0.311*	-0.333*	0.937**	1.000	-0.495**	0.607**	-0.204	0.185	-0.435**	-0.517**	-0.330*
Primary Rachis	-0.652**	-0.567**	2.005	-0.073	-0.495**	1.000	-0.317*	0.157	-0.052	-0.247	0.082	-0.157
Panicle Exertion Length	0.321*	-0.170	0.187	0.284	0.607**	-0.317*	1.000	0.516**	0.241	-0.434**	0.121	0.250
Panicle type	-1.073	-0.743**	-0.339*	0.357*	-0.204	0.157	0.516**	1.000	0.265	-0.304	-0.059	-0.199
Panicle Length	-1.013	0.291	-1.076	0.113	0.185	-0.052	0.241	0.265	1.000	-0.454**	-0.133	-0.093
Maturity Days	0.874**	0.183	0.339*	0.167	-0.435**	-0.247	-0.434**	-0.304	-0.454**	1.000	-0.242	-0.079
Panicle Weight	-0.145	-0.113	0.297	-0.489**	-0.517**	0.082	0.121	-0.059	-0.133	-0.242	1.000	0.959**
1000 Grain Weight	0.329*	0.058	0.092	-0.254	-0.330*	-0.157	0.250	-0.199	-0.093	-0.079	0.959**	1.000

** = Significant at 1 % and * = Significant at 5 % level of significance

Table 5. Estimates of variability parameters for yield and its component traits in browntop millet

	Tiller Number	Plant Height	Leaves Number	50% Flowering Days	Flag Leaf Length	Primary Rachis	Panicle Exertion Length	Panicle type	Panicle Length	Maturity Days	Panicle Weight	1000 Grain Weight
SED	1.307	7.114	3.648	2.489	1.477	1.018	0.35	0	1.509	3.521	0.518	0.233
Heritibility	6.23	51.74	3.66	42.2	32.48	80.83	63.52	100	53.48	43.39	70.6	88.46
Gen-Adv	0.103	6.45	0.167	1.696	0.717	2.308	0.452	1.366	1.452	2.492	0.828	0.747
Gen. Adv. % Mean	3.032	27.706	0.8	3.105	11.731	54.613	23.649	73.41	21.459	3.093	47.61	60.058
GCV	5.896	18.698	2.029	2.302	9.991	29.48	14.404	35.7	14.244	2.279	27.5	30.996
PCV	23.61	25.99	10.6	3.572	17.52	32.79	18.07	35.7	19.47	3.46	32.73	32.954

(Chaudhary *et al*., 2015), foxtail millet (Ramesh *et al*., 2023). Similarly PCA based correlation has been reported in foxtail millet parentals and RILs for four seed micronutrients, explaining highest variation of about 87% (Sameena *et al.,* 2024).

Hierarchical Cluster Analysis

Hierarchical Cluster Analysis was carried out by average linkage method with a euclidean distance range from 0 to 25. Cluster dendrogram investigation illustrated high phenotypic variation among all genotypes of browntop millet. Dendrogram analysis classified BTM genotypes into 8 cluster groups based on phenotypic observations (Figure: 7). BTM-5 showed higher genetic distance from other BTM genotypes showing higher genetic diversity. BTM-10 and BTM-4 exhibited near distance with BTM-5 compare to other BTM. Another group of clusters consist of BTM-9, BTM-7, BTM-6, BTM14, BTM-13, BTM-2 and BTM-1. BTM-11, BTM12 and BTM-8 showed less distance from each other.

Similar studies were reported in various millets which provide a comprehensive way to understand agronomic trait associated phenotypic and genotypic relation. Six genotypes of finger millet showed four cluster groups based on the their various agronomic traits observation (Kandel *et al*., 2019), while phenotypic and genotypic characterization of 149 genotypes showed four cluster groups A1, A2, B1 and B2 consisting of 43, 47, 42 and 17 genotypes of finger millets respectively (Babu *et al*., 2017). Comprehensive clustering of 40 gentoypes of pearl millet were able to separate them into ten clusters based on eight economically important traits among them (Shashibhushan *et al*., 2022). Clustering of 103 kodo millet germplasm was accomplished based on their economically important qualitative characters (Nirubana *et al*., 2019). While in foxtail millet GCV, PCV and cluster

Table 6. PCA Scores and Eigen Value and Contribution of first five principal component axes to Agronomic Trait Variation in browntop millet Germplasm

Genotypes	P C •	PC,	PC*ƒ*	PC„
BTM1	0.2072	-1.8511	1.6288	-0.6327
BTM2	0.8889	0.1099	2.2149	0.0215
BTM3	-0.6784	0.06918	-1.1783	-1.7218
BTM4	-0.3919	-0.9981	-1.1331	-2.8192
BTM5	0.8308	-0.08006	0.5527	0.9589
BTM6	3.4271	-0.4825	-1.5405	0.1017
BTM7	1.9495	1.5499	-0.9033	-0.2068
BTM8	0.3467	2.3836	1.2091	1.1217
BTM9	0.7377	0.1537	0.9878	-0.1549
BTM10	-1.4507	-0.2232	-2.9136	2.2965
BTM11	-2.0733	-0.47	-0.4111	0.09579
BTM12	-2.6094	3.0609	0.545	-0.709
BTM13	-1.5615	-2.8909	1.0979	1.0931
BTM14	0.3773	-0.3312	-0.1562	0.5553
Eigenvalue	2.6261	2.3763	2.0268	1.6044
% of Variance	21.8843	19.8029	16.8896	13.3699
Cumulative (%)	21.8843	41.6872	58.5768	71.9467

based characterization of 51 germplasm lines has been employed for the identification of promising genotypes (Mokkaraj and Geetanjali, 2016). Further, phenotypic data for various traits among 119 proso millet genotypes has been utilized for identification of elite lines based on clustering of the gentoypes that fall in a seminal genetic variability groups (Uddin *et al*., 2020). Foxtail millet parental genotypes along with a subset of segregating RIL's were effectively clustered representing the variability for seed micronutrient content (Sameena *et al*., 2024).

CONCLUSIONS

Browntop millet is one of the neglected minor millets with no or very few available reports on their genetic variability and phenotypic characterization. To our knowledge it is one of the first systematic report, where, we are reporting development of browntop millet purelines using single seed descent method from bulk collections from farmer's fields across Rayalaseema region of Andhra Pradesh. Present investigation revealed significant variation among all 14 genotypes of browntop millet. The ratio of GCV and PCV exerted high trait-associated variability. GCV and PCV showed fixed heritable traits for panicle type and significant relation with panicle weight and thousand grains weight. Path coefficient analysis suggested direct and indirect effects of selected agronomic trait for the 1000 grain weight. The present analysis is a comprehensive study, where pure lines of browntop millet were developed and evaluated

for identification of superior lines. Hence, based on the above investigation a significant genotypic diversity was observed among the lines/genotypes. However, BTM-6 displayed the highest divergence with PC score of 3.43. Based on the present investigation selection of the germplasm is effective for browntop millet breeding oriented program by effective agronomic trait phenotyping. The pure lines thus developed in the present investigation will be of stepping stone to deciphering genetic and genomic signatures underlying agronomic and nutritional traits in this resource-poor millet crop of nutritional importance.

AKNOWLEDGEMENTS

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ENHANCED LIPASE PRODUCTION FROM *CELOSIA ARGENTEA* SEED OIL USING MUTANT *BACILLUS PUMILUS* UVM6

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ABSTRACT

A mutant strain was developed by random mutation using UV-C radiation from wild parent strain *Bacillus pumilus* KMAS7. Following mutagenesis, eleven bacterial isolates were used for maximum lipase production and found that the strain UVM6 produced high lipase of 36.46±0.05 UmL^{-1} from *C. argentea* seed oil. It was 1.38 times more abundant than the wild parent strain. Robust mutant strain UVM6 was selected and designated as *B. pumilus* UVM6. Then this mutant strain was cultivated in SmF for production of lipase using *C. argentea* seed oil under different nutritional sources. An overall 2.95-fold enhanced extracellular lipase production (62.42±0.03 UmL^{-1}) was obtained from *C. argentea* seed oil by SmF using 4% v/v *C. argentea* seed oil, 0.5% w/v glucose, 1% w/v ammonium sulphate and 10 μML^{-1} Zn as inducer, carbon, nitrogen and trace element sources respectively. Seed oil of *C. argentea* has been used in traditional folk medicine, but this is the first time we're reporting lipase production from C. argentea by the newly isolated mutant *B. pumilus* UVM6.

Keywords: *Bacillus pumilus*, *Celosia argentea* seed oil, lipase, mutation, submerged fermentation

INTRODUCTION

In the future, enzyme lipases (EC.3.1.1.3, triglyceride-based hydrolases) will dominate the global enzyme market as they are very important class of biocatalysts in new biotechnological applications. The market place value of microbial lipases was estimated at $425 million in 2018 and is expected to reach $590.2 million by 2023 (Chandra *et al.,* 2020). Microorganisms, including bacteria and fungi, possess the ability to produce both intracellular and extracellular lipases. Since their discovery in 1856, microbial lipases, particularly those of bacterial origin, have been extensively used in various biotechnological applications. Recently, a new method of cleaning septic tanks, grease traps and other systems using lipases has been investigated in environmental research (Al Mohaini *et al.,* 2022).

For commercial applications, bacterial lipases need to be produced on a large scale by fermentation. Due to its primarily extracellular nature, microbial lipase can be

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generated through either SmF or SSF. The high-cost of production resulting from costly carbon and nitrogen inputs, which make up half of the total cost of enzyme production, is one drawback of commercial lipase enzyme production. The use of cheap resources is crucial in developing microbially derived lipase production (Gaonkar and Furtado, 2021). The current focus is on creating new methods for producing commercially valuable enzymes to ensure the overall process is economically feasible (Sodhi *et al.,* 2022).

Exploring new substrates is helpful because it can lower enzyme production costs and reduce waste disposal issues (Gaonkar and Furtado, 2021). Most bacterial lipases reported to date are constitutive and non-specific in their substrate specificity, and a few bacterial lipases are thermostable. Various physicochemical parameters of fermentation affect extracellular lipases production by bacteria (Choundhary *et al.,* 2023).

This article focuses on high lipase production using low-cost raw materials under suitable conditions. To date, no attempts have been made to produce lipase from agriculture weed *Celosia argentea* L., seed oil. Therefore, the main aim of this present study was lipase production from *C. argentea* seed oil by newly isolated mutant strains under optimized nutritional conditions.

MATERIAL AND METHODS

Bacterial strain

Bacterium *Bacillus pumilus* KMAS7 (GenBank accession number: OR264494) was isolated from soil contaminated by edible oil. Then this strain was used for lipase production from *C. argentea* L. seed oil. The strain *B. pumilus* KMAS7 was maintained in a nutrient agar slant and stored at 4 °C. The culture was revived every month.

Seeds collection and oil extraction from *C. argentea* seeds

Agricultural weed *C. argentea* L. seed oil was used as an inducer for lipase enzyme production using mutant *B. pumilus*. Matured flowers of *C. argentea* were collected from agriculture land of Cheyyar Taluk in the Tiruvannamali District, Tamil Nadu, India in middle of February - March 2022. The seeds were harvested from flowers and dried in the hot air oven at 60 °C for 24 h. The dried seeds were weighed and ground into a powder. Then oil was extracted from seed by Soxhlet extraction using solvent n-hexane with the ratio 5:1 (5L solvent:1kg seeds). Oil extraction was performed until the complete extraction from seed powder. Finally, the oil was recovered from the solvent using rotary evaporator. The mass percentage of oil extracted from seeds was calculated using the following formula.

$$\text{Mass } \% = \frac{\text{Weight of the oil}}{\text{Weight of the oil seed}} \text{x } 100$$

Bacterial strain improvement by UV-C mutation

Random mutation induced in *B. pumilus* KMAS cells by UV-C irradiation (Hopwood *et al*., 1985). Mutant strains screened for production of extracellular lipase from *C. argentea* seed oil. The production medium was supplemented with 1.0% C.argentes seed oil and inoculated with 1% (v/v, OD 0.92) of each mutant strain separately. Olive oil (1%, v/v) contained medium was used as control. Then the Erlenmeyer flasks (EF) were incubated at 35 °C for 48 h. At the end of the experiment, the culture was centrifuged for 15 minutes at 14,000 rpm, and the cell-free supernatant was utilized as crude lipase to measure lipase activity under conventional assay parameters. The robust mutant bacterial strain that produced the most lipase was chosen and used for further study.

Lipase Analysis

Taking p-nitrophenyl palmitate as the substrate, spectrophotometric assay was used to quantify the amount of extracellular lipase activity (Krieger *et al.,* 1999). A mixture of substrate and enzyme solutions was allowed for 20 min at 37 ^{o}C before adding 0.2 M Na_2CO_3 to stop the reaction. The released *p*-nitrophenol was quantified at 410 nm using a Shimadzu UV-1601 spectrophotometer to determine lipase activity, with one unit defined as releasing 1 ìmole *p*-nitrophenol per minute.

Influence of various concentrations of *C. argentea* seed oil on production of lipase

Influence of *C. argentea* seed oil concentrations ranging from 1% to 10% v/v on production of lipase by the selected mutant strain was investigated. The experiment was carried out in 250 mL EF contained 100 mL of production media enriched with varying amounts of *C. argentea* seed oil. The determined optimal concentration was subsequently employed for additional media optimisation investigations.

Screening the best nutritional factor for production of lipase from *C. argentea* seed oil

The classical method of optimization (one-parameter-at-a-time) was performed to screen the following nutritional factors for highest lipase production. Main nutritional factors such as carbon sources (0.5% w/v of glucose, fructose, sucrose, maltose and starch), nitrogen sources (1% w/v of yeast extract (YE), peptone, beef extract (BE), ammonium chloride, and ammonium sulphate) and metal ions (10 μML^{-1} of iron (Fe), copper (Cu), Selenium (Se), nickel (Ni) and ninc (Zn) were optimized. All experiments were carried out in 250 mL EF contained 100 mL of source-free basal medium, with the optimal concentration of *C. argentea* seed oil as an inducer. The cell-free supernatant served as crude lipase to assess lipase activity under standardised test conditions.

Statistical Study

All studies were conducted in triplicate, and the data are presented as the mean ± standard deviation from each of the three replicates. The standard deviation did not surpass 5% of the mean values. Statistical significance was established at $p < 0.05$.

RESULTS AND DISCUSSION

Selection of robust mutant strain for lipase production from *C. argentea* seed oil

Significant increases in fermentation efficiency and mutagenesis resulted in decreased expenses. In the present investigation, suspensions of selected wild parent strain *B. pumilus* KMAS was exposed to UV-C radiation for 3, 6, 9, 12, 15, and 18 min. The UV-C survival percentage at each exposure time was tabulated. The mutation frequency was mentioned to be high when the survival rates were between 10 and 0.1%. Plates having less than 1% survival rate of the parent strain were chosen. Eleven mutant strains were obtained and they are labeled as UVM1 to UVM11. Subsequently, all the eleven strains were screened for highest lipase production from *C. argentea* seed oil. As given in Table 1, the mutant strain UVM6 was produced maximum lipase of 36.46 ± 0.05 UmL^{-1}. It was 1.38 times more abundant than the wild parent strain KMAS7 (26.34±0.05 UmL^{-1}), thus it was designated as a robust mutant strain and the name *B. pumilus* UVM6 was added and used for further study. Lakshmi and Dhandayuthapani (2022) also conducted a similar study. Mutation breeding has become a better method for bacterial strain development than genetic engineering.

Table 1. Quantitative screening of robust mutant strain for extracellular lipase production from *C. argentea* seed oil

Culture Code	Lipase activity (UmL^{-1})
Parent strain - KMAS7	26.34±0.05
UVM1	26.48±0.04
UVM2	29.45±0.11
UVM3	24.15±0.05
UVM4	22.15±0.11
UVM5	35.12±0.12
UVM6	36.46±0.05
UVM7	31.24±0.05
UVM8	29.41±0.11
UVM9	25.42±0.12
UVM10	24.15±0.05
UVM11	28.64±0.10

***UVM – Ultra Violet Mutant**

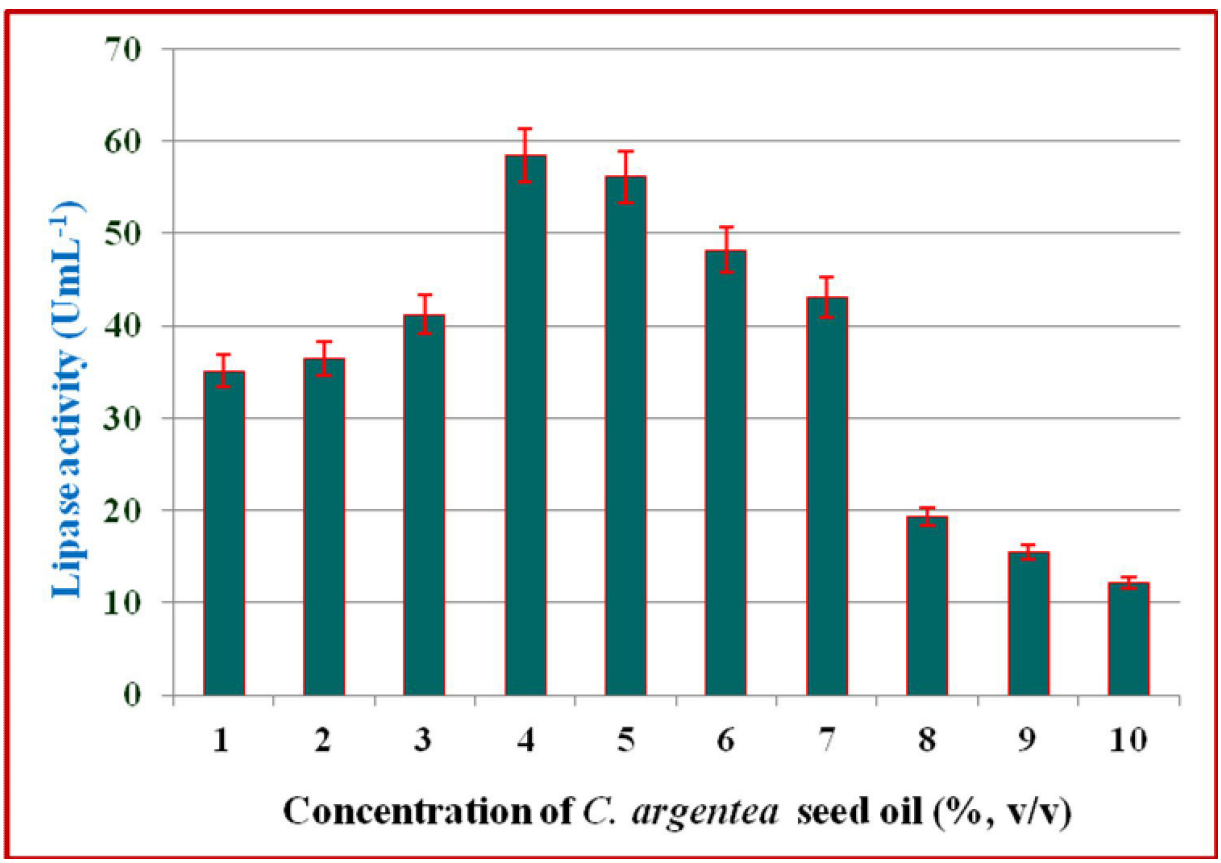

Figure 1. Effect of different concentration of *C. argentea* seed oil on lipase production by *B. pumilus* UVM6

Inducing ultraviolet mutation is the easiest and most effective way to make the random mutation in the bacterial strains.

Influence of various concentrations of *C. argentea* seed oil on lipase production

Influence of *C. argentea* seed oil concentrations ranging from 1% to 10% (v/v) on production of lipase using mutant strain *B. pumilus* UVM6 was investigated. When increase the concentration 1% to 4% increased in extracellular lipase production from 35.12 ± 0.12 to 58.48±0.05 UmL^{-1}. A further increase in *C. argentea* seed oil concentration showed no significant effect on production of lipase by mutant *B. pumilus* UVM6. However, highest lipase production of 58.48 ±0.05 UmL^{-1} was obtained at 4 % (v/v) *C. argentea* seed oil supplemented basal medium (Fig. 1). Hence, the 4% (v/v) *C. argentea* seed oil was found as best concentration and used for further study. To date, no attempts have been made to produce lipase from agriculture weed *C. argentea* seed oil. This study presents the very first results on lipase production from the seed oil of the agricultural weed *C. argentea* in SmF utilizing the newly identified mutant *B. pumilus* UVM6.

Influence of various carbon sources on lipase production

In the present study, five different carbon sources—glucose, fructose, sucrose, maltose, and starch—were supplemented to the lipase production medium at a concentration of 0.5% (w/v) to examine their influence on lipase production during SmF, using 4% (v/v) *C. argentea* seed oil as an inducer. As illustrated in Fig. 2, glucose-supplemented medium showed a highest lipase activity at 59.68 ± 0.11 U/mL. In contrast, other carbon sources, viz fructose, sucrose, maltose, and starch, exhibited inhibitory effects on production of lipase from *C. argentea* seed oil by the mutant strain *B. pumilus* UVM6. This study found that *B. pumilus* UVM6 utilized glucose for maximum lipase production with 4% (v/v) *C. argentea* seed oil. The newly isolated mutant was able to simultaneously utilize both glucose and *C. argentea* seed oil for lipase production. However, it could not utilize fructose, sucrose, maltose, or starch alongside *C. argentea* seed oil. This finding aligns with the report by Balaji *et al.,* (2020), which indicated that glucose and olive oil were the mainly efficient carbon sources for enhancing lipase activity. It is noteworthy that excessive glucose concentrations can inhibit enzyme synthesis. In microorganisms, carbon catabolite regulation optimally catabolizes carbon to provide energy and carbon for growth (Akhter *et al.,* 2022). In this investigation, glucose (0.5%, w/v) supported the growth of *B. pumilus* UVM6 as well as maximum lipase production, making it the preferred carbon source for further studies.

Influence of various nitrogen sources on lipase production

Organics and inorganic forms of nitrogen are necessary for enzyme production. In this experiment, a nitrogen-free production medium containing 0.5% (w/v) glucose and 4% (v/v) *C. argentea* seed oil was supplemented with 1% (w/v) of various nitrogen sources, including BY, YE, peptone, ammonium chloride, and ammonium sulfate, to evaluate their impact on lipase production during SmF. As depicted in Fig. 3, the highest lipase activity of 61.57 ± 0.12 UmL^{-1} was recorded in the medium contained 1% YE, followed closely by 61.44 ± 0.05 UmL^{-1} with 1% ammonium sulfate. Ammonium chloride and peptone produced the next highest lipase activities of 61.00 ± 0.14 $UmL^{-1}$and 59.34 ± 0.13 UmL^{-1}, respectively. In contrast, *B. pumilus* UVM6 exhibited significantly lower lipase activity in the medium contained BE (23.15 ± 0.11 UmL^{-1}). These

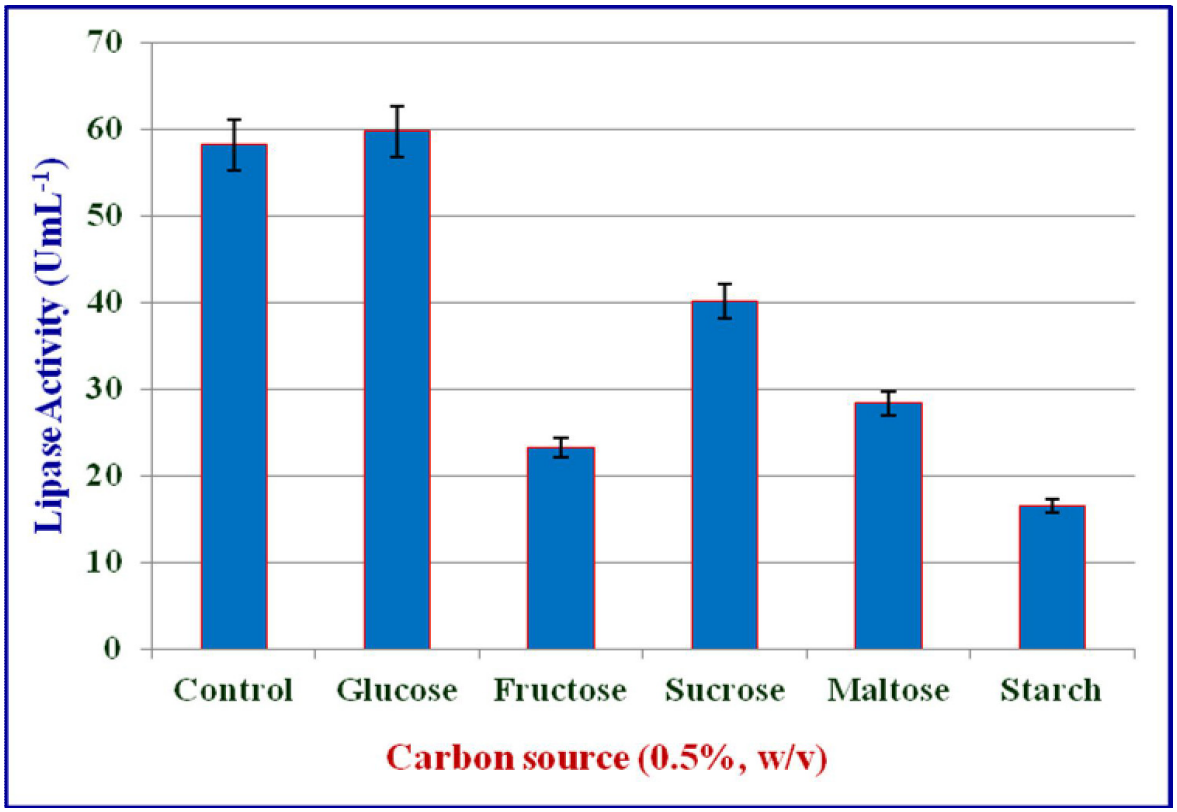

Figure 2. Effect of various carbon sources on lipase production from *C. argentea* seed oil by *B. pumilus* UVM6

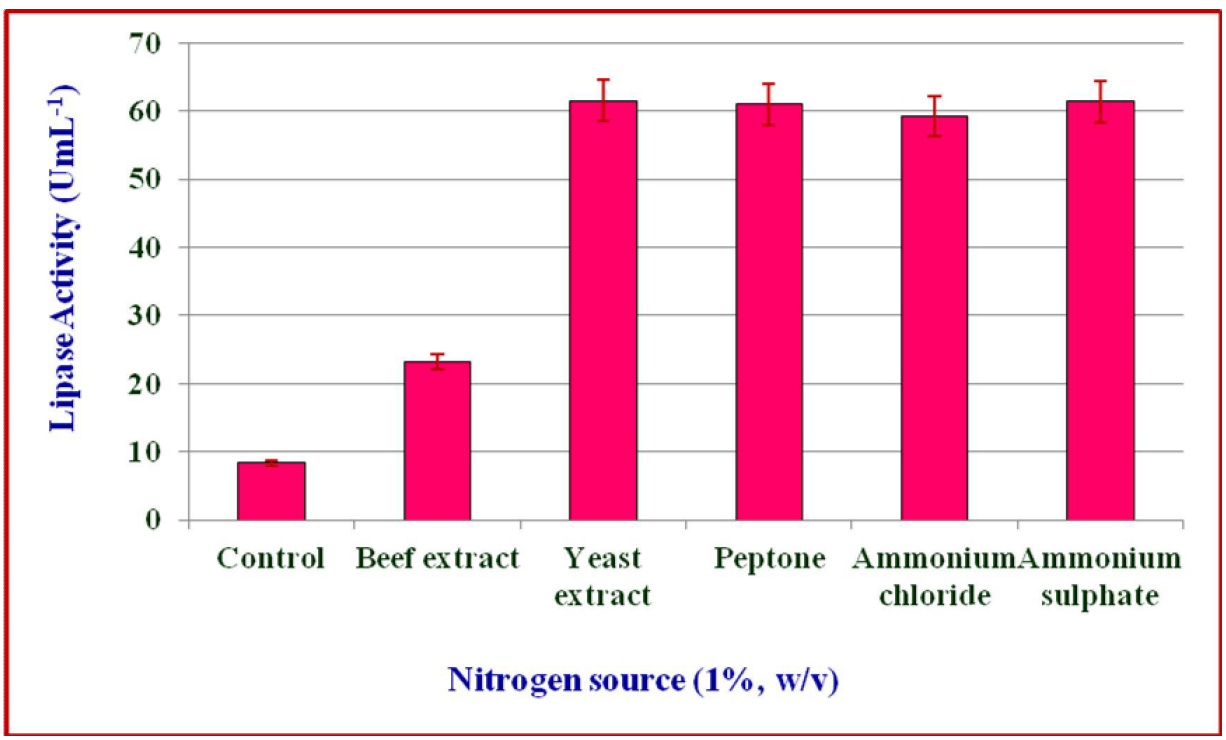

Figure 3. Effect of various nitrogen sources on lipase production from *C. argentea* seed oil by *B. pumilus* UVM6

result are reliable with those reported by Mazhar *et al.* (2023). Given that YE is more expensive than ammonium sulfate, 1% (w/v) ammonium sulfate was selected as the N source for further studies.

Influence of various metal ions on lipase production

The effect of different metal ions, viz Fe, Cu, Se, Ni, and Zn, on lipase production from *C. argentea* seed oil by the newly isolated mutant *B. pumilus* UVM6 was investigated by supplementing the production medium with 10 µM of each metal ion individually. The control was made without any metal ions, and the rest of the experiments were carried out using the same method. Figure 4 illustrates that the maximum lipase production occurred in the medium enriched with 10 μML^{-1} Zn (62.42 ± 0.03 UmL^{-1}), followed by 10 µM Ni (61.25 ± 0.11 UmL^{-1}). A 2.95-fold enhancement in lipase synthesis was observed relative to the control with these metal ions. Other metal ions, including Fe (59.32 ± 0.04 UmL^{-1}), Cu (60.11 ± 0.03 UmL^{-1}), and Se (58.21 ± 0.12 UmL^{-1}), also supported lipase production from *C. argentea* seed oil by the mutant *B. pumilus* UVM6. The highest lipase production was obtained in the medium containing 10 μML^{-1} Zn, therefore it was used for further study. This finding aligns with the work of Akhter *et al.* (2022). However, the literature does not provide a clear pattern regarding the influence of metal ions on lipase production from bacterial sources. The impact of various metals can change dramatically, and even identical metals may have opposite impacts depending on the lipase source.

Table 2, shows the effect of different concentration of *C. argentea* seed oil on lipase production with different nutrients sources including carbon sources (glucose, fructose,

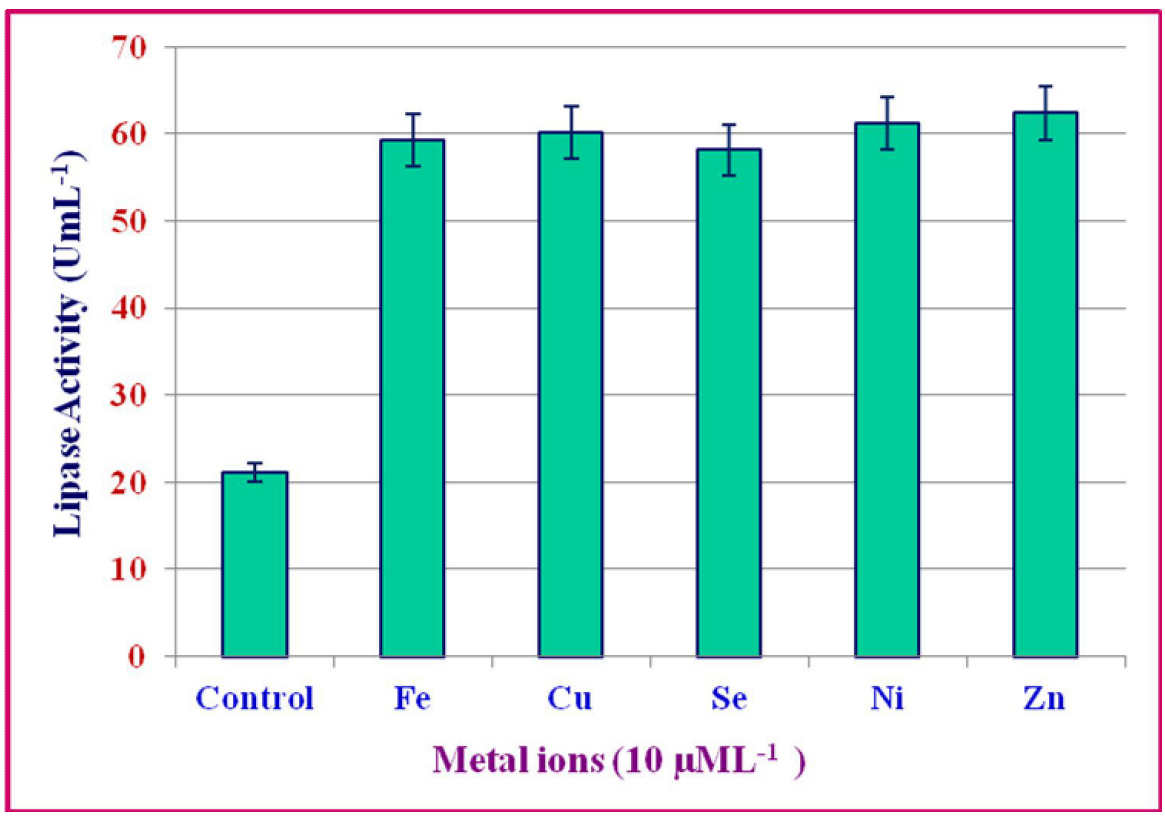

Figure 4. Effect of various metal ions on lipase production from *C. argentea* seed oil by *B. pumilus* UVM6

Table 1. Effect of different concentration of *C. argentea* seed oil on lipase production with different carbon, nitrogen and metal ion source

Nutrient source	Lipase Activity (UmL^{-1})									
	Concentration of *C. argentea* seed oil (%, v/v)									
	1	2	3	4	5	6	7	8	9	10
Control	35.12±0.02	36.45±0.11	41.25±0.02	58.48±0.04	56.12±0.05	48.21±0.05	43.15±0.04	19.24±0.04	15.44±0.05	12.14±0.04
Glucose	39.45±0.11	46.23±0.05	53.41±0.05	59.68±0.05	57.34±0.05	41.24±0.02	38.41±0.11	31.44±0.012	19.32±0.11	13.44±0.05
Fructose	16.35±0.05	19.44±0.06	21.78±0.01	23.15±0.03	22.41±0.06	21.78±0.04	16.84±0.013	12.14±0.05	10.82±0.12	9.43±0.12
Sucrose	33.49±0.02	36.81±0.02	39.51±0.02	40.12±0.05	38.42±0.02	30.18±0.07	28.45±0.05	18.34±0.13	11.41±0.05	8.64±0.05
Maltose	16.84±0.05	18.95±0.04	24.87±0.03	28.33±0.06	26.51±0.04	20.49±0.05	19.84±0.11	15.34±0.06	12.47±0.06	10.24±0.03
Starch	10.24±0.03	15.34±0.02	16.05±0.04	16.48±0.02	14.57±0.03	12.84±0.06	10.34±0.06	8.54±0.11	7.35±0.11	6.24±0.07
Beef extract	16.34±0.04	19.34±0.11	20.48±0.05	23.15±0.03	19.84±0.11	18.77±0.04	15.43±0.11	12.48±0.05	10.82±0.14	9.92±0.08
Yeast extract	39.84±0.13	48.35±0.05	58.34±0.03	61.57±0.04	60.15±0.12	54.38±0.02	49.57±0.05	42.81±0.11	35.48±0.08	22.71±0.11
Peptone	40.18±0.05	46.58±0.03	59.64±0.04	61.00±0.03	59.64±0.05	50.14±0.11	43.25±0.12	39.84±0.06	24.78±0.12	19.84±0.12
Ammonium chloride	38.55±0.07	48.24±0.05	49.34±0.11	59.34±0.05	53.48±0.07	48.76±0.02	34.18±0.10	29.84±0.11	18.35±0.11	14.22±0.05
Ammonium sulphate	41.54±0.06	54.84±0.05	58.67±0.02	61.44±0.05	59.88±0.06	43.28±0.05	38.11±0.05	31.84±0.05	28.44±0.05	19.84±0.06
Fe	38.49±0.02	48.34±0.04	56.48±0.03	59.32±0.04	55.48±0.04	41.87±0.03	32.49±0.05	18.84±0.06	12.77±0.05	10.29±0.012
Cu	39.48±0.05	52.48±0.06	58.77±0.04	60.11±0.04	56.48±0.02	45.58±0.05	42.15±0.06	24.58±0.07	20.84±0.07	17.35±0.05
Se	35.88±0.03	49.38±0.11	56.48±0.02	58.21±0.03	55.34±0.03	38.49±0.07	25.55±0.05	19.48±0.08	15.24±0.04	10.75±0.06
Ni	43.88±0.04	56.87±0.07	59.54±0.04	61.25±0.04	58.77±0.05	46.55±0.06	36.55±0.04	27.48±0.02	20.94±0.06	12.44±0.04
Zn	55.34±0.02	59.34±0.05	60.48±0.06	62.42±0.03	60.15±0.02	58.34±0.04	55.48±0.05	43.25±0.05	36.15±0.03	20.15±0.05

sucrose, maltose, starch), nitrogen sources (ammonium chloride, ammonium sulphate, BY, peptone and YE) and mineral sources (Fe, Cu, Se, Ni, Zn). In this study, it was noted that the robust mutant *B. pumilus* UVM6 was capable to produce an overall 2.95-fold increase in lipase production from 4% (v/v) *C. argentea* seed oil with supplement of 0.5% (w/v) glucose, 1%, (w/v) ammonium sulphate and 10 μML^{-1} Zn.

CONCLUSIONS

A robust mutant strain *B. pumilus* UVM6 was created through random mutation using UV-C irradiation from newly isolated *B. pumilus* KMAS7(GenBank accession number OR264494). This mutant strain produced maximum lipase of 62.42±0.03 UmL^{-1} in basal medium contained 4 % (v/v) *C. argentea* seed oil as inducer with 0.5% (w/v) glucose, 1%, (w/v) ammonium sulphate and 10 μML^{-1} Zn. The robust mutant *B. pumilus* UVM6 was able to produce an overall 2.95-fold increase in lipase production from *C. argentea* seed oil under improved conditions production medium. This is the first report on utilization of agriculture weed *C. argentea* seed oil for production of lipase in SmF using robust mutant *B. pumilus* UVM6. The findings of this investigation suggest that the agriculture weed *C. argentea* seed oil is best lipase inducer, which may be utilized to produce lipase on a large scale and at a reasonable cost using bacterial strains.

Confilict of Interest

The authors assert that no conflicts of interest exist.

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CHARACTERIZATION OF ARSENIC TOLERANT *RHIZOBIUM Sp.* ISOLATED FROM ROOT NODULES OF *VIGNA RADIATA*

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ABSTRACT

The rationale of the study was to characterize arsenic tolerant *Rhizobiumsp*. from root nodules of *Vigna radiate* in the vicinity of the fertilizer production plant contaminated with arsenic. The current investigation involved the interactions of *Rhizobium sp*. in remediating arsenic has been studied by isolating root nodules of Mung Bean (*Vigna radiata*) and analyzed for strain characterization, CFU/mL counts, biomass yield, enzymes (cellulase and amylase), and proteins. The screened bacteria were shown to be both arsenic tolerant and sensitive. All isolates were determined to be *Rhizobium* sp. based on colony, morphology, biochemistry, and nodulation ability analysis. The arsenic sensitivity of the chosen isolates was confirmed by low CFU/mL counts and low biomass output in the medium. The results showed that strain MRR121 is sensitive to arsenic, while strain VBCK1062 showed significant tolerance levels based on the arsenic sensitivity tests. The results emphasized that the sensitivity and tolerance of *Rhizobium sp*. isolates to arsenate was determined, with reference to their growth and biomass yields, enzyme assays, and protein profiles. The isolated *Rhizobium* strains exhibited growth retardation when the As concentration was raised beyond 25 mg/mL, as confirmed by the CFU and biomass. The study has clearly evidenced that while increased amounts of arsenic are extremely harmful to the *Rhizobium* strain The As tolerant strain VBCK1062, outproduced the sensitive strain in terms of proteins and enzymes (cellulase and amylase). Based on the computed similarity coefficient, there is a 76% similarity between the tolerant strain and the commercial (MTCC 616) strains. This study gives better understanding of plant-metal-microbe interactions and hence can be used as a criterion for isolation of As (V) tolerant *Rhizobium sp.*from metal contaminated agro-geo-ecosystems.

Keywords: Rhizobium identificaton, *Vignaradiata,*Arsenic tolerance, cellulase and amylase

INTRODUCTION

Heavy metals can end up in farmland due to human activities such as smelting, mining, power plant operations, application of metals containing fertilizers, and sewage sludge (Robinson *et al.,* 2001). Insecticides, herbicides, fungicides, and wood preservatives that include arsenate are other causes of Arsenic (As) pollution.As is most serious among heavy metal pollution which might be global problem in terms of heavy metal contamination in Bangladesh, India, China, and the United States are among the numerous countries that have reported arsenic-contaminated groundwater. Typically, the concentrations of As (V) in non-contaminated soils vary from 0.1 to 10 mg kg^{-1} (Kabata-Pendias 1992). However, the natural and

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anthropogenic sources contribute to the levels of arsenic found in soil. As (V) can bioaccumulate in humans from agricultural crops and drinking water, increasing the likelihood of arsenic poisoning in food chain. There is a rising global interest in the screening of novel microbes producing enzymes that are well-suited for novel industrial applications, due to the increasing importance of enzymes in many industries. In order to remove arsenic from groundwater, many chemical techniques have been developed (Mandal *et al*., 2008). It is worth noting that there is significant interest in the biotechnological use of microorganisms for arsenic sequestration. The following symbiotic bacteria viz. *S.meliloti*, *Mesorhizobium loti, R.tropici, R.radiobacter* and *R. leguminosarum biovartrifolii* can tolerate high arsenic levels, can alter the oxidation states of arsenic, methylate and demethylate and biovolatilize arsenic into less toxic arsenic compounds.

Rhizobium sp. interacts with plant roots, and they play a significant role in the biogeochemical processes of arsenic, including sorption and desorption in soils, methylation and demethylation, and reduction and oxidation. *Rhizobium* symbiosis can help plants tolerate arsenic (As) and reduce the amount of arsenic that accumulates in them. *Rhizobium*have various ways of coping with high levels of arsenic, including reduced uptake, methylation following the reduction of arsenate to arsenite, the adsorption of negatively charged arsenic ions by the oppositely charged amino groups in bacterial cell walls, sequestration by a range of cysteine-rich peptides, chelation, compartmentalization, exclusion, immobilization, and dissimilatory arsenate respiration. Whereas non-symbiotic bacteria cannot convert atmospheric nitrogen into ammonia that the plant can use. In addition to producing reactive oxygen species (ROS), arsenate disrupts a number of microbial metabolic activities, including oxidative phosphorylation and ATP production (Carbonell Barrachina *et al*., 1998). Metal biosorption, precipitation, and enzymatic metal transformation are just a few of the ways bacteria react to metal ions; these responses make bacteria useful tool for environmental restoration studies (Valls and de Lorenzo, 2002). The symbiosis between *rhizobia* and leguminous *plants* is a fundamental contributor to nitrogen cycling in natural and agricultural ecosystems. Consequently, in order to overcome the growth restriction caused by arsenic stress, bacteria have evolved diverse detoxifying mechanisms. Nonetheless, the *Rhizobium sp*. are able to withstand elevated levels of arsenate by assertively effluxing the reduced form of arsenate, known as As (III), into the environment. There have been reports of arsenic-tolerant *Rhizobium* strains that are symbiotically thriving (Mandal *et al*., 2008). The current work aims to characterize and comprehend the responses of metal contaminated agriculture zones to the presence of arsenic-resistant *Rhizobium* bacteria that can produce mucosal EPS.

MATERIAL AND METHODS

Collection of Bacterial strains

Mung bean plants (*Vigna radiata*) were collected from several areas of the Kakinada Industrial area in Andhra Pradesh, India, and their root nodules were examined for the presence of root nodulating bacteria in the laboratory. At IMTECH, Chandigarh, we acquired a commercial strain of *Rhizobium sp*. (MTCC 616) so that we could compare the field isolates' phenotypic features. The present study was conducted in January 2016.

Isolation of *Rhizobium* species

The field-grown Mung Bean plants were harvested for their effective root nodules. After

collecting the nodules, they were surface sterilized using 75% ethanol, then treated with 0.1% $HgCl_2$, for 5 mins and then rinsed with distilled water. The crushed root nodules were streaked onto Yeast Extract Mannitol Agar (YEMA) plates to obtain the *Rhizobium* strain, which was then incubated at 28±2°C. It took 2 days of incubation to obtain axenic *Rhizobium* colonies. Pure cultures were isolated with the use of visual assessment of colony shape, streaking, and spreading. Isolates that were obtained were biochemically characterized using methods outlined in Bergey's Manual of Determinative Bacteriology.

Biochemical characterization of *Rhizobium* strains

The pure isolates were grown in YEM broth (pH 7) on the orbital shaker at 150 rpm. The 24h fresh cultures were used for different biochemical characteristics namely catalase test, oxidase test, starch hydrolysis test, citrate utilization test, urease test, TSI test, Flourescent assay and gelatin liquefaction tests were following standard procedures.

Symbiotic properties

Surface sterilization and germination of seeds

Before being acidified with 0.5% HCl for two minutes, the *Vigna radiate* seeds were rinsed in 95% ethanol. After that, they were immersed in 0.2% $HgCl_2$. After a thorough washing in sterile distilled water (with at least 5 changes), the seeds were placed immediately onto petri plates that contained 1% agar. To ensure that the seedlings grew uniformly and straight, the plates were inverted and incubated at 30±2°C.

Testing of nodulation ability of the isolates

48 hr old seedlings were planted in glass tubes containing nitrogen-free plant development Hoagland medium. It was then incubated at 28°C with *Rhizobium* isolates cultured two days earlier.Using a black paper, the roots were shielded from any direct light. The appearance of nodules on each Mung Bean plant was recorded after 4 weeks.

Evaluation of *Rhizobium* isolates in the presence of As(V)

(i) Determination of CFU/mL counts:

Inoculating 50 mL of YEM broth with 10^6 Rhizobial cells, the mixture was incubated in a rotary shaker set at 100 rpm/minute for 48 hours to obtain cell suspensions. For five minutes, the cultures were spun in a centrifuge at 3000xg. This process was performed twice, each time discarding the supernatant and re-suspending the pellet in 30 mL of ultrapure distilled water. The last step was to suspend the cleaned cells in sterile deionized water. A stock solution of arsenic was created using sodium arsenate. From this, stock concentrations (0, 10, 15, 20, and 20 mM) of sodium arsenate were prepared, with pH set to 6.5-7.0. The solutions were filtered through a pore size of 0.2 ìm. The test solutions were made by adding 30ìL of washed cells to 50 mL flasks. The flasks were subsequently incubated in a rotary shaker incubator set at 32°C for 48 hours at 100 rpm/ minute. After 24, 48, and 72 hours, the cell viability was evaluated by spreading 0.1 mL of each test solution and its subsequent dilutions onto a YEMA plate. The numbers of colonies (CFU/ mL) were measured after incubating the plates overnight at 32°C.

CFU/mL – (Number of colonies X dilution factor) / Volume of culture plate

(ii) Measurement of the growth/ biomass yield:

The rhizobial cells were washed and placed in 50 mL of YEM broth that contained varying doses of arsenic (5, 10, 15, 20 mM). The mixture was then incubated at

32°C for 48 hours at 100 rpm/minute. The solution was centrifuged at 6,000 rpm for 10 minutes after incubation. To get rid of the leftover spent medium, centrifuged the pellet after dissolving it in 0.5% saline and discarded the supernatant. A final step involved re-suspending the pellet in 2 mL of saline water. The optical density (OD) of the suspensions was then measured at 600 nm, with the control being saline water.

Screening of Rhizobium isolates

According to the CFU/mL counts that were taken after 72 hours, the strain was considered tolerant if it produced the highest number of colonies at the highest concentration of As (20 mM), and sensitive if it produced the lowest number of colonies.

Enzymatic assays (Cellulase and Amylase)

(i) Preparation of crude enzyme

Three different strains of *Rhizobium sp,* a tolerant, sensitive MTCC 616 (standard strain), were inoculated into 200 mL of YEM broth. The mixture was then cultured at 30°C for 48 h using a shaker set at 100 rpm/min. The culture was centrifuged at 6,000 rpm for 10 min after the incubation period ended. The resulting supernatant was filtered using 0.45 µ membrane filter and then moved to a separate tube and utilized as a crude enzyme to measure the enzyme's activity.

(ii) Qualitative estimation of Amylase and Cellulase activity

Isolates were spot inoculated into carboxy methylcellulase containing media for cellulase enzyme estimation and starch-containing media for amylase enzyme assessment. The presence of a zone of hydrolysis surrounding the colony was identified after 48 h of incubation by examining the plates.

(iii) Quantitative estimation of Amylase and Cellulase activity

The method for determining the enzyme's activity mainly involved calculating the amount of reducing sugars produced when the enzyme was applied to an appropriate substrate. The amylase activity was estimated using the dinitrosalicylic acid (DNSA) technique. The enzyme substrate was a maltose solution with a concentration of 1%. The following ingredients were combined in a tube: 0.4 mL enzyme extract, 1.8 mL substrate, and 2 mL DNS. The mixture was then incubated at 37°C for 10 minutes. A 40 percent sodium potassium tartarate solution was added to 1 milliliters of reaction mixture to halt the process. The optical density (OD) was measured at 575 nm, and a color change was noted. As the concentration of the enzyme increases, the optical density (OD) also increases. The greater the OD, the more vibrant the color will be, which is a direct result of the enzyme activity. This study also used the dinitrosalicylic acid (DNSA) technique to measure cellulase activity. The reagents utilized were identical to those in the amylase activity experiment; however, a 1% solution of carboxymethyl cellulose (CMC) was utilized as the substrate for the enzyme (Gianfreda *et al*.2005).

Protein content estimation of the sensitive and tolerant isolate

Preparation of crude protein extract

Furthermore, the tolerant, sensitive, and standard MTCC 616 *Rhizobium* strains were introduced into 100 mL of YEM broth and left to incubate at 32±2°C for 48 hours while being shaken at 100 rpm/minute. When the incubation time was up, the cultures were spun in a centrifuge for 10 minutes at 6,000 rpm. The resulting supernatant was then used as a crude protein extract after being transferred to an additional tube.

Quantitative estimation of proteins

For quantitative estimation of protein was done by standard method given by Lowry *et al*. (1951).

Statistical analysis

All measurements were expressed as Mean ± Standard Deviation (SD) and Standard Error (S.E) with each experiment conducted in triplicates. MS Excel 11.0 software version was used in the statistical analyses.

RESULTS AND DISCUSION

The adverse soil arsenic contamination could lead to negative environmental impacts and socioeconomic consequences such as reduction of crop productivity and soil fertility. However, serious environmental concerns associated to these arsenic stresses shall prompt the scientists to find out environment-friendly approaches for sustainable agriculture. Consequently the understanding the mechanism of adaptation in symbiotic rhizobium will contribute to the long-term goal of enhancing plant-microbe interaction for the improvement of leguminous crops grown in a specific agricultural niche. Interestingly the symbiotic plant growth-promoting rhizobacteria (PGPR) have evolved with several biochemical mechanisms to cope with the environmental and abiotic stressor, *viz.,* heavy metal. In the current study, nineteen Rhizobial strains were isolated from root nodule of *Vigna radiate* (Fig 1A) depicts the selected *Rhizobium* isolate VBCK1062 isolated from the *Vigna radiata* root nodules. The selected mucoid colonies were grown on YEMA medium for two days of incubation at 32±2°C. The morphological analysis of the colonies revealed spherical in shape, transcluent for three to four days of growth, and then turned yellowish after four days. The diameter of each colony was about 5-7mm and gram-negative rods.

The release of oxygen around the bacterial colonies revealed that selected isolates were catalase positive. Mixed isolates also showed oxidase positive and urease findings. On agar plates that included 0.1% methylene blue, 0.1% gentian violet, glucose peptone, and 0.1% citrate, not a single strain grew. On lactose peptone agar, every single isolate multiplied. When the infected plates were tested with iodine, a clear zone around the colonies revealed positive results from the starch hydrolysis assay (Fig.1B). Since no clearing zone was observed surrounding the colonies, it may be concluded that all of the isolates tested negative for gelatinase. By observing their ability to grow on King's medium when exposed to a UV light, the fluorescent assay confirmed that each of the isolates tested negative. All isolates passed the triple sugar iron test. The isolated organisms all grew in Hoeffer's Alkaline Broth, could withstand 8% KNO_3 in the medium, and even precipitated calcium glycerophosphate. All of the isolates exhibited traits that were comparable to the commercial strain (MTCC 616), as reported in Table 1.Selected isolates showed significant nodulation ability with *Vigna radiata*.

For the As sensitivity tests, (after 24, 48, and 72 hours of incubation), the best growth for various isolates was observed at a concentration of 10 mM As, with concentrations of 2.58 CFU/mL, 1.49 CFU/mL, and 1.0 CFU/ mL, respectively. After 24 hours of incubation, the isolate VBCK1062 exhibited the highest CFU count at all As concentrations, including 0 mM (3 CFU/mL), 5 mM (3 CFU/ mL), 10 mM (2.58 CFU/mL), 15 mM (2.46 CFU/mL), and 20 mM (0.99 CFU/mL). In contrast, the isolate MRR121 showed the lowest count at various concentrations, including 0 mM (2.38 CFU/mL), 5 mM (2.24 CFU/mL), 10 mM (1.82 CFU/mL), 15 mM (1.44 CFU/mL), and 20 mM (0.57 CFU/ mL). After 48 and 72 hours of incubation,

similar findings were observed in the present study (Fig. 2). The number of CFUs detected during 72 hours of incubation was substantially lower than the number detected at 24 hours.

Despite all, the As(V) concentration levels, the VBCK1062 isolate depicted the highest biomass, while the MRR121 isolate had the lowest (Fig. 3). This lines up with the fact that at various As(V) concentrations, the CFU count of As(V) tolerant isolates increases. The zone of hydrolysis revealed qualitative evidence that the tolerant strain (VBCK1062) (Fig 1B) out produced the standard and sensitive strains in terms of cellulase production (MRR121). Table 2 shows that the tolerant strain produces the most cellulase and amylase, followed by the standard strain and the sensitive strains respectively. Quantitative estimation of proteins revealed the maximum production by VBCK1062 (0.24mg/mL) followed by standard strain (0.20 mg/mL) (Table 2).The protein estimation content shown in theresults of the tolerance strain revealed it to be 73% similarity with commercial strain (MTCC 616).

Bacteria that form root nodules were isolated from *Vigna radiata* plants grown in various parts of the Kakinada Industrial area for this investigation. The samples were identified as rod-shaped, gram-negative bacteria upon microscopic analysis. The chosen isolates tested positive for oxidase, catalase, and urease, according to the biochemical analysis. A 1% concentration of the dyes methylene blue and gentian violet inhibited the growth of all of the isolates tested, which is in agreement with previous research by Wei *et al*. (2003) that found Rhizobial cells to be ineffective in this medium. Lactose peptone agar allowed all of the isolates to grow, while glucose peptone agar did not. Hunter *et al*. (2007) demonstrated that *Rhizobium* is characterized by negative gelatinase activity, and the isolates did not produce this enzyme. When the isolates were subjected to starch-containing media, positive results were found. The fluorescent test yielded negative results for every single isolate. For some isolates, the triple iron sugar test yields positive findings. Only four of the isolates (VBCK1048, MRR108, MRR120, and VBCK1062) mentioned above demonstrated nodulation ability with *V.radiata*.

Rhizobia and other microbes can have their growth tracked using two metrics: cell number and cell mass/biomass. At 24, 4, 8, and 72 hours of incubation, the optimal CFU count and biomass was determined at an As(V) concentration of 25 mg/mL. The isolated *Rhizobium* strains exhibited growth retardation when the As(V) concentration was raised beyond 50 mg/mL, as confirmed by the CFU and biomass findings. According to the research conducted by Gauri *et al*. (2010), this is because a higher concentration has a microbiostatic impact. When exposed to

Figure 1A. Selected *Rhizobium* isolate VBCK1062 isolated from the *Vigna radiata* root nodules

Table 1. Biochemical characteristics of 19 *Rhizobium* isolates recovered from *Vigna radiata.*

Characteristics	VBCK1062	VBCK1042	MRR108	MRR120	MRR121	MRR126	MRR101	MRR102	MRR103	MRR122	MRR123	MRR104	MRR110	MRR124	MRR111	MRR1112	MRR106	MRR114	MRR105
Gram staining	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Growth on methylene blue and gentian violet agar at (0.1%) conc.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oxidase	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Growth on GPA	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Growth on LPA	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Urea hydrolysis	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Starch hydrolysis	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Gelatin hydrolysis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Fluorescent assay	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TSI test	A/K	A/K	A/K	A/K	A/K	A/K	A/K	A/K	A/K	A/K	A/K	A/K	A/K	A/K	A/K	A/K	A/K	A/K	A/K
Catalase test	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Citrate utilization	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Growth on HAB	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
8% KNO_3 Tolerance	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

+ Positive

-Negative

Fig 1B. A. Cellulase activity B. Amylase Activity, C. Protease activity of arsenic tolerant *Rhizobium* strain (VBCK1062)

Table 2. Qualitative and Quantitative estimation of Cellulase, Amylase and protein.

Isolates	Qualitative (Zone of hydrolysis)		Quantitative (mg/mL)		
	Cellulase	Amylase	Cellulase	Amylase	Protein
Tolerant strain (VBCK1062)	+++	+++	1.05	2.70	0.24
Sensitive strain (MRR121)	+	+	0.75	2.66	0.19
Standard strain (MTCC 616)	++	++	0.98	2.68	0.24

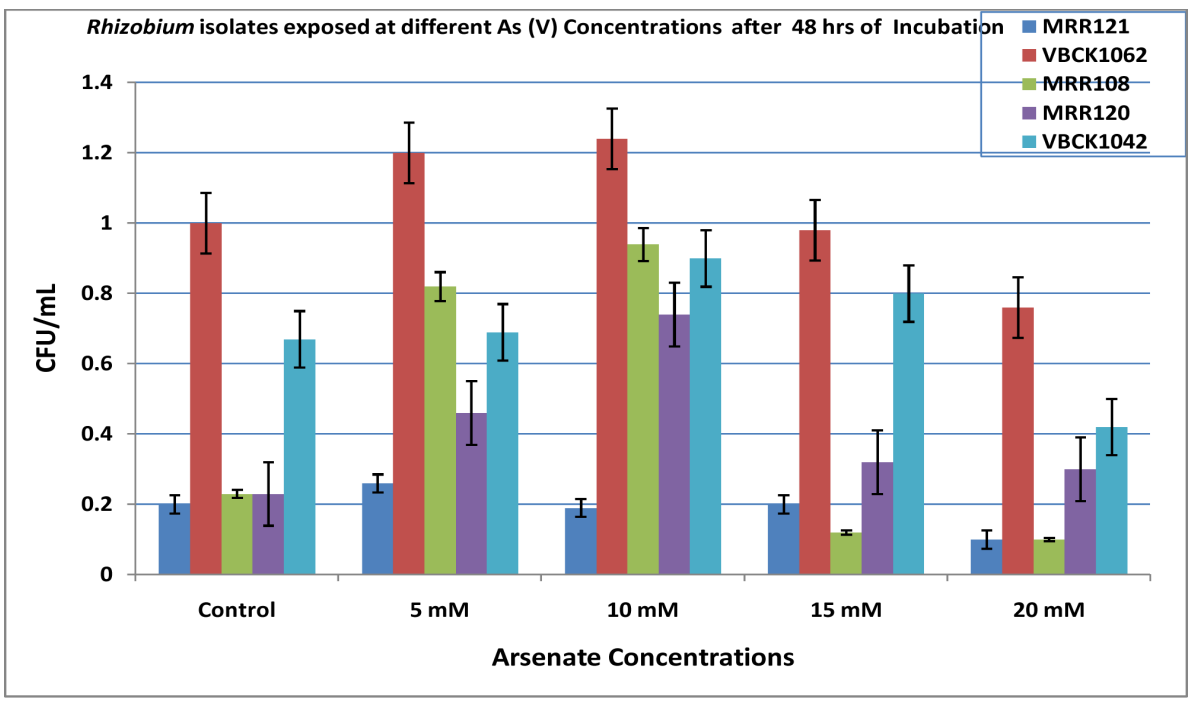

Figure 2. CFU/mL count observed after 48 hr incubation period at different As (V) concentrations.The histogram represents the measure of three replicates, error bars represents SD/SE

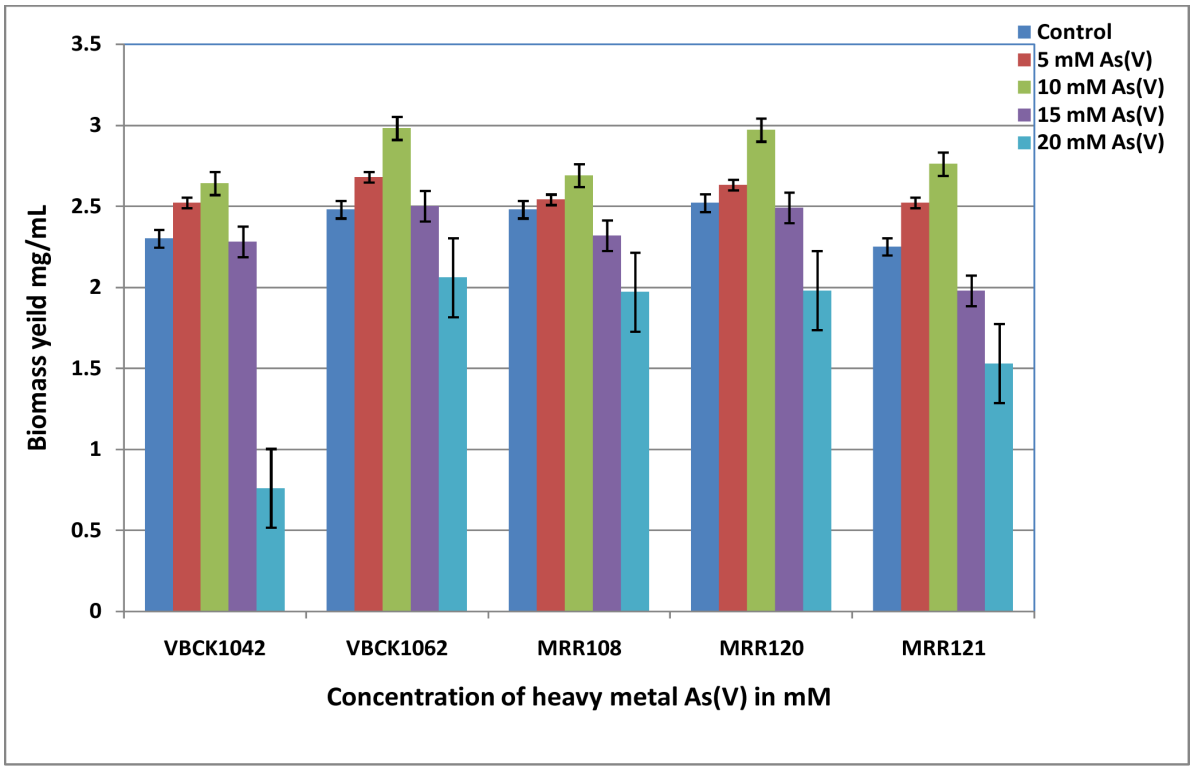

Fig 3. Biomass yields of selected Rhizobial strains isolated at different As (V) concentrations. The histogram represents the measure of three replicates, error bars represents SD/SE

varying doses of As (V) (0, 25, 50, 75, and 100 mg/mL), the VBCK1062 isolate showed the most growth, while the MRR121 isolate showed the least. In a study conducted by Ahmad *et al.,* (2001), it was discovered that soils with the greatest levels of As (V) had the lowest population density of *R. meliloti*, whereas soils with moderate contamination had the highest population wise.

A higher concentration of cellulase and amylase was detected in the VBCK1062 strain in comparison to the control strain, according to the enzyme estimate results. The MRR121 strain exhibited the lowest enzyme production at As(V) concentration of 25 mg/mL. Amylase production was also found to be affected by As(V). The standard strain produced the least amount of protein (0.20 mg/mL), while VBCK1062 produced the most (0.22 mg/mL). Sofia Isabel *et al*. (2006) found that metal affects the *Rhizobium* protein content, with most changes leading to decreased polypeptide expression; these changes are more pronounced in metal tolerant isolates compared to sensitive ones. Therefore this arsenate resistant *Rhizobium* strain may serve as an impending biotechnological agent to bioremediate arsenate contaminated agrogeoecosystems. From this point of view, cellular and physiological studies of strain VBCK1062 are very indispensable in understanding mechanisms of arsenic resistance.

CONCLUSIONS

We characterized the responses of metal-contaminated agriculture zones by employing arsenic-resistant *Rhizobium* bacteria, which produced mucosal EPS. This

current study also emphasized the sensitivity and tolerance of *Rhizobium sp*. isolates to arsenate, as well as their growth and biomass yields, enzyme assays, and protein profiles. The study has clearly evidenced that while increased amounts of arsenic are extremely harmful to the *Rhizobium* strain, VBCK1062 isolated from *Vigna radiata*. Nevertheless, the biochemical and molecular basis of Arsenic resistance in Rhizobial strains should be emphasized in detail as a future study for the sustained agricultural crop productivity.We also anticipated that our results would significantly contribute to better understanding of plant-metal-microbe interactions and cellular-metabolic changes, hence can be used as a criterion for the isolation of As (V) stress tolerant microorganisms from metal contaminated agro-geo-ecosystems.

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ANTIBACTERIAL POTENTIAL OF NANOENCAPSULATED CURCUMIN BY ELETROSPRAYING TECHNIQUE

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ABSTRACT

The study was undertaken during the year 2020–21 to study the nanoencapsulation of curcumin through electrospraying for embracing its ability as a nutraceutical and exploring possible health benefits. To facilitate nanoencapsulation process, electrospraying as a modern technique was used to coat curcumin as a bio-functional ingredient. Curcumin has been utilized for the treatment of several ailments due to its functional capacity and vast variety of medicinal, biological, and pharmacological qualities. Curcumin was encapsulated with zein protein and Tween 80 as coating materials in different combinations (Curcumin: Zein 1:10, 1:15, and 1:20 with 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, 1.0% and 1.5% Tween 80).This combination was studied for the particle size, zeta potential and concentration of nanoparticles along with morphological characteristics. The smallest particle size that was noticed was 250nm in 1:10 Curcumin: Zein with 0.4% Tween 80 combination with zeta potential of -7.51 ± 0.15 mV and concentration of nanoparticles was 5.94×10^{8}. Zein and Tween 80 coated curcumin (ZTC) nanoencapsulated powder showed a good antibacterial activity against gram-positive (*Bacillus subtilis*, *Bacillus cereus*, *Staphylococcus aureus*) and gram-negative (*Escherichia coli*, *Pseudomonas aeruginosa*, *Proteus vulgaris*) bacteria.

Keywords: Bioavailability, Morphology, Nanoparticle,Nutraceuticals, Particle size

INTRODUCTION

Curcumin, the bioactive component of *Curcuma longa* (turmeric) provides a broad variety of beneficial biological and pharmacological properties (Blanco *et al*., 2017; Tejada *et al*., 2016). Hence, it can be applied to a various kind of industries, includingfood industry, modern pharmacology, agrochemicals, cosmetics, nano-bio-science, geo-medicine, plant science, etc. Indian turmeric is considered to be the best in the world with its natural qualities and higher amount of significant bioactive compound curcumin.

At present, the main challenge is the way of delivering the curcumin in gut without noticeable sensory changes in food. For this, nanoencapsulation is a novel and efficient branch of nanotechnology in the healthcare and food sectors which exhibited a novel and significant improved means of retaining physical, chemical and biological properties of a component (Perez-Masia *et al*., 2014). The

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Table 1. Preparation of solution for nanoencapsulation

S. No.	Sample code	Ratio (Curcumin: Zein)	Tween 80 %
1	A	1:10	0.1
2	B	1:10	0.2
3	C	1:10	0.3
4	D	1:10	0.4
5	E	1:10	0.5
6	F	1:10	1.0
7	G	1:10	1.5
8	H	1:15	1.0
9	I	1:20	1.0

product has no sensory impact and enhance the stability of any bioactive or nutraceutical ingredients (Pateiro *et.al*., 2021).

Moreover, improving bioavailability by nanoencapsulation technique, it also offers various benefits which include ease inhandling, taste masking, reduction in oxidation time due inherent possession of antioxidant property, enhanced stability, retention of volatile ingredients, moisture, pH triggered controlled release and successive delivery of multiple active ingredients and long-lasting organoleptic perception (Onyeaka *et al*., 2022).

The current investigation was conducted to explore the selection and optimization of encapsulating material and electrospraying of bioactive component (curcumin) with encapsulating material like Zein and Tween 80. Uses of curcumin, zein and tween 80 in different combinations for the preparation of nanoparticles through electrospraying technique have been reported in limited scientific studies, hence present investigation was ideal to evaluate their role. The study's primary goal was checking suitability of bio-component in the preparation of nanoencapsulated powder of curcumin which has minimum particle size. The investigation also focused on the morphological traits, distribution of particle sizes, and antibacterial properties of nanoencapsulated powder of curcumin.

MATERIAL AND METHODS

An experiment was conducted in the laboratory of Department of Dairy Microbiology, College of Dairy Science, Kamdhenu University, Amreli during 2020-21.

Food grade curcumin ($C_{21}H_{20}O_6$) and zein protein derived from maize was purchased from Sigma-Aldrich while Tween 80 ($C_{64}H_{124}O_{26}$) was purchased from Himedia, India.

Preparation of solution for nanoencapsulation

80% (v/v) alcohol solution was used to prepare various concentrations of curcumin, zein and Tween 80 as mentioned in Table 1. After subjecting the solutions prepared to electrospraying optimum flow rate at 0.14 mL/h; voltage at 14 kV and a tip-to-collector distance was 10 cm was confirmed for nanoencapsulation of powder.

Method of Gomez-Estaca *et al*. (2012) with slight alteration was used to prepare combination of curcumin (5 mg/mL),different concentration of zein protein (*i.e.* 50, 75 and 100 mg/mL), different concentrations of Tween 80 and 80% (v/v) alcohol solution. The

combinations used in the study are given in Table 1.

Preparation of ZTC nanoencapsulated powder through electrospraying

Electrospraying instrument (Model: FLUIDNATEK LE-10, Make - Bioincia S. L., Valencia, pain) was used for electrospraying. The solution prepared for nanoencapsulation was electro sprayed at different combinations of flow rate, voltage and tip to collector distance.

Determination of particle size, zeta potential value, size distribution and concentration number of particles)

Zetasizer Nano series (Model: ZS90, Make - Malvern Panalytical Ltd., UK) was used to measurement of the particle size and zeta potential analysis. For particle size analysis, different combinations of nanoencapsulated curcumin powders were used. 80% (v/v) ethanol was employed as a reference having refractive index - 1.361, viscosity - 0.9830mPa.s, dielectric constant - 25.30å at temperature 30° C.

Nanoparticle tracking device (Nanosight Model - NS300, Make - Malvern Panalytical Ltd. UK) equipment was used to determineparticle size distribution and concentration (number of particles). All measurements were conducted at 30° C.

Morphological studies of ZTC nanoencapsulated powder

Scanning electron microscope (SEM) (Model - ZEISS EVO-18, Make - Carl Zeiss, Germany) was used to study the morphological characteristics of nanoparticles. 2 mg of ZTC nanoencapsulated powder sample was used and coated with gold by using vacuum sputtering machine EMITECH SC 7620 sputter coater at 500 kV for 4 min and pressure was 10 mA. An individual powder sample was fixed on aluminium stub with double-sided adhesive tape. SEM image data of nanoencapsulated curcumin powder was collected over a selected area of the samples and 2D image was visualized that display properties include size, shape and texture of nanoencapsulated curcumin powder samples (Rosenberg and Young, 1993).

Study on antibacterial activity of ZTC nanoencapsulated powder

A method adapted from Venkatasubbu and Anusuya (2017) with slight variationwas usedto study the antibacterial activity of curcumin nanoparticles. Antibacterial activity of nanoencapsulated curcumin nanoparticle was examined against gram-positive bacterial strains (*Bacillus subtilis* ATCC 19659, *Bacillus cereus* ATCC 14579, *Staphylococcus aureus* ATCC 9144) and gram-negative bacterial strains (*Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 10145, *Proteus vulgaris* ATCC 33420) using the agar well diffusion technique (Zhou *et al*., 2006; Gong and Guo, 2009; Zhang *et al*., 2009). These strains of pathogen were obtained from Hi-media Laboratories, Mumbai. In this investigation, curcumin nanoparticle samples at varying doses (500, 750, and 1000 ìg/mL) were employed. Nutrient agar and dimethyl sulfoxide (DMSO) were used for examination of test organisms. Streptomycin was employed as an effective positive control to measure antibacterial activity. The plate with different concentration of ZTC nano encapsulated powder (sample D) shown different zone of inhibition at the end of 24-hour incubation at 37 °C will be measured and recorded (diameter in mm). Higher zone of inhibition will have more antibacterial activity and vice-versa.

Statistical Analysis

Collected data of three replications were subjected to statistical analysis by analysis of variance (ANOVA) and critical difference test at 5% level of significance (P d" 0.05) using IBM SPSS statistics software version 26 to compare the various treatment means.

RESULTS AND DISCUSSION

Characterization of ZTC nanoencapsulated power production through electro spraying Particle Size Analysis

Size of the ZTC nanoencapsulated powder particle was found in the range between 250.4 to 451.8 nm (Table 2). The minimum size (250.4 nm) of ZTC nanoencapsulated powder particle was found in 1:10 Curcumin: Zein containing 0.4% Tween 80 combination while maximum size (451.8 nm) was found in 1:20 Curcumin: Zein contain 1.0% Tween 80. Polymeric particles are considered to be the nano-size if they are below 500 nm in size (Cheraghian,2017), although the average range obtained in conducted study was below 500 nm.This could be because of increased surface to volume ratio as smaller size of nanoparticles contributed more in caparison with large size particle.

Gomez-Estaca *et al.* (2012) prepared a curcumin nanoparticle using zein by electrohydrodynamic atomization technique and they found nanoparticle size between 175 and 900 nm. Baspinar *et al*. (2018) prepared a curcumin nanoparticle using zein, piperine and chitosan by electrospying technique and they found nanoparticle size between 310 and 527 nm. The results obtained in the present study were at par with cited studies. Sari *et al*. (2015) prepared a curcumin nanoemulsion by using medium chain triglycerid eoil, whey protein concentrate - 70 and Tween 80 and observed average particle size 141.6 ± 15.4 nm in diameter which was lower than the results of particle size under present investigation.

Particle size of ZTC nanoencapsulated powder of curcumin, zein and Tween 80 significantly ($p < 0.05$) decreased with the increased concentration of Tween 80 from 0.1% to 0.4% subsequently, following a notable increase in particle size with the Tween 80 concentration increased from 0.5% to 1.5%.

Table 2. Particle size, zeta potential and size distribution and concentration (number of particles)of ZTC nanoencapsulated curcumin powder

S. No.	Sample code	Sample		Average Particle size (d. nm)	Average Zeta potential (mV)	Average number of particles/mL
		Curcumin: Zein	Tween 80%			
1	A	1:10	0.1	282.9 ± 2.2	-4.76 ± 0.10	9.21×10^{7} ± 0.31
2	B	1:10	0.2	276.9 ± 1.5	-5.82 ± 0.17	1.58×10^{8} ± 0.12
3	C	1:10	0.3	260.9 ± 1.8	-6.53 ± 0.09	1.95×10^{8} ± 0.12
4	**D**	**1:10**	**0.4**	**250.4 ± 2.5**	**-7.51 ± 0.15**	**5.94×10^{8} ± 0.14**
5	E	1:10	0.5	295.3 ± 2.1	-7.97 ± 0.08	3.47×10^{8} ± 0.13
6	F	1:10	1.0	330.3 ± 2.7	-7.13 ± 0.11	2.96×10^{8} ± 0.08
7	G	1:10	1.5	431.2± 2.3	-3.62 ± 0.08	7.10×10^{7} ± 0.14
8	H	1:15	1.0	359.8 ± 3.3	-4.49 ± 0.04	1.54×10^{8} ± 0.12
9	**I**	**1:20**	**1.0**	**451.8 ± 2.7**	**-4.26 ± 0.06**	**9.94×10^{7} ± 0.05**

Zeta Potential Analysis

Zeta potential value of the ZTC nanoencapsulated powder was analyzed by the zetasizer (ZS90). The zeta potential analyses of different combinations of ZTC nanoencapsulated powder aredepicted in Table 2. The zeta potential values of nanoencapsulated curcumin nanoparticle in the range between -3.62 mV and -7.97 mV were found. The minimum zeta potential (-3.62 mV) of nanoencapsulated curcumin powder particle was found in 1:10 Curcumin: Zein containing 1.5% Tween 80 combination while maximum zeta potential (-7.97 mV) was found in 1:10 Curcumin: Zein containing 0.5% Tween 80 combination.

Sari *et al*. (2015) with 40 mg curcumin dissolved in a 2% MCT + 2% Tween 80 + 0.5% WPC (70%) solvent having zeta potential of -6.9 ± 0.2 mV. Asadi *et al*. (2021) used walnut protein isolate for encapsulation of curcumin by electrospraying technique and they found zeta potential of -17.7 mV ± 0.94. Zeta potential value in present study was found at par.The zeta potential of ZTC nanoencapsulated powder of curcumin, zein and Tween 80 significantly ($p < 0.05$) increased with the increased Tween 80 concentration from 0.1% to 0.5% than after zeta potential significantly decreased with the Tween 80 concentration increased to 1.5%.

Size Distribution and Concentration (Number of Particles)

Size distribution and concentration (number of particles) analyses ofZTC nanoencapsulated powder were performed (Table 2). The particle size distribution of ZTC nanoencapsulated powder particles was within the range of 266 and 450.2 nm. The minimum particle size distribution (266 nm) of ZTC nanoencapsulated powder particle was found in 1:10 Curcumin: Zein containing 0.4% Tween 80 combination while maximum particle size distribution (450.2 nm) was found in 1:20 Curcumin: Zein containing 1.0% Tween 80 combination.

Concentration (number of particles) of ZTC nanoencapsulated powder particles was in the range between 7.10×10^7 and 5.94×10^8. The minimum concentration (number of particles) (7.10×10^7) of ZTC nanoencapsulated curcumin powder particles found in 1:10 Curcumin: Zein contain 1.5% Tween 80 combination while maximum concentration (number of particles) (5.94×10^8) was found in 1:10 Curcumin: Zein contain 0.4% Tween 80 combination.

Mazzarino *et al*. (2012) prepared curcumin loaded nanoparticle in mucoadhesive polysaccharide chitosan by nanoprecipitation method. They reported mean diameterof curcumin nanoparticles around 170 and 180 nm for uncoated and chitosan coated nanoparticles, respectively, by NTA technique. Sabra *et al.* (2019) prepared curcumin-loaded modified citrus pectinate-chitosan nanoparticle suspensions by ionic gelation method. They reported mean diameter of curcumin nanoparticle around 291.7 ± 7.8 nm by NTA technique. The results obtained in present investigations were at par with above mentioned studies.

Morphological Characteristics

Scanning electron microscopy (SEM) images showed, ZTC nanoencapsulated curcumin powders which have spherical shape without any fracture or crack on the outside surface of the nano-capsules.

With combination of 1:10 Curcumin: Zein with 0.4% Tween 80, ZTC nanoencapsulated powder showed good round shape with 250.4 nm size and without any fracture on the surface. Gomez-Estaca *et al*. (2012) and Baspinar *et al*. (2018) prepared nanoencapsulated particle of curcumin with the

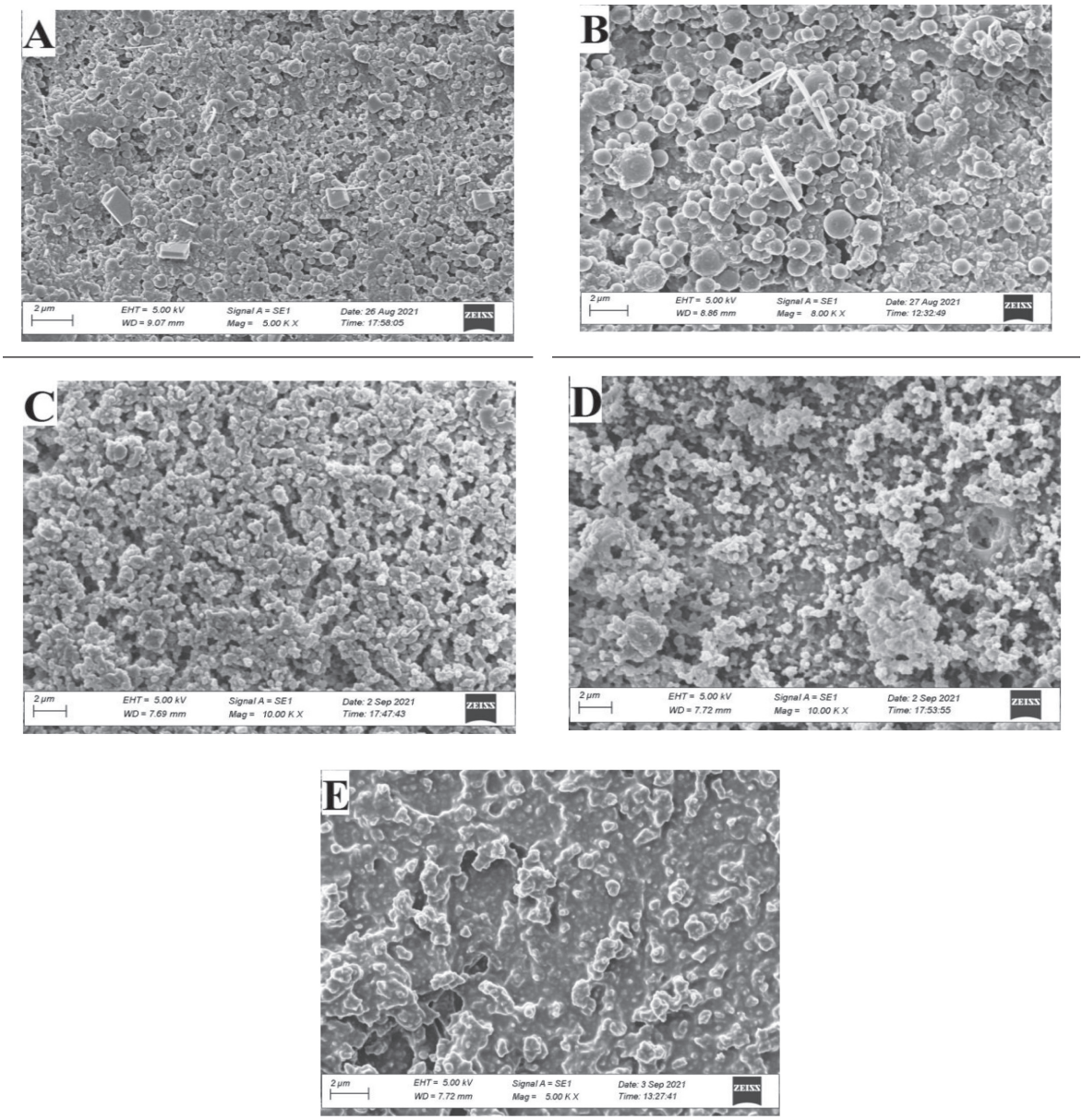

Figure 1. SEM images of ZTC nanoencapsulated curcumin powders with different combinations (A)1:10 Curcumin: Zein with 0.1% Tween 80, (B) 1:10 Curcumin: Zein with 0.4% Tween 80, (C)1:10 Curcumin: Zein with 1% Tween 80, (D) 1:15 Curcumin: Zeinwith1% Tween 80, (E) 1:20 Curcumin: Zein with 1% Tween 80

combination of zein protein by electrospying method. They observed spherical shape morphology of nanoencapsulated particle of curcumin with zein protein, thus it showed a good dispersion in an aqueous food matrix (semi-skimmed milk).Lopez-Rubio and Lagaron (2012) also found that electrospraying technique gave the best spherical shape structure to nanoencapsulated bioactive. Asadi *et al*. (2021) reported a relatively round shape nanoparticle of curcumin using walnut protein isolate.

Table 3. Zone of inhibition including well diameter of ZTC nanoencapsulated powder

S.No.	Organisms	Inhibition zone diameter (mm)			
		Positive control (Streptomycin 10 µg/mL)	Curcumin concentration (µg/mL)		
			500	750	1000
1	*Bacillus subtilis* (ATCC 19659)	23	13	15	19
2	*Bacillus cereus* (ATCC 14579)	12	6	8	10
3	*Staphylococcus aureus* (ATCC 9144)	24	12	14	18
4	*Escherichia coli* (ATCC 25922)	18	8	10	13
5	*Pseudomonas aeruginosa* (ATCC 10145)	20	10	12	15
6	*Proteus vulgaris* (ATCC 33420)	20	14	15	16

Antibacterial Activity

The 1:10 Curcumin: Zein with 0.4% Tween 80 (sample D) was used to investigate the antibacterial activity of ZTC nanoencapsulated powder. Each of the three gram-positive and gram-negative bacteria was subjected to an analysis of antibacterial activity using agar diffusiontechnique. Sample D in different concentrations (500, 750 and 1000 ìg/mL) were used. Antibacterial activity was examined using streptomycin (10 ìg/mL) as a positive control. Zone of inhibitions obtained in well sagainst the different bacteria were different. This might

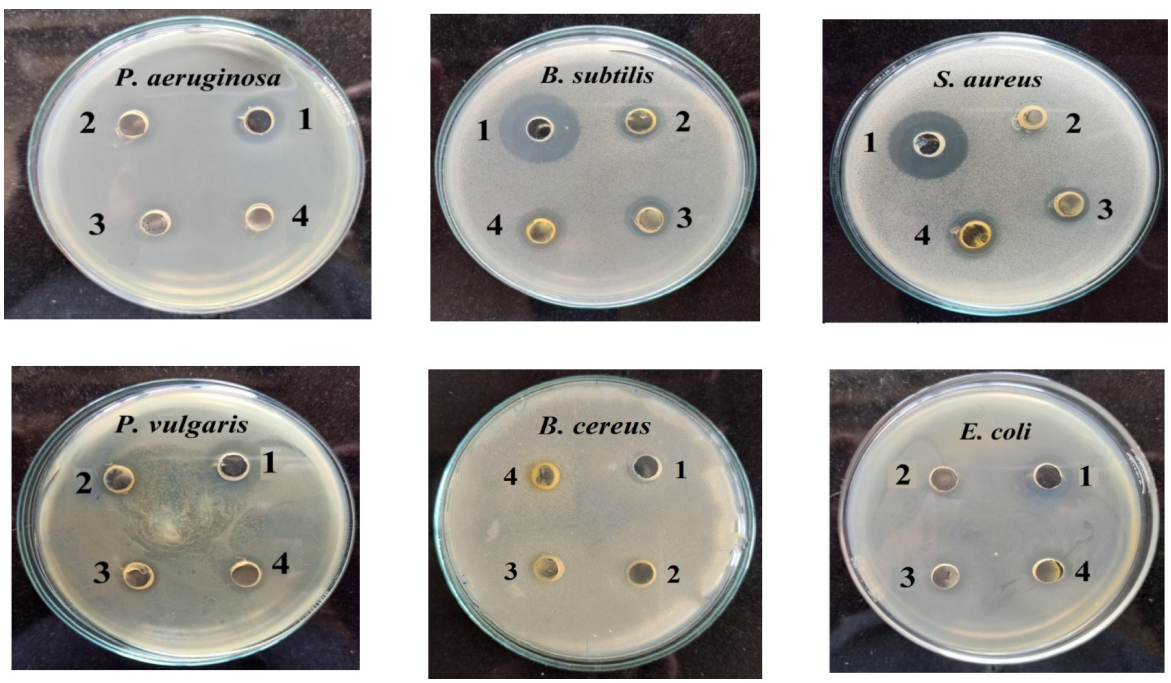

Figure 2. Zone of inhibition aginst 1. Streptomycin (10µg/mL) 2. Nanoencapsulated curcumin (500µg/mL) 3. Nanoencapsulated curcumin (750µg/mL) 4. Nanoencapsulatedcurcumin (1000µg/mL) of ZTC nanoencapsulated powder (1:10 Curcumin: Zeinwith 0.4% Tween 80) for different gram-positive and gram-negative bacteria

be due use of different concentration of 1:10 Curcumin: Zein with 0.4% Tween 80. The diameter of the inhibitory zone was measured, and the results are represented in Table 3 in diameter (mm). Figure 2 shows the different zones of diameter against different organisms with streptomycin following a 24-hour incubation period at 37 °C

Different diameters of inhibition zones shown against different bacteria was because of the differences in their cell wall membrane constituents and structure. Gram-negative bacteria contains thin peptidoglycan layer and have an outer lipid membrane while gram-positive bacteria contains thick peptidoglycan layer and no outer lipid membrane layer; both of which undergo different types of interactions when come in contact with curcumin.

The study's findings showed that the zone of inhibition increased with the increase in ZTC nanoencapsulated powder concentration, minimum and maximum zones of inhibition were showed in 500and 1000 µg/mL of ZTC nanoencapsulated powder concentration, respectively. In 1000 µg/mL curcumin concentration, *Bacillus subtilis* (19 mm) gave higher zone of inhibition followed by *Staphylococcus aureus* (18 mm) >*Proteus vulgaris* (16mm) >*Pseudomonas aeruginosa* (15 mm) >*Escherichia coli* (13 mm) >*Bacillus cereus* (10 mm).

Venkatasubbu and Anusuya (2017) prepared a curcumin nanocomposite and studied the antibacterial activity against *Escherichia coli*, *Bacillus subtilis*, *Staphylococcus aureus*, *Proteus vulgaris*, *Enterococcus faecalis*, *Staphylococcus epidermidis*, *Klebsiella pneumoniae*, *Enterobacter aerogenes*, *Pseudomonas mendocina* and Coliform by using different concentrations of curcumin nanocomposite samples (250, 500, 750 and 1000 µg/mL) in dimethylsulfoxide. They observed that 1000 µg/mL concentration of curcumin nanocomposite exhibited greaterantibacterial activity compared to other concentrations of curcumin nanocomposite (250, 500 and 750 µg/mL) against all the test organisms. In case of 1000 µg/mL concentration, highest and lowest zone of inhibition showed by *Enterobacter aerogenes* (28 mm) and *Staphylococcus aureus* (14 mm), respectively. Selvi *et al*. (2018) prepared a curcumin contains titanium dioxide nanoparticles and different concentrations (25, 50, 75 and 100 µg/mL) in dimethyl sulfoxide and used for study of antibacterial activity against *Bacillus subtilis*, *Klebsiella pneumonia*, *Staphylococcus aureus* and *Escherichia coli*. In comparison to other concentrations (25, 50, and 75 µg/mL), researchers found that the 100 µg/mL concentration exhibited greater antibacterial activity in all other organisms. The broadest zone of inhibition was observed against *Bacillus subtilis* (12 mm) and *Staphylococcus aureus* (12 mm), while the lowest zone of inhibition was observed against *Klebsiella pneumonia* (9 mm).

Bhawana *et al*. (2011) analysed antimicrobial activity of curcumin and curcumin nanoparticles against two gram-negative (*Escherichia coli* and *Pseudomonas aeruginosa*) and two gram-positive (*Staphylococcus aureus* and *Bacillus subtilis*) bacteria by using 400 µg/mL curcumin concentration. In their study, *Bacillus subtilis* (20 mm) showed maximum efficiency followed by *Staphylococcus aureus* (16 mm), *Pseudomonas aeruginosa* (14 mm) and *Escherichia coli* (12 mm). From this study, we observed that nanoencapsulated curcumin by electrospraying could acted as better means to deliver it to the host which exhibiteddecent antibacterial activity against selected pathogenic bacteria.

CONCLUSIONS

Process of nanoencapsulation is an ideal technique to preserve the functionality of bioactive compounds. Curcumin as a functional ingredient of turmeric have many important properties which are significant for the health of human beings. Such ideal component can be persevered with all its valuable properties. Electrospraying is one of the modern techniques used for the nanoencapsulation, in which there is no requirement of controlled conditions like temperature, gaseous conditions etc. This novel technique has advantage in contrast with other methods by providing higher surface to volume ratio of nanoparticles. Apart from many ideal properties of curcumin, antibacterial property helps in inhibition of variety of bacteria whose population need to be controlled for betterment of host. Hence, such component prepared by a novel technique like nanoencapsulation by electrospraying is the need of present time.

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DEVELOPMENT OF INSTANT SHAKE MIX FROM SPROUTED RAGI POWDER

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ABSTRACT

Ragi or finger millet (*Eleusine coracana* L.) is a common millet grown in several regions of India.The sprouted ragi powder was incorporated in different proportions ranging from 80 per cent to 40 per cent,along with skimmed milk powder and nuts. The best treatment was obtained through sensory evaluation using a scorecard with a nine-point hedonic scale. Based on the organoleptic evaluation, the shake mix prepared with 50 per centsprouted ragi powder and 45per cent skimmed milk powder had a highest mean score of 8.36 for overall acceptability other than control (100% skimmed milk powder).The selected instant shake mix was subjected to chemical analysis and was observed to have energy (383.84 Kcals), carbohydrate (72.66 g per 100 g), protein (19.43 g per 100 g), fat (1.72 g per 100 g), calcium (1450 mg per 100 g) and iron (12.96 milli gram per 100 gram). A highly acceptable, nutritionally superior, and shelf-stable instant shake mix can be successfully developed using sprouted ragi powder.

Keywords: Instant shake mix, organoleptic evaluation, skimmed milk powder, sprouted ragi

INTRODUCTION

Apart from cost, health, sensory appeal, and other associated factors, the multifaceted concept of convenience is often mentioned as the most important factor that impacts people's food choices. What, when, how, and where people eat food are mainly dictated by convenience. As a result, in this convenience-driven society, there has been a noticeable rise in the demand for minimally processed, ready-to-eat or ready-to-cook foods in recent years. Convenience products save time and effort and compensate for poor cooking skills. An affinity for naturalness and a high level of nutritional knowledge are related to a lower intake of convenience foods. Today, consumers demand healthy food; therefore, the food industry is developing and producing more healthy convenient food options (Brunner, 2016).

Sensory qualities like taste, appearance, flavour, texture, colour, and freshnessplay an important role in motivating consumers to buy and consume convenience food products. Recent advancements in food processing and packaging technology have significantly enhanced the sensory qualities and appeal of these products (Imtiyaz *et al*., 2021).

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The term 'instant food mix' refers to easy, convenient, and easy-to-prepare food products, where some ingredients are pre-mixed to offer a simple, homemade option. These mixes typically include cereals, pulses, condiments, spices, or other food items which are processed and in various combinations. Instant mixes can save a lot of time and energy, making them highly convenient for homemakers as well as working people with multiple responsibilities. Additionally, they can be nutritious as they provide a high dietary fibre content and other health benefits (Dhiman *et al*., 2017).

Finger millet (*E. coracana*) is also known as African millet or Ragi. It is used in the making of various products. Sprouting can be done on ragi to improve its nutritional value. Ragi is rich in calcium, iron, protein, phosphorous, fibre and vitamins. Ragi is distinguished by its superior protein quality and contains essential amino acids, vitamin A, vitamin B, and phosphorus (Gopalan *et al*., 2004).

Watanabe *et al.* (2004) described germination as a biological process that commences when dry seeds absorb water, resulting in the activation of enzymes under specific physical conditions favourable for seed sprouting. According to Fouad and Rehab (2015), germination can enhance the nutritive and bioactive compounds in edible seeds. This process is emphasized as a key bioprocessing method that enhances nutritional values by increasing the levels of bioactive compounds (Anthony *et al*., 2020).

Kang *et al.* (2008) reported that ragi contains the highest levels of calcium, antioxidants, and phytochemicals, contributing to its slow and easy digestibility. Consequently, ragi is highly effective in regulating blood glucose levels in diabetic patients.

Instant shakes are well-received by consumers in the market. However, there is increasing awareness about the health concerns associated with the consumption of processed shake mixes. To address this, a study was conducted to assess the suitability of sprouted ragi powder as an ingredient for developing a nutritionally superior and cost-effective instant shake mix..

MATERIAL AND METHODS

Raw materials

The experiment was done in 2022 at the Department of Community Science, College of Agriculture, Kerala Agricultural University, Thrissur.Ragi was collected from the local market. It was sprouted according to standardised procedures and made into powder (Kokani *et al*., 2018).Skimmed milk powder and cashew nuts needed for the study were also procured locally.

Standardisation of instant shake mix from sprouted ragi powder

Sprouted ragi powder was prepared using a standard procedure with some modifications. (Kokani *et al*., 2018).The sprouted ragi powder (SRP) and skimmed-milk powder (SMP) were incorporated in various proportions from 80per cent to 40 per centand 15 per cent to 55 per cent(SRT_1- SRT_5),respectively and 5 per cent of nuts remained constant in all treatments, as detailed in Table 1. 100 per cent skimmed-milk powder served as the control (SRT_0). The experiment was done in a Completely Randomised Design (CRD) including 6 treatment combinations and replicated thrice.

Preparation of shake from instant shake mix

The instant shake mix was developed using the standard procedure of Remya *et al*. (2018) with a few modifications.The prepared instant shake mix (25 g) was reconstituted with

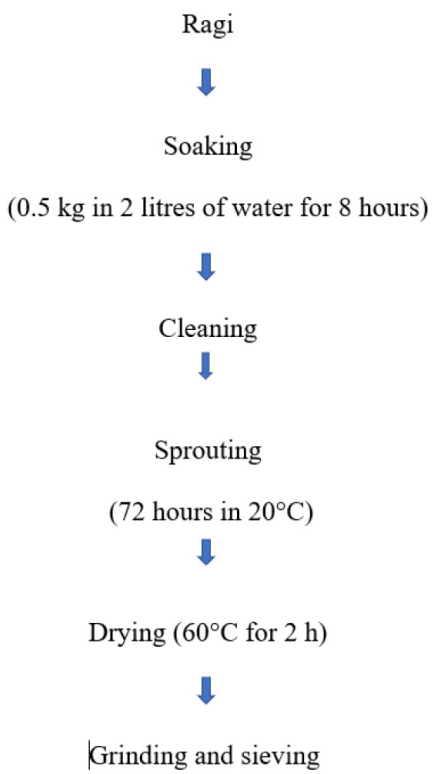

Fig.1. Preparation of sprouted ragi powder

chilled milk (100ml) and sugar and served chilled for organoleptic and sensory evaluation.

Sensory evaluation

A series of acceptability trials were conducted using a simple triangle test at the laboratory level, with a panel of twenty judges aged between 18 and 35 years, as recommended by Jellinek (1985). The sensory evaluation of the instant shake mix and the resulting shake was done by the judges using a 9-point hedonic scale.

Nutritional evaluation of the instant shake mix

The nutrient qualities like energy, carbohydrate, protein, fat (Sadasivam and Manickam, 1997), calcium and iron (Perkin-Elmer, 1982) of the best-selected instant shake mix, along with control, were determined. The analyses were done in triplicate.

Statistical analysis

The nutrient analysis of the control and the best treatments were statistically interpreted by T-test using SPSS software. The scores obtained from the organoleptic evaluation were analysed using Kendall's Coefficient of Concordance (W).

Cost of Production

The cost of production of the most acceptable treatment of sprouted ragi instant shake mix was calculated on the basis of the market prices of procured ingredients used for the preparation of the shake mix, electricity charges, labour charges, and packaging costs.The price for 100 grams of the product was calculated and then compared to the prices

Table 1. Combinations of instant shake mix from sprouted ragi powder

Treatments	Combination
SRT_0	100 % SMP (Control)
SRT_1	80 % SRP + 15 % SMP + 5 % N
SRT_2	70 % SRP + 25 % SMP + 5 % N
SRT_3	60 % SRP + 35 % SMP + 5 % N
SRT_4	50 % SRP + 45 % SMP + 5 % N
SRT_5	40 % SRP + 55 % SMP + 5 % N

*SRP- Sprouted ragi powder,SMP- Skimmed milk powder, N- Nuts

of other comparable products available in the market.

RESULTS AND DISCUSSION

Sensory evaluation of instant shake mix

The sensory evaluation of the sprouted ragi instant shake mix was conducted. In this study, the instant shake mix made with sprouted ragi powder (SRP) was supplemented with skimmed milk powder (SMP). The control treatment SRT_0, which contained 100% SMP, achieved the highest meanscores for all sensory attributes: appearance (8.73), colour (8.67), flavour (8.71), texture (8.64), taste (8.71), and overall acceptability (8.73). Among the experimental treatments, SRT_4, which comprised 50% SRP, 45% SMP, and 5% N, received the highest mean scores for appearance (8.67), colour (8.67), flavour (8.29), texture (8.16), taste (8.04), and overall acceptability (8.36). The mean scores for organoleptic evaluation of instant shake mix from sprouted ragi powder are expressed in Table 2.

Yadav and Singh (2017) formulated an instant *mangodi* mix which is a legume based fried Indian cuisine prepared from green gram.It was reported that the treatment having 50 % green gram + 25 % soy flour + 25 % rice showed the highest overall acceptability of 8.65for sensory evaluation. The sensory qualities of the *mangodi* were increased by the addition of 25 per cent soy flour.

Sensory evaluation of instant shake

The sensory evaluation of the sprouted ragi instant shake was conducted separately.

Table 2. Mean scores for organoleptic evaluation of instant shake mix from sprouted ragi powder

Treatments	Appea-rance	Colour	Fla-vour	Tex-ture	Taste	Overall accep-tability
SRT_0 Control - 100 % SMP	8.73 (4.23)	8.67 (4.73)	8.71 (5.77)	8.64 (5.71)	8.71 (5.87)	8.73 (5.87)
SRT_1 80 % SRP + 15 % SMP + 5 % N	8.22 (2.03)	8.07 (2.13)	7.62 (2.03)	7.58 (1.93)	7.20 (1.40)	7.72 (1.37)
SRT_2 70 % SRP + 25 % SMP + 5 % N	8.49 (3.23)	8.38 (3.13)	7.89 (2.90)	7.69 (2.33)	7.47 (2.23)	7.98 (2.33)
SRT_3 60 % SRP + 35 % SMP + 5 % N	8.60 (4.00)	8.42 (3.67)	8.09 (3.33)	8.11 (3.97)	7.76 (3.20)	8.20 (3.30)
SRT_4 50 % SRP + 45 % SMP + 5 % N	8.67 (4.10)	8.67 (4.90)	8.29 (4.43)	8.16 (4.03)	8.04 (4.10)	8.36 (4.17)
SRT_5 40 % SRP + 55 % SMP + 5 % N	8.47 (3.40)	8.21 (2.43)	7.91 (2.53)	7.94 (3.00)	8.36 (4.20)	8.28 (3.97)
Kendalls W	.223*	.426*	.581*	.615*	.761*	.702*

SRP- Sprouted ragi powder, SMP- Skimmed milk powder, N- Nuts

Values in parentheses are mean rank score based on Kendall's coefficient of concordance (W) (*significant at 1% level)

Table 3. Mean scores for organoleptic evaluation of instant shake from sprouted ragi powder

Treatments	Appea-rance	Colour	Fla-vour	Tex-ture	Taste	Overall accep-tability
SRT_0 Control - 100 % SMP	8.60 (5.10)	8.60 (5.07)	8.69 (5.33)	8.60 (5.33)	8.51 (5.23)	8.62 (5.50)
SRT_1 80 % SRP + 15 % SMP + 5 % N	7.53 (1.60)	7.62 (1.73)	7.60 (2.00)	7.51 (1.73)	7.42 (1.83)	7.38 (1.47)
SRT_2 70 % SRP + 25 % SMP + 5 % N	7.82 (2.60)	7.82 (2.33)	7.78 (2.47)	7.72 (2.50)	7.58 (2.37)	7.60 (2.10)
SRT_3 60 % SRP + 35 % SMP + 5 % N	8.09 (3.53)	8.27 (4.03)	8.11 (3.27)	8.04 (3.50)	7.84 (3.27)	7.87 (3.80)
SRT_4 50 % SRP + 45 % SMP + 5 % N	8.58 (4.87)	8.58 (4.70)	8.44 (4.37)	8.44 (4.60)	8.31 (4.53)	8.31 (4.90)
SRT_5 40 % SRP + 55 % SMP + 5 % N	8.04 (3.30)	8.11 (3.13)	7.91 (3.07)	8.00 (3.33)	8.07 (3.77)	7.84 (3.23)
Kendalls W	.567**	.563**	.468*	.514**	.538**	.716**

SRP- Sprouted ragi powder, SMP- skimmed milk powder, N- Nuts

Values in parentheses are mean rank score based on Kendall's coefficient of concordance (W) (**significant at 1% level)

In this evaluation, the control treatment SRT_0, which contained 100% skimmed milk powder (SMP), achieved the highest mean scores for all sensory attributes: appearance (8.60), colour (8.60), flavour (8.69), texture (8.60), taste (8.51), and overall acceptability (8.62). Among the other treatments, SRT_4, consisting of 50% sprouted ragi powder (SRP), 45% SMP, and 5% N, received the highest mean scores for appearance (8.58), colour (8.58), flavour (8.44), texture (8.44), taste (8.31), and overall acceptability (8.31).

Nutritional analysis of the instant shake

The sprouting process proved beneficial in enhancing the nutrient content of ragi flour and increases the levels of calcium, phosphorus, and vitamin C. Sprouting of finger millet improves digestibility and bioavailability of nutrients and improves sensory and nutritional quality. The significant increase in vitamin C after malting is attributed to the enzymatic hydrolysis of starch by amylases and diastases, which degrade starch and produce glucose. This increased amount of glucose becomes the precursor of vitamin C (Kokani *et al*., 2018).

As per the sensory evaluation, in the case of the sprouted ragi instant shake mix, the treatment SRT_4 (50 % SRP + 45 % SMP + 5 % N) was identified to be the best. The selected instant shake mix from sprouted ragi powder along with the control were analysed for their nutrient qualities (Table 4), and found that the best treatment has moisture (4.18%), energy (383.84 Kcals), carbohydrate (72.66 gram per 100 g), protein (19.43 g per 100 g),

Table 4. Nutritional qualities of instant shake from sprouted ragi powder

Treatments	Energy (Kcal)	Protein (g/100 g)	Fat (g/100 g)	CHO (g/100 g)	Calcium (mg/100 g)	Iron (mg/100 g)	Crude fibre (g/ 100 g)
SRT_0 (100% SMP) Control	357.00	35.00	1.00	52.0	1200.00	0.00	0.00
SRT_4 (50 % SRP + 45 % SMP + 5 % N)	383.84	19.43	1.72	72.66	1450.00	12.96	1.43

SRP- Sprouted ragi powder, SMP- skimmed milk powder, N- Nuts

fat (1.72g per 100 g), calcium (1450 milligram per 100 g) and iron (12.96 mg per 100 gram).

Remya *et al*. (2018) found that the protein of probiotic shake mixes from *koozha* and *varika* variety of jackfruit were 26.30 and 26.67 $g100g^{-1}$, Goswami *et al*. (2017) identified that the protein content increased with the incorporation of sprouted ragi in ragi based halwa mix (13.1 g 100 g^{-1}). The fibre content seems to be increased with an increase in millet flour blended in a ragi-based halwa mix. They also found that the mineral content of the halwa mix was increased, which might be due to more mineral content present in ragi.

As per the above findings, the sprouted ragi instant shake mix was more nutrient-dense in terms of protein, fibre, and mineral content. Ragi is the least expensive source of calcium. It can be utilised to make common foods to boost the nutrient content, acceptability and flavour.

Cost of instant shake from sprouted ragi powder

The development cost of the instant shake mix made from sprouted ragi powder was found to be Rs.49.53 per 100 grams. This price is less when compared to commercially available products, where the market price for a millet-based instant shake mix is Rs. 75 per 100 grams. Additionally, Remya *et al.* (2017) found that the cost of a jackfruit-based instant shake mix was Rs.138.54 per 100 grams.

CONCLUSIONS

Sprouted ragi powder is a valuable source of nutrients and can be effectively utilized in the development of convenient foods. The instant shake mix made from sprouted ragi powder exhibited excellent organoleptic qualities, including a notably smooth texture, and contained a significant amount of essential nutrients. The study indicates that a highly acceptable instant shake mix can be prepared from sprouted ragi powder in a cost-effective manner.

In the instant shake mix made from sprouted ragi powder, the formulation containing 50% sprouted ragi powder, 45% skimmed milk powder, and 5% nuts (T_4) was found to have a high calcium content, iron content, and also maximum acceptability. The inclusion of millet varieties such as ragi in the development of convenient foods significantly enhances their nutritional value.

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HEALTH ISSUES EXPERIENCED BY POST-MENOPAUSAL WOMEN IN RURAL AREA OF TENGNOUPAL DISTRICT, MANIPUR

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ABSTRACT

The study was conducted during the year 2022-23 with an aim to study the health related issues among post-menopausal women in Pallel rural area of Tengnoupal district, Manipur. The sample comprised of a total number of 100 rural women in the age group of 55-60 years from Tengnoupal district, Manipur. A pre-structured interview schedule was used for the purpose of studying the post-menopausal health issues. The findings of the study showed that post-menopausal women respondents had felt and experienced changes in their appearance or tone of skin (100%) followed by suffered from backache or mobility problems (90%), easily forgetting things (67%), changes in health and energy (63%), decrease in physical strength (64%), lesser interest in sexual desire (57%), and difficulty in urinating (21%). The factors, avoidance of intimacy with partner, rate of discomforts/problems faced and feelings of health and energy were found to have an association at 5% level of significance on age of the women. The study showed that these requires some educational programs to enhance their quality of life, better health, well-being and wellness.

Keywords: Health issues of women, Manipur, Post-menopause stage, Rural area.

INTRODUCTION

Menopause is one the most crucial stages in a female's life. Menopause is a natural stage in a woman's life marked by the cessation of fertility and menstrual periods. Post menopause denotes the period following menopause. During post menopause, the symptoms previously associated with menopause may diminish or disappear entirely. Nevertheless, some women may continue to experience menopausal symptoms for a decade or more. Once a woman transitions into post menopause, she remains in this stage for the rest of her life. Hormone levels stabilize at lower levels, and monthly menstrual periods cease. Pregnancy is no longer possible as the ovaries have ceased releasing eggs. Despite this, certain women may still experience side effects due to low hormone levels. A woman is considered to be in post menopause if her period has been absent for more than one year, regardless of her age. (Rupa and Sudha, 2023)

On average, women go through menopause around 46 years of age (Maninder, 2016). During this stage, menopausal symptoms such as hot flashes for most women. But health risk related to the loss of estrogen rise as the women ages. Thangamani *et al.* (2022) study reported that the most common

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problem after menopause among woman was anxiety/depression (80 %) and pain/ discomfort (75.2 %). Roy *et al*. (2020) in their study indicated that, 43 per cent of the post-menopausal woman were found to be normal, 29 per cent of the respondents were at the increased risk of adiposity and 6per cent belonged to category grade I obesity or higher risk of adiposity whereas, 22 per cent were underweight or chronic energy deficiency. Regarding waist hip ratio, 36 per cent of the post-menopausal women were at high risk, 42 per cent belonged to moderate risk and 22 per cent at low risk among post-menopausal women.

With increasing life expectancy, women will spend one third of their life in the postmenopausal stage. Care needs to be taken during this stage in order to have better health. Promoting health and providing a good feeling in each of a woman's life periods will determine a better quality of life for her and will prove fruitful for a society. Identifying the education gaps regarding menopause is important, Hence, it is important to study the health issues among post-menopausal women especially in rural areas, so that awareness about post-menopausal changes can be brought and available treatment modalities will improve the quality of life among the Indian women and get access to affordable gynaecological and psychiatric health services through channel of primary health care. Hence, the study was attempted to find out the "Health issues among post-menopausal women" living in rural area of Manipur state. The objective of the study was to record the health issues experienced by post-menopausal women in Pallel rural area of Tengnoupal district, Manipur.

MATERIAL AND METHODS

Procedure: The study was limited to 100 rural women who were in their post-menopausal period between 55 and 60 years living in Pallel areaof Tengnoupal district, Manipur state. Simple random sampling method was used for identifying the sample and data collection was done in the year 2022-2023. A pre-structured interview schedule was validated by the experts who were from the field of department of Human Development and statistician. The prepared interview schedule comprised of two parts related to menopausal changes and health issues. The two parts namely- Part A comprised of basic data and

Table 1. Respondents by health and energy during post-menopausal period n =100

S.No.	Aspects	Category	frequency	Percentage
1.	Feel/observe changes in your health and energy during post menopause	No	4	4.0
2.	Feel your health and energy is	Better	12	12.0
		Lower	63	63.0
		Worse	21	21.0
		Negative	4	4.0
3.	Feel change in sexual desire	Lesser interest	57	57.0
		No change	24	24.0
		Don't know	19	19.0

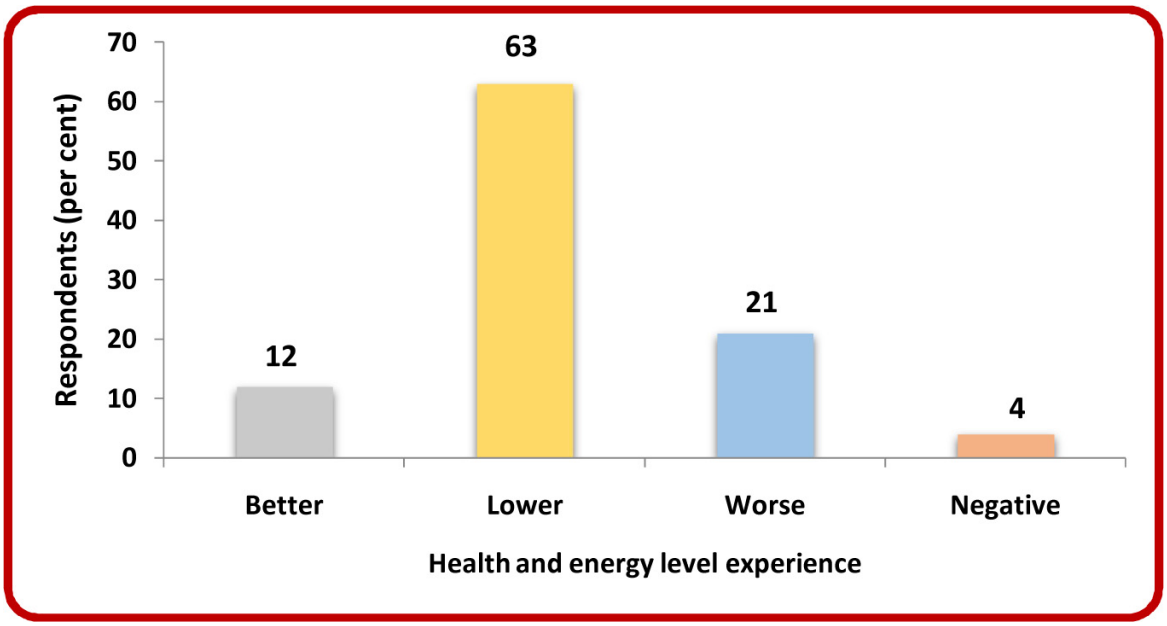

Figure 1. Respondents health and energy levels experience during post-menopausal period

Part B - specific data, which consisted of 41 items, each item has different optional responses ranging from 2 to 4 point scale, where the respondent has to select one answer out of the given options. All the 41 statements were positive items, and scoring was given from 1 to 4 based upon the type of scale. For two point scale, it was yes and no, for three point, it was always, sometimes and never 3, 2 and 1 scoring was given for four point scale as agree, some time, disagree and never 4,3,2, and 1 score was given respectively. The collected data were analysed by using frequency, per cent and chi-square statistical method.

RESULTS AND DISCUSSION

Table 1 and Figure1 showed post-menopausal health issues being faced after complete stoppage of periods, which reveals the health and energy level experienced during post menopause. It is clear from the table 1 that, majority (96 %) of the respondents felt and experienced the changes in health and energy during post menopause (Debosree *et al*., 2019). With respect to changes in sexual desire, majority (57%) of the respondents had lesser interest in sexual desire, it might be due to the various health issues faced by the women during post menopause, followed by 24 per cent did not feel any changes in the sexual desire and 19 per cent of the respondents don't know the changes in sexual desire. It might be due to medication use, loss of their partners and widowhood. Pronob and Manu (2015) study also reported that sexual dysfunction during post menopause was due to decreased interest or desire to initiate activity, as well as decreased arousal or ability to achieve an orgasm during sexual relations.

Table 2 indicates the distribution of respondents by various health issues during post menopause. This includes difficulty in urinating, vaginal dryness, muscular discomforts; easily forget things, aches in back of head or neck, urination while laughing or coughing, excessive sweating, pain during sex and urinary tract infections. It is clearly evident from the Table 2 that majority (67%) of the respondents easily forgets things and 55 per

Table 2. Classification of respondents by various health issues experienced during post-menopausal period

n=100

S.No.	Statement	Response (%)		
		Always	Sometimes	Never
1.	Difficulty in urinating	21.0	41.0	38.0
2.	Vaginal dryness	28.0	40.0	32.0
3.	Muscular discomforts	32.0	37.0	31.0
4.	Easily forget things	67.0	28.0	5.0
5.	Aches in back of head or neck	55.0	36.0	9.0
6.	Urination while laughing or coughing	15.0	38.0	47.0
7.	Observe excessive sweating	29.0	48.0	23.0
8.	Experience pain during sex	12.0	28.0	60.0
9.	Urinary tract infections	14.0	26.0	60.0

cent had aches in back of head or neck always. Whereas 42 Per cent of the respondents have difficulty in urinating, followed by 40 per cent vaginal dryness, 37 percent muscular comforts and 48 per cent observed excessive sweating sometimes

Similarly Ankita *et al*. (2017) conducted a comparative study of morbidity pattern among rural and urban post-menopausal woman of Allahabad, in the Indian state of Uttar Pradesh. Study reported that vaginal dryness was reported by 2.5 per cent of rural women and 6 per cent of urban woman. Majority of the respondents (60%) have never experienced pain during sex, followed by urinary tract infections (60%) and urinates while laughing and coughing (47 %).

Table 3. Changes experienced by women during post-menopausal period in appearance of skin and mobility problems

n=100

S.No.	Aspects	Category	Respondents	
			Frequency	Percentage
1.	Observe changes in appearance or tone of skin	Yes	100	100.0
		No	0	0.0
2.	Changes observed in skin	Wrinkles	35	35.0
		Dryness	13	13.0
		Skin elasticity	30	30.0
		Pigmentation	22	22.0
3.	Suffered from back ache/ fracture/ mobility problems in the recent past	Yes	90	90.0
		No	10	10.0

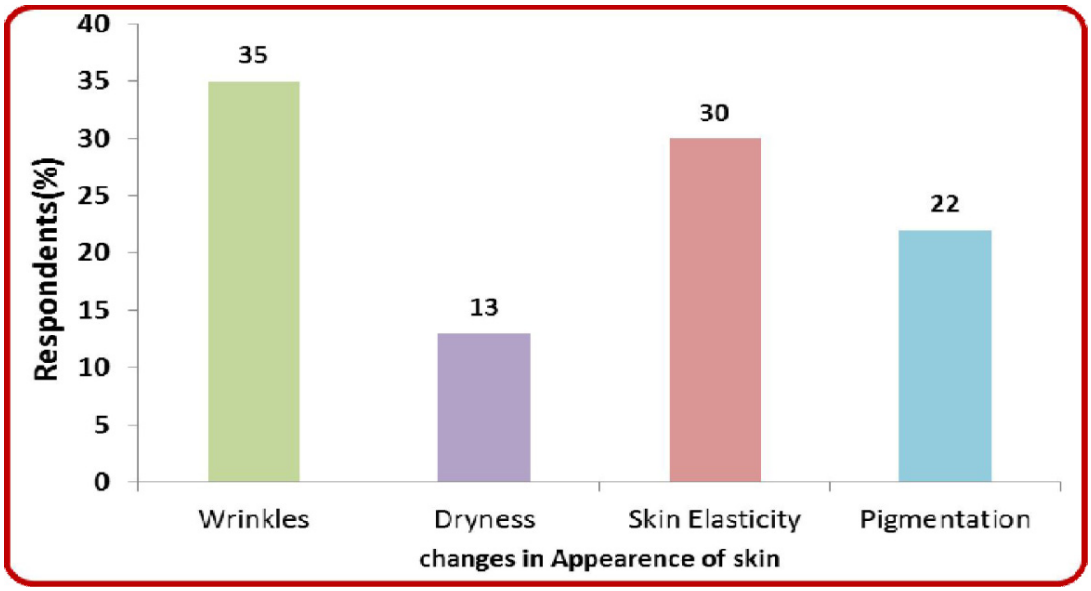

Figure 2. Changes experienced by women in appearance of skin during post-menopausal period.

The data with aspect to changes in appearance and mobility problems includes changes observed in appearance or tone of skin, types of changes experienced and back ache or fracture or mobility problems during post menopause is found in the Table 3 and Figure 2 that, cent per cent of the respondents have observed changes in appearance or tone of skin and followed by 90 Per cent of respondents suffered from back ache or fractures or mobility problems during post menopause.The types of changes observed in appearance or tone of skin are higher per cent of (35 %) respondents have wrinkles, 30 per cent of respondents have skin elasticity, 22 per cent have pigmentation and 13 per cent of respondents have dryness in their skin. Bruna *et al*., (2024) reported from the findings that skin and hair changes during menopause occur gradually and generally receive less attention than vasomotor symptoms. More than 60 per cent of women report skin problems, and about half indicated that menopause had caused changes to their skin.

From the data in the Table 4 and Figure 3, it is clearly evident that majority (64%) and (60%) of the respondents have always felt their physical strength is decreased and they were

Table 4. Classification of respondents by feeling experienced on various aspects during post menopausal period

n=100

S.No.	Statements	Respondents (%)		
		Always	Sometimes	Never
1.	Exhausted physically and mentally	60.0	32.0	8.0
2.	Wanting to be alone	27.0	38.0	35.0
3.	Physical strength is decreasing	64.0	33.0	3.0
4.	Depressed about health	28.0	49.0	23.0

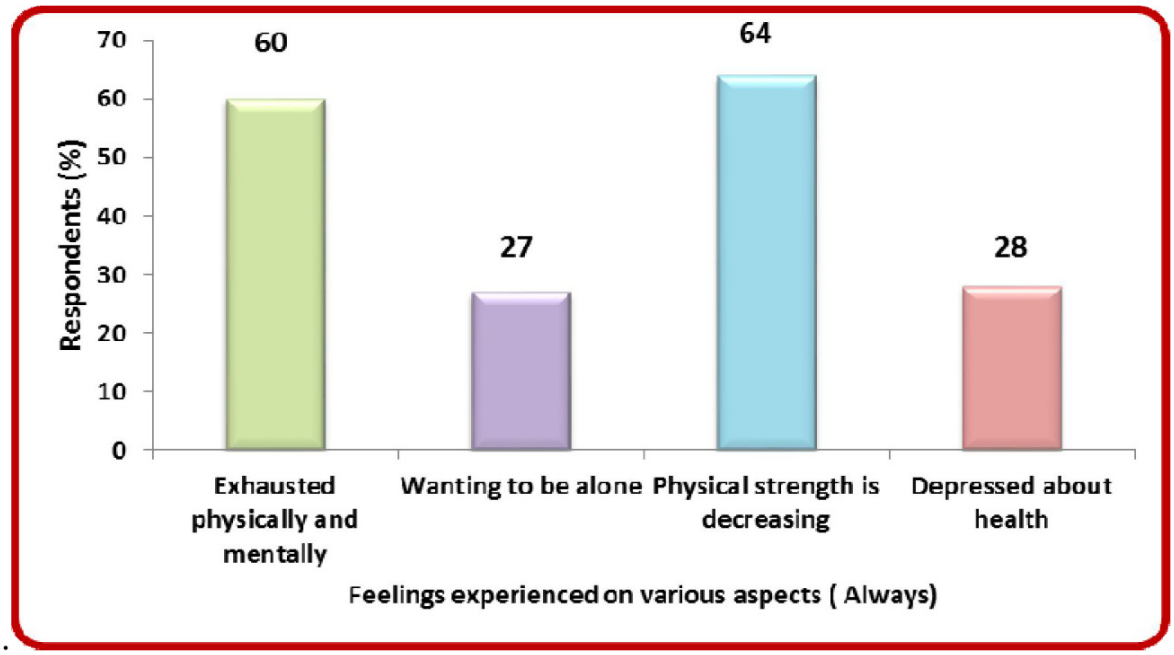

Figure 3. Feelings experienced on various aspectsby women during post-menopausal period

exhausted physically and mentally (Fatima and Kalpak, 2022). Further with respect to depression about health and feelings of wanting to be alone, majority (49 %) of the respondents have feelings of depression about their health sometimes and 38 per cent have feelings of wanting to be alone most of the times during post menopause. Pillay and Pathak (2023), the study concludes that women should make lifestyle and sleep improvements before and after menopause because doing so will promote their overall health and well-being. Positive emotions will also help to prevent bad emotions like despair

Table 5 depicts the association between age group with health and energy status of respondents'. Which depicts that in the age group 55-56 years; higher per cent(70.2) of respondents had feelings of lower health and energy, followed by 60.9 per cent in the age group of 57-58 years and 53.3 per cent in the age group of 59-60 years who had experienced lower health and energy after menopause. However, statistically it was found to be significant at 5 per cent level (÷ 2 =9.488) which shows the association between age group of the respondents and feelings about health and energy level during postmenopausal. The study shows that the respondents from age group 55-60 years had lower feelings of health and energy, it could be because of the various health issues (hot flashes, depression, abnormal bleeding, weight gain, less appetite, etc.) as they experienced during the menopause and post-menopause.

Table 6 shows the association between the age group and consulting of doctor for post-menopausal problems. Majority (68.1 %) of the respondents in the age group of 55-56 years did not consult the doctors, whereas, 31.9 per cent of them consulted doctor for post-menopausal problems. About 52.2 per cent respondents in the age group 57-58 years consult doctor and 47.8 per cent did not consult doctor, followed by 56.7 per cent, in the age group 59-60 years who consults doctor and 43.3 per cent of respondents do not consult doctor.

Table 5. Respondent's health and energy status by age group **n=100**

S.No.	Age (years)	Sample	Respondents						X^2 Test
			Better		Lower		Poor		
			f	%	f	%	f	%	
1.	55-56	47	1	2.1	33	70.2	13	27.7	**10.51***
2.	57-58	23	3	13.0	14	60.9	6	26.1	
3.	59-60	30	8	26.7	16	53.3	6	20.0	
	Total	**100**	**12**	**12.0**	**63**	**63.0**	**25**	**25.0**	

*Significant at 5 per cent Level, $\div^2$ (0.05,4df) =9.488

Table 6. Respondents' Consultation for doctor during post-menopausal problems by Age group

n=100

S.No.	Age (years)	Sample	Respondents				X^2 Test
			Consultation		No consultation		
			f	%	f	%	
1.	55-56	47	15	31.9	32	68.1	6.36*
2.	57-58	23	12	52.2	11	47.8	
3.	59-60	30	17	56.7	13	43.3	
	Total	**100**	**44**	**44.0**	**56**	**56.0**	

*Significant at 5 per cent Level, $\div^2$ (0.05,2df) =5.991

The statistical analysis was found to be significant at 5 per cent level (÷ 2 =5.991). Rana and Panghal (2022), in their study concludes that there must be well planned, balanced health education and necessary treatment arrange for the welfare of peri menopause women for better quality of life. The findings on the present study related to consulting doctors for post-menopausal problems indicating higher per cent of respondents donot consult doctor and there is a need to have well balanced health education and necessary treatment for the menopause and post-menopause women.

CONCLUSIONS

During post menopause period, women in rural area experienced many changes in their health. The feelings about health and energy level experienced during post menopause by respondents were found to have a significant influence on age. The noteworthy findings of the study were, post-menopausal rural woman of Pallel area Tengnoupal district Manipur had felt and experienced the changes in health and energy level especially decreasing physical strength, observed changes in their appearance or tone of skin and suffered from backache and mobility problems. Hence, there

is a need to give awareness about post-menopausal health issues especially for the rural woman which leads to them have a better quality of life and minimize their health issues.

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DEVELOPMENT OF NONWOVEN FABRIC USING TEXTILE WASTE AND ITS CHARACTERIZATION

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ABSTRACT

The study was conducted during the year 2021. Textile waste fibers are a significantly byproduct of the fashion and textile industries, stemming from various stages of production, consumption and disposal. These fibers include leftover fabric scraps, trimmings and post-consumer garments that are discarded. With the rise of fast fashion and increased consumption, textile waste has become a pressing environmental concern globally. These waste fibers contribute to landfills, water pollution and greenhouse gas emissions. Finding sustainable solutions for managing and repurposing textile waste fibers is crucial for mitigating their environmental impact and promoting circularity within the textile industry. About 5.8 million tons of textile waste are generated every year whereas only 1.5 million tons of such textiles waste are recycled by industrial and tailoring enterprises. This has led the investigator to select one such waste that could be explored for the present study. Therefore, tailor discards were considered along with Kapok which has good conductivity and also has good insulation for both thermal and acoustic properties because of its hollow nature and light weight. The study was carried out by blending wool and Kapok with three blending ratios of wool 100%, kapok 100% and wool kapok (50:50%) to form nonwoven sheets and the properties of the sheets were investigated.

Keywords: Biodegradable, Blending, Insulation, Nonwoven, Textile waste

INTRODUCTION

A crucial need exists for the development of biodegradable, biocompatible, and affordable materials that are environmentally friendly. As a result, nowadays due to the advanced technology textile wastes are increasing day by day which may harm the environment to a great extent. A very large numbers of companies are currently developing manufacturing process using alternative materials for their products and seeking new markets. With the significant production of waste fibrous materials, different companies are looking for applications where waste materials may represent an added-value material. Textile waste is considered a potential source of income also be utilized as raw material for insulation structures. Hypothetically, 97 per cent of textile waste has an ecological benefit as well as the economical benefits in the past decades, as stated by Tedesco and Montacchini (2020). Employing woolen textile waste alongside renewable Kapok fibers supports sustainability efforts by

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diminishing waste and lessening the environmental footprint of textile manufacturing. These resources present an eco-friendly substitute for traditional insulation materials, thus fostering a greener approach to construction. To truly promote sustainability and mitigate environmental consequences within the textile and apparel industry, adopting a circular economy framework is imperative. Textile waste recycling is a fundamental component for realizing the objectives of such a model. Utebay *et al.* (2020), in their finding, provide a comprehensive assessment of textile waste utilization, aiming to ensure sustainability and reduce environmental burdens.

Wool fiber is a natural fiber obtained from the fleece of sheep and other animals such as goats, alpacas and rabbits. It is one of the oldest textile fibers used by humans and is prized for its exceptional qualities and versatility, warmth, comfort, durability and eco-friendly products, as stated by Gokarneshan *et al.* (2020). Kapok fiber, sourced from the fruit of the kapok tree, is a renewable agricultural byproduct that is primarily composed of cellulose, hemi-cellulose, lignin, and a small amount of waxy coating. More or less similar observations were reported by Justyna and Malgorzata, (2023); Zhou *et al.* (2020). In this study, the fibers were blended and preparation of needle punched nonwoven sheets was carried out to enhanced the properties of the material by developing nonwoven sheets ensuring better performance.

MATERIAL AND METHODS

Based on the literature review, a comprehensive understanding of waste upcycling led to the collection of wool discards for research purposes. To enhance the efficiency of the research, these wool discards were combined with kapok, a natural fiber. This blend was used to create three distinct types of nonwoven sheets: Wool (A), Kapok (B), and a Wool-Kapok blend (C). Initial trials showed that using wool waste alone did not yield satisfactory results. However, blending wool with kapok achieved the desired physical properties, as wool retains warmth even when wet and tends to extinguish when removed from a flame. The research involved manually unraveling the fibers from the textile discards and blending them. The preparation of needle-punched nonwoven sheets began with carding the separated wool and kapok fibers using a TRYTEX carding machine to form a web or lap. These webs were then processed individually through a DILO needle-punching machine. The layers of the web were entangled using barbed needles in the needle loom to produce the nonwoven sheets. The resulting nonwoven sheets were evaluated for their thickness and solidity. Three different nonwoven samples were prepared using various blend ratios of

A B C

Figure 1. Nonwoven samples A, B and C

wool and kapok, and their properties were assessed to determine their effectiveness.

Design of Experiment

In the nonwoven, the punch density (25 punches /cm^2) and penetration depth (12 mm), were used. A fabric thickness gauge with a capacity of 0.01 mm was used to measure the thickness of the nonwovens generated less than 2 k Pa pressure. The areal density of the produced nonwoven textiles was measured using an electronic balance with a capacity of 0.001 g, in accordance with ASTM D-1910. Thermo gravimetric analysis was used to determine the temperature transition and decomposition rate of the samples. Field emission scanning electron microscopy (FESEM) was used to examine the fiber morphology. Using geo-textile abrasion tester abrasion resistance was evaluated and recorded. Oil sorption capacity was also studied according to the (American Society for Testing and Materials) 726-99 method. The experiment was further supported by statistical analysis (ANOVA).

RESULTS AND DISCUSSION

Thermo Gravimetric Analysis (TGA)

The results of TGA of all the three nonwoven sheets A, B, and C are presented in Figure.2 (A), (B), (C) and found that the temperature required for the decomposition was highest in the sample B with 24.2 °, followed by the sample C with 23.7°, and sample A with 22.3°, respectively. The decomposition percentage was highest in the sample C with 102.4%, followed by the sample B with 99.9 per cent and sample A with 98.1 per cent. The rate of decomposition depends on the heating rate. The higher the heating rate, the higher the decomposition temperature. More or less similar results were reported by Subramanian *et al*. (2020). The systematic degradation is observed under a nitrogen atmosphere, which is due to the chain scissors of polypropylene. The curves for nitrogen show only slight differences in the degradation temperatures; however, they do not change systematically, but they do decrease with the number of extrusion cycles again due to the scission of the polyethylene chains, which become shorter and prone to thermal degradation at lower temperatures as reported by Diez *et al.* (2020) and Bianco *et al.* (2023).

Hence, it is revealed that the systematic decrease in degradation temperature under nitrogen atmosphere might be due to presence of polypropylene chains and as such, sample A has a slight decreased degradation temperature, whereas sample B has a higher degradation temperature, which means that there is no presence of propylene chains.

Abrasion Resistance

Abrasion resistance of a test specimen was measured according to ISO-13427 standard in Geo-Textile Abrasion Tester. The

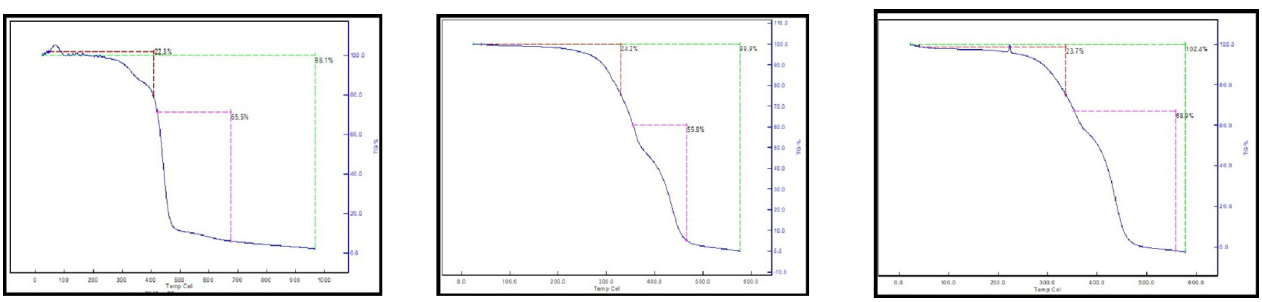

Figure. 2 TGA of sample A, B & C

results of abrasion resistance of all three nonwoven sheets A, B, and C were expressed. With reference to the abrasion resistance, the values of needle punched nonwoven samples A, B, and C were found to be 1.58 per cent, 6.97 per cent and 18.94 per cent respectively. As shown from the figure; that the abrasion mass loss of sample C was 18.9 per cent after 50 times of abrasion. Furthermore, it could be observed that the appearance was seriously damaged just after 50 times of abrasion, nearly totally losing the textile features of the nonwoven boards. However, sample A could withstand more than 50 times of abrasion against the load with relatively low abrasion mass loss of approximately 1 percent.

Accordingly, the lesser the abrasion mass loss percent of tested samples, the better will be the abrasion resistance. This strong abrasion resistance may improve the sound and thermal insulation properties and will prolong the service life of the nonwoven boards. Therefore, it is concluded that sample A plays an essential role in abrasion resistance activity and found that p-value is greater than 0.05, which indicates that there is no significant difference between the samples.

Oil Absorption

The ASTM F726-99 method was followed for oil sorption capability tests. The results of the oil absorption of all the three nonwoven sheets A, B, and C were evaluated. With reference to the maximum oil sorption capacities of sample A, B, and C for vehicle oil, machine oil and castor oil theywere

Table 2. Abrasion resistance of nonwoven samples

Sl. Nos.	Sample	Initial weight (g)	Final weight (g)	Abrasion Mass loss percent (%)
1.	A	22.060	21.710	1.58
2.	B	13.030	12.180	6.97
3.	C	14.040	11.380	18.9
	S.E(d)	0.034	0.009	0.16
	CD (0.05%)	0.05*	0.18	0.17

***Significant at 5% level**

Table 3. Oil absorption capacity of nonwoven samples

Sl.Nos.	Samples	Temperature		
		20°	**40°**	**60°**
		Vehicle oil (g/g^{-1})	**Machine oil (g/g^{-1})**	**Castor oil (g/g^{-1})**
1.	A	6.35	5.02	2.58
2.	B	12	11.6	15.3
3.	C	10.09	10.1	9.25
	S.E(d)	1.92	0.20	0.09
	CD (0.05%)	40.02*	6.52	16.2

***Significant at 5% level**

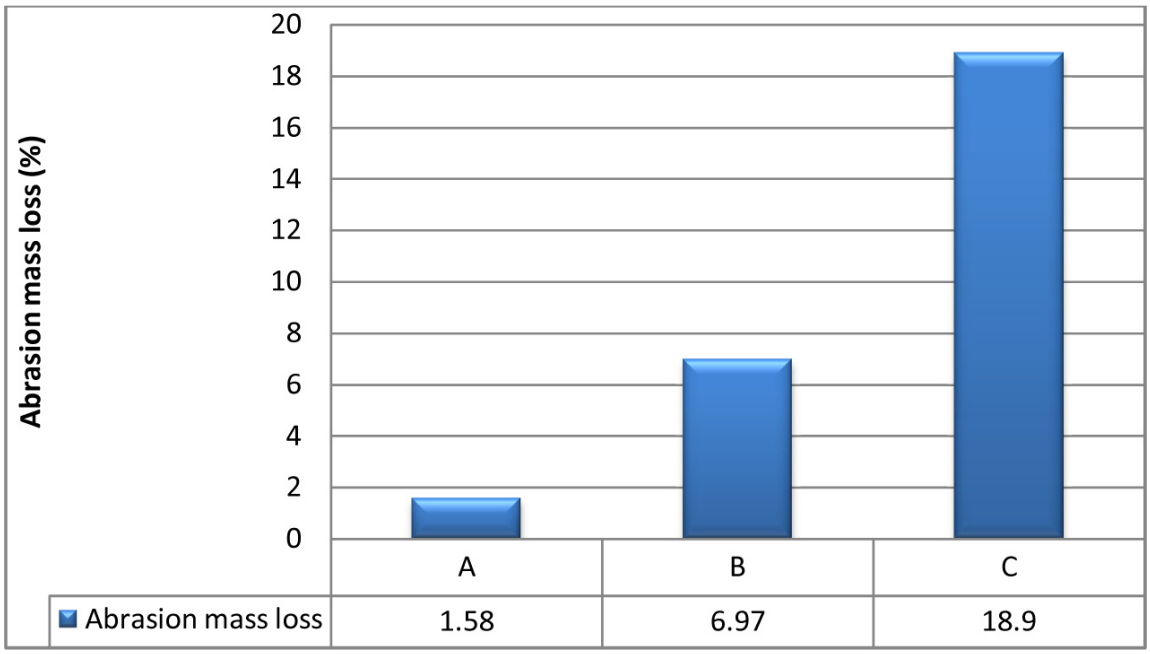

Figure 3. Graphical representation of abrasion resistance of nonwoven samples

evaluated by batch adsorption experiments. The maximum sorption capacity of sample A was 6.35, 5.02 and 2.58 g g”1 for vehicle oil, machine oil and castor oil, respectively. The sorption capacity of sample B for vehicle, machine oil and castor oil was 12, 11.6 and 15.3 g g”1, respectively. The oil sorption capacity of sample B was superior to that of sample A, probably which increased the roughness of the surface of sample B. The

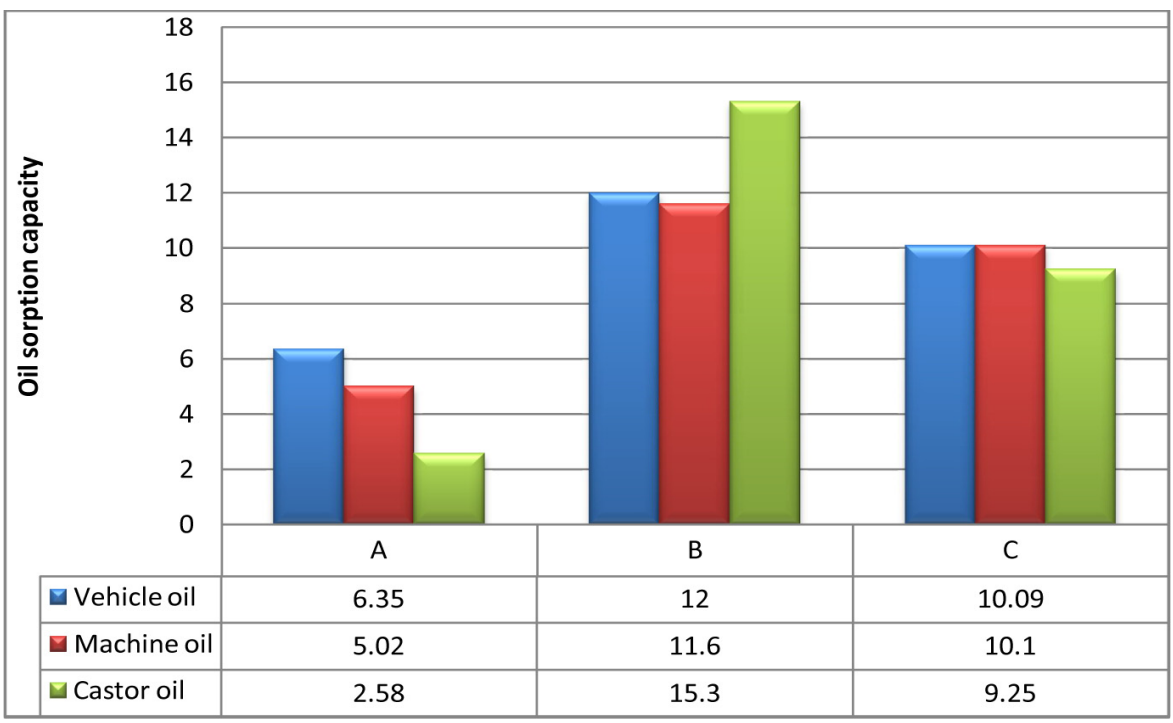

Figure 4. Graphical representation of oil sorption capacity of nonwoven fabric

sorption capacity of sample C has reached 10.09, 10.1 and 9.25 g g”1 for the three kinds of oils.

Because kapok fiber is a naturally occurring fiber with a high absorption capacity. It is widely available and has promising potential as an oil sorbent. As such, it is an excellent material for oil sorption. Quite similar results were reported by Graecia *et al.* (2020) that the porous property of kapok fiber is beneficial for oil sorption. Hence; from the results, it is found that the surface modification of sample B very effectively improved its oil sorption capability, with improvement in oil sorption capacity of 12 per cent, 11.6 per cent and 15.3 per cent for vehicle oil, machine oil and castor oil. This result implies that the sorption capacity was affected by the viscosity of the oil as suggested by Cao *et al*. (2022). It was found from the statistical analysis that the p-value is greater than 0.05 which indicates that no effect was observed between the samples.

Water Absorbency

The water absorption behavior of the nonwoven fabricis determined by the capability of their fiber to consume water or moisture due to the existence of hydroxyl groups that mainly responsible for water absorption throughout the creation of hydrogen (H) bonding. Hossen and Rahman (2021), in their study, reported that the effect of absorption variation is due to the consumption of water in the air-filled voids and pores, which contribute to taking more water and increase the weight of the samples.

Water absorption test was carried out by taking 2g of the sample**.** The samples were first dried by heating in electric oven at 70 for about 2 hours; they were then taken out and soaked in a bath of distilled water at room temperature. After 24 hours, the samples were removed from water, dried by a cotton cloth and weighed again. From the results, it was found that sample A absorbed more water with 278.9%, followed by sample B and sample C with 246.3% and 276.5% respectively. The results showed that sample A absorbs more water. Accordingly, similar results are in compliance with the findings stated by Kamran *et al.* (2022) that the surface morphology of the sample leads to moisture affinity. Hence, it could be concluded that sample A has maximum water absorbency and sample B has minimum water absorbency capacity. As such, sample B has good hydrophobic properties and can be value added for different technical products.

Wicking Height

In this strategy, a piece of sample, namely A, B and C (30cm x 2cm) was cut individually and submerged vertically with an edge inside the beaker containing distilled water. At that point, the sample is being kept for some consistent time of 1 min to record the sponginess of the strip. To evaluate the absorbency of the water, a colored line was marked on the sample and color was also

Table 3. Water absorbency of nonwoven samples

Sl. Nos	Samples	Water absorbency (%)
1.	A	136
2.	B	120
3.	C	160
	S.E(d)	2.91
	CD (0.05%)	8.26*

***Significant level at 5%**

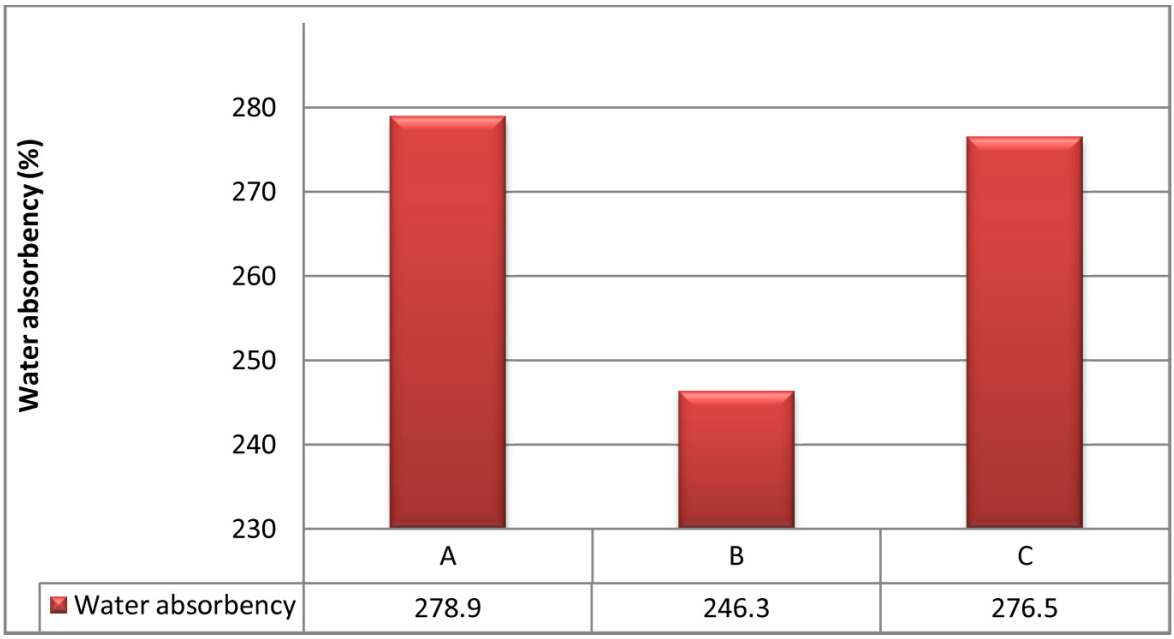

Figure 5. Water absorbency of nonwoven samples

added to assimilate water. The wick ability of the three-needle punched nonwoven sheets was noted and recorded. The results of wick ability of the three nonwoven sheets A, B and C are expressed and found that the wick ability of the samples A, B and C was nil. The combined nonwoven sheets showed good insulation as well as thermal properties and also exhibited a good hydrophobic nature. Hence, it was found that all three nonwoven sheets A, B and C exhibited very poor absorbency of water, thereby giving way for good sound and thermal insulation.

CONCLUSIONS

Natural resources are considered to be sustainable and construction activity is a great consumer of these. Sustainable materials are products that offer environmental, social, and economic advantages. Sustainable products protect the earth over their entire life cycle, from the extraction of raw materials until the last disposal. The whole life cycle of a material incorporates the extraction, the production process, the in-situ establishment, the maintenance, and ultimately the disposal or reusing techniques. With the huge creation of waste fibrous materials, various companies are searching for applications wherein waste materials may represent an additional-worth material**.** An insulation material increasingly plays a vital role in the energy performance of buildings as well as in the process reducing negative environmental impacts of the built environment. Few investigations have identified insulation materials that have lower ecological expenses, for example, those that are made of natural or reused materials. As such, wool has a good insulating property as well as sound absorbing properties. Cellulose-based biodegradable fibers such as cotton, kapok and coir fibers are broadly used to create nonwovens because of their unique properties like biodegradability, softness, absorbency and breathability.

Therefore, from the experiment, it was observed that wool (A) exhibited higher strength, thickness, abrasion resistance and water absorbency, whereas, WK(C) blended nonwoven sheets exhibited good insulating properties. Thus, the result shows that sample

C has the best combination with good thermal and sound insulation properties and these samples can be used in various applications such as acoustic boards, automobiles, home furnishings, civil engineering, geo-textiles and industrial filters also.

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INTERPERSONAL INTELLIGENCE OF UPPER PRIMARY STUDENTS IN KOTTAYAM DISTRICT

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ABSTRACT

The research was conducted in the sub-districts of Kottayam and Pala, within the Kottayam educational district. A total of 550 fifth-grade students (343 girls and 207 boys) following both state and CBSE syllabus from different type of schools (government, aided and unaided) and areas (urban schools and rural schools) were obtained using stratified random sampling. A multiple intelligence checklist, developed by the researcher, was utilized as the tool for this study. The statements about interpersonal intelligence had a cronbach's alpha value of 0.76. Using the test-retest method, spearman-brown coefficient, and guttman split-half coefficient value ranged from 0.78 to 1. The tool was validated by subject matter experts. The data was evaluated through the application of multiple statistical techniques. The results showed that more than half of the students had strong interpersonal intelligence (57.3%), with significant differences in gender, area and type of school. There was no notable difference observed between interpersonal intelligence and family type

Keywords: Fifth grade, Interpersonal Intelligence, Multiple Intelligences.

INTRODUCTION

Understanding interpersonal intelligence, or the skill to perceive and respond effectively to others' thoughts, emotions, and behaviours, is critical for navigating social interactions (Herpertz, 2022). People with high interpersonal intelligence possess empathy, enabling them to comprehend and relate to the emotions of others (Sutarman *et al.*, 2019). Furthermore, they succeed in gathering others around common goals, making them skilled at collaboration and conflict resolution (Sadiku and Musa, 2021). Students with strong interpersonal skills mingle with peer groups easily, actively participate in group activities, and achieve superior learning outcomes (Istapra *et al*., 2021). Teachers have a crucial role in fostering empathy, promoting risk-taking, and enhancing students' conflict resolution abilities (Dien and Wustqa, 2018). Despite the critical importance of interpersonal intelligence in educational settings, limited research focused on assessing the interpersonal intelligence of fifth-grade children, necessitating more research into this developmental period.

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Consequently, this study seeks to fill this gap by investigating the interpersonal intelligence profiles of fifth-grade students and analyzing potential variations across different demographic groups. The objectives of the study are 1) To identify the interpersonal intelligence profile of fifth-grade students, 2) To compare the interpersonal intelligence of fifth-grade students concerning gender, type of school, area of school and type of family.

MATERIAL AND METHODS

The sample comprised 550 fifth-grade students (343 girls and 207 boys) aged between 9 and 11 years from different types of schools (Government, Aided, Unaided) following the CBSE and state syllabi, and from different areas (rural and urban) of Kottayam and Pala sub-districts of Kottayam Educational District. To collect the data, the researcher employed a multiple intelligence checklist tailored to the Indian setting and appropriate for the age group selected for the study. It comprised of 64 statements out of which eight statements assessed interpersonal intelligence. Initially, the checklist had ten statements about interpersonal intelligence, which were eventually reduced to eight after the pilot study and item analysis. An evaluation checklist for subject experts was created to gather expert feedback and comments on the statements. Changes were made based on their comments, thereby validating the multiple intelligence checklist. The reliability was checked using cronbach's alpha and the test-retest method. The Cronbach's alpha score for interpersonal intelligence was 0.76. The results of the test-retest method, the spearman-brown coefficient and the Guttman split-half coefficient for all eight statements ranged between 0.78 and 1.

Stratified random sampling was utilized for data collection. The data were gathered from the samples by filling out the multiple intelligence checklist, administered by the researcher. The researcher explained the statements to the students individually by showing them pictures relating to each statement on a powerpoint presentation and through face-to-face interaction. The statements had three possible responses: "Always", "Sometimes" and "Never". The scoring pattern was 2 marks for "Always",1 mark for " Sometimes " and 0 for" Never". Thus, the maximum score was 16 and the least score was zero. The score range was 0-4 (Weak), 5-8 (Fairly strong), 9-12 (Strong) and 13-16 (Very Strong). The data were statistically analyzed using relevant techniques, including percentage analysis, mean, standard deviation, and Z-test.

RESULTS AND DISCUSSION

The Interpersonal Intelligence of Grade Five Students

The percentages of students with weak, fairly strong, strong, and very strong interpersonal intelligence is given in Table.1 below.

From Table 1 and Figure 1, It can be deduced that more than half (57.3 %) of the

Table 1.The Interpersonal Intelligence of Fifth Grade Students

Interpersonal Intelligence	Frequency	Percent	Mean	SD
Weak	9	1.6	2	0
Fairly strong	28	5.1	6.5	0.86
Strong	198	36.0	10.5	1.11
Very Strong	315	57.3	14.5	1.29

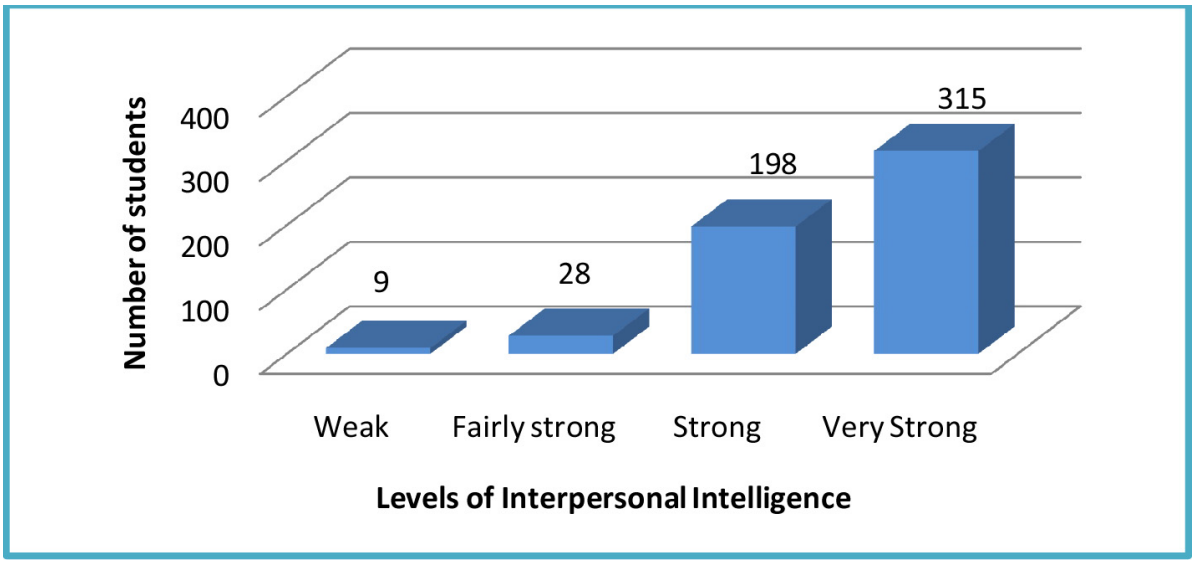

Figure 1. Number of Students with Different Levels of Interpersonal Intelligence

samples had a very strong profile of interpersonal intelligence (M=.14.5, SD=1.29). Thirty-six per cent had a strong profile of interpersonal intelligence (M=10.5, SD =1.11). Twenty-eight students exhibited fairly strong interpersonal intelligence (M=6.5, SD=0.86) and only 1.6 per cent of the students were weak in inter personal intelligence (M=2, SD=0). This is consistent with the study carried out by Ishak *et al*. (2022) where the interpersonal intelligence of seventh-grade students was strongly developed. The results of the current study are similarly aligned with the research carried out by Yavich and Rotnitsky (2020) which revealed that about forty five per cent of the students in the ordinary classes had dominant levels of interpersonal intelligence. However, the results are contrary to the conclusion by Oommen (2023) who noted that sixty one per cent of the higher secondary students had only average interpersonal intelligence. Furthermore, through observation and self-assessment instruments, it was found that most of the students had low interpersonal intelligence (Astuti *et al*., 2020).

Comparison of Interpersonal Intelligence of Based on Gender

The scores gathered from the students (boys and girls) through the checklist were analyzed by applying a test of significance to compare the means, and the resulting Z-value was assessed for significance. The data and analysis results are presented in Table 2.

From Table 2, it can be concluded that there is no significant difference between the mean scores of boys and girls regarding interpersonal intelligence, since the p-value (0.311) exceeds 0.05. The findings of the current study are supported by Neupane

Table 2. Result of the Test of Significant Difference between Means in Interpersonal Intelligence of the Fifth-Grade Students Based on Gender.

Variable	Gender	n	Mean	SD	Z	p value
Interpersonal	Boy	207	12.36	3.23	-1.014	0.311
Intelligence	Girl	343	12.60	2.33		

Table 3. Result of the Test of Significant Difference between Means in Interpersonal Intelligence of the Fifth-Grade Students Based on the Type of Area.

Variable	Area	n	Mean	SD	Z	p value
Interpersonal Intelligence	Urban	317	12.09	2.89	4.401	<0.001
	Rural	233	13.09	2.30		

(2018), Alez *et al.* (2020) and Roy (2021) who reported that there is no notable difference in interpersonal intelligence based on gender. Nevertheless, these results contradict the conclusion that girls possess higher interpersonal intelligence than boys, as the t-test analysis for the interpersonal intelligence of female and male students yielded a value of -4.208, with a significance level of 0.05 (Masyithoh *et al.,* 2023).

Comparison of Interpersonal Intelligence of Urban and Rural School Students

The scores collected from the samples of both urban and rural schools using the checklist were compared using a test of significance of the difference between means and the obtained Z-value was tested for significance. The data and results of the analysis are given in Table 3.

From Table 3, It can be concluded that a significant difference is present between the mean scores of urban and rural school students concerning interpersonal intelligence, as the p-value (0.001) is less than 0.05. Students studying in rural schools (M=13.09, SD=2.30) outperform students in urban school (M=12.09,SD=2.89). Possible explanations for this may include the diverse lifestyles of rural and urban localities, the close interaction among urban children, the freer interaction of rural children, and increased social interactions and community engagement in rural environments compared to urban environments.The result aligns with the research done by Iziana (2020) which found significant differences in inter personal intelligences between children attending urban and rural schools. Shahzada *et al.* (2014), found comparable results, indicating that rural school students outperformed urban school students in terms of interpersonal intelligence. On the contrary, Subramanian and Muthuduraichi (2019) and Kasiranjan (2018) found no significant difference between rural and urban school students in interpersonal behavior.

Comparison of Interpersonal Intelligence of Students from Nuclear and Joint families

The scores collected from students (from both nuclear and joint families) using the checklist were analyzed using a test of significance to compare the means, and the resulting Z-value was evaluated for significance. The data and analysis results are presented in Table 4.

Table 4. Result of the Test of Significant Difference between Means in Interpersonal Intelligence of the Fifth-Grade Students Based on the Type of Family

Variable	Family type	N	Mean	SD	Z	p value
Interpersonal Intelligence	Joint	116	12.71	2.48	0.871	0.384
	Nuclear	434	12.46	2.76		

Table 5.Result of the Test of Significant Difference between Means in Interpersonal Intelligence of the Fifth-Grade Students Based on the Type of Family

Variable	School type	n	Mean	SD	Z	p value
Interpersonal	Government	48	13.06	2.35	19.26	<0.001
Intelligence	AidedUnaided	317185	13.0011.54	2.283.17		

The results show that the mean scores of students from nuclear families (M = 12.46, SD = 2.76) and those from joint families (M = 12.71, SD = 2.48), do not show a significant difference in interpersonal intelligence as the p-value (0.384) is greater than 0.05. This result is in agreement with the study carried out by Gupta (2016), who found that the family structure do not influence interpersonal intelligence. On the contrary, Sunarti and Zukdi (2019) revealed a partially significant influence between the family size and multiple intelligences.

Comparison of Interpersonal Intelligence of Students from Different Types of School

The scores gathered from the students of government, aided and unaided schools through the checklist were compared using a test of significance of the difference between means and the obtained Z-value was tested for significance. The data and results of the analysis are given in Table 5.

The ANOVA test results indicate that the p-value is less than 0.05, suggesting a significant difference between school typeand interpersonal intelligence.This result is corroborated by Heera and Arjunan (2021) and Dasarath *et al*. (2018) who reported a notable difference in interpersonal intelligence based on school type. Madhu, (2021) discovered significant differences in interpersonal intelligences between government and private secondary school students. However, Priyanka and Sudha (2021) did not find a significant difference in interpersonal intelligence between students from government and private rural schools.

CONCLUSIONS

From the findings of this research paper, it can be deduced that the goal of identifying the interpersonal intelligence of fifth-grade students was met. The majority (57.3%) of the sample demonstrated very strong interpersonal intelligence, indicating a significant ability to understand and communicate well with others. Furthermore, the study found no notable difference between interpersonal intelligence and gender and family type in this particular group of fifth-graders. Significant differences were identified between interpersonal intelligence concerning the area of the school and the type of school.

Students studying in rural schools showed interpersonal intelligence than those students studying in rural schools. This suggests that, at least within the scope of this study, gender and the type of family do not seem to influence the development of interpersonal intelligence in children at this level of their education. These findings improve our knowledge of the distribution of interpersonal intelligence among fifth-grade students and emphasize the necessity of recognizing and developing this element of intelligence in educational settings. In summary, this study illuminates the interpersonal intelligence of fifth-grade children and highlights the need for further exploration and support of this critical skill in educational

practices. Future research could explore the implications for teaching and learning methodologies.

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CONJOINT ANALYSIS OF SHRIMP ATTRIBUTES FOR EXPORTS FROM ANDHRA PRADESH

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ABSTRACT

The shrimps export demand was influenced by various attributes. To determine which characteristics have contributed most to shrimp exports over time, a conjoint analysis is employed. This method is mostly used in marketing research to determining the relative significance of each attribute for a commodity/service. This study identified the important attributes to develop the successful marketing strategies for shrimp exports.The survey was conducted during August-September 2022.The results indicated that all the eight attributes *viz:* physical form, odour, colour, size, nature of shrimp, certification and labeling, price and branding were significant in nature. The individual utilities of physical form of the shrimp *viz.,* raw frozen, cooked/ value added (breaded, prawn pickle, *etc.*) and live shrimp was 0.815, 0.472 and 0.343, respectively. Shrimp exporters are preferred to export raw frozen shrimps with minimal processing. Certification and labelling attribute are categorized into three sub attribute levels *i.e.* high standards, medium standards and low standards, the utilities for these are 0.722, 0.547 and -1.263. Whereas, sensory attributes like colour and odour were bright pink colour with strong marine odour had highly preferred attribute levels with utility values 1.471 and 0.97.

Keywords: Conjoint analysis, JEL classification: c25, Relative importance, Shrimp exports.

INTRODUCTION

Indian fishery industry has a good export potential.The overall export of fishery products during 2022-23 was 17.35 lakhmt with value of USD 8094.31. South-East Asia is to be the largest market (4.31 lakh mt) followed by China (4.05 lakh mt), USA (3.06 lakh mt), EU (2.07 lakh mt), Japan (1.09 lakh mt) and Middle East (0.77 lakh mt) (MPEDA, 2018).

Frozen shrimp is the major item of export among fishery exports in terms of quantity and value accounting for a share of 53.18% in quantity and 75.11% of the value of total USD earnings. In sea food exports, frozen shrimp maintained a key contributor with a quantity of 7.11 lakh mt with a value of USD 5481.63 during 2022-23.

Among the states in India, Andhra Pradesh ranks first with shrimp production of 6.5 mt during 2021-22 followed by West Bengaland Odisha. Andhra Pradesh has a total cultivable brackish water area of about 28,000 ha out of which 60% of area is under shrimp farming. The shrimp exports in Andhra Pradesh were 10.67% in FY 2015 as compared with 7.33% in FY 2014. Vannamei

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culture in the state had increased by 31% in FY 2015 which helped the state to retain the status of leading exporter of shrimp. Vizag port in Andhra Pradesh is the major port in marine exports from India with exports worth Rs.15,648 crore during 2021-22 followed by Kolkata port (Rs.6168.78 crore) and Kochi port (Rs.6167.69 crore) (MPEDA 2021-22).

The growing business volume of frozen shrimps in India has encouraged many medium to large players to set up seafood processing units, feeds manufacturing facility and cold storage chains to take part in the potential growth in seafood export industry. India has 35,894 mt of processing capacity with 623 processing plants. Andhra Pradesh had 16.5% of processing capacity to the total capacity. There is an ample opportunity for Andhra Pradesh's shrimp in international market. Seafood quality is multidimensional and includes attributes related to safety, freshness, appearance, and taste. Shrimp exports are depended upon extrinsic and intrinsic quality parameters. Extrinsic quality parameters are certification and labeling, price and branding and country of origin, while intrinsic quality parameters are color, odour, and texture of the seafood. There is a need to closely identify the relative value of shrimp quality attributes that influences global shrimp export demand. A study was undertaken with an objective of analyzing the factors influencing the export performance of shrimps in Andhra Pradesh.

MATERIAL AND METHODS

A multivariate method called conjoint analysis is employed to determine how respondents develop preferences for goods or services during decision-making. (Hair *et al.,* 2013). The analysis evaluates the value or utility of a product or service by combining the separate amounts of utility provided by each attribute. The analysis is frequently seen in marketing studies (Green and Rao, 1971) and behavioural research (Green and Srinivasan, 1978), where the dependent variable is for an overall assessment of a product and the predictor variables are called attributes. Conjoint analysis is based on the fundamental idea that a product is made up of attributes, and that each attribute might have two or more levels. The objectives of conjoint analysis were to determine the significance of attributes in terms of their contribution to overall utility and to find attribute combinations that provide consumers with the maximum level of utility (Bellundagi *et al.* 2020). Thulasiram *et al.* (2016) employed this kind of conjoint model to examine the quality attributes for mango exports.

Conjoint measurement uses underlying product attributes to predict and quantify exporters' overall assessment. The current study aims to identify the most desired attributes for shrimp exports presented in Table 1. The full-profile technique was used since it takes into account all relevant factors at once and is therefore more realistic.

The analysis consisting of three procedures in Statistical Package for Social Science (SPSS version 24) are ORTHOPLAN, PLANCARD and CONJOINT. With the use of orthogonal arrays (fractional design to capture only main effects) 27 combinations were took for better reliability of the answering the survey. These stimuli were nothing but PLAN CARDS and then printing the full concept cards in ready to use format. The total number of plan cards given for the attributes was 27 which is presented in Table 1.

A random sample of 30 exporters was selected from Visakhapatnam, West Godavari and Nellore districts of Andhra Pradesh based on export potentiality of shrimp, and selecting a minimum of 10 exporters in each selected district. Each exporter in the study has been elicited to indicate preferences for the export

Table 1. Shrimp attributes and their levels used in conjoint analysis

S.No.	Attribute	Attribute levels
1	Physical form	Raw frozen, Cooked/Value added and Liveshrimp
2	Odour	Strong marine and Weak marine
3	Colour	Bright pink and Light pink
4	Size (count/lb)	Large (16-25), Medium (26-45) and Small (46-95)
5	Nature of shrimp	Farm raised and Sea caught
6	Price (Rs./kg)	Rs. 400-600, Rs. 600-800 and Rs. 800-1000
7	Certification and labeling	High, Moderate and Low standards
8	Branding	Highlysignificant, Less significant and Non-significant

of shrimps by giving a complete set of cards. The survey was conducted during August-September, 2022.

The exporters were asked to assign a rank for 27 cards as per their preferences. The lower ranking (1, 2, 3...*etc.,*) signifies the higher preferences and higher ranking (25, 26, 27) signifies the lower preferences so that exporters gave ranking from most preferred to least preferred which is presented in table 4. Based on these rankings the conjoint analysis was carried out to obtain utility scores for each factor level of attributes. These utility scores are analogous to regression coefficients which are called part-worths. These utility scores give relative importance of each attribute so that most preferred attribute was identified which is responsible for shrimp exports. To determine the relative significance of each attribute, the part-worth functions were compared across multiple attributes across segments (Moore, 1980).

RESULTS AND DISCUSSION

The important attributes which influence the shrimp exports namely, physical form, price, odour, colour, size, nature of shrimp, certification and labeling, and branding were studied. Part-worths and relative importance of these attributes have been estimated using OLS regression analysis in the conjoint analysis framework. The fit of this additive model to the individual data was good based on Pearson rank correlation being 0.621 ($p = 0.0002$) and this testifies the suitability of the model**.** The average utilities of attribute levels and the relative importance of each attribute are presented in Table 2. A higher positive or lower negative part-worth denotes, *Ceterisparibus,* a higher perceived preference.

The physical form of the shrimp was found to be most important attribute among all the attributes inshrimp exports as it accounted for 24.17 per cent of relative importance. The individual utilities of physical form of the shrimp *viz.,* raw frozen, cooked/ value added (breaded, prawn pickle, *etc.*) and live shrimp was 0.815, 0.472 and 0.343, respectively. Shrimp exporters are preferred to export raw frozen shrimps with minimal processing like Peeled Divined (PD), Peeled Un-Divined (PUD), Head Less (HL), Head On (HO) and butterfly cut, *etc.,* due to easy market access to the South-East Asian countries such as Thailand, Vietnam, Indonesia and Malaysia. These markets import bulk quantities of raw frozen shrimps from Andhra Pradesh, where thosecountries re-process the raw shrimps into high value-added products and export to other

Table 2. Part-worth utilities of attributes

S.No.	Attribute	Level	Utility	Relative Importance (%)
1.	Physical form	Raw frozen	1.815	24.174
		Cooked/Value addded	0.472	
		Live shrimp	0.343	
2.	Certification & labeling	High standards	0.722	18.414
		Moderate standards	0.547	
		Low standards	-1.263	
3.	Price	400-600/kg	0.880	16.135
		600-800/kg	1.741	
		800-1000/kg	-2.641	
4.	Size (count/lb)	Large (16-25)	1.064	12.258
		Medium (26-45)	0.491	
		Small (46-95)	0.873	
5.	Nature of shrimp	Farmed	0.708	10.174
		Sea caught	-0.708	
6.	Branding	High significant	0.408	8.723
		Low significant	0.322	
		Non-significant	-0.731	
7.	Colour	Bright pink	1.417	6.936
		Light pink	-1.417	
8.	Odour	Strong marine	0.97	1.197
		Weak marine	-0.97	

Constant= 14.097, Pearson's R= 0.621, (p = 0.0002)

developed markets. Due to lack of skilled labour, technical knowledge and fear of microbial contamination and technical and financial hurdles to create new value-added innovation and air transportation, cooked and value-added shrimps and live shrimps have not given significant role in Andhra Pradesh's shrimp exports.

The relative importance of certification and labelling was 18.41 per cent, which indicates that certification and labelling plays a significant role in promotion of shrimp exports. Various accreditations and certifications (*viz.,* Hazard Analysis Critical Control Point (HACCP) approvals, British Retail Consortium (BRC) and Best Aquaculture Practices (BAP) certifications) are mandatory for shrimp processing units to enable themselves to export the products to various global markets. Certification and labelling attribute is categorized into three sub attribute levels *i.e.* high standards, medium standards and low standards, the utilities for these are 0.722, 0.547 and -1.263. The exporters are preferred to more certified and labeling products to gain high demand in the market. Customers are

Table 3. Plan cards for the exporters based on SPSS categorization procedure of conjoint analysis

Exporters	Preferences																											
1	17	16	13	18	15	12	4	11	20	26	10	5	9	6	22	14	19	2	21	23	3	1	25	24	7	8	27
2	19	19	6	3	24	3	25	24	26	27	2	2	27	4	12	25	15	6	7	9	17	4	16	2	1	9	26
3	20	3	16	18	10	15	21	1	15	5	12	6	14	23	2	24	13	9	17	5	19	8	4	27	14	7	25
4	14	10	21	17	24	12	1	27	16	22	4	5	8	7	19	18	15	3	20	26	9	2	23	11	6	13	25
5	4	10	25	5	14	24	16	17	18	26	11	23	15	22	9	27	12	2	20	6	7	8	21	13	1	3	19
6	19	19	6	3	24	3	25	24	26	27	2	2	27	4	12	25	15	6	7	9	17	4	16	2	1	9	26
7	26	14	27	22	19	5	17	16	12	4	1	6	20	3	23	2	24	7	21	24	15	11	8	9	13	10	18
8	17	16	13	18	15	12	4	11	20	26	10	5	9	6	22	14	19	2	21	23	3	1	25	24	7	8	27
9	27	13	1	4	10	15	16	24	26	19	13	14	25	2	17	14	5	12	13	8	17	4	11	15	6	4	24
10	4	15	17	20	23	20	16	27	8	21	4	10	11	6	5	14	1	6	24	15	19	2	22	15	27	18	26
11	19	27	6	2	9	20	7	14	13	8	16	22	18	15	11	10	12	3	25	21	26	1	4	23	5	24	17
12	16	19	14	21	2	9	7	27	16	25	24	10	6	11	22	8	3	13	26	5	12	1	23	17	4	18	15
13	17	16	13	18	15	12	4	11	20	26	10	5	9	6	22	14	19	2	21	23	3	1	25	24	7	8	27
14	11	15	3	16	12	6	18	4	22	10	9	8	20	1	14	24	10	27	26	17	7	5	23	25	21	2	13
15	16	12	11	9	5	6	22	15	20	21	3	10	26	18	17	4	1	2	14	26	8	13	7	19	24	23	25
16	19	27	6	2	9	20	7	14	13	8	16	22	18	15	11	10	12	3	25	21	26	1	4	23	5	24	17
17	15	17	22	16	11	10	27	20	23	5	14	2	6	8	25	7	4	3	21	9	12	18	19	26	1	13	24
18	19	19	6	3	24	3	25	24	26	27	2	2	27	4	12	25	15	6	7	9	17	4	16	2	1	9	26
19	27	9	15	21	3	11	1	6	8	16	22	13	21	14	12	26	1	24	6	26	3	27	10	22	6	11	21
20	17	16	13	18	15	12	4	11	20	26	10	5	9	6	22	14	19	2	21	23	3	1	25	24	7	8	27
21	27	13	1	4	10	15	16	24	26	19	13	14	25	2	17	14	5	12	13	8	17	4	11	15	6	4	24
22	16	12	11	9	5	6	22	15	20	21	3	10	26	18	17	4	1	2	14	26	8	13	7	19	24	23	25
23	27	9	15	21	3	11	1	6	8	16	22	13	21	14	12	26	1	24	6	26	3	27	10	22	6	11	21
24	16	7	2	10	9	9	19	22	11	8	24	3	25	22	12	22	1	7	9	22	11	15	11	20	17	11	20
25	17	16	13	18	15	12	4	11	20	26	10	5	9	6	22	14	19	2	21	23	3	1	25	24	7	8	27
26	14	8	10	22	27	7	22	20	17	24	5	4	19	1	4	21	5	19	18	3	11	24	9	11	18	11	9
27	17	16	13	18	15	12	4	11	20	26	10	5	9	6	22	14	19	2	21	23	3	1	25	24	7	8	27
28	20	3	16	18	10	15	21	1	8	5	12	6	16	23	2	24	1	15	17	5	19	15	4	19	21	2	25
29	14	10	21	17	24	12	1	27	16	22	4	5	8	7	19	18	15	3	20	26	9	2	23	11	6	13	25
30	16	12	11	9	5	6	22	15	20	21	3	10	26	18	17	4	1	2	14	26	8	13	7	19	24	23	25

Table 4. Preference ranks of quality attributes of shrimps indicated by exporter

Number of cases read = 2 Number of cases listed = 27

CARD	Physical form	Odour	Colour	Size (count/lb)	Nature of shrimp	Price (Rs/kg)	Certification & labeling	Branding
1	3.00	1.00	2.00	2.00	1.00	3.00	2.00	3.00
2	2.00	1.00	1.00	1.00	2.00	2.00	2.00	3.00
3	2.00	2.00	2.00	1.00	1.00	3.00	2.00	1.00
4	1.00	2.00	2.00	1.00	2.00	3.00	1.00	1.00
5	3.00	1.00	1.00	2.00	2.00	1.00	2.00	1.00
6	3.00	2.00	2.00	3.00	2.00	1.00	1.00	1.00
7	2.00	1.00	2.00	2.00	1.00	1.00	1.00	3.00
8	1.00	2.00	2.00	3.00	1.00	1.00	2.00	3.00
9	2.00	1.00	2.00	3.00	2.00	2.00	3.00	1.00
10	1.00	2.00	1.00	2.00	1.00	2.00	3.00	3.00
11	2.00	2.00	2.00	2.00	2.00	2.00	1.00	2.00
12	3.00	1.00	1.00	3.00	1.00	2.00	1.00	3.00
13	2.00	1.00	2.00	1.00	1.00	1.00	2.00	1.00
14	3.00	1.00	2.00	3.00	1.00	3.00	1.00	1.00
15	3.00	1.00	2.00	1.00	1.00	2.00	3.00	2.00
16	1.00	1.00	1.00	3.00	2.00	3.00	2.00	2.00
17	2.00	2.00	1.00	3.00	1.00	1.00	3.00	2.00
18	1.00	1.00	1.00	1.00	1.00	2.00	1.00	1.00
19	1.00	1.00	1.00	2.00	2.00	3.00	3.00	1.00
20	2.00	1.00	1.00	3.00	1.00	3.00	3.00	3.00
21	1.00	1.00	2.00	3.00	1.00	2.00	2.00	2.00
22	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00
23	1.00	1.00	2.00	2.00	1.00	1.00	3.00	3.00
24	3.00	2.00	1.00	1.00	1.00	3.00	3.00	2.00

Table 4 Contd.....

CARD	Physical form	Odour	Colour	Size (count/lb)	Nature of shrimp	Price (Rs/kg)	Certification & labeling	Branding
25	2.00	1.00	1.00	2.00	1.00	3.00	1.00	2.00
26	3.00	2.00	2.00	2.00	1.00	2.00	2.00	2.00
27	3.00	1.00	1.00	1.00	2.00	1.00	3.00	3.00

Physical form 1.Raw frozen; 2. Cooked/Value added; 3. Live shrimp

Odour 1. Strong marine; 2. Weak marine

colour 1. Bright pink; 2. Light pink

Size 1 Large; 2. Medium; 3. Small

Nature of shrimp 1. Farm raised; 2. Sea caught

Price (Rs./kg) 1.400-600; 2.600-800; 3.800-1000

Certification & labeling 1.Highh level; 2. Moderate level; 3.Low level

Branding 1. Highsignificant; 2. Low significant; 3.Non-signifi

willing to pay more for products with certification and labeling. Pieniak and Verbeke (2008) observed that consumers in European countries consider labeling as an essential guarantee for safe seafood. They also found that consumers correlate information of product safety with information of product quality. While importing the products, countries such as EU, USA and Japan are particular about certification and labeling of the product. Therefore, having certified and labelled products is important to have a competitive edge in the market. Some SEA counties are slightly liberal in certification and labeling process. However, no country entertains the non-certified products.

Price attribute has a significant impact on exports with relative importance is 16.135. The price and quality are inter- dependent. If the quality of shrimp is good, the price would be high. Price attribute is divided into three sub attributes such as Rs. 400-600/kg, Rs. 600-800/kg and Rs. 800-1000/kg. Majority of the exporters are willing to sell their product at Rs. 600-800/kg, this sub attribute has a with utility value of 1.741. However, the price decision taking place between exporters and foreign buyers through price quotations.

Size is another focused attribute with relative importance value of 12.26. The exporters prefer highly for large shrimps for which the utility value was 1.064 to gain more income. This is followed by small shrimps for which utility value is 0.873. The Water based Limited (TWL), a leading shrimp industry said that there is an increased preference towards higher count shrimp (smaller sized) due to growth in volumes of exports to South East Asian Countries (MPEDA, 2018).

Nature of the shrimp attribute has relative importance value of 10.174. Majority of exporters prefer farm raised shrimp for which utility was 0.708. Even though there is demand

for sea caught shrimp, exporters prefer farm raised shrimp because Indian shrimp culture diversification from low volume shrimp (black tiger) to high-volume shrimp vannamei. There is also a huge production base and favorable conditions for shrimp farming in Andhra Pradesh.

Branding is one of the attributes with relative importance of 8.72 and it categorized into three sub levels *i.e.,* high, low and non-significant levels for which utilities were 0.408, 0.322 and -0.731, respectively. Andhra Pradesh shrimps have a strong branding in the international market. Even though exporters have their own branding of the shrimp but majority of the exports are doing on the name of foreign buyers' brand. So that there is still need to increase brand value of exported shrimp in order to empower and maximize the trade advantage.

The sensory attributes like colour and odour were fewer significant attributes for exports for which relative importance values were 6.936 and 1.197, respectively. Bright pink colour with strong marine odour had highly preferred attribute levels with utility values 1.471 and 0.97 respectively.

CONCLUSIONS

The shrimp exporters from Andhra Pradesh gave major preference to the raw frozen shrimp form and least preference to live shrimp due to greater demand from SEA countries for raw shrimp products. The role of certification and labelling is essential in promoting the shrimp exports. Highly developed countries like USA, EU and Japan gave preference to the certified and labelled products, so that exporters can realized higher unit value by meeting certain specifications. Price attribute had a strong influence on exports, major preference price range was Rs. 600-800/kg. The exporters were highly preferable for large size shrimps followed by small size shrimps. In case of branding, the exporters of Andhra Pradesh exported their shrimps in the name of foreign buyers' brand. Therefore, there was a need to increase brand value of Indian exported shrimp. In the increasingly competitive seafood market, there is a need to differentiate Indian export products from competitor's products to increase profits. In order to grab the trade advantage, some measures need to be followed such as adoption of appropriate advanced technologies, creation of new infrastructure and other enabling facilities for increasing the utilization of shrimp products in Andhra Pradesh. By creating a unique brand for Indian shrimp will go long way in export earnings. Further, the branding has to be promoted through MPEDA by highlighting country of origin which may address the issues like low unit value realization. The Department of Fisheries, MPEDA and Government have to look closely at farming practices and product marketing through necessary support to ensure product standards and orderly marketing.

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COMPARATIVE ANALYSIS OF TRENDS, GROWTH, AND INSTABILITY IN THE AREA, PRODUCTION, AND YIELD OF MAIZE IN BIHAR AND KARNATAKA

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ABSTRACT

The present study has attempted in the year 2022 to analyze maize production trends, growth, and instability in Bihar and Karnataka. Average, Compound Annual Groth Rate (CAGR), and Cuddy Della Valley Index (CDVI) were employed to essess the data from 2002 to 2003 and 2021 to 2022, divided into three periods. As far as kharif maize's average trend and CAGR of area, production, and yield were concerned, it was dominated by Karnataka during all the periods. For rabi maize, it was dominated by Bihar for the same, but its yield was less than the nation's yield during both seasons. In case of India, kharif maize's area and production were much more than the rabi maize, but the yield was low during the entire period for the same. It was also revealed that production growth was due to both the area and yield growth. However, the yield effect was highly significant during all the periods for all the seasons for Bihar, Karnataka, and India. Instability in production for the entire period was more, *i.e.*, 31.32 in Bihar during the kharif season, and it was more in Karnataka, *i.e.,* 22.38 during the rabi season.

Keywords: Average, Bihar, CAGR, CDVI, Karnataka, Trends

INTRODUCTION

After rice and wheat, maize (*Zea mays L.*) is the third-most significant cereal crop world wide. In addition to being used as food and animal feed, maize has many other industrial uses that make it essential (Singh *et al.,* 2018). In India's uplands, maize is a promising crop for diversifying agriculture. It is currently India's third most important food grain crop. The maize acreage and production has gradually increased over the last few years (CMIE States of India Report, 2002-03 to 2021-22). Furthermore, production will keep growing to fulfill future demands for food, feed, and other necessities, given the nation's thriving cattle and poultry industries. Future increases in maize supply will come from bolstering and commercializing existing systems, as there aren't many opportunities to expand maize production (Yadav *et. al.,* 2016). Farmers may maintain the soil's declining quality by producing maize, which uses 90% less water and 70% less power than rice and has much higher yields than wheat and paddy (Sharma and Mehta, 2012). According to the Economic Survey 2020-21, three Indian states, *i.e.,* Karnataka (16.45%), Madhya Pradesh (11.37%), and Maharashtra (10.91%), produce

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around 38% of the nation's total maize. Other major maize-producing states are Rajasthan, Utter Pradesh, and Bihar.

In Bihar, maize is grown in all three seasons (Kharif, Rabi, and spring/summer); however, most of the crop is grown in the rabi season, followed by kharif and spring (Singh *et al.,* 2022). Rabi maize is popular in Bihar because of its high production potential, as the area is planted mostly with high yielding varities (HYV) seeds. Maize suffers from water logging and floods throughout the kharif season, while the crop suffers from moisture stress in the autumn (www.icar.orgreport, 2021). The state's average rabi maize productivity is substantially greater than the national average, demonstrating that Bihar is a significant maize-producing state in India. Its yields are higher during rabi season due to factors such as mild and favorable weather throughout the growing season, better water management, increased use of high-yielding hybrid and composite varieties, ease of control over harmful pests and diseases, improved availability of plant nutrients, better weed management, and better plant food establishment (Meera Kumari, 2015) Karnataka is blessed with various agro-climatic conditions that enable the farmers in the state to grow a wide range of crops throughout the year, including cereals, pulses, maize, oilseeds, commercial commodities, and horticultural crops (Kishore and Murthy, 2016). Karnataka is India's largest maize-producer state (Economic Survey 2020-21). The majority of the maize is planted during kharif season using hybrid seeds. Approximately at 1.6 million hectares of land, maize is grown in Karnataka, yielding 52.21 lakh tonnes of grain, especially in the districts of Shimoga, Davangere, and Chitradurga in the central region of Karnataka. Over the last ten years (2012-13 to 2021-22), maize has grown in an area more than any other crop in the state, displacing other crops that were grown in rainfed areas, such as tobacco, cotton, groundnuts, ragi, potato, and sorghum because of it's yield potential and favourable climate. However, the biggest hurdles to increasing productivity are the lack of high-yielding single cross-hybrid seed and the vulnerability to downy mildew disease (www.icar.orgreport, 2020).

Madhya Pradesh is the second largest maize producing states of India producing 11.37 per cent of total maize of India (Economic Survey 2020-21). With an average production of 4489.58 thousand tonnes and productivity of 2.92 tons/ha, it is grown over an area of 1537.09 thousand hectares (Madhya Pradesh Economic Survey 2020–21). In the Madhya Pradesh districts of Chhindwara, Seoni, Betul, Barwani, and Dhar, it is primarily grown as a *Kharif* crop. These districts supplied the state with more than 60% and 70% of the area and production of maize, respectively.

MATERIAL AND METHODS

Karnataka and Bihar were chosen purposively for the study as Karnataka is the top producer of Maize in India (Economic Survey 2021-22), particularly for *kharif* maize, and Bihar is also a major state for maize production, particularly for rabi maize. So, these states were selected to see the comparative status of maize production in both seasons.

According to the data availability, the study was made from 2002-03 to 2021-22. Time series data on the area, production, and yield of the maize crop was collected for the same period (2002-03 to 2021-22) from Centre for Monitoring Indian Economy (CMIE) States of India Report, 2023. The whole period was divided into decadle wise, i.e., the first decade (2002-03 to 2011-12), the second decade (2012-13 to 2022-23), and the total period (2002-03 to 2021-22).

An average method is used for knowing the trend of maize during all the periods for all the seasons for Bihar, Karnataka, and India. The growth in the area, production, and yield for maize was estimated using the compound annual growth rate (CAGR).

The equation was used to calculate the growth rate:

$$\log Y_t = a + b_t \text{Or,}$$

$$\text{CAGR (\%)} = \frac{\text{Ending Value}}{\text{Beginning Value}}^{(1 \div t)} - 1$$

Where,

Y = acreage/production/productivity of maize

a = constant

b = expresses the rate of change, and when multiplying by 100, gives the percentage growth rate

t = time variable in a year (1, 2……n)

The formula gives the growth rate.

r = antilog (b^ – 1).100

Where b^ = estimated value of b.

There are numerous ways to quantify instability, including the coefficient of variation (CV), dispersion, Cuddy Della Valle Index (CDVI), Coppock Instability Index, etc. (Sharma and Mehta, 2012). The Cuddy Della Valle Index (CDVI) is used in the current study. In order to measure the instability in time series data that is defined by trend, first established the CDI. The following is the equation's estimable form.

$$\text{CDI} = \text{CV} * \sqrt{1 - R^2}$$

Where CV is the coefficient of variation in percent, and R^2 is the coefficient of determination from time trend regression adjusted by the number of degrees of freedom.

The ranges of instability are as follows:

· Low instability = between 0 to 15

· Median instability = greater than 15 and lower than

· High instability = greater than 30

RESULTS AND DISCUSSION

Trend of area, production, and yield of maize in all seasons in Bihar, Karnataka and India

Table 1 compares the average area, production, and yield of Maize in Bihar, Karnataka, and India from 2002-03 to 2021-22, divided into three periods, *i.e.,* from 2002-03 to 2011-12, from 2012-13 to 2021-22 and the entire period *i.e.,* from 2002-03 to 2021-22.

As far as Kharif maize's area, production, and yield were concerned, it was dominated by Karnataka, as it had more area, production, and yield than Bihar during all three different periods *i.e.,* the first decade (2002-03 to 2011-12), the second decade (2012-13 to 2022-23), and the total period (2002-03 to 2021-22). It's share of India for the area was 13.14 per cent, 16.81 percent, and 15.05 respectively. For production, it was 19.25 per cent, 19.11 per cent, and 19.16 per cent, respectively, and yield was also more than India during all the periods.

Bihar surpassed *Rabi* maize's area, production, and yield during all the periods than Karnataka. Bihar's share of India's area during the first, second, and overall periods is 37.47 per cent, 24.87 per cent, and 29.38 per cent, respectively. Production accounts for 29.3 per cent, 22.9 per cent, and 24.9 per cent, respectively. The yield surpasses Karnataka's in all periods except the first, yet remains below the national average throughout all periods.

Table 1: Period-ise Trends in Average Area, Production and Yield of Maize in India from 2002-03 to 2021-22.

S. N.	States	Components	*Kharif* Maize			*Rabi* Maize			Total Maize		
			Period 01 (2002-03 to 2011-12)	**Period 02** (2012-13 to 2021-22)	**Total Period** (2002 -03 to 2021-22)	**Period 01** (2002-03 to 2011-12)	**Period 02** (2012-13 to 2021-22)	**Total Period** (2002 -03 to 2021-22)	**Period 01** (2002-03 to 2011-12)	**Period 02** (2012-13 to 2021-22)	**Total Period** (2002 -03 to 2021-22)
1.	**Bihar**	**Area** (in '000' ha.)	254.6 (3.71)	234.8 (3.13)	244.7 (3.41)	380.6 (37.47)	453.1 (24.87)	416.85 (29.38)	635.2 (8.06)	687.9 (7.38)	661.55 (7.69)
		Production (in '000' ta.)	417 (3.16)	512.4 (2.72)	464.7 (2.9)	1088.8 (29.3)	1859.9 (22.9)	1474.35 (24.9)	1505.9 (8.91)	2372.7 (8.8)	1939.3 (8.84)
		Yield (in kg ha^{-1})	1640 (85.82)	2126.8 (84.71)	1883.4 (85.19)	2864.9 (80.41)	4099.6 (92.57)	3482.25 (87.15)	2368.6 (111.37)	3450.4 (111.6)	2909.5 (116.11)
2.	**Karnataka**	**Area** (in '000' ha.)	901.8 (13.14)	1260.3 (16.81)	1081.05 (15.05)	105.5 (10.38)	141.1 (7.74)	123.3 (8.69)	1007.3 (12.78)	1401.4 (15.03)	1204.35 (14)
		Production (in '000' ta.)	2537.2 (19.25)	3603.3 (19.11)	3070.25 (19.16)	296.5 (7.97)	471.4 (5.8)	383.95 (6.48)	2833.6 (16.76)	4074.8 (15.10)	3454.2 (15.74)
		Yield (in kg ha^{-1})	2735.4 (143.14)	2847.5 (113.42)	2791.45 (126.26)	2767.9 (77.68)	3316.5 (74.89)	3042.2 (76.13)	2738.5 (128.77)	2893.2 (100.28)	2815.85 (112.37)
3.	**India**	**Area** (in '000' ha.)	6861.5 (100)	7496.1 (100)	7178.8 (100)	1015.7 (100)	1822 (100)	1418.85 (100)	7877.5 (100)	9318.8 (100)	8598.15 (100)
		Production (in '000' ta.)	13183.6 (100)	18853 (100)	16018.3 (100)	3716.3 (100)	8123.2 (100)	5919.75 (100)	16900.2 (100)	26976.6 (100)	21938.4 (100)
		Yield (in kg ha^{-1})	1910.9 (100)	2510.5 (100)	2210.7 (100)	3562.8 (100)	4428.3 (100)	3995.55 (100)	2126.6 (100)	2884.9 (100)	2505.75 (100)

Source: Author's calculation based on data from CMIE States of India Report, 2023

Table 2: Growth rates of area, production, and yield of maize in all seasons in Bihar, Karnataka, and India during 2002-03 to 2021-22

S. N.	States	Components	*Kharif* Maize			*Rabi* Maize			Total Maize		
			Period 01 (2002-03 to 2011-12)	**Period 02** (2012-13 to 2021-22)	**Total Period** (2002 -03 to 2021-22)	**Period 01** (2002-03 to 2011-12)	**Period 02** (2012-13 to 2021-22)	**Total Period** (2002 -03 to 2021-22)	**Period 01** (2002-03 to 2011-12)	**Period 02** (2012-13 to 2021-22)	**Total Period** (2002 -03 to 2021-22)
1.	**Bihar**	**Area** (in '000' ha.)	-1.02	-4.83*	-1.41*	2.11*	1.04	1.72**	0.87**	-0.96	0.59**
		Production (in '000' ta.)	1.21	-11.08**	-0.11	1.01	2.36	4.53**	1.22	-0.23	3.59**
		Yield (in kg ha^{-1})	**2.23**	-6.54	1.33	**-1.09**	**1.31**	2.77**	0.35	0.75	2.99**
2.	**Karnataka**	**Area** (in '000' ha.)	8.85**	2.28	4.13**	10.05**	1.03	3.94**	8.96**	2.33	4.12**
		Production (in '000' ta.)	**13.31****	**3.75**	5.24**	**13.01****	**5.26**	6.05**	13.25**	3.91	5.33**
		Yield (in kg ha^{-1})	**4.12**	**1.44**	1.07	**2.66**	**2.44**	2.02**	**3.94**	**1.54**	1.16
3.	**India**	**Area** (in '000' ha.)	**1.85****	0.67	0.99**	8.60**	3.87**	6.23**	2.68**	1.29*	1.78**
		Production (in '000' ta.)	5.04*	3.66**	3.88**	12.83**	6.33**	8.86**	6.60**	4.46**	5.06**
		Yield (in kg ha^{-1})	**3.13**	2.97**	2.86**	**3.90***	**2.37**	2.47**	3.82*	3.13**	3.22**

Source: Author's calculation based on data from CMIE States of India Report, 2023

Notes: (*) indicates significant at 1 % level, (**) indicates significant at 5 % level,

Karnataka dominated the total maize area, production, and yield. Thus, Karnataka has consistently been the top *Kharif* maize producer, and Bihar was the top *Rabi* maize producer than Karnataka. As we see the total production in the context of India, then *kharif* maize is produced more than *Rabi* maize in all over India. During the entire period, the average area and production of *kharif* maize in India were 7178.8 thousand hectares and 14531.55 thousand metric tonnes, respectively, which is much more than the total average area and production of *Rabi* maize which was 1418.85 thousand hectares, 5370.3 thousand metric tonnes, respectively. But the yield of *kharif* maize was 2210.7 kg ha^{-1},which was less than the yield of *Rabi* maize, i.e.,3995.55 kg ha^{-1}.

Compound Annual Growth Rate (CAGR) of area, production, and yield of maize in all seasons in Bihar, Karnataka, and India

This section gives a detailed account of compound annual growth rates of maize crop for Bihar, Karnataka, and India for all the seasons during all three periods**.**

Period 01 (2002-03 to 2011-12)

Table 2 shows that throughout this period, the compound growth rates for the area, production, and yield of *Kharif* maize in Bihar were, respectively, -1.02, 1.21, and 2.23 per annum. It indicates that there is positive growth in production and yield, while it is negative for area. It was 8.85, 13.31, and 4.12, respectively, for Karnataka, indicating that there is significant growth in *Kharif* maize area, production and yield. It was 1.85, 5.04, and 3.13, respectively, for India. It inferred that the increase in production was driven by contributions from both area expansion and yield improvement (Kiran *et al.,* 2018).

For *Rabi* maize, Bihar's annual compound growth rates for area, production, and yield were 2.11, 1.01, and -1.09, respectively, indicating that both the growth of area and yield contributed to the growth of production. It was 10.05, 13.01, and 2.66, respectively, for Karnataka. It suggests that increases in area and yield are both responsible for rising production. Additionally, it was 8.60, 12.83, and 3.90, respectively, for India. It suggests that the expansion of production was driven equally by the growth rates of area and yield (Author's analysis).

In Bihar, the annual compound growth rates for the area, production, and yield of total maize were 0.87, 1.22, and 0.35, respectively. It suggests that increases in area and yield cause rising production. It was 8.96, 13.25, and 3.94, respectively, for Karnataka. It implies that the increase in production is completely attributable to the area's expansion. The figures for India were 2.68, 6.60, and 3.82 annually, indicating that the increase in production was equally driven by growth in both area and yield.

Period 02 (2012-13 to 2021-22)

The area, production, and yield of *Kharif* maize in Bihar saw compound annual growth rates of -4.83%, -11.08%, and -6.54%, respectively, indicating negative growth across all variables during this period. In contrast, Karnataka experienced positive growth, with corresponding rates of 2.28%, 3.75%, and 1.44%. For India, it was 0.67, 3.66, and 2.97, which shows positive growth in all the variables.

In Bihar, it was 1.04, 2.36, and 1.31 per annum, respectively, for *Rabi* maize, suggesting that yield and area increase contribute to the growth in production. In Karnataka, it was, 1.03, 5.26, and 2.44 per annum respectively, indicating that there has been no increase in yield and just a decrease in area and production. The growth rates were 3.87% for area, 6.33% for production, and

2.37% for yield for India. This indicates that both the area and yield growth rates have contributed equally to the increase in production.

In Bihar, it was -0.96, -0.23, and 0.75 per annum for total maize, indicating that yield growth drives output growth. For Karnataka, they were, 2.33, 3.91, and 1.54 per annum respectively. It indicates that the yield growth rate is negative and that there is very little growth in the area, leading to negative production growth. India, it was 1.29, 4.46, and 3.13, respectively, per year, indicating that growth in yield is more responsible for the rise in production than growth in the region.

Total Period (2002-03 to 2021-2022)

In Bihar, it was -1.41, -0.11, and 1.33 per annum for *Kharif* maize during this time. It suggests that rather than area growth, the increase in the growth rate of *Kharif* maize output was caused by an increase in maize yield growth. In Karnataka, it was 4.13, 5.24, and 1.07, respectively, indicating that the increase in the growth rate of *Kharif* maize output was caused more by an increase in yield than by an increase in area. And for India, it was 0.99, 3.88 and 2.86 per annum, respectively. It indicates that both area and yield increase are the major reasons for the rise in production (Ayalew and Sekar, 2016).

For *Rabi* maize in Bihar, the growth rates were 1.72% for area, 4.53% for production, and 2.77% for yield, indicating that the expansion in both area and yield contributed equally to the rise in production. In Karnataka, the rates were 3.94%, 6.05%, and 2.02%, respectively, reflecting that both yield and area growth contributed equally to the production increase. For India as a whole, the growth rates were 6.23% for area, 8.86% for production, and 2.47% for yield per annum, suggesting that the expansion of area played a more significant role in the increase in production than the rise in yield.

In Bihar, it was 0.59, 3.59, and 2.99 per annum respectively, for total maize, indicating that yield increase is more responsible than area growth, it was 4.12, 5.33, and 1.16, respectively, for Karnataka, showing that the area's expansion is more responsible than yield, and for India, it was 1.78, 5.06, and 3.22, respectively, meaning that yield and area increase are equally responsible for the growth in production.

Instability in the area, production, and yield of maize in all seasons in Bihar, Karnataka, and India

Period 01 (2002-03 to 2011-12)

Instability in the area, production, and yield of Bihar's *Kharif* maize were 5.72, 22.09, and 20.62, respectively, as shown in Table 3. It infers that variations in crop area and yield contributed to change in production, but the yield is more responsible. For Karnataka, it was 6.84, 16.29, and 14.02, respectively, indicating that area and yield were equally responsible for the production's variability. For India, it was 1.13, 10.87, and 9.76 per annum, suggesting that yield is the only factor influencing production changes (Ayalew and Sekar, 2016).

For *Rabi* maize, instability in the area, production, and yield during this period in Bihar were 2.37, 14.14, and 13.84, respectively, which implies that yield is solely responsible for the fluctuations in production. For Karnataka, it was 9.86, 11.40, and 11.08, respectively, which implies that area and yield were equally responsible for fluctuations in production. For India, it was 6.25, 13.9, and 9.06, respectively, implies that area and yield were equally responsible for the fluctuations in production.

For total maize, instability in the area, production, and yield in Bihar were 1.99, 8.36,

Table 3. Instability in Area, Production, and Yield of Maize in Bihar, Karnataka and india during 2002-03 to 2021-22 for all the seasons during all the three periods

S. N.	States	CDVI for the Components	*Kharif* Maize			*Rabi* Maize			Total Maize		
			Period 01 (2002-03 to 2011-12)	**Period 02** (2012-13 to 2021-22)	**Total Period** (2002 -03 to 2021-22)	**Period 01** (2002-03 to 2011-12)	**Period 02** (2012-13 to 2021-22)	**Total Period** (2002 -03 to 2021-22)	**Period 01** (2002-03 to 2011-12)	**Period 02** (2012-13 to 2021-22)	**Total Period** (2002 -03 to 2021-22)
1.	**Bihar**	**Area** (in '000' ha.)	5.72	5.72	9.03	2.37	3.61	3.09	1.99	2.72	4.14
		Production (in '000' ta.)	22.09	34.45	31.32	14.14	12.91	16.07	8.36	10.75	14.69
		Yield (in kg ha^{-1})	20.62	16.63	25.14	13.84	11.94	15.1	8.18	10.64	12.65
2.	**Karnataka**	**Area** (in '000' ha.)	6.84	7.42	9.34	9.86	20.14	19.41	5.56	8.17	9.64
		Production (in '000' ta.)	16.29	12.74	17.08	11.40	23.83	22.38	12.46	7.48	16.92
		Yield (in kg ha^{-1})	14.02	8.51	12.63	11.08	9.42	9.77	13.35	8.14	11.84
3.	**India**	**Area** (in '000' ha.)	1.13	2.65	2.82	6.25	6.47	6.48	1.97	2.88	8.43
		Production (in '000' ta.)	10.87	4.96	7.14	13.9	7.68	9.75	9.18	5.20	6.37
		Yield (in kg ha^{-1})	9.76	4.38	6.60	9.06	5.86	7.20	8.27	4.22	5.74

Source: Author's calculation based on data from CMIE States of India Report, 2023

and 8.18, respectively, yield is solely responsible for the fluctuations in production. For Karnataka, it was 5.56, 12.46, and 13.35, respectively, implies that area and yield were equally responsible for the fluctuation in production. For India, it was 1.97, 9.18, and 8.27, respectively, means that yield is solely responsible for fluctuation in production.

Period 02 (2012-13 to 2021-22)

During this period, for *Kharif* maize, it was 5.72, 34.45, and 16.63, area, production and yield respectively, for Bihar, which implies that both area and yield were responsible for the production. For Karnataka, it was 7.42, 12.74, and 8.51, respectively, the yield is more responsible than the area for the fluctuation in production. For India, it was 2.65, 4.96, and 4.38, both area and yield were equally responsible for the fluctuations in production.

For *Rabi* maize, it was 3.61, 12.91, and 11.94, respectively, for Bihar, in Karnataka, it was 20.14, 23.83, and 9.42, respectively, for India, it was 6.47, 7.68, and 5.86, respectively, which means that area and yield were equally responsible for the fluctuations in production. For total maize, it was 2.72, 10.75, and 10.64, respectively, for Bihar, in Karnataka, it was 8.17, 7.48, and 8.14, respectively, for India, it was 2.88, 5.20, and 4.22, respectively, which means that yield is solely responsible for fluctuation in production in Bihar, Karnataka and India.

Total Period (2002-03 to 2021-2022)

During the overall period, for *Kharif* maize, it was 9.03, 31.32, and 25.14, respectively, for Bihar, which means that yield was more responsible than area in fluctuation of production. In Karnataka, it was 9.34, 17.08, and 12.63, respectively, for India, it was 2.82, 7.14, and 6.60, which means that area and yield were equally responsible for fluctuations in production in Karnataka and India. For *Rabi* maize, it was 3.09, 16.07, and 15.10, respectively, for Bihar, which implies that yield was solely responsible for the fluctuations in production. In Karnataka, it was 19.41, 22.38, and 9.77, respectively, for India, it was 6.48, 9.75, and 7.20, respectively, which means that area and yield was equally responsible for the fluctuations in production in Karnataka and India. For total maize, it was 4.14, 14.69, and 12.65, respectively, area, production and yield for Bihar, which implies that yield is solely responsible for the fluctuation were production. For Karnataka, it was 9.64, 16.92, and 11.84, respectively, which implies that area and yield were equally responsible for the fluctuations in production. And for India, it was 8.43, 6.37, and 5.74, respectively, which implies that area and yield were equally responsible for the fluctuations in production.

CONCLUSIONS

The study found that maize's area, production, and yield have increased in Bihar, Karnataka, and India during 2002-03 to 2021-22, although its yield was lower than the world's average. Bihar dominates rabi maize, kharif maize was dominated by Karnataka, and *kharif* maize was cultivated more in India than *Rabi* maize. The instability of the area and production of maize in both seasons has increased over periods in Bihar, while it has declined in Karnataka. The instability of yield has declined over the periods in both seasons in Karnataka, while it has increased during rabi maize and declined during the *kharif* maize in Bihar over the periods. For India, the instability of the area, production, and yield has declined in both seasons during both the periods. The study also found that while *rabi* maize production is falling in Karnataka, it is steadily rising in Bihar. Regarding *kharif* maize, both states' growth in area and production are

APPENDIX

Table 4. Area under maize production in India, Bihar, and Karnataka (in '000' hectares)

YEAR	Total Area			*Kharif* Area			*Rabi* Area		
	India	Bihar	Karnataka	India	Bihar	Karnataka	India	Bihar	Karnataka
2002-03	6635	603	649	5976	255	578	659	349	71
2003-04	7343	616	618	6590	259	545	753	357	73
2004-05	7430	614	850	6594	268	784	836	346	66
2005-06	7588	648	936	6757	276	842	830	372	94
2006-07	7894	641	961	6960	259	866	933	382	95
2007-08	8117	639	1113	7118	263	1015	998	376	98
2008-09	8173	640	1069	6894	245	933	1279	395	136
2009-10	8261	631	1240	7063	227	1108	1198	404	132
2010-11	8553	645	1288	7282	231	1141	1271	414	147
2011-12	8781	675	1349	7381	263	1206	1400	411	143
2012-13	8672	685	1322	7214	261	1162	1458	424	160
2013-14	9066	732	1377	7309	276	1246	1756	456	131
2014-15	9185	706	1337	7563	277	1210	1622	429	127
2015-16	8806	705	1220	7179	270	1091	1626	434	129
2016-17	9633	720	1370	7841	241	1263	1791	479	107
2017-18	9380	677	1307	7433	223	1183	1946	454	124
2018-19	9027	669	1339	7330	223	1231	1696	446	108
2019-20	9569	673	1424	7552	209	1287	2016	464	137
2020-21	9892	649	1726	7755	194	1532	2136	456	194
2021-22	9958	663	1592	7785	174	1398	2173	489	194

Source: CMIE States of India Report, 2023

Table 5. Total production of maize in India, Bihar, and Karnataka (in '000' tonnes)

YEAR	Total Area			*Kharif* Area			*Rabi* Area		
	India	Bihar	Karnataka	India	Bihar	Karnataka	India	Bihar	Karnataka
2002-03	11151	1350	1343	9272	428	1165	1879	921	178
2003-04	14984	1473	1209	12734	438	1066	2250	1035	144
2004-05	14172	1465	2512	11476	421	2325	2695	1044	187
2005-06	14708	1361	2728	12156	420	2458	2554	941	270
2006-07	15097	1714	2719	11556	397	2459	3540	1317	260
2007-08	18955	1455	3254	15106	252	2936	3848	1203	318
2008-09	19731	1714	3029	14120	372	2632	5610	1342	397
2009-10	16719	1478	3013	12293	402	2676	4426	1076	337
2010-11	21726	1439	4444	16637	418	4011	5088	1021	433
2011-12	21759	1610	4085	16486	622	3644	5273	988	441
2012-13	22258	2476	3475	16204	646	2978	6053	1829	497
2013-14	24259	2112	3984	17145	581	3578	7114	1530	406
2014-15	24172	2340	4214	17013	687	3788	7159	1653	426
2015-16	22567	2517	3310	16053	692	2983	6514	1824	327
2016-17	25900	2690	3314	18919	624	2989	6980	2066	325
2017-18	28753	2355	3853	20118	535	3393	8634	1819	460
2018-19	27715	2482	3757	19413	464	3392	8301	2018	365
2019-20	28766	2002	4258	19429	435	3740	9336	1567	518
2020-21	31647	2084	5362	21555	225	4674	10092	1859	688
2021-22	33729	2669	5221	22681	235	4518	11049	2434	702

Source: CMIE States of India Report, 2023

Table 6. Yield of maize in India, Bihar, and Karnataka (in kg./hectare)

	Total Area			*Kharif* Area			*Rabi* Area		
YEAR	**India**	**Bihar**	**Karnataka**	**India**	**Bihar**	**Karnataka**	**India**	**Bihar**	**Karnataka**
2002-03	1680	2236	2067	1551	1679	2013	2851	2643	2511
2003-04	2040	2390	1957	1932	1691	1954	2986	2897	1980
2004-05	1907	2385	2955	1740	1571	2965	3223	3016	2833
2005-06	1938	2098	2914	1799	1518	2919	3075	2529	2872
2006-07	1912	2671	2829	1660	1532	2839	3792	3444	2737
2007-08	2335	2274	2923	2122	956	2892	3854	3197	3245
2008-09	2414	2676	2833	2048	1517	2821	4386	3393	2919
2009-10	2023	2340	2429	1740	1772	2415	3694	2659	2553
2010-11	2540	2230	3450	2284	1806	3515	4003	2467	2945
2011-12	2477	2386	3028	2233	2358	3021	3764	2404	3084
2012-13	2566	3611	2628	2246	2475	2562	4151	4309	3106
2013-14	2675	2884	2893	2345	2103	2872	4050	3358	3099
2014-15	2631	3312	3151	2249	2475	3130	4414	3853	3354
2015-16	2562	3570	2713	2235	2559	2734	4005	4201	2535
2016-17	2688	3731	2419	2412	2585	2366	3896	4309	3037
2017-18	3065	3476	2948	2706	2400	2868	4436	4005	3709
2018-19	3070	3708	2805	2648	2078	2755	4893	4524	3377
2019-20	3006	2975	2990	2572	2078	2906	4631	3380	3781
2020-21	3199	3211	3107	2779	**1163**	3051	4723	4081	3546
2021-22	3387	4026	3278	2913	1352	3231	5084	4976	3621

Source: CMIE States of India Report, 2023

slowing down from the first to the second period.

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IMPACT OF TURMOIL ON PINEAPPLE PRODUCTION IN MANIPUR: A SCENARIO-BASED FORECAST

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ABSTRACT

The current turmoil in Manipur State has significantly impacted agriculture, likely to reduce agricultural or horticultural productions including pineapple. Traditional forecasting models typically assume ideal conditions and may not account for such extreme events. This study forecasts pineapple production using Regression, ARIMA, and ARIMAX models, incorporating cultivation area series to train the data. The high correlation (0.8979) between production and cultivation area supports using the area series as a covariate. For scenario-based forecasting, the cultivation area series is generated/simulated anticipating the impact of the turmoil on the cultivation area. The regression model explains 90.68% of the variance in production series, the ARIMA model (0, 2, 2) explains 81.79%, and the ARIMAX model explains 89.17%, effectively capturing changes in cultivation area. This study suggests that the Regression and ARIMAX models can provide realistic forecasts by considering anticipated changes in cultivation areas using scenario-based simulation of cultivation area making them adaptive to change in cultivation area.

Keywords: Adaptive, ARIMA, ARIMAX, Extreme Events, Forecasting, Pineapple Production, Regression, Scenario-based Forecasting, Simulation.

INTRODUCTION

Manipur is a hill state in the North Eastern Region of India having a charming landscape with nine encircling hill ranges with an oval- shaped valley in the center. The State is predominantly hilly with about 90% (20,089 sq. km) of its total area (22,327 sq. km) covered by hills, while the remaining 2,238 sq. km form the valley (Economic Survey, Manipur 2021-22) including Loktak Lake covering an area of 246.72 sq. km (National Wetland Atlas, 2009). The State presents an eye-catching landscape, with nine hill ranges and a beautiful oval-shaped valley at its core. Imphal, the capital, sits at an altitude of about 780-790 meters above sea level, surrounded by higher hill ranges (Economic Survey, Manipur 2021-22). This blend of majestic hills and a charming valley makes Manipur an enchanting hilly state in India's geographical landscape.

Manipur's pineapple industry is thankful for high-yielding varieties like Queen and Kew, known for exceptional taste and aroma. Sustaining this success requires ongoing research and sustainable practices for long-term prosperity. The productivity of pineapple increased abruptly for Manipur from the period 1990-2000 to 2001-2013 (Mog *et al.,* 2017).

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In 2014-2015, pineapple cultivation in Manipur expanded significantly, covering 14,271 hectares, making it a leading pineapple-producing state in India with overall production of 1,36,746 MT. In 2021-22, Senapati district in Manipur excelled in pineapple cultivation, with 2780 hectares and 33360 metric tons produced. This success is attributed to favourable agro-climatic conditions and dedicated farmers.

Starting in May 2023, this research explores obtaining improved forecasting of Manipur's pineapple production during instability. It analyses the statistical link between production series and cultivated area series using statistical methods and models. Understanding the relationship between pineapple production and cultivation areas can inform resource allocation, risk management, and policy decisions. Identifying the best forecasting model during turmoil situations can help provide decision-makers with reliable insights for addressing agricultural uncertainties. A review study was conducted for modeling and forecasting Agricultural Commodity production under changing climatic conditions (Banerjee *et al.,* 2022). An ARIMA (0,2,1) model was used for forecasting milk production in India (Devi *et al.,* 2022).This research focused on studying the impact of current turmoil on pineapple production by using the cultivation area, which is directly affected by the turmoil, as a key predictor. Three forecasting models—Regression, ARIMA, and ARIMAX—are evaluated for their effectiveness in providing reliable predictions during uncertainty. Instead of relying solely on dummy variables, which may not suit short annual time series data, the study emphasizes the locally relevant area variable for pineapple cultivation. The subsequent sections will detail the methodology, results, discussions, and conclusions/recommendations for pineapple production forecasting in Manipur's challenging context.

MATERIALS AND METHODS

Data Collection

For the present study, a secondary dataset from the Horticulture Department of the Government of Manipur was acquired. The dataset contains two primary variables: "production of pineapple" and "pineapple cultivation area". These data points span from the fiscal year 1993-94 to 2021-22, forming a continuous annual time series.

Data Preprocessing

The obtained dataset underwent a meticulous preprocessing phase to establish uniformity, accuracy, and compatibility, ensuring its appropriateness for subsequent analytical procedures. Feature selection, data transformation, and data exploration will all play essential roles (Thivakaran and Ramesh, 2022). A second-order differencing operation

Table 1. Test Statistics and corresponding p-values for ADF and KPSS tests

Sl.No.	Series	ADF Test		KPSS Test	
		Statistic	p-Value	Statistic	p-Value
1	Original	-3.248137132	0.097841057	0.976885293	0.01
2	First Differenced series	-3.149952705	0.132611819	0.065908684	0.1
3	Second Differenced series	-3.266923213	0.09590915	0.073856037	0.1

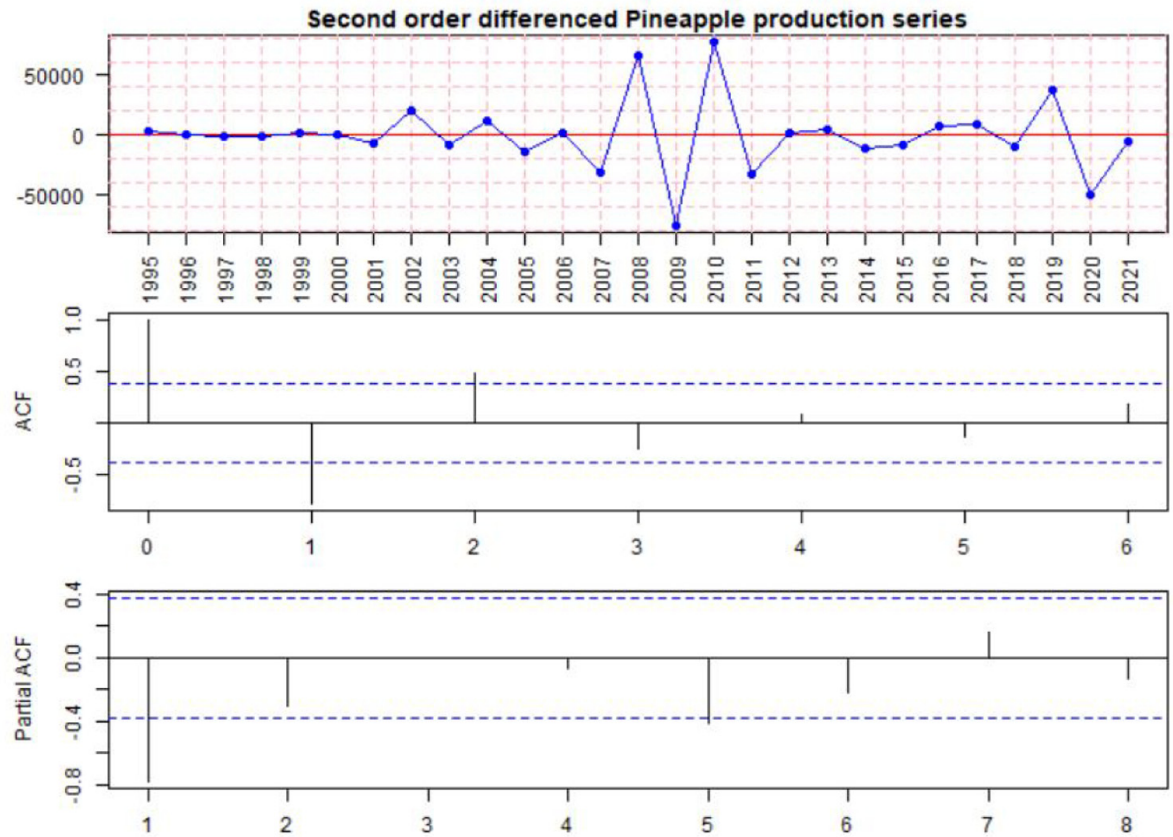

Figure 1. ACF and PACF plot of the second order differenced series

was performed on the data of the Pineapple production series to make it stationary for the application of ARIMA and ARIMAX models.

Determination of d in ARIMA (p,d,q):

Table 1 presents the results of Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests conducted on the original pineapple production series, as well as on the first and second differenced series.

According to the test results in Table 1, only the original series and the second-order differenced series meet the stationarity requirement at a 10% significance level for the ADF test. Conversely, for the KPSS test, both the first-order differenced and second-order differenced series demonstrate stationarity. Therefore, the second-order differencing method was selected for further analysis.

Determination of values p and q in ARIMA (p,d,q) :

The autoregressive $'p'$ and moving average $'q'$ components can be determined using the Partial Autocorrelation Function (PACF) and Autocorrelation Function (ACF) plots of the series.

The ACF and PACF for the second order differenced pineapple production series was provided in Fig. 1.

The PACF and ACF plots presented in Fig. 1 suggest that the potential values for p and q are 1 and 2, respectively. However, it is judicious to explore various combinations of p, d and q to determine the optimal model by selecting the one with the lowest AIC and BIC values. Given the values p=1 and q=2 as indicated by the PACF and ACF plots, and fixing d=2, we have six pos-

sible combinations for experimentation. The six combinations of (p,d,q) are as follows: (0,2,0), (0,2,1), (0,2,2), (1,2,0), (1,2,1) and (1,2,2).

Correlation Analysis

To explore the potential relationship between pineapple production and the cultivated area, we conducted a correlation analysis. This statistical technique allowed us to assess the degree of linear dependency between the two-time series variables. The Pearson correlation coefficient was calculated to quantify the strength and direction of the correlation. The correlation coefficient between the Production series (P_t) and Area series (A_t) is defined as

$$r = \sum_{t=1}^{n} \frac{(P_t - \overline{P_t})(A_t - \overline{A_t})}{(n-1)\sigma_P \sigma_A} \qquad (1)$$

where $\sigma_P \& \sigma_A$ represent SD of $P_t \& A_t$ respectively and n represents the series length.

Regression Model for Time Series

Regression is a parametric model to predict the dependent variable based on independent variables (Thivakaran and Ramesh, 2022). Incorporating the Regression model, the impact of the area variable on pineapple production was investigated. A multiple linear regression model quadratic in the 'time' covariate where pineapple production was treated as the dependent variable, and the 'cultivated area' and 'time' served as the independent variables. A model is considered linear if it is linear in parameter even though it is non-linear in one or all of its explanatory variables. The Ordinary Least Squares (OLS) method was utilized to estimate the regression coefficients. The significance of the coefficients and the goodness-of-fit of the model were evaluated.

Assuming that the dependent time series, say, P_t for t=1,2,…,n is influenced by a collection of independent series, say, A_t (Area) and t (time) for t=1,2,…,n and i=1,2,…,m. However, the assumption of independence of inputs may be relaxed in the case of time series. The model may be described as:

$$P_t = \beta_0 + \beta_1 A_t + \beta_2 t + \beta_3 t^2 + \omega_t \qquad (2)$$

where β_0, β_1, β_2, β_3, are unknown fixed regression coefficients. And $\{\omega_t\}$ is a random error or noise process consisting of iid normal variables with mean zero and variance $\sigma 2$; however, the assumption of white noise is relaxed for time series.

Using OLS, we can minimize the error sum of squares

$$Q = \sum_{t=1}^{n} \omega_t^2 = \sum_{t=1}^{n} [P_t - (\beta_0 + \beta_1 A_t + \beta_2 t + \beta_3 t^2)]^2 \qquad (3)$$

Auto Regressive Integrated Moving Average (ARIMA)

The ARIMA model, a powerful tool for time series forecasting, was employed to model pineapple production. The series was assessed for stationarity, and if necessary, differencing was applied to achieve stationarity. Model identification, including the orders of autoregressive (AR) and moving average (MA) terms, was tentatively determined through analysis of autocorrelation and partial autocorrelation plots as described in the data pre-processing section above. However, the identification of the final model was based on Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). The ARIMA model was then fitted to the data, and forecasts were generated. An ARIMA model predicts a value in a response time series as a linear combination of its past values, and past errors (also called shocks or noise). In the case of stationary series, the underlying process that generates the time series has the form ARMA (p,q), i.e.

$$P_t = \theta_0 + \sum_{i=1}^{p} \Phi_i P_{t-i} + \varepsilon_t - \left(\sum_{j=1}^{q} \theta_j \varepsilon_{t-j} \right) \qquad (4)$$

where P_t and $\sum_t$ are the actual value and random error at time t, respectively;

i (i = 1,2,…,p) and j (j = 0,1,2,…,q) are model parameters. p and q are referred to as orders of AR and MA in the model. Random errorse ε_t are assumed to be independently and identically distributed with a mean of zero and a constant variance of σ2 and there is no common factor between auto regressive polynomial, $\Phi(L) = 1 - \Phi_1 L - \Phi_2 L^2 - \cdots - \Phi_p L^p$ and moving average polynomial $\theta(L) = 1 + \theta_1 L + \theta_2 L^2 + \cdots + \theta_q L^q$ where L is a lag operator.

In the case of difference-stationary, the underlying process that generates the time series has the form ARIMA (p,d,q), i.e.

$$\Phi(L)(1-L)^d P_t = \theta(L)\varepsilon_t \quad (5)$$

Where d is the dth difference operator.

Autoregressive Integrated Moving Average With Exogenous Variable

To further enhance the forecasting accuracy, we introduced an exogenous variable, i.e., the cultivated area, into the ARIMA framework to construct the ARIMAX model. The optimal ARIMA orders and the impact of the exogenous variable were evaluated through model selection criteria, such as Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC).

The result of this model covers the advantages of both regression and ARIMA models. The regression method describes the dependency on the explanatory series while the ARIMA method takes care of the autocorrelation in the series itself. i.e.

$$\emptyset(L)(1-L)^d P_t = \beta(L)A_t + (L)\varepsilon_t \quad (6)$$

where β(L) is the function that allows A_t to influence P_t via a distributed lag.

In time series modeling, forecast accuracy is crucial (Anusha *et al.,* 2020). Models with smaller AIC and BIC values are better for forecasting. The model with the lowest AIC or BIC should be selected for future predictions.

RESULTS AND DISCUSSION

Exploratory Data Analysis and Correlation

There is a remarkable correlation between the temporal trends and fluctuations in the production and cultivation area series as seen in the comparative analysis of Figures 2 and 3. Thus, the use of area variables in the modeling of production series may prove useful.

There is a highly significant correlation coefficient of 0.897915 (t-value: 10.6 and p-value <0.001) between the production series and the area series.

Simulating Future Cultivation Area For Forecasting

The goal of this study is to forecast pineapple cultivation in Manipur, from 2022-23 to 2031-32, incorporating the anticipated

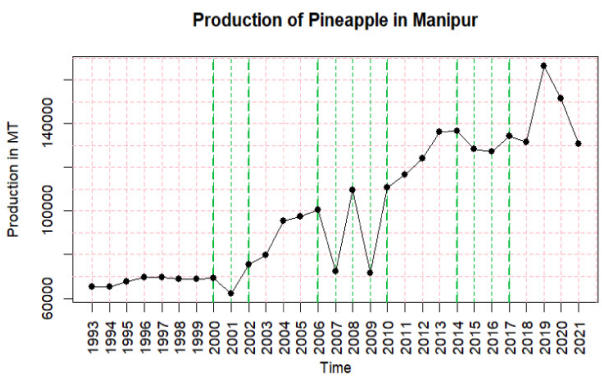

Figure 2. Time plot of Production series

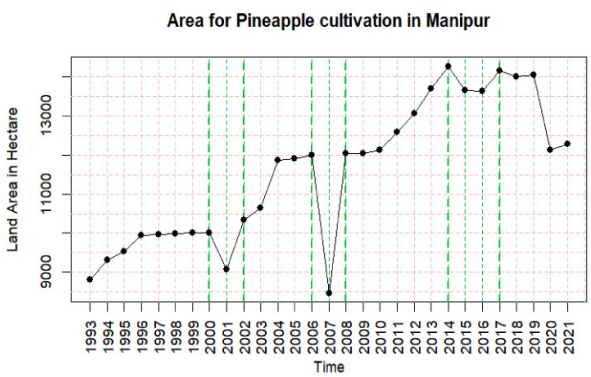

Figure 3. Time plot of Area series

impact of recent turmoil using scenario-based simulated cultivation area series. For the period 2023-24 to 2026-27, the area series was generated at 40%, 50%, 60%, and 70% from the 2021-22 baseline. Anticipating the impact of the turmoil to end by 2026-27; the area series for the remaining years is allowed to fluctuate by up to ±5% relative to the 2021-22 baseline, capturing the variability and unpredictability of agriculture and historical trends. However, this generated series is used exclusively for scenario-based forecasting and is not used in the training process. The selection of models and training process are solely based on the actual data available from the year 1993-94 to 2021-22.

Regression Model

Three candidate models Model 1: Production ~ Area; Model 2: Production ~ Area + Time; and Model 3: Production ~ Area + Time + Time^2 were evaluated for autocorrelation in the residual using the Durbin-Watson and Ljung-Box tests at a 5% significance level. While both Model 2 and Model 3 passed the Ljung-Box test, Model 2 exhibited borderline autocorrelation according to the Durbin-Watson test (p-value = 0.0748). To prioritize model stability and explanatory power, the adjusted R-squared values of the two models were compared. Model 3 demonstrated a superior fit (adjusted R-squared = 0.9068) compared to Model 2 (adjusted R-squared = 0.8812), justifying its selection for further analysis. This choice prioritizes a model with a stronger explanatory power for the data. The test statistics and corresponding p-values are provided in Table 2.

Table 3 shows that an increase in cultivation area correlates with an increased pineapple production, a statistically significant correlation at a high confidence level *(p-value = 0.000199)*. Moreover, the quadratic time component ("time^2") contributes a coefficient estimate of 8.26E+01, signifying a nonlinear relationship between time and pineapple production.

A t-value of 2.853 and a p-value of 0.008578 validate the statistical significance of this quadratic effect. The model fits well, showing an R-squared value of 0.9168

Table 2. p-values for DW and Ljung Box tests for residuals

S. No.	Model_Name	DW Test p-value	Box Test p-value	Adj. R^2	Remarks
1	Model 1	0.003866	0.027304	0.799076	Rejected
2	Model 2	0.074772	0.323902	0.881217	Rejected
3	Model 3	0.357693	0.736689	0.906802	Selected

Table 3. Estimated Regression Coefficients for pineapple production

S. No.	Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	Sig	R^2	Adj. R^2
1	(Intercept)	3.29E+08	1.17E+08	2.82E+00	9.31E-03	**	0.9168	0.9068
2	Area	8.43E+00	1.94E+00	4.35E+00	1.99E-04	***		
3	time	-3.30E+05	1.16E+05	-2.84E+00	8.94E-03	**	F-statistic	p-value
4	time^2	8.26E+01	2.90E+01	2.85E+00	8.58E-03	**	91.81	1.26E-13

Sig. codes: (P > 0.05: ' '), (P d" 0.05 : '*'), (P d" 0.01 : '**'), (P d" 0.001 : '***')

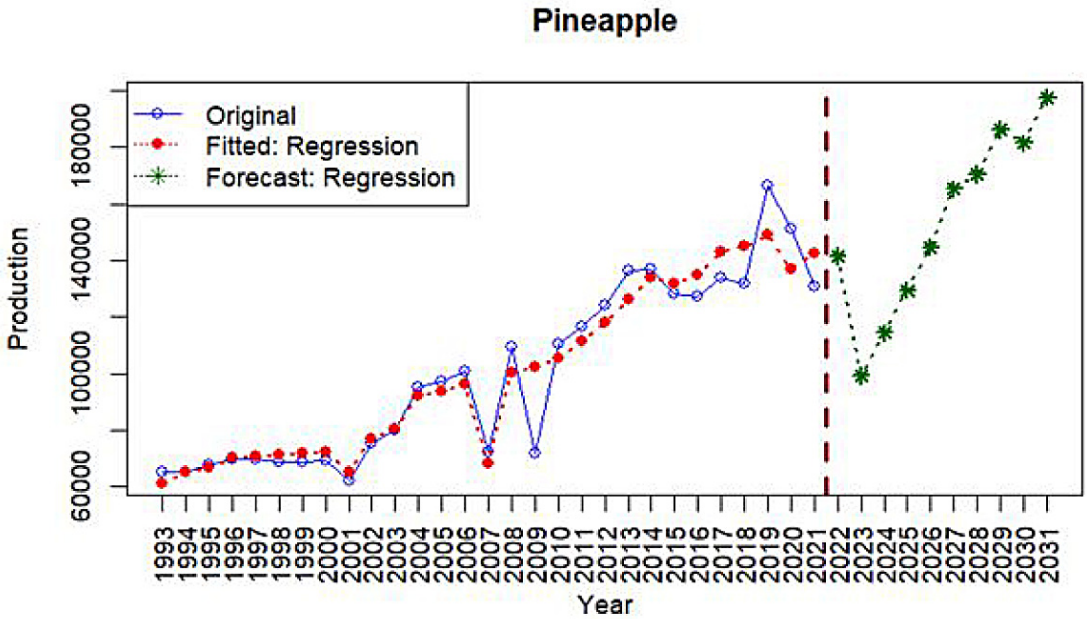

Fig. 4. Forecast with Regression Model

indicating that roughly 91.68% of the variability in pineapple production can be explained by the model. The adjusted R-squared value of 0.9068 reaffirms this explanatory power while considering model complexity.

In conclusion, this analysis highlights how the cultivation area variable/series and time factors impact pineapple production in Manipur. The cultivation area has a positive effect, and time, along with its quadratic component, helps explain how production changes over time. Putting it all together, these findings give us a better grasp of what influences pineapple production in the region. Fig. 4 displays the pineapple production forecast series derived from the regression model. The significant fall in the forecast for the year 2023-24 reveals the model's sensitivity to the "Area" covariate showing the model incorporated a substantial impact of the current situation in the State through the generated area series.

Autoregressove Integrated Moving Average (ARIMA) Model

Among the 6 candidate models described in the data pre-processing section and shown in annexure-2, ARIMA (0, 2, 2) is the best model having the lowest AIC (602.98) and BIC (606.86) values, indicating a balanced trade-off between model fit and complexity. ARIMA (0, 2, 2) was also used to forecast rice production (Mahajan *et al.*, 2020).The parameter estimates of the model are provided in Table 4. The ARIMA model, with an R-squared value of 0.8179, effectively captures

Table 4. Estimated Coefficients for ARIMA model for pineapple production

Sl. No.	Coefficients	Estimate	Std. Error	z-value	Pr(>|z|)	Sig	$\widehat{\sigma^2}$	log-likelihood
1	MA-1	-1.69238	0.34681	-4.8798	1.062e-06	***	201430937	-298.49
2	MA-2	0.69240	0.28224	2.4532	0.01416	*	R^2	$Adj.R^2$
							0.817921	0.811178
Sig. codes: (P > 0.05: ' '), (P ≤ 0.05 : '*'), (P ≤ 0.01 : '**'), (P ≤ 0.001 : '***')								

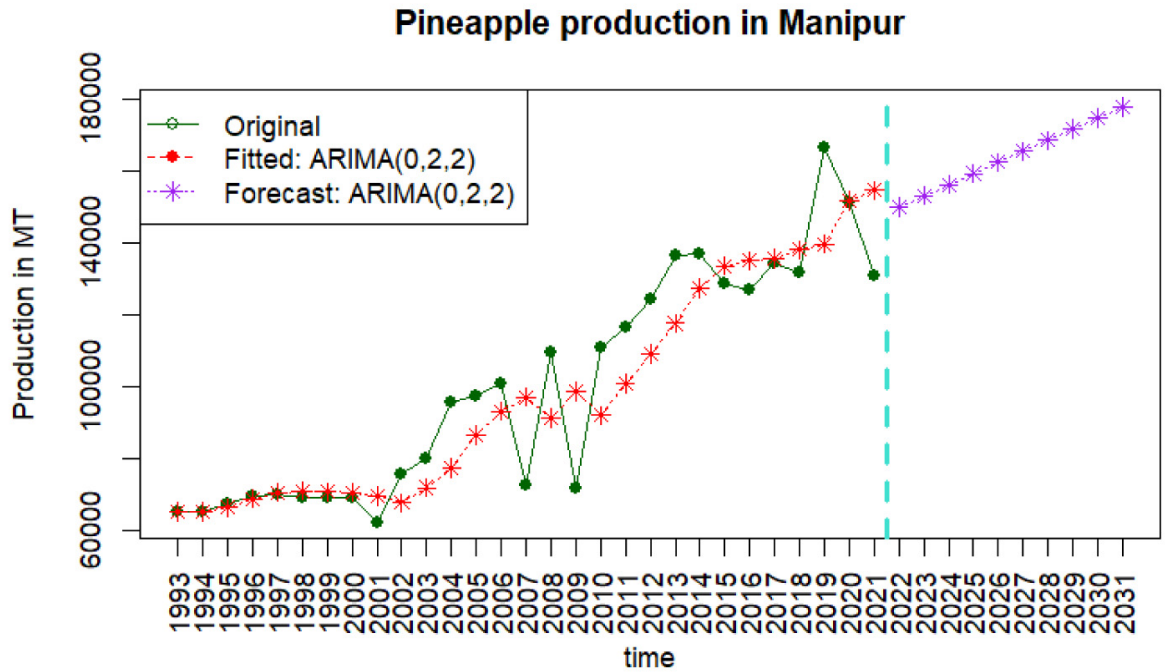

Fig. 5. Forecast with ARIMA Model

81.79% of the variance in Pineapple Production, showing a robust fit without overfitting, supported by the adjusted R^2 value (81.12%).

It highlights the importance of considering past prediction errors (MA terms) for accurate forecasting. Fig. 5 shows the forecast series of the ARIMA model employed. The model failed to account for the current turmoil's impact on pineapple production, resulting in an uninterrupted linear upward trend in the production forecast series, without reflecting any down turn as it did not involve area series.

Autoregressive Integrated Moving Average With Exogenous Variable

To account for the potential influence of changes in pineapple cultivation land area ('Area') in Manipur due to the ongoing turmoil, we incorporated this variable as a regressor in ARIMA to construct a robust ARIMAX (Autoregressive Integrated Moving Average with Exogenous Variables) model. Among the 6 candidate models described in the data pre-processing section and shown in appendix, ARIMAX (0, 2, 2) emerged as the most suitable model supported by its lowest AIC (Akaike Information Criterion) value of 590.8063 and BIC (Bayesian Information Criterion) value of 595.9897. These information criteria serve as valuable indicators of model performance, a balance between goodness of fit and model complexity. The parameters estimate for the ARIMAX (0, 2, 2) model are presented in Table No. 5. These estimates show the relationships between the lagged values of pineapple production, differencing, moving averages, and the exogenous variable 'Area'. Specifically, the coefficient estimates reveal the strength and direction of these relationships, providing information into how changes in 'Area' affect pineapple production while the auto-correlation is captured by the ARIMA components. The ARIMAX model, with an R^2 value of 0.8994612, effectively captures 89.95% of the variance in pineapple production, showing a robust fit without overfitting, supported by the adjusted

Table 5. Estimated Coefficients for ARIMAX model of pineapple production

Sl. No.	Coefficients	Estimate	Std. Error	z-value	Pr(>|z|)	Sig	$\widehat{\sigma^2}$	log-likelihood
1	MA-1	-1.93158	0.17164	-11.2539	< 2.2e-16	***	115858991	-291.4
2	MA-2	1.00000	0.17530	5.7046	1.166e-08	***	R^2	$Adj.R^2$
3	Area	8.07094	1.71652	4.7019	2.577e-06	***	0.8994612	0.8917275
Sig. codes: (P > 0.05: ' '), (P ≤ 0.05 : '*'), (P ≤ 0.01 : '**'), (P ≤ 0.001 : '***')								

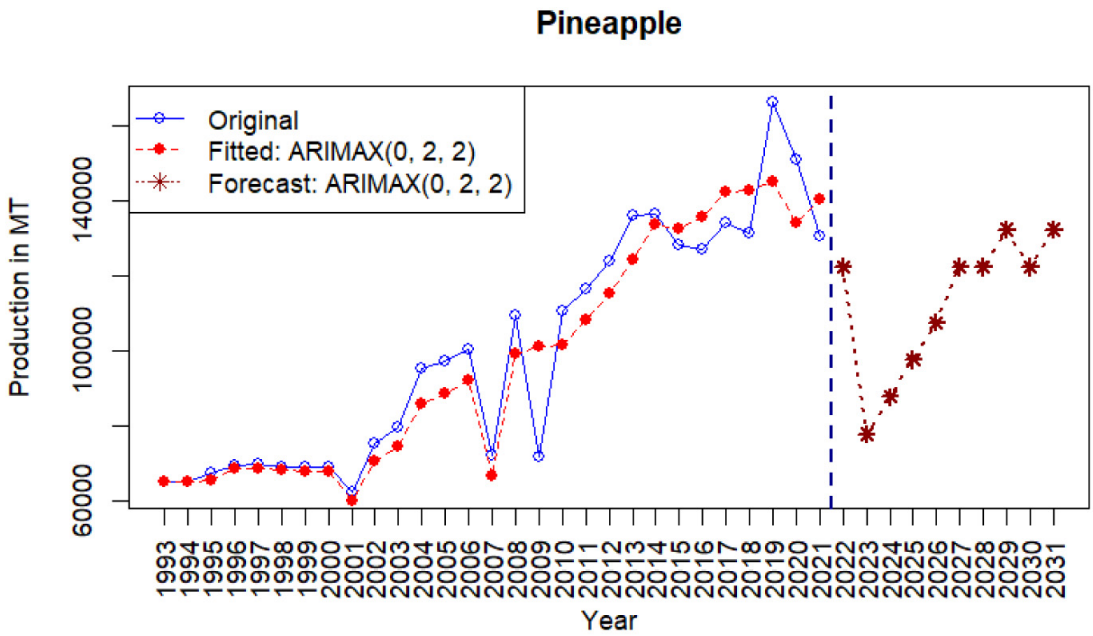

Fig. 6. Forecast of Pineapple Production with ARIMAX Model

Appendix-1

Table 6. Model evaluation using statistical metrics of various candidate models of Regression

Sl. No.	Model_Name	DW Test p-value	Box Test p-value	R^2	Adj. R^2	Remark
1	Model 1	0.003866	0.027304	0.8063	0.799076	Rejected
2	Model 2	0.074772	0.323902	0.8897	0.881217	Rejected
3	Model 3	0.357693	0.736689	0.9168	0.906802	Selected

Appendix-2

Table 7. Model evaluation using statistical metrics of various candidate models of ARIMA

Sl. No.	Order	R^2	Adj_R^2	MSE	RMSE	AIC	BIC
1	ARIMA(0,2,0)	0.1657	0.1945	795675986.11	28207.73	633.91	635.20
2	ARIMA(0,2,1)	0.7215	0.7215	265620101.32	16297.86	609.62	612.21
3	ARIMA(0,2,2)	0.8179	0.8112	173647359.87	13177.53	602.98	606.86
4	ARIMA(1,2,0)	0.6682	0.6682	316458324.56	17789.28	611.85	614.44
5	ARIMA(1,2,1)	0.8060	0.7988	185046203.35	13603.17	603.03	606.91
6	ARIMA(1,2,2)	0.8082	0.7935	182881326.52	13523.36	604.93	610.12

Appendix-3

Table 8. Model evaluation using statistical metrics of various candidate models of ARIMAX

Sl. No.	Order	R^2	Adj_R^2	MSE	RMSE	AIC	BIC
1	ARIMAX(0,2,0)	0.5774	0.5774	403063457.73	20076.44	617.55	620.14
2	ARIMAX(0,2,1)	0.8299	0.8236	162236249.27	12737.20	598.31	602.19
3	ARIMAX(0,2,2)	0.8995	0.8917	95883302.82	9792.00	590.81	595.99
4	ARIMAX(1,2,0)	0.7240	0.7138	263236093.61	16224.55	608.62	612.51
5	ARIMAX(1,2,1)	0.8555	0.8444	137826166.73	11739.94	596.75	601.94
6	ARIMAX(1,2,2)	0.8994	0.8873	95985952.07	9797.24	592.30	598.78

R-squared of 89.17%. Both MA terms (ma^1 and ma^2) are highly significant, as indicated by their very low p-values. Area covariate is also highly significant as indicated by the very low p-value of 2.577e-06. In conclusion, the ARIMAX (0, 2, 2) model, selected based on the AIC and BIC criteria, offers valuable information into the autocorrelation patterns of Manipur's pineapple production. It highlights the importance of considering past prediction errors (MA terms) and area covariates for realistic forecasting using scenario-based generated area covariates during turmoil in the State.

Figure 6 presents the pineapple production forecast series generated by the ARIMAX model.

As anticipated, a significant drop is evident in the forecast for the year 2023-24, aligning with the current state's challenges. This pattern closely resembles what was observed in the regression model, reaffirming the impact of variation in area of cultivation during the ongoing situation on pineapple production forecasts.

CONCLUSIONS

Regression, ARIMA and ARIMAX models were applied to the pineapple production series, revealing valuable insights into the factors influencing production. The regression model showed a strong positive correlation between pineapple production and cultivated land area (regression coefficient: 8.430, p-value <0.01) and a non-linear relationship with time (regression coefficient of time^2: 82.63, p-value <0.01), but it did not capture autocorrelation. The ARIMA (0,2,2) addressed autocorrelation effectively, identified by the lowest AIC (602.9771) and BIC (606.8646) values, and the highest Adjusted R^2 (81.12%). However, it failed to account for changes in the cultivation area as it lacked exogenous variables. The ARIMAX(0,2,2), incorporating the cultivated area as an exogenous variable, emerged as the optimal model with the lowest AIC (590.8063) and BIC (595.9897) values, and the highest Adjusted R^2 (89.17%), significantly improving the model's explanatory power by including the "Area" series.

In summary, the ability of the ARIMAX model to account for the impact of cultivation area makes it suitable for scenario-based forecasting. By simulating various cultivation area scenarios for the future, a realistic forecast for pineapple production can be provided and help farmers take precautions to mitigate risks or optimize their production strategies. In future work, additional exogenous variables, such as climate conditions and agricultural practices will be explored to further enhance the understanding of external factors affecting pineapple production.

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CALL OF PROSPERITY: FARMERS' ATTITUDE AND SUCCESS FROM THE KISAN CALL CENTRE IN ASSAM

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In an effort to close the gap between the needs of farmers and the distribution of agricultural information, this study examines how farmers perceive the advice offered by Kisan Call Centres (KCCs). KCCs are vital sources that provide knowledge on different farming techniques, professional counsel, and agricultural guidance. However, enhancing the efficacy of agricultural extension services requires an understanding of how farmers interpret and apply these advisories. The study uses a mixed-methods approach, including surveys and in-depth interviews with 100 farmers from the State of Assam, representing a heterogeneous sample. The findings show a range of opinions, impacted by variables *viz.*, age, education, landholding, experience and annual income. The study shows 41 % of respondents were under 30 years old, with 68 % depending on farming and 61 % holding 7.6-15 bighas of land. Farmers appreciated KCC's quick responses, especially for weather forecasts, but noted issues with insufficient information, pest symptom descriptions, and long wait times. Age, experience, landholding, and income positively correlated with favourable attitudes towards KCC, while education had a negative impact.

Keywords: Advisory services, Assam, attitude, farmers, Information and Communication Technology (ICT), Kisan Call Centre (KCC)

INTRODUCTION

Agriculture is the primary source of income for rural residents in emerging nations, accounting for 18.8 per cent of India's GDP (Ministry of Finance, 2021). Since the Green Revolution, customers have demanded modern agricultural technologies, leading to the development of extension operations to assist farmers, farm women, and rural youth in achieving social, psychological, and economic empowerment. Information and communication technologies (ICTs) have seen significant progress and revolution, facilitating electronic information retrieval, exchange, manipulation, and transmission. Recent advances in ICT, have fostered an environment conducive to the dissemination of cutting-edge agricultural technology (Manjuprakash *et al.,* 2020).

E-Agriculture, a relatively new field of extension research, has the potential to improve and transform the agricultural industry, with scientists, farmers, and extension agents as the three key pillars. India has a history of using ICT to fulfil farmers' needs by providing necessary information at the right moment (Rao, 2006 and Rao, 2008). Projects such as the Gyandoot Project, e-Choupal, and the Village Information Centre (VIC) have been

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developed to address farmers' challenges. Mobile money transfers, also known as m-money, have been introduced by mobile phone providers to address "missing markets" that may hinder the adoption of new technologies (Foster and Rosenzweig, 2010). Voice and SMS are used to collect information on farmers' adoption, yields, and costs more frequently than annual agricultural surveys (Dillon, 2011; Duflo and Hanna, 2007).

Over 35 per cent of ICT-based projects provide farmers with market updates via SMS, radio, or the Internet. The Ministry of Agriculture launched the "Kisan Call Centres (KCCs)" program in 2004 to utilize ICT in agriculture (Ali and Kumar 2011). The KCC call escalation process consists of three levels: Level I, Level II, and Level III. Level I operators answer farmers' calls and record basic information. Level II consists of Subject Matter Specialists (SMS) at Agricultural Colleges, Research Stations, KVKs, and ATIC, Level III consist of experts. If experts are unable to answer, a mechanism is in place to contact farmers again within 72 hours (Ministry of Agriculture, 2014).

Scope and importance of the study

The present study emphasises how crucial the Kisan Call Centre is to the farming community's ability to get need-based services in their native tongue. The effectiveness and efficiency of KCC in responding to and resolving the questions and problems, respectively, are also highly valued in this study. The study's conclusions include information on how Assam's farmers feel about Kisan Call Centre advisory services, as well as information on how successful and efficient they are in addition to offering reliable solutions.

Kisan Call is addressing the issues of ignorance and adopting best practices in producing, growing and marketing through intervention and the appropriate use of ICT tools. The research findings will make it easier to come up with ideas for how to make KCC operations and services more efficient. The conclusions about the limitations and recommendations will have policy implications.

METERIAL AND METHODS

The current study employed an *ex-post-facto* research design. A mixed-methods approach is used in the research, incorporating focus group discussions, interviews, and surveys. To find out how farmers in Assam feel about using the Kisan Call Centre, a structured survey was administered to 100 of the benefited farmers. Qualitative observations were obtained through in-depth interviews conducted with farmers, agricultural specialists, and KCC operators. Furthermore, focus group discussions enabled a more thorough investigation of community viewpoints. Both quantitative and qualitative approaches, such as statistical tools, were used in data analysis. This thorough approach seeks to provide a nuanced picture of farmers' attitudes on KCCs' recommendations for improving Assam's farmers' sustainable lives.

RESULTS AND DISCUSSION

The study reveals that 41 per cent of respondents were young, aged below 30 years, with the older generation being the next contributing factor. Elderly farmers, who are traditionalists, seek assistance from friends and other farmers rather than using the KCC's advisory services. Over 28 per cent of farmers were in the middle age range (31 to 45 years old), with an increased interest in using advisory services to stay current on newest technologies and agricultural techniques. After completing their Higher Secondary education, nearly two-fifths (39.00 %) of the beneficiaries stopped their formal education and pursued a career in agriculture. The majority of beneficiaries were literate, emphasizing the

Table 1. Distribution of respondents according to their profile.

Sl No	Profile	Frequency	Percentage (%)
I	**Age (in years)**		
1	< 30	41	41.00
2	31 – 45	28	28.00
3	> 45	31	31.00
		100	**100.00**
II	**Education**		
1	Primary	4	4.00
2	Secondary	27	27.00
3	Higher Secondary	39	39.00
4	Graduate	30	30.00
		100	**100.00**
III	**Occupation**		
1	Farming only	68	68.00
2	Farming + Business	30	30.00
3	Farming + Service	2	2.00
		100	**100.00**
IV	**Experience (in years)**		
1	< 10	29	29.00
2	11 – 20	51	51.00
3	>20	20	20.00
		100	**100.00**
V	**Land Holding (in Bigha)**		
1	< 7.5	28	28.00
2	7.6 – 15	61	61.00
3	> 15	11	11.00
		100	**100.00**
VI	**Annual Income (in Rupees)**		
1	< 50,000	31	31.00
2	50,001 – 1,00,000	60	60.00
3	> 1,00,000	9	9.00
	Total	**100**	**100.00**

Table 2. Distribution of the beneficiaries according to their attitude towards the services of KCC

Sl.No	Statements	SA	A	CS	D	SD	Mean Score	Rank
I	**Service of the KCC Advisories**							
1	KCC offers advice on a variety of topics related to agriculture and related industries.	58	25	15	1	1	4.38	II
2	KCC helps farmers get their questions answered more quickly.	68	15	10	3	4	4.4	I
3	KCC doesn't spread knowledge about schemes related to agriculture and related fields.	31	10	20	13	26	2.93	IV
4	Through its advice services, KCC has assisted farmers in improving their financial circumstances.	51	15	13	13	8	3.88	III
II	**Feedback of the KCC Advisories**							
1	KCC receives farmers' feedback more quickly than other traditional techniques.	54	33	8	3	2	4.34	IV
2	To benefit from KCC's agro-advisory services, farmers must be made aware of the benefits.	56	32	7	2	3	4.36	III
3	KCC agents answer farmers' queries in a kind and helpful manner.	69	23	5	1	2	4.56	I
4	Farmers get benefit from KCC advisories without requiring to be educated.	61	28	5	3	3	4.41	II
5	KCC does not offer relevant and up-to-date data in response to the inquiries.	50	19	10	9	12	2.14	V
III	**Crop Management Advisory Services**							
1	KCC helps farmers improve crop yields.	42	28	13	7	10	3.85	IV
2	KCC suggests a solution without examining the symptoms thoroughly.	38	21	17	9	15	2.42	V
3	KCC advisories helped implementing effective plant protection measures.	51	28	12	4	5	4.16	II

Sl.No	Statements	SA	A	CS	D	SD	Mean Score	Rank
4	KCC's practical advises encourage farmers to implement them on their farms.	54	29	14	2	1	4.33	I
5	Finding difficulty connecting with KCC and discussing diseases over the phone.	48	25	16	6	5	4.05	III
III	**Marketing Advisory Services**							
1	KCC's market intelligence lacks accurate supply and demand analysis.	41	24	12	11	12	2.29	IV
2	KCC advisories provide current prices for commodities in several marketplaces.	68	20	9	2	1	4.52	I
3	Farmers can't rely on KCC for marketing-related information.	39	20	13	12	16	2.46	III
4	KCCs support farmers in linking to regulated markets.	61	21	11	4	3	4.33	II
IV	**Weather Advisory Services**							
1	KCC weather forecasting have saved my crops and increased productivity under bad conditions.	59	22	14	3	2	4.33	I
2	KCC provides possibilities depending on weather conditions.	56	25	12	4	3	4.27	II
3	KCC's recommended contingency crops have provided revenue even when the primary crop fails due to bad weather conditions.	47	20	17	7	9	3.89	III
4	KCC does not accurately estimate weather conditions in advance.	11	13	11	31	34	3.64	IV

*SA= Strongly Agree (5), A= Agree (4), CS= Can't Say (3), D= Disagree (2), SD= Strongly Disagree (1)

need for additional educational initiatives in the region. The vast majority (68.0 %) were solely farmers, with 30 per cent in business and farming, possibly due to their relatives' centuries-old traditions or the family's needs not being met by agriculture alone.

The respondents had between 11 and 20 years of experience in farming, reflecting

their involvement in agriculture and educational attainment. Over three-quarters (61.0 %) of the beneficiaries were small farmers with 7.6-15 bighas of land, as larger land holdings provide a larger financial foundation for farmers to experiment with new agricultural technologies. The majority of the beneficiaries earned between Rs. 50,001 and Rs. 1,000,000 annually, with 31.0 per cent making less than Rs 50,000 and 9 per cent making more than

Table 3. Statement wise knowledge level of farmers towards KCC Advisory services

Sl.No.	Statements	Yes		No		Rank
		F	P (%)	F	P (%)	
1	1551 serves as a toll-free number for KCC.	99	99.00	1	1.00	I
2	KCC offers a free advisory service.	97	97.00	3	3.00	II
3	KCC intends to provide farmers with solutions in their native language.	97	97.00	3	3.00	III
4	KCC provides all agriculture-related information.	92	92.00	8	8.00	IV
5	KCC's advising services do not need travel.	90	90.00	10	10.00	V
6	KCC gives knowledge on marketing and post-harvest technology.	89	89.00	11	11.00	VI
7	If the issues cannot be resolved immediately, KCC delivers a remedy within 48 hours of receiving the call.	86	86.00	14	14.00	VII
8	KCC provides information on subsidies, loans, and financial assistance for agriculture and related sectors.	84	84.00	16	16.00	VIII
9	The KCC is a scheme of the Indian government.	80	80.00	20	20.00	IX
10	Agricultural graduates or post graduates and experienced professionals give agriculture-related information.	78	78.00	22	22.00	X
11	The KCC online support is available between 6:00 a.m. and 10:00 p.m.	77	77.00	23	23.00	XI
12	KCC is located in Guwahati, Assam.	73	73.00	27	27.00	XII
13	KCC meets farmers' needs by promptly responding to their calls.	71	71.00	29	29.00	XIII
14	KCC offers SMS facility to farmers.	62	62.00	38	38.00	XIV
15	KCC offers a conference call facility.	51	51.00	49	49.00	XV

*F = Frequency, P = Percentage

Table 4. Relationship between the farmers' profile with their attitude towards use of Kisan Call Centre

(n = 100)

Sl No	Independent Variables	Correlation Coefficient ('r' value)
X_1	Age	0.468**
X_2	Education	-0.391**
X_3	Occupation	-0.137^{NS}
X_4	Experience (in Years)	0.433**
X_5	Landholding (in Bigha)	0.547**
X_6	Annual Income (in Rs)	0.553**

**Significant at 0.01 level, NS: Non significant

Rs 1,00,000. This could be due to the majority of beneficiaries being literate and having completed secondary education.

The KCC, a government agency, has been praised for its quick response to farmers' queries, particularly in horticulture, animal husbandry, and weather forecasting. However, 31 per cent of beneficiaries felt that the centre did not create awareness of agricultural schemes. Most farmers found KCC officials friendly and cordial, and 61 per cent believed that farmers don't need to be educated to benefit from their advisories. Over half of beneficiaries agreed that KCC's response is faster than traditional approaches, but 50 per cent felt they provided insufficient information. The KCC's crop management services were found useful, with 51 per cent implementing appropriate plant protection measures. However, 48 per cent struggled to explain pest and disease symptoms over the phone due to lack of education at the PUC level. About 68 per cent of farmers believe KCC advisories help them learn agricultural product prices and connect to regulated markets. However, 41 per cent disagreed that the information provided by KCC is not grounded in a sound supply and demand analysis. The KCC's weather advisories have significantly impacted farmers' attitudes, with 59 per cent stated that they have saved their crops and increased productivity under bad conditions.

Table 3 shows that 99 per cent of farmers were aware of the KCC's toll-free number (1551), its free advisory service, all agricultural information, and the fact that traveling is not necessary for using its services. About 77 per cent of the beneficiaries were aware of the KCC's working hours and 73 per cent were aware about the location of the KCC, which is in Guwahati, Assam. However, the remaining 27 per cent were unaware of the KCC's location. 71 per cent of respondents were aware of KCC's response time to calls and SMS services. This may be due to the KCC's initial focus on advisory services and later expanding its offerings to include SMS facility. Only 51 per cent of respondents were aware of the KCC's conference call facility. This may be due to the organization's three tiers, where experts answer questions from farmers at each level. The majority of questions are answered and resolved at the centre level, so it wasn't necessary to put the farmers' phone on hold or use conference mode to move to the next level.

The data presented in Table 4 clearly reveals that Age (0.468**), Experience (0.433**), Landholding (0.547**), and Annual

Income (0.553**) were positively and significantly correlated at 0.01 level of probability with the attitude of farmers towards Kisan Call Centre. Education (-0.391**) was found negatively and significantly correlated with the attitude of respondents towards use of Kisan Call Centre. Only Occupation (-0.137^{NS}) had negative non-significant contribution towards the attitude of use of KCC by the farmers. The results presented by Goswami (2012), Lal (2012), Patel *et al.* (2018), and Vinaya Kumar *et al.* (2018) were in accordance with these findings.

CONCLUSIONS

The study reveals that, farmers have commended the KCC, a government body, for their prompt response to their inquiries, especially about weather forecasts, animal husbandry, and horticulture. However, according to 31 per cent of beneficiaries, the centre did not raise the public's awareness of agricultural initiatives. The majority of farmers thought that KCC officials were pleasant and generous, and 61 per cent claimed that farmers could use their advice without having to be taught. Although more than half of the recipients said KCC responded more quickly than other methods, 50 per cent thought they didn't give enough information. Although the KCC's crop management services were deemed beneficial, 48 per cent of respondents found it difficult to describe pest and disease symptoms over the phone because of a lack of PUC-level knowledge. The majority of respondents had a somewhat positive attitude towards KCC advisories, suggesting improvements in expert efficacy and efficiency. Staff numbers could be increased during peak seasons and months. Long wait times on the KCC landline are a major issue. Age, experience, landholding and annual income positively correlate with farmers' attitudes towards Kisan Call Centre, while education negatively affects attitudes, and occupation negatively impacts KCC usage. The research results will benefit policy makers, governmental agencies, development planners, and other non-governmental organizations supporting ICT initiatives to close the digital divide.

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ADOPTION OF RECOMMENDED BENGALGRAM PRODUCTION TECHNOLOGIES IN GUNTUR DISTRICT OF ANDHRA PRADESH

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ABSTRACT

During the year 2022-23, the Extension Department of RARS, Lam, Guntur conducted a study to analyse the extent adoption of recommended production technologies among Bengalgram farmers in Guntur district. A sample of one hundred Bengalgram farmers was surveyed. All surveyed farmers adhered to recommendations regarding varieties, soils, and harvesting practices. The survey revealed that 75.00 per cent of farmers adopted water management practices, while 69.00 per cent and 63.00 per cent adopted weed and disease management practices, respectively. However, a significant majority of farmers were not adopting recommendations for fertilizer management (92.00%), seed rate (82.00%), seed treatment (78.00%), spacing (75.00%), sowing time (68.00%), and insect management (59.00%). Regarding constraints faced by Bengalgram farmers, a large majority reported issues such as untimely seed supply (83.00%), dry root rot/wilt incidence (71.00%), increased cost of cultivation and lower MSP (69.00%), lack of government procurement (65.00%), challenges in weed management (56.00%) and labor scarcity during weeding and harvesting (51.00%). Significant relationships between the adoption of recommended production technologies and factors such as education, extension contact and trainings undergone of the farmers were found. Land holding, farming experience, economic motivation, social participation and risk orientation of farmers did not exhibit a significant relationship with adoption of Bengalgram production technology.

Keywords: Adoption, Recommended production technology, Bengalgram, constraints, correlation

INTRODUCTION

Bengalgram is the world's third most important food legume with 96% cultivation in developing countries. It is the major pulse in India which occupies about 35 per cent of area of pulses (Ramalakshmi Devi *et al.*, 2023). India is the largest producer of world gram followed by Australia, Myanmar and Ethiopia (FAO 2019). India contributes 70 per cent of total world Bengalgram production of 116.2 lakh tonnes cultivated in 112 lakh hectares with productivity of 1036 kg/ha in 2020-21. Andhra Pradesh produces 5.32 lakh tonnes in an area of 4.69 lakh hectares with 1136 kg/ha productivity in 2020-21 (ANGRAU Bengalgram Outlook Report, 2021). Andhra Pradesh accounts for 4.43 per cent of India's Bengalgram production. According to 2nd advance estimates during 2021-22, Bengalgram was grown in 4.45 lakh hectares with a production of 5.05 lakh tonnes and productivity was 1135 kg/ha. In Guntur district,

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Bengalgram is cultivated in 17,000 ha with a production of 28,000 tonnes and productivity 1684 kg/ha (2nd highest productivity in the state of Andhra Pradesh) (ANGRAU Bengalgram Outlook Report-January to December 2021).

In view of significant area under Bengalgram cultivation in Guntur district, efforts were undertaken by the Extension Department of the Regional Agricultural Research Station, Lam, Acharya N.G. Ranga Agricultural University for transfer of production technology during the 2022-23 period. Hence, the study aimed to assess the adoption of ANGRAU recommended Bengalgram production technologies among farmers in Guntur district, identify reasons for non-adoption, explore the relationship between farmers' socio-economic and psychological characteristics and their adoption behaviour, and pinpoint constraints in production.

MATERIAL AND METHODS

The Extension Department of the Regional Agricultural Research Station in Lam, Guntur conducted an investigation utilizing an *ex post facto* research design during the year 2022-2023. A multi-stage sampling procedure was followed to select the sample for the study. Initially, five mandals with the highest Bengalgram cultivation areas were purposively chosen. Subsequently, within each selected mandal, two villages with the highest Bengalgram cultivation areas were purposively identified. From each village, 10 farmers were randomly selected, resulting in a total sample size of 100 Bengalgram cultivating farmers. Data collection was carried out through in-person interviews. The collected data were then tabulated and analysed using various statistical tools including frequency analysis, percentage calculations, rankings, and correlation analysis. These analytical methods were utilized to derive comprehensive results and draw meaningful conclusions from the study findings.

To analyse extent of adoption of Bengalgram production technology package of practices recommended by the Acharya NG Ranga Agricultural University were considered. (Table 1). Adoption was assessed concerning various aspects including recommended variety, sowing time, suitable soils, seed rate, spacing, seed treatment, water management, fertilizer management, weed management, insect and disease management, and post-harvest management. Instances of significant deviation from recommended practices were noted, and respondents were queried about reasons for non-adoption, responses were tabulated using frequencies and percentages. Correlation analysis was conducted to explore the relationship between farmers' personal, socio-economic, and psychological characteristics and their adoption of the recommended package of practices. Additionally, to identify prominent constraints in Bengalgram cultivation, farmers were asked open-ended questions, and their responses were categorized and tabulated using frequency and percentage analysis.

RESULTS AND DISCUSSION

Adoption pattern of recommended Bengalgram production technologies by the farmers. The data (Table.1) indicates that all farmers surveyed adhered to recommendations regarding varieties, soils and harvesting. The results clearly indicated that all the respondents were very well aware of high yielding recommended varieties and suitable soils for Bengalgram cultivation. The majority of farmers were found to be adopting water management (75.00%), weed management (69.00%), and disease management (63.00%) practices. Even with respect to critical stages of irrigation for increased yields, effective control of weed at initial stages with pre-emergence herbicide application and using Trichoderma for effective

wilt and root rot management were very well acquainted by the sample farmers. However, a significant majority of farmers were not following recommendations regarding fertilizer management (92.00%), seed rate (82.00%), seed treatment (78.00%), spacing (75.00%), sowing time (68.00%) and pest management (59.00%). Majority of the farmers with their assumption of poor soil fertility were using more complex fertilizers even after 30 days after sowing. Seed rate was another aspect where farmers were going for more than the recommended dose due to various reasons like using own seed continuously, severe incidence of wilt and root rot diseases. Seed treatment was another neglected aspect due to lack of awareness. Ramalakshmi Devi *et al.* (2023) reported an eighty percent gap in seed rate adoption, consistent with our findings. Similar conclusions regarding seed rate and fertilizer use were also drawn by Brunda *et al.* (2019). Nidhi Sharma *et al.* (2020) reported a high adoption rate of 97% regarding sowing time, which contrasts with the findings of the study. This discrepancy could be attributed to the prevailing climatic conditions in the study area, where delayed rains might have influenced farmers' decisions differently.

Reasons for non-adoption of ANGRAU recommended Bengalgram package of practices

Table 2 elucidates the reasons behind the non-adoption of the recommended Bengalgram package of practices by farmers.

Seed rate: Reasons for non-adoptionwere poor seed germination (80.00%), wilt and dry root rot (78.00%), with the fallacy of lower seed rate results in lower yields (72.00%), to avoid weed growth at early stages (53.00%), delayed seed supply by the government (45.00%), and low soil fertility (26.00%). The majority of farmers were found to be using their own seeds from previous seasons for an extended period, leading to poor germination percentage. Additionally, wilt and root rot problems resulted in plant mortality, prompting farmers to use more seed rate than recommended. Therefore, there is a pressing need to introduce wilt and root rot resistant varieties and ensure the availability of such seeds locally through the state department of agriculture.

Seed treatment: Approximately three-quarters of Bengalgram farmers were not adopting seed treatment, with the presumption that they were already using treated seeds. Sixty-eight percent of the respondents lacked confidence in the practice, while labor issues (51.00%) and difficulties in implementing it in larger areas (50.00%) were also cited as reasons for non-adoption. Non-adoption of seed treatment increased the occurrence of wilt and root rot diseases, ultimately leading to use of two to three times more seed rate than recommended, by the farmers. These results are consistent with the findings of Nidhi Sharma *et al.* (2020).

Spacing: Seventy one percent of the farmers cited using a higher seed rate than recommended as the sole reason for maintaining close spacing between plants, which in turn facilitates the spread of diseases.

Fertilizer management: The primary reason for non-adoption of recommended fertilizers in Bengalgram cultivation was a lack of awareness regarding the correct recommendations (81.00%), followed by non-availability of Farm Yard Manure (FYM) (73.00%), poor soil fertility (60.00%), lack of confidence (44.00%), and influence from neighbouring farmers (29.00%). Farmers were using nearly double the recommended dose of fertilizers, particularly chemical fertilizers in complex form, applying them one month after sowing instead of the recommended basal application of 8 kg N, 20 kg P, and 20 kg Zn.

Pest management: Fifty-seven per cent of farmers cited a lack of awareness about recommended chemicals as the primary reason for deviating from recommended pest management practices. Additionally, almost fifty per cent mentioned the influence of dealers and neighbouring farmers as a factor for non-adoption of pest management recommendations. Majority of farmers were neglecting Integrated Pest Management (IPM) practices such as timely sowing, summer ploughing, intercropping, border crops, trap crops, using bird perches, bio-control measures, and neem oil use at the time of egg laying as recommended. Instead, they relied solely on chemical management of insects, leading to insecticide resistance and the indiscriminate use of high doses of insecticides.

Ramalakshmi Devi *et al.* (2023) also reported that using high seed rate was the reason expressed by the eighty per cent of respondents for deviation in adoption of recommended spacing. Regarding fertilizer management she reported that farmers were using more chemical fertilizers than recommended with the expectation of getting more yields. She found lack of awareness, delayed sowing, more labour requirement for adoption of IPM practices were some of the reasons for the non-adoption of recommended pest management.

Constraints experienced by the farmers in Bengalgram cultivation

Great majority of Bengalgram farmers expressed untimely seed supply (83.00%), dry root rot/wilt (71.00%), increased cost of cultivation and lower Minimum Support Prices (69.00%), non-procurement of produce by the Govt. agencies (65.00%), weed management (56.00%) and labour scarcity at the time of weeding /harvesting (51.00%). Below fifty per cent of the farmers felt untimely excess rains (48.00%), moisture stress (40.00%), rejection of high moisture content seed at the time of procurement (39.00%) and incidence of *Helicoverpa* (36.00%). The constraint analysis clearly emphasized the interrelation between the non-adoption of recommended practices and the consequent effects on cultivation. Due to the failure of timely seed supply by government agencies, farmers were compelled to use their own seed for several years, which led to use of higher seed rates due to fears of poor germination and the to maintain optimal plant stand. Most of the farmers identified weed management during the crop stage as a major constraint, as there was no recommended post-emergence herbicide for broad leaved weeds. Farmers faced two extremes regarding rainfall: delayed monsoons led to delayed sowing and moisture stress, significantly reducing yields, while untimely excess rains negatively affected the germination and growth of the Bengal gram crop. Surat Singh *et al*. (2015) reported low market price, problem of insect, pest and disease, crop damage due to unfavourable weather conditions and incidence of weeds were the major constraints in Bengalgram cultivation. Non-availability of inputs at the proper time, high incidence of Fungal diseases, inadequate MSP and delay in Govt. procurement on MSP were the some of the major constraints expressed by Saurabh *et. al*. (2023) in their study on “Constraint Faced by Chickpea Growers in Adoption of Recommended Chickpea Production Technology by VNMKV In Hingoli District of Maharashtra”.

Relationship between profile of Bengalgram Farmers with their Adoption

Analysis from Table 4 reveals significant relationships between education, extension contact and trainings undergone, and adoption of Bengalgram recommended prod uction technologies. Specifically, education showed a significant positive relationship at the 5% level of significance, while extension contact and trainings

Table 1. Adoption pattern of recommended production technology by the Bengalgram growers

n=100

S.No	Practice	ANGRAU recommendation	Adopted		Not Adopted	
			Frequency	%	Frequency	%
1.	Varieties	JG11, JAKI 9218, NBeG 3, NBeG 47, NBeG 49, NBeG 452, NBeG 857, NBeG 776, KAK 2, Vihar, MNK 1, NBeG 119	100	100.00	0	0.00
2	Sowing time	October 15 to November 15	32	32.00	68	68.00
3	Soils	Black soils	100	100.00	0	0.00
4	Seed rate (per acre)	Medium size seed-30-35kg Bold size seed-45-50 kg Extra bold size seed-60-70 kg	18	18.00	82	82.00
5	Seed trea-tment	carbendazim or captan or thiram @ 3g/kg or tebuconazole or vitavaxpower @1.5 g/kg seed	22	22.00	78	78.00
6	Spacing	30×10 cm	25	25.00	75	75.00
7	Fertilizer management per acre	8kg N, 20kg P and 20 kg Zn as basal	8	8.00	92	92.00
8	Weed management	Pendimethalin 1-1.2 ltwithin 24 hrs of sowing and intercultivation	69	69.00	31	31.00
9	Water management	Two light irrigations at 30-35 days after sowing and at grain hardening stages considering water availability enhances 15-20% yields	75	75.00	25	25.00
10	Pest management	Chlorpyriphos @ 2.5 ml/lt or emamectin benzoate @ 0.4 g/lt or renaxypyr @ 0.2 ml/lt for control of *Spodoptera exigua.*Chlorpyriphos 2.5 ml or quinolphos 2 ml or acephate 1 g per litre, in severe case, spray spinosad 0.35 ml or rynaxypyr 0.2 ml or indoxacarb @ 1 ml per litre for control of *helicoverpa* pod borer.	41	41.00	59	59.00
11	Disease management	Seed treatment and soil application of *Trichoderm*a for wilt and root rot	63	63.00	37	37.00
12	Harvesting	Yellowing of leaves and pods	100	100.00	0	0.00

Table 2 . Reasons for non-adoption of ANGRAU recommended package of practices by Bengalgram farmer

n=100

S.No	Technology recommendation	Reasons for Non-adoption	Frequency	%
1	Seed rate per acre	Poor germination due to own seed usage	80	80.00
		With wilt & Dry root rot incidence low plant density	78	78.00
		Misconception that low seed rate gives less yields	72	72.00
		To avoid weed at early stages high plant stand is needed	53	53.00
		Delayed seed supply by the Govt. forcing farmers to use their own seed continuously	45	45.00
		Low soil fertility resulting in low germination	26	26.00
		Insufficient rains affecting germination	19	19.00
2	Seed treatment	Believing that using treated seed only	73	73.00
		Lack of confidence on effectiveness of seed treatment	68	68.00
		Labour problem at the time sowing	51	51.00
		Not possible when cultivating in large area	50	50.00
		Lack of awareness on recommended chemicals	28	28.00
3	Spacing	Due to high seed rate inter row spacing is not possible	71	71.00
4	Fertilizer	Lack of awareness on exact recommendation	81	81.00
	management (8 kg N, 20 kg P	Non availability of FYM due to low animal population at villages	73	73.00
	and 20 kg Zn)	With an assumption of Poor soil fertility	60	60.00
		Lack of confidence on recommended doses	44	44.00
		Influence of neighbor farmers	29	29.00
5	Pest management (IPM for *Helicover* pa, For *Spodoptera exigua* either chlorpyriphos @ 2.5 ml/lt or acephate @ 1.0 g/lt	Lack of awareness on recommended chemical	57	57.00
		Dealers and neighbor farmers influence	48	48.00

Table 3 . Constraints experienced by the farmers in Bengalgram cultivation

n=100

S.No.	Constraint	Frequency	%
1.	Untimely seed supply by the Govt.	83	83.00
2.	Severe dry root rot/Wilt incidence	71	71.00
3	Increased cost of cultivation	69	69.00
4.	Lower MSP	69	69.00
5	No Procurement by the Government	65	65.00
6.	Weed management at later stages of crop growth	56	56.00
7	Labour scarcity at the time of weeding /harvesting	51	51.00
8	Untimely excess rains	48	48.00
9	Moisture stress at critical stages of crop period	45	45.00
10	Rust disease incidence	40	40.00
11	Due to high moisture in seed is rejected	39	39.00
12	Incidence of *Helicoverpa*	36	36.00

Table 4 . Relationship between profile of Bengalgram farmers with their Adoption

S.No.	Independent variable	Correlation co-efficient ('r')
1.	Education	0.211*
2.	Land holding	0.160NS
3	Farming experience	0.111NS
4	Economic motivation	0.129NS
5	Social participation	0.146NS
6	Extension contact	0.278**
7	Risk orientation	0.109NS
8 .	Trainings undergone	0.364**

* and ** indicate significance of values at p=0.05 (r value 0.205) and 0.01 (r value 0.267) respectively

demonstrated a highly significant positive relationship at 1% level of significance. Conversely, variables such as land holding, farming experience, economic motivation, social participation, and risk orientation did not exhibit any significant relationship with adoption.

Rajbhar *et al.* (2018) reported that extension contact and training exposure had a positive and significant association with adoption level of the respondents at 1% level of probability. These findings were consistent with those of Ramalakshmi Devi *et al.* (2023).

CONCLUSIONS

The findings from the study on Bengalgram cultivation in Guntur district highlight both strengths and weaknesses in the adoption of recommended production technology. All surveyed farmers adhered to recommendations regarding recommended varieties and certain management practices. However there were significant gaps in the adoption of certain other practices. Water management, weed management and disease management were areas where a majority of farmers were following recommendations,

indicating a positive trend in these aspects. However, there were notable deficiencies in fertilizer management, seed rate, seed treatment, spacing, sowing time, and pest management, with a significant majority of farmers not adhering to recommendations in these areas.The study also identified significant relationships between education, extension contact, and trainings undergone, and the adoption of recommended production technology. This underscores the importance of education and extension services in improving adoption rates among farmers. Moreover, major constraints identified by the most of Bengalgram farmers included untimely seed supply, dry root rot/wilt, increased cultivation costs coupled with lower Minimum Support Price (MSP), lack of procurement by government agencies, weed management challenges, and labor scarcity during weeding/ harvesting period. Addressing these constraints is crucial for enhancing Bengalgram cultivation practices and improving overall productivity and profitability for farmers in the region.

In conclusion, while there are areas of success in Bengalgram cultivation practices, there are significant challenges that need to be addressed through targeted interventions, education, and support services to reap higher productivity and production in Bengalgram cultivation in Guntur district of Andhra Pradesh.

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SCALE DEVELOPMENT FOR MEASURING THE FARMERS' ATTITUDE TOWARDS SUSTAINABLE AGRICULTURAL PRACTICES

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ABSTRACT

This study was conducted in Manipur in the year 2021-2022 to create an attitude scale for measuring of farmers' attitudes towards sustainable agricultural practices in the state. In the procedure of the scale construction, after editing and modifying the statements 68 statements were sent to 55 experts for relevancy test. Out of this 27 experts responded, and the statements with a relevancy percentage (>75), relevancy weightage (>0.75), and mean relevancy score (>2.30) were included in the analysis of item for the statement. Altogether, item analysis included 25 statements. The statements were allotted to 27 farmers from a non-sampling area to specify their degree of favourable and unfavourable of each statement on five continuum. Based on the criterion groups t value was calculated for each item, and statements were selected with a "t" value greater than or equal to 1.75. The final scale comprised of 13 statements among which 8 were positive and 5 were negative. Moreover, these statements demonstrated strong reliability and validity, supported by a correlation coefficient of 0.71, indicating their robustness. This validated instrument will be used to gauge farmers' attitudes towards adopting sustainable agricultural practices.

Keywords: Agriculture, attitude, farmers, Likert scale, Manipur and sustainable practices.

INTRODUCTION

Sustainable agriculture aims to reduce poverty, increase incomes, and enhance food security, particularly for 80% of the population residing in rural areas and relying on agriculture for their livelihoods (World Bank, 2023). Recognizing the diverse impacts of agriculture on the environment, it is important to ensure availability of sufficient food is not only the sole determinant of food security (Benton and Harwatt, 2022). Accessibility, utilization, and stability also play critical roles in achieving comprehensive food security (Rai *et al*., 2022). Sustainability, in this context, signifies the harmonious coexistence of the environment and human civilization. Given the intricate connections between the world economy, human societies, and biodiversity with agriculture, the concept of sustainable agriculture emphasizes adaptability across environmental, economic, and social dimensions (Biasutti and Frate 2017). Understanding the psychological dimensions influencing the adoption of sustainable farming practices is imperative for the successful

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transition to sustainable agriculture. According to (Serebrennikov *et al*., 2020) the significant impact of information source utilization towards attitudes of farmers on the adoption of organic farming. This emphasizes the need to address psychological factors for sustainable agriculture production. Cognitive factors, such as knowledge and beliefs are known to influence the adoption of sustainable practices. Farmers are more likely to embrace sustainable practices when they perceive them to bring environmental or financial benefits with low risks (Dessart *et al.,* 2019).

Attitude as a crucial psychological factor which plays a pivotal role in shaping an individual's decisions toward a specific object or idea. It affects how people think, so it has a foreseeable and influential effect on individual behaviour, which has the potential to predict someone's behaviour towards a certain object. Farmer attitudes toward sustainable agricultural practices, being the primary actors in technology adoption or rejection, are pivotal for the successful implementation of sustainable agriculture. As attitude influence the farmers behaviour (Gupta *et al*., 2022), farmers with favourable attitudes towards the idea increase the probability of adoption or effective application of the technology (Chandran *et al.,* 2023). Developing an instrument to measure the attitude becomes vital for obtaining valuable insights into farmers' behaviours and guiding efforts toward sustainable agricultural practices. As such, constructing an attitude scale in the field of sustainable agriculture serves as a valuable tool to assess and understand farmers' attitudes, contributing to the overall success and adoption of sustainable farming practices (Pandey *et al*., 2020). Measuring farmers' attitudes toward sustainability in agricultural production is essential for predicting behaviour, identifying barriers and tailoring effective communication strategies. Attitude scale helps allocate resources strategically, inform policy development and promote farmer engagement in decision-making processes. They serve as a baseline for monitoring changes over time, evaluating educational programs and fostering collaboration among stakeholders. Understanding farmers' attitudes is crucial for enhancing the effectiveness of interventions, and ensuring that initiatives are aligned with their perspectives, needs, and preferences. Attitude scale can assess the empowerment of farmers by acknowledging their ownership and commitment to sustainable practices, fostering a sense of responsibility. By actively involving farmers, policy makers can create more meaningful and impactful sustainability initiatives that address challenges and reinforce positive attitudes. The data from attitude scales contribute to evidence-based decision-making, allowing for targeted interventions that drive progress toward sustainability goals in agriculture (Chauhan *et al.,* 2017).

MATERIAL AND METHODS

The research was carried out in 2021-2022. To carry out the methodologies of scale construction, this study took place in Manipur, a north-eastern state of India. Likert summated rating scale(1932), commonly called the summated rating method or summated scale, was adopted in the study because this scale gives more detailed information by allowing respondents to provide responses to single-choice and close-ended questions at various levels of agreement, favorability, and disagreement for accurate insights about a subject. The validity of statements was measured by the expert's opinion through the relevancy test *i.e.* Relevancy percentage (RP), Relevancy Weightage (RW) and Mean Relevancy Score (MRS). Analysis of items was done in a non-sampled area pilot survey at the

Bishnupur district of Manipur for calculating the "t" value. The eventual scale was created using a "t" value (>1.75) criteria based on the Likert Scale. The reliability of the developed scale was measured by the test-retest method. The standardized procedure for constructing a scale to measure attitude is given below:

Items collection or collection of statements

The selection of statements or items is the first criterion in developing the Likert scale process. A statement can be considered an expression of ideas and thoughts that individuals can provide opinions or react to a certain point of view. Using these statements, the unseen cognitive behaviour of an individual can be drawn into a meaningfully seen behaviour of the individual. By following the rules of Likert scale construction, in the first criterion, a list of 93 statements, including 39 negative statements and 54 positive statements, was collected based on the idea of adoption of sustainable agriculture practices. Such statements were collected to express the desired behaviour by avoiding factual statements. Therefore, a total of 93 statements were generated by studying relevant literature and journals and discussing them with experts, extension educationists, and social scientists.

Editing of items or filtering of statements

Filtering a statement is a second criterion of scale creation process; it helps improve the quality of a statement by removing irrelevant and unrelated information from the subject being dealt with. In this step, the collected items were carefully edited based on 14 criteria proposed by Edwards (1957), and 93 statements were processed for refinement. After removing the ambiguous, lengthy, confusing, and double-negative statements, only 68 statements were selected. Out of these (60), negative (30) and positive (38) statements. Hence, only a total of 68 statements were involved in the subsequent stages.

Constructing the scale

Following the procedure of collection and editing of statements, the subsequent step carried out in the scale construction was the relevancy test.

Relevancy test

All the collected statements or items may not be significant to measure the attitude of farmers towards the adoption of sustainable agricultural practices. Therefore, 68 statements were sent to 55 experts with the request to inspect each statement and determine relevancy on a 3-point continuum, *i.e.* most relevant response (3 score), relevant response (2 score) and non-relevant response (1 score). The statements were judged by a panel of experts from research units of concern, university professors and from the extension education field. Out of the 55 experts, only 27 judges responded in 30 days. Following the feedback received from the experts, the statements were processed for further analysis. Relevancy score for each statement was calculated by aggregating the ratings from all 27 judges' responses. From these data three types of tests where RP (relevancy percentage), RW (relevancy weightage) and MRS (mean relevancy scores) were worked out for all the statements by using the following formula.

Relevancy Percentage (RP): To calculate the Relevancy Percentage, the overall score of the Most Relevant Response (MRR) and Relevant Response (RR) were changed into percentages using the following formula.

$$RP = \frac{SFS}{N} \times 100$$

Relevancy Weightage (RW): To calculate the Relevancy Weightage, the total score of Most relevant response (MRR), Relevant response (RR) and Not relevant response (NRR) were added and divided by the Maximum possible score (MPS). RW is obtained by applying the following formula

$$RW = \frac{MRR \times 3 + RR \times 2 + NRR \times 1}{MPS}$$

Mean Relevancy Score (MRS): To calculate the mean relevancy score the total sum of Most relevant response (MRR), Relevant response (RR) and Not relevant response (NRR) is divided by number of judges (N).

$$MRS = \frac{MRR \times 3 + RR \times 2 + NRR \times 11}{N}$$

Where;

SFS= Sum of Frequency Score of MRR and RR

MRR=Most relevant response (multiplied by 3)

RR= Relevant Response (multiplied by 2)

NRR= Not relevant response (multiplied by 1)

MPS= Maximum possible score (27×3=81)

N= Number of judges (27).

In the relevancy test, the statements with a relevancy percentage (>75), relevancy weightage (>0.75) and mean relevancy score (>2.30) were included in the next selection procedure (item analysis) for the statement. Through this process out of the total 68 statements, 43 statements were discarded, only 25 statements were remained for further analysis which is presented in Table 1. Out of these, 7 were negative and 18 positive statements.

Item Analysis (Calculation of t value):

The selected 25 statements underwent item analysis to identify those that effectively differentiated respondents with a more favorable attitude toward sustainable agricultural practices from those with less favorable attitudes. These statements, reflecting farmers' attitudes, were administered to 27 farmers from a non-sampled area. Participants rated each statement on a five-point scale: Strongly Agree (SA) scored 5, Agree (A) scored 4, Undecided (UD) scored 3, Disagree (DA) scored 2, and Strongly disagree (SD) scored 1. Reverse scoring was applied for negative statements. The responses were tabulated to calculate a total summated score for each respondent based on the 25 statements, with scores ranging from 25 to 125. Scores were ranked in descending order, and the top 25% (high group) and bottom 25% (low group) were selected for further item analysis. This process involved evaluating how well each statement differentiated between high and low score groups. Specifically, seven respondents with the highest scores and seven with the lowest scores were used as criterion groups. The criterion ratio, or t-value, assessed the significance of each statement's ability to distinguish between high and low score groups. This value was calculated using the formula recommended by Edwards (1957)

$$t = \frac{\bar{X}_H - \bar{X}_L}{\sqrt{\frac{\left(\sum \bar{X}_H 2 - \frac{(\sum[\bar{X}_H)]^2}{n}\right) \times \left(\sum \bar{X}_L 2 - \frac{(\sum[\bar{X}_L)]^2}{n}\right)}{n(n-1)}}}$$

Where;

XH= The mean score on the given statement of the high group

XL= The mean score on the given statement of the low group

Table 1. Relevancy percentage, relevancy weightage, mean relevancy score and t value of statements of farmers' attitude towards the adoption of sustainable agriculture practices

S.No.	Statements	RP	RW	MRS	t value
1	I follow the agricultural technologies which is eco-friendly (+)	92.59	0.81	2.44	1.109
2	I prefer the use of crop residues, animal waste and FYM rather than usingagro-chemicals for soil management (+)	92.59	0.80	2.41	1.369
3	Farmers should always protect natural resources at the earliest as it belong to all generations (+)	96.30	0.86	2.59	2.683
4	Farmers should not use excessive chemicals to avoid harmful effects on the environment (+)	88.89	0.83	2.48	4.178
5	One should apply FYM and compost to improve water holding capacity of soil(+)	92.59	0.80	2.41	0.972
6	One shouldn't go for frequent use of tillage and monoculture as it damages soil health (+)	92.59	0.84	2.52	1.399
7	I adopt diversified farming to maintain the farm sustainability (+)	96.30	0.89	2.67	1.732
8	Integration of crop and animal production is difficult to manage the farm resources (-)	96.30	0.85	2.56	1.583
9	Sustainable agricultural practices are costly and can be only adopted by rich farmers (-)	88.89	0.81	2.44	2.309
10	Agriculture will be sustainable by attracting young farmers to take up a career in farming (+)	96.30	0.84	2.52	2.611
11	I am very proud that I am the first one who follows sustainable farming system in my village (+)	92.59	0.83	2.48	1.427
12	In my village, most of the farmers believed utilization of chemical fertilizers gives better crop yield (-)	88.89	0.80	2.41	2.573
13	Youths are not involved in seeking information to protect the natural resources (-)	96.30	0.80	2.41	1.015
14	Cultivation without chemicals gives nutrients food and good health in society (+)	96.30	0.84	2.52	1.832
15	Government should devise strict rules to act on the farmers who waste natural resources (+)	92.59	0.81	2.44	3.134

Table 1. Contd.....

Table 1. Contd.....

S.No.	Statements	RP	RW	MRS	tvalue
16	Enhancing the relationship between farmers and the research centre may increase the adoption of sustainable technologies (+)	92.59	0.80	2.41	1.213
17	I am not aware of the importance of natural resource conservation in agricultural practices (-)	96.30	0.81	2.39	1.849
18	NGOs come forward to help us in educating and helping to follow sustainable farming practices (+)	92.59	0.81	2.44	0.893
19	Promotion of technology by grass root institutions will be able to promote sustainable farming (+)	88.89	0.79	2.37	1.217
20	Education and training on sustainable agriculture will attract youths to agriculture (+)	92.59	0.80	2.41	0.866
21	Agricultural practices of my village are not concerned about health and natural resources (-)	96.30	0.84	2.52	2.165
22	There is a shortfall of social support regarding environmental issues and its protection (-)	96.30	0.83	2.48	1.943
23	I look forward to participate in training and demonstration on sustainable technologies for adoption (+)	92.59	0.83	2.48	2.038
24	In my village, the farmers who practice sustainable farming system have a quality life (+)	96.30	0.84	2.52	2.121
25	I follow integrated farming practices to maintain cash flow throughout the year and increase sustainability (+)	92.59	0.88	2.63	1.979

Note: RP- Relevancy percentage, RW-Relevancy weightage, MRS- Mean Relevancy Score

$\sum$X2H= Sum of the square of the individual score on a given statement for high group

$\sum$X2L= Sum of the square of the individual score on a given statement for low group

n= Number of respondents in each group

t= The extent to which a given statement differentiates between the high and low groups.

RESULTS AND DISCUSSION

After evaluating the t-values for all items in the attitude scale using the designated formula, the values were arranged in descending order from highest to lowest. Following Edwards' (1957) guideline, items with a "t" value below 1.75 were excluded from further consideration. This selection criterion ensured that only items demonstrating strong discriminatory power and robust validity were retained in the scale. Thus, a total of 13 statements were retained for consideration in the final scale based on a “t” value greater than 1.75. The finalised statements

Table 2. List of final statement for the scale of the attitude of farmers towards the adoption of sustainable agriculture practices

S.No.	Statement	t value
1.	Farmers should not use excessive chemical fertilizers to avoid harmful effects on the environment (+)	4.178
2.	Government should devise strict rules to act on the farmers who waste natural resources (+)	3.133
3.	Farmers should always protect natural resources at the earliest as it belong to all generations (+)	2.683
4.	Agriculture will be sustainable by attracting young farmers to take up a career in farming (+)	2.611
5.	In my village most of the farmers believed utilization of chemical fertilizers give better crop yield (-)	2.573
6.	Sustainable agricultural practices are costly and can be only adopted by rich farmers (-)	2.309
7.	Agricultural practices of my village lack concerns about health and natural resources (-)	2.165
8.	In my village, the farmers who adopted sustainable farming system have a quality life (+)	2.121
9.	I look forward to engage in training and demonstration on sustainable technologies for adoption (+)	2.038
10.	I follow integrated farming practices to maintain cash flow throughout the year and increase sustainability (+)	1.979
11.	There is a shortfall of social support regarding environmental issues and its protection (-)	1.943
12.	I am not aware of the importance of natural resource conservation in agricultural practices (-)	1.849
13.	Cultivation without chemicals gives nutrients food and good health in society (+)	1.832

(13) based on the "t" value presented new idea, and the statements were worded as depicted in Table 2.

Reliability and validity of the scale

In the creation of the attitude scale for assessing farmers' perspectives on the adoption of sustainable rice-based farming systems, the study employed rigorous testing procedures to ensure that the instrument was reliable and valid. Reliability, indicative of the scale's consistency was assessed through the test-retest method and we administered the scale containing a points continuum to 60 farmers in two intervals with a gap of eight weeks. This involved administering the same test to the same group of subjects on two separate occasions. Correlation was calculated with the

total score of the items included in the scale resulting correlation coefficient of 0.71 which demonstrated a high level of reliability. It suggests that the instrument was reliable in measuring the farmers' attitudes over time.

Validity, which speaks to the accuracy of measurement, was addressed through content validity. This process scrutinized whether the scale's items were relevant to the intended content area of the adoption of sustainable sustainable agriculture practices. The utilization of content validity ensures that the scale effectively measures what it claims to measure. With both high reliability and content validity, the attitude scale emerged as a robust and trustworthy tool for gauging farmers' attitudes toward adoption of sustainable rice-based farming systems in the research study.

Administration and scoring of the scale

The final scale, comprising 13 statements as outlined in Table 2, was utilized to assess farmers' attitudes toward adopting sustainable agriculture practices. Each statement employed a 5-point continuum: for positive statements, Strongly Agree (SA) scored 5, Agree (A) scored 4, Undecided (UD) scored 3, Disagree (DA) scored 2, and Strongly Disagree (SDA) scored 1. Conversely, negative statements were scored in reverse: Strongly Disagree (SDA) scored 5, Disagree (DA) scored 4, Undecided (UD) scored 3, Agree (A) scored 2, and Strongly Agree (SA) scored 1. Attitude scores ranged from a minimum of 13 to a maximum of 65, providing insights into farmers' varying degrees of support for sustainable agriculture practices. Lower scores indicated less favorable attitudes, whereas higher scores indicated stronger support for adopting sustainable agriculture practices.

CONCLUSIONS

In this research, an attitude scale was created to measure farmers' attitudes towards sustainable agriculture practices and was observed to be reliable and valid. The final scale consisting of 13 statements with a continuum was tested with 60 farmers. With a reliability factor of 0.71, the scale is highly reliable and applicable in different contexts. It may be inferred that the scale was helpful in assessing the attitude towards the acceptance of sustainable agriculture practices because it was conducted to farmers in a non-sampled area and there were no issues with its use. In future, researchers can measure farmers' attitudes using this scale. The association between attitude and other variables can also be examined using this scale. The present scale has the potential to understand farmers' attitudes regarding adoption of sustainable farming practices whether favourable or unfavourable and may prove very helpful in undertaking suitable strategies for promotion of adoption of sustainable agricultural practices among farmers.

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FIELD SCREENING FOR POWDERY MILDEW DISEASE RESISTANCE IN SUNFLOWER (*Helianthus annuus L.*) GENOTYPES

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Sunflower is a prominent oilseed crop that accounts for 3.85% of the country's total oil seed production. Sunflower oil is rich source of oleic and linoleic acid. In India, sunflower recorded a production of 2.79 lakh tonnes from 2.69 lakh ha with productivity of 1037 kg ha^{-1} in the year 2022-23 (IIOR Annual report 2023). Sunflower cultivation in India, particularly Andhra Pradesh, faces significant challenges due to various diseases which includes powdery mildew, necrosis disease, *Alternaria* leaf spot, and leaf curl. This disease has the potential to inflict substantial economic yield losses ranging from 30-74% (Prakash *et al*., 2021). In Andhra Pradesh, the yield losses due to this disease was reported to extent of 43% in manifestation trials (2012-2015) under AICRP on sunflower at RARS, Nandyal (Venkataramanamma *et al*., 2016).

Currently, a combination of cultural practices, chemical fungicides, and resistant sunflower hybrids are employed to manage powdery mildew. Among these management strategies,usage of fungicides indisease management can lead to the emergence of resistant pathogen populations and the breakdown of resistance in sunflower cultivars. The development of sunflower hybrids with genetic resistance to powdery mildew represents the preeminent and most cost-effective long-term solution.This focus on genetic resistance offers a sustainable and environmentally friendly solution for mitigating yield losses, therefore, present study is aimed to identify resistant genotypes of sunflower for powdery mildew that could be exploited in heterosis breeding programme.

The field experiment was conducted during *Rabi*, 2023-24 at the Regional Agricultural Research Station in Nandyal, Andhra Pradesh, India. The experimental material consists of 20 genotypes along with a resistant check (PM-81) and a susceptible check (KBSH-44). Each genotype was evaluated in three replications in single row of length 3m with spacing of 60x30 cm. All the recommended agronomical practices were followed throughout the crop growing period. Powdery mildew was assessed on five randomly selected plants in each genotype as per the 0– 9 scale proposed by Mayee and Datar (1986). Disease severity was recorded at 15 days interval starting from the appearance of disease symptoms *i.e.*, 45 DAS (Days After Sowing), 60 DAS and 75 DAS and percent disease index (PDI) was evaluated by using below formula suggested by Vander Plank (1963).

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The rate of development of disease (r) at different intervals is computed with the formulaoutlined by Van der plank (1963).

$$PDI = \frac{\text{Sum of disease ratings}}{\text{Number of plants rated}} X \frac{100}{\text{Highest score}}$$

Where,

r-Apparent rate of infection or spread

X_1- Percent disease index at time t1

X_2- Percent disease index at time t2

t_2-t_1-Time interval in days between the consecutive observations

Further, AUDPC values were calculated using PDI at 45, 60 and 75 DAS of each genotype, using the formula recommended by Wilcoxson *et al*. (1975) and curves were drawn.

$$r = \frac{2.3}{t_{2-}t_1}\left[\log\frac{X_2}{1-X_2} - \log\frac{X_1}{1-X_1}\right]$$

Where,

Si = Severity at end of time i,

k = Number of successive evaluations,

Ti-Ti-1= Constant time interval (15 days)

The PDI values calculated at three intervals were utilized for performing analysis of variance (ANOVA).

The analysis of variance (ANOVA) revealed substantial variations across the genotypes for powdery mildew disease reaction at 45, 60 and 75 DAS (Table 1). Similarly, Reddy *et al.* (2013) recorded substantial variability for powdery mildew disease reaction in sunflower genotypes. The variability parameters were calculated and represented in Table 1. Phenotypic coefficient of variance (PCV) is observed slightly greater than Genotypic coefficient of variance (GCV). It implies that the influence of environment over the trait response of genotypes is very low. High heritability and genetic advance as a percentage of mean (GAM) indicate additive gene action, implying great potential for advancement through breeding selection.

$$AUDPC = \sum_{i=1}^{k} 1/2\ (Si\ +\ Si-1)\ \times\ (Ti-Ti-1)$$

The PDI values at 45, 60, 75 DAS are furnished in Table 2 and the results of the current investigation displayed that out of 22 genotypes, one genotype R-106 showed resistance. Two genotypes NDSI-3 and NDI-43 reported moderate resistant, five genotypes COSF-6B, COSF-7B, NDLR-40, NDLR-36 and RSFH-11 were found susceptible. All other remaining inbred lines exhibited high susceptibility for powdery mildew on comparison with KBSH-44.

At 45 DAS, the disease symptoms were observed mostly on lower leaves. Among the 22 genotypes, PDI values ranged from 0.25 to 12.1% with 5.52% mean value. Less PDI of 0.25% was noted in R-106 genotype whereas, highest PDI of 12.1% was noted in LTRR-341.

At 60 DAS, more disease incidence was observed in all entries compared with 45 DAS and the disease progression was identified in middle leaves. PDI values ranged from 1.73% (R-106) to 68.13% (RHA-1096), with 36.10% mean value. The genotypes such as R-106, NDSI-3, PM-81 and NDI-43 demonstrated greater negative deviation from the mean value. In contrast, RP-16, RHA-1096, PB-120, NDI-20, and NDI-55 showed greater positive deviation from the mean value.

At 75 DAS, disease was observed on almost all the plant parts in susceptible genotypes. PDI values ranged from 9.63% (R-106) to 91.11% (RP-16), with 59.20% average. R-106 and PM-81 showed more negative deviation from the mean. Similarly, RP-16, RHA-1096, and PB-120 showed a higher positive deviation from the mean. Similarly, Venkataramanamma *et al*. (2016) reported the

Table 1. Analysis of variance for PDI at different growth stages

PDI at different growth stages	Mean Sum of Squares		Mean	CV	SE (m)	CD (5%)	Heritability (bs)	PCV	GCV	GAM
	Treatment	Error								
PDI@45 DAS	34.368**	0.48	5.57	12.75	0.40	1.15	95.84	61.64	60.34	121.70
PDI@60 DAS	1110.04**	8.34	36.03	8.02	1.67	4.76	97.80	53.79	53.19	108.35
PDI@75 DAS	1967.36**	21.067	59.20	7.75	2.65	7.56	96.85	43.72	43.03	87.24

* and ** significant at 5% and 1% LOS, respectively. bs= broad sense.

Table 2. Percent disease index of Powdery mildew disease at different growth stages

S.No	Genotype	PDI @ 45 DAS (%)	PDI @ 60 DAS (%)	PDI@ 75 DAS (%)	Score on 0-9 scale	Host reaction
1	NDSI-3	4.44	10.62	23.46	5	MR
2	RP-16	9.14	61.46	91.11	9	HS
3	OPH-74	4.44	49.12	84.20	9	HS
4	CMS- 104B	4.20	38.75	76.30	9	HS
5	RHA-1096	4.20	68.13	90.74	9	HS
6	R-106	0.25	1.73	9.88	3	R
7	NDLR40	0.74	28.15	46.42	7	S
8	RSFH 5	5.19	27.57	56.48	9	HS
9	PB-110	5.19	35.06	78.89	9	HS
10	COSF-6B	4.20	35.25	48.15	7	S
11	COSF-7B	1.98	34.57	47.69	7	S
12	PB-120	7.16	63.21	90.74	9	HS
13	PM-81	0.25	2.22	9.63	3	R
14	KBSH-44	7.90	35.06	65.93	9	HS
15	ARM-243-B	10.12	27.90	59.38	9	HS
16	LTRR-341	12.10	40.39	84.07	9	HS
17	NDI-43	6.67	12.59	24.69	5	MR
18	NDLR-36	4.44	27.90	46.91	7	S
19	RSFH-11	2.22	28.40	47.16	7	S
20	CMS-249B	7.90	44.44	71.11	9	HS
21	NDI-20	7.41	57.78	68.89	9	HS
22	NDI-55	11.60	64.01	80.74	9	HS

R= resistant, MR= moderately resistant, S= susceptible, HS=highly susceptible.

resistant lines, GMU-1004(0), GMU-1005 (0.7), GMU-1017 (0.6), GMU-1043 (1) based on field screening of 200 lines. The reports of Kulkarni *et al.* (2015) and Reddy *et al.* (2013) supported this study.

The apparent rate of infection 'r value' for powdery mildew is summarized in Table3. The average r value ranged from 0.0025 (LTRR-341) to 0.034 (NDLR-40). The genotypes R-106 and PM-81 exhibited r value of 0.03. Even though these genotypes exhibited higher rate of disease spread, the disease severity was extremely low in contrast to other inbred lines with lower r value and high initial disease infection. In PB-120, high early-stage disease development in combination with low r value shows late spread of disease. High early-stage disease infection coupled with higher r value is identified in all highly susceptible genotypes. These findings demonstrated that the low apparent rate of infection not necessarily imply the genotype's resistance level. The apparent rate of infection alone is insufficient to identify the disease

Table 3. Apparent rate of infection "r" values and AUDPC valuesfor powdery mildew resistance in sunflower genotypes

S.No	Genotype	45 to 60 days r-value	60 to 75 days r- value	Mean r value	AUDPC
1	NDSI-3	0.01	0.004	0.007	401.85
2	RP-16	0.0066	0.0004	0.0035	1742.33
3	OPH-74	0.0156	0.0006	0.0081	1434.90
4	CMS- 104B	0.0164	0.0009	0.0086	1216.50
5	RHA-1096	0.0171	0.0002	0.0087	1765.50
6	R-106	0.016	0.05	0.033	103.80
7	NDLR40	0.067	0.001	0.034	781.50
8	RSFH 5	0.0118	0.0013	0.0065	915.00
9	PB-110	0.0123	0.0011	0.0067	1195.43
10	COSF-6B	0.0162	0.0005	0.0084	952.88
11	COSF-7B	0.045	0.0005	0.0228	905.93
12	PB-120	0.009	0.0003	0.0046	1736.10
13	PM-81	0.033	0.033	0.033	109.28
14	KBSH-44	0.0071	0.0009	0.004	1138.88
15	ARM-243-B	0.0045	0.0013	0.0029	1015.65
16	LTRR-341	0.0041	0.0009	0.0025	1417.88
17	NDI-43	0.005	0.003	0.004	474.08
18	NDLR-36	0.015	0.001	0.008	836.93
19	RSFH-11	0.037	0.001	0.019	813.00
20	CMS-249B	0.0075	0.0006	0.004	1318.43
21	NDI-20	0.0085	0.0002	0.0043	1494.53
22	NDI-55	0.005	0.0002	0.0026	1739.70

Table 4. Categorization of the sunflower genotypes for powdery mildew resistance.

Disease Reaction	Disease Index Scale	No. of genotypes	Range of 'r' values
Immune	0	Nil	-
Highly resistant	1	Nil	-
resistant	3	2	0.033
Moderately resistant	5	2	0.004-0.007
susceptible	7	5	0.008-0.034
Highly susceptible	9	13	0.002-0.075

resistance. It can, however, be used to study disease development in various genotypes and it was detailed by Wilcoxson *et al.* (1975) and Nargund (1989). The obtained results align with the earlier reports of Kulkarni *et al*. (2015) in sunflower.

The AUDPC was derived for each genotype using the PDI values obtained and represented in Table 3. AUDPC values were used to compare the rates of disease progression amongst genotypes. The AUDPC values were in range of 103.80 (R-106) to 1765.50 (RHA-1096), with a mean of 1680.64. Genotypes with low AUDPC values develop disease at a slower rate than genotypes with high AUDPC values. In sunflower Reddy *et al*. (2014) identified similar results (AUDPC readings) for *Alternaria* disease.

The categorization of genotypes based on DIS (Disease Index Scale) value is summarized in (Table 4), which revealed a lack of alignment between DISvalues and r values, indicating a lack of clear distribution pattern of r values based on DIS values.

It is observed that powdery mildew resistance trait is having high heritability and GAM. The heritability is mainly due to additive gene action and selection is effective for improvement of this character. Identification of the resistant genotype (R-106) and moderately resistant genotypes (NDSI-3, NDI-43) helps in breeding initiatives aimed to develop powdery mildew resistant sunflower varieties / hybrids. These genotypes can be included in such breeding initiatives as a potential donors of disease resistance.

Genotype R-106 is found to be resistant to powdery mildew which can be further utilized as parent in breeding programmes aimed at developing powdery mildew disease resistance in sunflower.

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HEALTH AND HYGIENE READINESS OF ANGANWADI CHILDREN: A COMPREHENSIVE STUDY

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The concept of school readiness is a multifaceted construct denoting the state in which a child possesses essential skills to actively engage in learning experiences with in the school environment (Williams and Lerner, 2019). This readiness spans diverse domains, encompassing physical health, sensorimotor development, communication skills, executive functions manifested in social competence and emotional maturity, general knowledge, cognition, and an intrinsic enthusiasm for learning (Williams and Lerner, 2019).

The commencement of school readiness is intricately tied to a child's overall well-being, and its achievement involves fostering positive development across various dimensions, including physical, social, emotional, learning, language, and cognitive domains (Early Childhood Learning and Knowledge Centre, 2021). The link between health and school readiness extends beyond the formal initiation of education, emphasizing that sustained well-being significantly facilitates learning throughout childhood and into adulthood (Early Childhood Learning and Knowledge Centre, 2021).

There is a noticeable research void in the existing literature regarding the interconnection of school readiness, gender, and location-specific elements concerning health and hygiene in Anganwadi children.The studyaimed to assess the level of school readiness in health and hygiene among Anganwadi children. It specifically focused on how gender impacted health andhygiene in Anganwadi children and explored the relationship between location and health and hygiene in Anganwadi children.

The study was conducted in the year 2022 in Kannur district, Kerala. Employing a cross-sectional design with random sampling, the study aimed to evaluate the health and hygiene readiness of Anganwadi children aged 4 to 6 years old through a self-designed observational scale. The sample consisted of 189 Anganwadi childrenencompassing both boys and girls. To evaluate readiness in Health and hygiene, the respondents were asked to perform activities. The responses were scored as 5 for 'able to complete', 4 for 'Almost done, but not completed.', 3 for 'Partially done', 2 for 'Tried but couldn't do' and 1 for 'Unable to do'. The total score of the 5 questions for all 189 respondents was found out, and based on that the mean % score of level of Health and hygienewas calculated usingthe formula, .

$$\left[MPS = \frac{MeanScore \times 100}{Maximumpossiblescore}\right]$$

An independent sample Z test was used to compare the mean scores of variables of two different groups, that is, boys and girls. Hence a Z test was conducted. A one-sample

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Table 1.Childs Readiness in health and hygiene

Sl.No.	Variable	n	Mean	Standard Deviation	Mean % score	CV	Z	p-value
1	Child readiness Health and hygiene	189	21.77	2.76	87.07	12.68	15.031	<0.001

analysis of variance was used to test hypotheses about means when there were three or more groups of one independent variable. In this case, age group was the independent variable, which included four age groups (a) 4 - 4.5 years (b) 4.5 - 5 years (c) 5 - 5.5 years (d) 5.5 - 6 years. Also, the location of Anganwadi was another independent variable, which included three locations (a) Rural (b) Urban (c) Tribal. Hence, ANOVA test was used to compare the mean scores of different age groups and locations. Ethical considerations involved obtaining informed consent, ensuring confidentiality, and securing approval from CDPO.

The mean percentage score of readiness in Health and hygiene was 87.07% which indicated that readiness in Health and hygiene of children was excellent. The Coefficient of Variation indicates that this score was stable as the value was less than 20%.

It was observed from the Table 1 that the p-value was less than 0.01 and z value (15.031) was positive, which indicated that the test was significant. The Z test is useful to determine if the observed mean (87.07%) is significantly different from the hypothesized population mean (75%). Hence, the null hypothesis was rejected, and it was concluded that the readiness in health and hygiene of children was more than 75% *i.e.,* excellent.

Attending a high-quality preschool resulted in a noteworthy, medium-sized, and statistically significant improvement of 2.76 standard deviation in the understanding and implementation of health and hygiene, nutrition, and safety practices for young children, in comparison to those who did not attend preschool ($p < .001$). This effect remained significant even after adjusting for demographic characteristics, initial scores, and union influences (Diazgranados *et al.*, 2016).

Table 2. Influence of Gender, Age, Location andreadiness in health and hygiene

Sl.No.	Variables	Gender	frequency	Mean	Standard Deviation	Z or F	p-value
1.	**Gender**	Female	91	22.07	2.64	Z=1.438	0.152
		Male	98	21.49	2.85		
2.	**Age**	4 - 4.5 years	143	21.73	2.75	F=0.237	0.870
		4.5 - 5 years	30	22.03	2.77		
		5 - 5.5 years	10	21.30	2.91		
		5.5 - 6 years	6	22.17	3.31		
3.	**Location**	Rural	95	21.77	2.59	F=0.013	0.987
		Urban	72	21.79	2.96		
		Tribal	22	21.68	2.90		

Arifiyanti and Prasetyo (2018), reported that every participant had tried to include lessons on personal hygiene in preschool. The most taught personal hygiene practice was washing one's hands in daily activities such before and after food. The susceptibility of children to disease transmission was underscored by their weakened immune systems and the proximity in which they interacted. Mohamed *et al*. , (2016) emphasized the role of the immune system and drew attention to the lack of awareness regarding basic hygiene practices, such as hand washing, which contributed to the increased likelihood of diseases spreading among preschoolers. Encouraging healthier habits early in childhood could enhance the effectiveness of interventions, preventing unhealthy choices from becoming ingrained in an individual's lifestyle (Rawal *et al*., 2022).

Table 2 revealed that there was no significant difference existed between boys and girls for Health and hygiene as the p-value in this case was more than 0.05. So, the hypothesis *H1a* was accepted. This finding was useful in recognizing that, within the scope of health and hygiene readiness, gender did not exert a noteworthy influence among the surveyed participants. It suggested that both boys and girls demonstrated similar levels of preparedness in health and hygiene, as evidenced by their mean scores.

The results depicted in Table 2. revealed that the statistical value of p was more than 0.05 for all the variables. Hence, it was concluded that the mean score of the variables does not differ with age groups. Hence, the hypothesis *H1b* was accepted. This result suggested that initiatives or programs aimed at boosting awareness of health and hygiene could be uniformly implemented across the age range examined in this study. In this context, age did not appear to be a discerning factor influencing readiness levels. This allows the adoption of broader and more encompassing strategies to encourage children's health and hygiene.

As value of p was more than 0.05 for all the variables, it was concluded that the mean score of all the variables did not differ with location. Hence,the hypothesis *H1c* was accepted. This discovery suggests that initiatives or programs focused on improving awareness of health and hygiene could be uniformly applied across diverse locations. The absence of noteworthy variations in mean scores across different settings enables the creation of broader and more inclusive strategies for fostering health and hygiene among children in various environments.

Preschoolers' perspectives on health vary with age; younger kids prioritize nutrition, whereas older ones connect health with avoiding illness. Across age groups, readiness for hygiene receives less attention (Sumer *et al*., 2022). Holley *et al.* (2017) revealed that older preschoolers (aged 4-5) exhibited a more advanced comprehension of and inclination towards vegetables compared to their younger counterparts (aged 2-3), indicating age-related disparities in nutritional awareness. Brou *et al.* (2022) highlighted the rural-urban divide in preschool attendance and access to home learning resources, which can affect school readiness among children in Ivory Coast. These disparities may also have implications for health and hygiene readiness among preschoolers. The vulnerability of children impacted by forced displacements was highlighted by UNICEF (2016). Such children often faced prolonged periods without access to essential services, including healthcare, sanitation, and nutrition. This lack of access not only affects their overall health but also has implications for their ability to engage effectively in educational activities.

In the conclusion, the study revealed an impressive readiness level of 87.07% among

the young children, which remained consistent across genders, different age groups within the 4-6 range, and various Anganwadi centre locations. The findings suggested that neither gender nor age significantly influenced health and hygiene readiness, implying that both boys and girls, as well as different age groups, exhibited similar levels of preparedness. The research also emphasized the consistency of preparedness in various locations, highlighting the opportunity to implement comprehensive approaches for promoting health and hygiene in diverse settings.

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