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ASSESSMENT OF GENETIC PARAMETERS AND TRAIT INTERRELATIONSHIPS IN EARLY MATURING SUGARCANE CLONES OVER THREE CROP CYCLES

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ABSTRACT

This study evaluated seven early maturing sugarcane clones across three crop cycles at the Regional Agricultural Research Station, Anakapalle, to estimate genetic variability, heritability, trait associations, and direct effects on key economic traits. The analysis of variance indicated significant effects of genotype, season and genotype × season interactions for all traits under this study, except for number of millable canes, cane girth and single cane weight. Among ten sugarcane clones across three crop cycles, clone 2018A 133 showed the best overall performance for cane yield, sugar yield and millable canes, while 2018A 65 excelled in juice quality traits.The ratoon crop consistently exhibited higher genotypic coefficients of variation, broad-sense heritability, and genetic advance, especially for cane yield, commercial cane yield and number of millable canes, signifying their selection potential in later stages. Brix, Sucrose and CCS% demonstrated moderate to low GCV values over crop cycles, suggesting limited genetic variability. Cane yield and CCS yield both exhibited high heritability across the three crop cycles. Traits like Brix, CCS%, and Sucrose showed low to moderate heritability in the early crop cycles but exhibited substantial increase in later crop cycles. Traits such as cane yield, CCS yield, and number of millable canes had both high heritability and high genetic advance as a percentage of mean in the ratoon crop. In contrast, traits like single cane weight and cane girth showed inconsistent heritability and genetic advance across cycles, reflecting genetic instability. Juice quality traits (Brix, Sucrose, CCS%) showed increased heritability and genetic advance in the ratoon crop. Cane yield showed a strong positive correlation with CCS yield in all crop cycles. Juice quality traits such as Brix, Sucrose, and CCS% showed very strong positive correlations among themselves in all cycles. CCS yield exhibited significant positive correlations along with substantial direct effects in each season, highlighting their importance as key selection criteria in sugarcane breeding programs.

Key words: Genetic advance, Genetic correlation,Heritability and Path analysis

INTRODUCTION

Sugarcane is cultivated extensively in the tropical and subtropical regions of India. It was grown across 56.48 lakh hectares, producing an annual yield of 446.43 million tonnes in the country (E&S, DAC - *2nd Adv. Est. - 2023).

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However, the area and production of sugarcane in Andhra Pradesh had been declining steadily since 2014–15. Over the past six years, there has been a drastic reduction in both the area under cultivation and production. Data from 2018–19 to 2023–24 indicated a drop in the area from 1.02 lakh hectares to 0.27 lakh hectares, representing a nearly 74% decline. Correspondingly, production fell from 8.09 million tonnes in 2018–19 to only 2.10 million tonnes in 2023–24 (E&S, DAC – *2nd Adv. Est. – 2023-2). The long duration conventional sugarcane varieties posed challenges, particularly when early crushing schedules of sugar mills did not align with the maturity of the crop. This mismatch led to poor sugar recovery and economic losses for both farmers and millers (Tyagi *et al.,* 2023). To address these challenges, the introduction of early maturing sugarcane clones was proposed as a strategic solution.

Effective selection of cultivars within a plant population across diverse environments requires a thorough understanding of the genetic relationships among key traits. Insights into genetic and phenotypic variances, covariances and associated statistical parameters are essential for predicting the response to selection and for developing best selection strategies (Tolera *et al.,* 2024). Genetic parameters are population and environment specific, meaning they are influenced by the particular genotypes and environmental conditions under which they are estimated (Barreto *et al.,* 2021). Misleading conclusions can arise from unrepresentative sampling of genotypes or production environments, including variations across years and locations (Tolera *et al.,* 2023). Consequently, genetic correlations among sugarcane traits reported in other studies had limited applicability to multi-yield traits under the North Coastal Zone of Andhra Pradesh over the crop cycles. Therefore, region-specific and cycle-wise genetic evaluations were essential to ensure accurate selection and genetic improvement of sugarcane cultivars in this agro-climatic zone.

The present study aimed to estimate the genetic correlations among key yield-related traits in sugarcane and to understand the nature of these correlations through path coefficient analysis. Additionally, the study sought to examine the influence of different crop cycles on the genetic relationships among sugarcane clones.The investigation was conducted using seven sugarcane clones evaluated under multi-yield trait trials across three cropping cycles at the Regional Agricultural Research Station, Anakapalle.

MATERIAL AND METHODS

The experimental material comprised seven early maturing sugarcane clones, namely 2018A 133, 2018A 30, 2018A 31, 2018A 37, 2018A 65, 2018A 107 and 2018A 152, which were evaluated along with three standard checks: 87A 298, CoC 01061, and 2000A 128. The field experiments were conducted at the Regional Agricultural Research Station (RARS), Anakapalle, located at 17.6914° N latitude and 83.0041° E longitude, with an altitude of 26 meters above sea level. The study was carried out over three crop cycles, including the first plant and ratoon crops during 2022–23 and 2023–24, respectively, and a second plant crop during 2023–24. The experiment was laid out in a Randomized Block Design (RBD) with three replications. Each genotype was grown in plots consisting of six rows, each six meters long, with a row-to-row spacing of 90 cm. Standard agronomic practices were uniformly followed throughout all three seasons, as recommended for the region (Sugeerthi *et al.,* 2018). Both the plant and ratoon crops were harvested at 10 months of age, specifically during the second fortnight of November, to maintain

uniformity in harvesting age for precise and comparable data analysis.

The present study recorded phenotypic data from nine quality and quantitative traits of sugarcane according to the guidelines provided by PPV & FR, 2001, under the DUS criteria. These traits included the number of millable canes (NMC) expressed in '000/ha, single cane weight (SCW) in kg, and cane yield (CY) in t/ha, it was measured on a per-plot basis and subsequently calculated per hectare. CCS yield (CCSY) was determined using the formula (Cane yield × CCS %) / 100. At the harvest stage, brix (%) (BP) and sucrose (%) (SP) were recorded using a Brix refractometer and a sucrolyser, respectively. The Commercial Cane Sugar percentage (CCSP) was calculated by the formula (Sucrose % × 1.022) – (Brix % × 0.292). Cane length (cm) and girth (cm) recorded at harvest stage (Nair *et al.,* 1999).

Phenotypic data from both plant crops and ratoon crop were collected and analysed to assess genetic variability and trait associations. Bartlett's test was performed to evaluate the homogeneity of error variances across three crop cycles using Grapes statistical software. The non-significant results obtained from the three crop cycles indicated consistent error variance, allowing the data to be pooled for further analysis. All genetic analyses were performed using Grapes statistical software. Genotypic and phenotypic variations were calculated following the method described by Burton and De Vane (1953). Coefficients of variation were computed according to the guidelines of Singh and Chaudhary (1999). Broad-sense heritability was estimated using the formula provided by Allard (1960). Genetic advance was recorded following the approach of Johnson *et al,* (1955). Genotypic correlations were calculated using the method suggested by Al-Jibouri *et al.* (1958) and were analyzed for direct and indirect effects based on the methodology of Dewey and Lu (1959).

RESULTS AND DISCUSSION

Analysis of variance and mean performance

Genetic analysis for cane yield and juice quality traits among ten early maturing sugarcane clones evaluated across three crop cycles is presented in Table 1. All traits exhibited statistically significant ($P < 0.05$) differences for genotype, season, and genotype × season interaction effects, except for number of millable canes, cane girth and single cane weight, which were non-significant for genotypic means. These results indicated the presence of considerable genetic variation among the clones, which is essential for effective selection and genetic improvement. Similar findings were reported by Shanmuganathan *et al*. (2015), who observed significant variation for cane yield and CCS yield. Yadawad *et al*. (2022) also reported significant genetic variability for sucrose content (%), Brix (%), and CCS (%). In contrast, Vinu *et al*. (2024) observed non-significant variation for number of millable canes and single cane weight across crop cycles, which support the current results. The detection of significant genotype × season interaction further emphasized the importance of evaluating genotypes across multiple environments, as also highlighted by Milligan *et al*. (1990), to ensure stable performance and reliable selection of superior clones.

The mean performance of ten early maturing sugarcane clones over three crop cycles was illustrated in Table 2. The IIP crop recorded the highest millable cane population, showing improved establishment during the second crop cycle.Clones 2018A 133 and CoC 01061showed superior stooling capacity (>115 canes in IIP), suggesting good ratoon

vigor.Sucrose and Brix content increased notably in the ratoon crop, indicating enhanced sugar accumulation in later crop stages.CCS improved with successive crop cycles, aligning with sucrose trends.*2018A 65* had the highest ratoon CCS (14.60%), suggesting strong recovery potential for sugar yield.The clones 2018A 107 and 2018A 37 maintained relatively high SCW (>1.0 kg) in IP, beneficial for early yield.Yield dropped notably in the ratoon crop ("21.6%), showing moderate ratoon decline.*2018A 133* achieved the highest cane yield across all cycles (average H" 101 t/ha), marking it as a top-performing genotype.The study indicates clone 2018A 133 as the best performer for both cane and sugar yield stability across cycles, while 2018A 65 shows strong potential for sugar recovery. The ratoon decline is evident mainly due to reduced cane weight and population, despite improvements in juice quality.

Genetic Variability Analysis

The genetic variance components for cane yield and juice quality traits among ten sugarcane clones over three crop cycles were summarized in Table 3. In this study, the phenotypic coefficient of variation (PCV) consistently exceeded the genotypic coefficient of variation (GCV) for all traits. The ratoon crop (RA) exhibited higher GCV values for most economic traits, except for cane length and girth, suggesting a greater potential for genetic gain in later cycles. Thus, selection was recommended to prioritize ratoon crop performance due to its pronounced genetic variability (Tena *et al.* 2016).

Cane yield, commercial cane yield, and single cane weight exhibited moderately to high GCV and PCV across all crop cycles, with the highest values observed in the ratoon crop, indicating greater genetic variability and selection potential at later stages. Particularly, cane yield and commercial cane yield showed GCV values of 21.20 and 20.24, respectively, suggesting strong prospects for genetic improvement. These results were in alignment with the findings of Tena *et al.* (2023), who reported increased genetic advance in older crop cycles. In contrast, single cane weight displayed erratic behavior, especially in the second plant stage, where a high PCV (26.01) and low GCV (2.07) indicated a strong environmental influence. Brix, Sucrose, and CCS% demonstrated moderate to low GCV values over crop cycles, suggesting limited genetic variability. Cane length and girth showed very high GCV and PCV in the second plant stage, suggesting that these traits were more influenced by genotype × crop interactions. These observations were consistent with Milligan *et al.* (1990), who highlighted strong genotype × crop and location interactions for stalk traits such as length and girth.

The heritability estimates across crop cycles revealed valuable insights for sugarcane improvement. In the present study, most traits showed higher heritability (CY: 90.28%, NMC: 89.18%, CCS Yield: 84.61%, and Sucrose: 80.39%) in the ratoon crop, suggesting that genetic factors played a more significant role in later crop cycles. These findings aligned with those of Abu-Ellail *et al.* (2017), who reported increased heritability and genetic gain in older ratoon crops due to reduced environmental variance and improved genotype differentiation. Cane yield and CCS yield both maintained high heritability across all stages, indicating strong selection potential for yield improvement throughout the crop cycle. Traits like Brix, CCS%, and Sucrose showed low to moderate heritability in the early crop cycles but exhibited substantial increases in later cycles. This trend indicated environmental sensitivity in the early stages but greater genetic determination as the crop matured. Milligan *et al.* (1990) observed similar increases in genetic parameters in

Table 1.Combined pooled analysis of variance for nine characters in ten sugarcane genotypes across three seasons

Source		NMC		BP		SP		CCS (%)		SCW		CCSY		CL		CG		CY	
	Df	Mean Sq	Pr (>F)	Mean Sq	Pr (>F)	Mean Sq	Pr (>F)	Mean Sq	Pr (>F)	Mean Sq	Pr (>F)	Mean Sq	Pr (>F)	Mean Sq	Pr (>F)	Mean Sq	Pr (>F)	Mean Sq	Pr (>F)
Location	2	4221	0	17	0	2365	0	9	0	2742	0	147	0	3822	0	440	0	440	0
Treatment	9	57	0	2	0	8	0	2	0	26	0	14	0	61	0	21	0	21	0
Replication with in location	6	1	1	0	1	1	0	0	0	3	0	1	0	3	0	2	0	2	0
Location x Treatment	18	29	0	2	0	6	0	2	0	14	0	10	0	29	0	11	0	11	0
Error	54	1		1		1		0		1		1		1		1		1	

NMC= Number of millable canes ('000/ha), BP= Brix (%), SP= Sucrose (%), CCS (%)= Commercial cane sugar, SCW= Single cane weight (kg), CCSY= Commercial cane sugar yield (t/ha), CL= Cane length (cm), CG=Cane girth (cm) and CY= Cane yield (t/ha).

Table 2a. Mean performance of ten clones over three crop cycles among nine agronomic traits

Clone	NMC			Brix (%)			Sucrose (%)			CCS (%)		
	IP	IIP	Ratoon	IP	IIP	Ratoon	IP	IIP	Ratoon	IP	IIP	Ratoon
2018A 133	109.57	118.29	108.33	17.73	16.97	19.30	16.25	15.97	17.27	11.43	11.36	12.01
2018A 30	76.85	100.71	100.52	18.83	19.20	17.23	16.73	18.27	16.68	11.60	13.06	12.01
2018A 31	92.08	102.63	78.70	17.79	18.40	18.80	15.61	17.09	17.73	10.76	12.09	12.63
2018A 37	88.58	93.21	83.95	18.53	16.83	19.90	16.89	15.25	18.83	11.84	10.67	13.43
2018A 65	87.14	96.53	100.31	18.58	18.60	21.40	17.87	17.39	20.40	12.84	12.34	14.60
2018A 107	67.28	101.31	98.36	18.83	18.08	19.80	16.37	16.97	18.20	11.24	12.06	12.82
2018A 152	84.98	100.54	99.28	17.34	17.50	18.80	16.00	16.23	17.10	11.29	11.48	11.98
87A 298	95.37	88.35	88.89	18.65	17.30	19.97	17.00	16.07	18.69	11.93	11.37	13.27
CoC 01061	96.09	118.75	93.42	19.66	17.73	19.60	17.59	16.21	17.76	12.23	11.39	12.42
2000A 128	84.67	81.33	66.15	19.35	18.60	19.33	18.36	16.90	17.35	13.11	11.85	12.09
Mean	88.26	100.16	91.79	18.53	17.92	19.41	16.87	16.64	18.00	11.83	11.77	12.73

older crops, emphasizing the need to evaluate advanced stages for juice quality traits. Single cane weight exhibited very high heritability in the first plant crop (91.43%) and the ratoon crop (85.81%) but showed almost negligible heritability in the second plant crop (0.63%), implying that environmental influence or inconsistency in expression strongly affected this trait during the second plant stage, as also discussed by Milligan *et al.* (1990) regarding the instability of stalk weight across cycles. Overall, the results suggested that ratoon crops offered a more reliable stage for the selection of key economic traits, while traits with fluctuating heritability required stage-specific breeding strategies.

Cane yield, commercial cane yield, and number of millable canes exhibited high heritability in the ratoon crop (90.28%, 84.61%, and 89.18%, respectively) along with high GAM values (41.49%, 38.35%, and 26.12%, respectively). These results indicated strong additive gene effects and suggested that direct phenotypic selection in the ratoon phase would be highly effective, as also emphasized by Jeena (2023), who reported greater selection efficiency in older crop stages due to increased genetic expression. Brix, Sucrose, and CCS% showed low to moderate heritability and genetic advance in the first and second plant crops, but exhibited substantial increases in the ratoon crop, where Brix reached 44.66% heritability and 6.35% GAM, and Sucrose reached 80.39% heritability and 10.71% GAM. This trend aligned with the findings of Abu-Ellail *et al.* (2022), who noted that environmental variation strongly affected juice quality traits in early crops, while ratoon crops provided more stable expression and better genetic differentiation.

Cane length demonstrated extremely high heritability (96.10%) and genetic advance (100.52) in the second plant crop, with GAM peaking at 45.98%, indicating strong selection potential at this stage. However, in the ratoon crop, although heritability remained high (92.93%), GAM dropped to 22.08%, likely due to a decline in mean values or increased environmental effects, as also noted by Saadan *et al.* (2025) in ratooning studies. Cane girth showed good potential in the second plant crop (81.38% heritability and 34.72% GAM) but dropped significantly in the ratoon crop (37.92% heritability and 12.34% GAM), suggesting instability and environmental sensitivity of this trait in later cycles. Single cane weight exhibited practically zero genetic advance and GAM in the second plant crop, reflecting poor genetic expression during this stage, potentially due to stress or environmental interactions, a phenomenon also reported by Milligan *et al.* (1990) in their studies on ratoon performance.

The results indicate that ratoon crops are most suitable for effective selection, particularly for yield traits like cane yield, CCS yield, and number of millable canes, due to high heritability and high genetic advance. Juice quality traits become more responsive to selection in later cycles, suggesting that early selection may be inefficient. Morphological traits like cane length and girth require crop-specific selection strategies and erratic traits like single cane weight must be interpreted cautiously.

Correlation Studies

Trait correlation analysis provided insights into the direction and strength of associations between traits, which was crucial for indirect selection in sugarcane breeding. The present study assessed genetic correlations among key agronomic and juice quality traits across three crop cycles, as presented in Table 4. The findings revealed both consistent and cycle-specific relationships, reflecting the dynamics of trait expression over time.

Table 2b. Mean performance of ten clones over three crop cycles among nine agronomic traits

	SCW (kg)			CCSY (t/ha)			Cane length (cm)			Cane girth (cm)			Cane yield (t/ha)		
Clone	IP	IIP	Ratoon	IP	IIP	Ratoon	IP	IIP	Ratoon	IP	IIP	Ratoon	IP	IIP	Ratoon
2018A 133	0.99	0.76	0.87	13.55	10.23	11.33	205.00	305.00	195.67	1.37	2.13	2.00	118.45	90.15	94.38
2018A 30	0.98	0.92	0.80	8.71	12.11	9.64	152.67	241.67	208.00	2.20	2.33	2.13	75.43	93.00	80.44
2018A 31	1.02	1.11	0.79	8.29	13.83	7.85	157.00	305.00	209.67	2.13	2.02	2.20	77.32	114.35	62.20
2018A 37	1.05	1.04	0.88	11.94	10.42	9.88	266.33	271.67	245.33	2.47	2.68	2.47	100.70	97.05	73.37
2018A 65	1.08	0.94	0.72	12.56	11.20	10.57	150.33	215.00	190.33	2.17	2.39	2.40	98.15	90.49	72.36
2018A 107	1.17	0.91	0.66	9.57	11.12	8.29	253.67	280.00	202.00	2.57	2.21	1.73	85.12	92.47	64.65
2018A 152	0.94	0.91	0.90	9.07	10.52	10.67	259.00	271.67	242.00	2.17	2.41	2.20	80.55	91.60	89.03
87A 298	1.03	0.77	0.70	10.38	7.66	8.27	258.33	287.67	183.67	2.23	2.45	2.20	87.03	67.69	62.30
CoC 01061	0.61	0.65	0.62	9.79	8.77	7.22	212.00	291.67	181.00	1.37	1.86	1.67	80.08	77.00	58.10
2000A 128	1.12	0.98	0.66	10.97	9.44	5.30	272.00	295.33	233.00	2.13	2.20	2.17	83.70	79.94	43.84
Mean	1.00	0.90	0.76	10.48	10.53	8.90	218.63	276.47	209.07	2.08	2.27	2.12	88.65	89.37	70.07

Cane yield showed a strong positive correlation with CCS yield in all crop cycles, particularly in the ratoon crop (r = 0.948**), indicating that selection for CCS yield would simultaneously improve cane yield. In the first plant and ratoon crops, cane yield was also positively correlated with single cane weight (r = 0.755** in the first plant and 0.804** in the ratoon), confirming the significant role of this trait in determining yield. These results were consistent with the findings of Reddy *et al.,* (2024), who identified stalk weight and number as primary determinants of yield. Number of millable canes and cane yield showed a strong positive correlation in the second plant (r = 0.646**) and ratoon crops (r = 0.809**), supporting indirect selection through number of millable canes, especially in the later stages. However, in the first plant crop, the number of millable canes showed a significant negative correlation with single cane weight (r = -0.555*) and cane girth (r = -0.724**), suggesting a trade-off between the number and size of canes a trend also observed in ratooning studies by Tabassum *et al.* (2023).

Juice quality traits such as Brix, Sucrose, and CCS% showed very strong positive correlations among themselves in all crop cycles. This reflected their shared biochemical basis and suggested that selection for one was likely to improve the others. However, Brix and the number of millable canes were negatively correlated in the second plant and ratoon crops, reflecting a dilution effect, where an increased number of canes might reduce overall juice concentration. The correlation between CCS percentage and cane yield in the first plant crop was positive and significant (r = 0.360*), suggesting that sucrose-based yield gains could be realized in later cycles. Single cane weight showed a strong positive correlation with cane girth in all crop cycles, while it was negatively correlated with the number of millable canes, highlighting the inverse relationship between cane number and cane size. Cane length and cane yield showed a weak to moderate correlation, suggesting that gains in cane length might not directly translate into higher yield unless supported by improvements in weight or juice traits. Cane girth and cane yield were mostly uncorrelated, except for a weak negative correlation in the second plant crop (r = -0.351*), possibly due to competition or lodging effects.

Path coefficient analysis

The results of the genotypic path coefficient analysis, presented in Table 5, revealed that cane yield exerted the strongest positive direct effect on Brix percentage and CCS yield across all crop cycles. CCS yield exhibited significant positive correlations along with substantial direct effects in each season, highlighting its importance as a key selection criterion in sugarcane breeding programs. Cane length and single cane weight showed positive direct effects on cane yield across the first and second plant crops. The number of millable canes also exhibited a positive direct effect on cane yield in the first plant and ratoon crops. Tena *et al.* (2023) reported similar findings for cane yield and CCS yield. Abu-Ellail *et al.* (2017) reported comparable results for the number of millable canes, and Reddy *et al.* (2024) observed similar effects for single cane weight.

CONCLUSION

This study highlights significant genetic variability, heritability, and trait interrelationships among ten early maturing sugarcane clones evaluated across three crop cycles. The analysis of variance suggesting that selection across seasons is necessary for stable trait expression. These findings emphasize that the ratoon crop is the most reliable stage for selection in early maturing sugarcane due to higher heritability, stronger genetic correlations, and better trait stability. Traits such as cane

Table 3.Genetic parameters of yield and quality related traits in ten sugarcane clones over three seasons

Response	GCV			PCV			Heritability			Gen-Advance			Gen-Adv % Means		
Variable	IP	IIP	RA	IP	IIP	RA	IP	IIP	RA	IP	IIP	RA	IP	IIP	RA
Number of millable canes ('000/ha)	11.20	12.87	13.43	12.66	13.11	14.22	78.35	96.25	89.18	20.46	22.95	23.98	20.43	26.00	26.12
Brix (%)	3.11	3.08	4.61	6.15	5.20	6.90	25.60	35.02	44.66	0.58	0.70	1.23	3.24	3.75	6.35
Sucrose (%)	4.00	4.47	5.80	6.95	6.25	6.47	33.18	51.02	80.39	0.79	1.11	1.93	4.75	6.57	10.71
Commercial cane sugar (%)	4.33	5.52	6.27	7.61	7.36	7.24	32.39	56.11	74.95	0.60	1.01	1.42	5.08	8.51	11.19
Single cane weight (kg)	15.18	2.07	12.92	15.87	26.01	13.95	91.43	0.63	85.81	0.27	0.00	0.19	29.90	0.34	24.66
Commercial cane sugar yield (t/ha)	15.63	14.91	20.24	17.81	19.63	22.00	77.06	57.66	84.61	2.98	2.45	3.41	28.27	23.32	38.35
Cane length (cm	8.62	22.77	11.12	13.17	23.23	11.54	42.85	96.10	92.93	32.15	100.52	46.17	11.63	45.98	22.08
Cane girth (cm)	9.06	18.68	9.73	12.59	20.71	15.79	51.78	81.38	37.92	0.31	0.72	0.26	13.40	34.72	12.34
Cane yield (t/ha)	13.44	12.92	21.20	15.28	18.63	22.31	77.32	48.09	90.28	21.75	16.36	29.07	24.34	18.45	41.49

IP= first plant crop, IIP= second plant crop, RA= ratoon crop

Table 4. Genotypic correlations for each season across nine agronomic and quality traits

Traits	Crop cycle	NMC	BP	SC	CCSP	SCW	CCY	CL	CG	CY
NMC	IP	1	-0.228	-0.016	0.049	-0.555*	0.114	0.284	-0.724**	0.117
	IIP	1	-0.364*	-0.054	0.029	-0.969**	0.555*	-0.102	-0.794**	0.646**
	RA	1	-0.035	-0.013	-0.007	0.309	0.800**	-0.408*	-0.36*	0.809**
BP	IP		1	0.999**	0.989**	0.473*	0.634**	-0.929**	-0.393*	0.37*
	IIP		1	0.753**	0.633**	-0.991**	-0.128	0.176	0.003	-0.41*
	RA		1	0.999**	0.986**	-0.404*	0.043	-0.333	0.03	-0.293
SP	IP			1	0.996**	0.293	0.612**	-0.946**	-0.32	0.359*
	IIP			1	0.986**	-0.859**	0.439*	0.184	-0.041	0.100
	RA			1	0.998**	-0.231	0.129	-0.278	0.506*	-0.194
CCSP	IP				1	0.24	0.613**	-0.964**	-0.301	0.360*
	IIP				1	-0.37*	0.549*	0.171	-0.05	0.221
	RA				1	-0.177	0.157	-0.261	0.667**	-0.164
SCW	IP					1	0.714**	-0.178	0.418*	0.755**
	IIP					1	-0.956**	0.958**	0.993**	-0.936**
	RA					1	0.755**	0.567*	0.641**	0.804**
CCY	IP						1	-0.28	-0.123	0.946**
	IIP						1	0.106	-0.301	0.937**
	RA						1	0.026	0.387*	0.948**
CL	IP							1	-0.526*	-0.032
	IIP							1	0.263	0.064
	RA							1	0.606**	0.096
CG	IP								1	-0.028
	IIP								1	-0.351*
	RA								1	0.157
CY	IP									1
	IIP									1
	RA									1

IP= First plant, IIP= Second plant, RA=Ratoon. NMC= Number of millable canes (‘000/ha), BP= Brix (%), SP= Sucrose (%), CCS (%)= Commercial cane sugar, SCW= Single cane weight (kg), CCSY= Commercial cane sugar yield (t/ha), CL= Cane length (cm), CG=Cane girth (cm) and CY= Cane yield (t/ha).

Table 5. Genotypic path coefficient analysis of cane yield and quality components for each crop season across nine agronomic and quality traits

	Crop cycle	NMC	BP	SC	CCSP	SCW	CCY	CL	CG	gen_corr with main variable
NMC	IP	**0.202**	-0.008	0.004	-0.001	-0.147	0.102	0.004	-0.039	0.117
	IIP	**-0.042**	-0.005	0.008	-0.008	-0.003	0.644	-0.003	0.054	0.646
	RA	**0.022**	-0.003	0.005	0.000	-0.002	0.785	0.005	-0.005	0.809
BP	IP	-0.046	**0.037**	-0.259	-0.024	0.125	0.571	-0.014	-0.021	0.370
	IIP	0.015	**0.013**	-0.112	-0.179	-0.003	-0.148	0.005	0.000	-0.410
	RA	-0.001	**0.085**	-0.371	-0.055	0.002	0.043	0.004	0.000	-0.293
SP	IP	-0.003	0.038	**-0.251**	-0.022	0.078	0.551	-0.014	-0.017	0.359
	IIP	0.002	0.01	**-0.149**	-0.279	-0.001	0.509	0.005	0.003	0.100
	RA	0.00	0.086	**-0.365**	-0.053	0.001	0.127	0.004	0.007	-0.194
CCSP	IP	0.01	0.039	-0.251	**-0.022**	0.064	0.552	-0.014	-0.016	0.360
	IIP	-0.001	0.008	-0.147	**-0.283**	0.000	0.637	0.005	0.003	0.221
	RA	0.00	0.088	-0.365	**-0.053**	0.001	0.154	0.003	0.009	-0.164
SCW	IP	-0.112	0.018	-0.073	-0.005	**0.265**	0.643	-0.003	0.022	0.755
	IIP	0.101	-0.033	0.128	0.105	**0.001**	-1.109	0.025	-0.311	-1.093
	RA	0.007	-0.034	0.084	0.009	**-0.005**	0.741	-0.007	0.008	0.804
CCY	IP	0.023	0.024	-0.153	-0.014	0.189	**0.901**	-0.004	-0.007	0.959
	IIP	-0.023	-0.002	-0.066	-0.155	-0.001	**1.16**	0.003	0.021	0.937
	RA	0.018	0.004	-0.047	-0.008	-0.004	**0.982**	0.000	0.005	0.948
CL	IP	0.057	-0.034	0.237	0.022	-0.047	-0.253	**0.015**	-0.028	-0.032
	IIP	0.004	0.002	-0.027	-0.048	0.001	0.124	**0.026**	-0.018	0.064
	RA	-0.009	-0.028	0.101	0.014	-0.003	0.026	**-0.013**	0.008	0.096
CG	IP	-0.146	-0.015	0.08	0.007	0.111	-0.111	-0.008	**0.054**	-0.028
	IIP	0.033	0	0.006	0.014	0.005	-0.349	0.007	**-0.068**	-0.351
	RA	-0.008	0.003	-0.185	-0.035	-0.003	0.38	-0.008	**0.013**	0.157

IP= First plant, IIP= Second plant, RA=Ratoon. NMC= Number of millable canes (‘000/ha), BP= Brix (%), SP= Sucrose (%), CCS (%)= Commercial cane sugar, SCW= Single cane weight (kg), CCSY= Commercial cane sugar yield (t/ha), CL= Cane length (cm), CG=Cane girth (cm) and CY= Cane yield (t/ha). Residual effect: IP-0.001, IIP-0.0009 & RA-0.0002.

yield, CCS yield, number of millable canes, and single cane weight emerged as primary targets for selection, particularly in the ratoon crop. Juice quality traits are best selected in advanced cycles due to reduced environmental interference. Meanwhile, traits like single cane weight and cane girth, which display inconsistent behavior, require stage-specific selection strategies or further environmental stabilization.

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RAPID *IN VITRO* PROPAGATION OF *ANANAS COMOSUS VAR. MICROSTACHYS* USING CROWN EXPLANTS

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ABSTRACT

The present study was conducted from December 2023 to August 2024 at the Department of Biotechnology, Ramniranjan Jhunjhunwala College, Mumbai, to develop an efficient in vitro propagation protocol for *Ananas comosus var. microstachys*. Crown explants were disinfected and cultured on Murashige and Skoog (MS) medium with varying concentrations of 6-benzylaminopurine (BAP) and kinetin (KN) (0.25 to 2.0 $mg.L^{-1}$) for shoot induction, and indole-3-butyric acid (IBA) and indole-3-acetic acid (IAA) (0.5 to 3.0 $mg.L^{-1}$) for rooting. The highest shoot proliferation was observed at 2.0 $mg.L^{-1}$ BAP, with 25 shoots/explant in the first subculture and 38 in the second. The maximum shoot length reached 5.5 cm. Rooting was optimal on full-strength MS medium supplemented with 1.0 $mg.L^{-1}$ IBA, yielding 10.67 roots/shoot with an average length of 7 cm. Primary hardening in a 1:1 cocopeat and vermiculite mixture resulted in 98% survival, while soil and sand (1:1) proved suitable for secondary hardening. The protocol ensures rapid, large-scale multiplication of dwarf pineapple for commercial floriculture applications.

Key words: BAP, Crown, Dwarf pineapple (*Ananas comosus var. microstachy*s), Hardening

INTRODUCTION

Floriculture, or flower farming as it is popularly called, is a discipline of horticulture that deals with study of growing and commercialising flowers, cut flowers, foliage, and ornamental plants (Wani *et al.*, 2018). Floriculture makes use of flowering and attractive plants for gardens and their use as raw materials in the pharmaceutical, cosmetic, and perfume industries (Sankari *et al.*,2020). The floral and ornamental plant market is characterised by its dynamic nature, always seeking new offerings.

Ananas comosus var. *microstachys* is the most economically and commercially important plant in the family *Bromeliaceae* (Nashima *et al.*, 2015) that has adapted to land or epiphytic habitats and endures extreme climates with shade or full sunlight (Sharma *et al.*, 2024). Dwarf pineapple is cultivated around the world for its ornamental properties and is now gaining a lot of demand (Hilo De Souza *et al.*, 2014) in Asian countries for its novelty and extended shelf life as a cut flower. Thus, due to the rarity of this plant, its monetary value is very high, and its planting material is in great demand.

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This perennial monocot features a central stem topped with an inflorescence and fruit, with the fruit sporting a crown (Benzing, 2023). Beneath every leaf axil of a pineapple crown is a dormant axillary bud from which new shoots, called slips, can develop and after fruiting, axillary buds may grow into suckers, producing a ratoon crop (Sulaiman *et al.*, 2020). However, natural propagation through structures like crowns is slow, posing a challenge for breeders aiming to efficiently boost selected clones.

All the conventional methods used to propagate the ornamental pineapple require a long time to produce a plant and then to flower. The conventional propagation technique gives rise to only one plant and thus is insufficient for mass production. Hence, a propagation technique that can produce several plants from a single vegetative part would be of great value. Thus, micro-propagation can be used as it allows rapid, efficient, and mass cultivation of plants. This was the first time to report *in vitro* multiplication of ornamental pineapple through the use of the crown as an explant. While several studies have successfully utilized crown explants for pineapple micropropagation in different varieties, including 'cv. Josapine' where crown explants achieved 88% shoot induction with 2.0 mg/L BAP (Sriskanda *et al*., 2025), the present study represents the first comprehensive protocol specifically optimized for *Ananas comosus var. microstachys* using crown explants. Previous pineapple tissue culture studies predominantly focused on commercial varieties such as MD2 (Sulaiman *et al.*, 2020) (Guzmán-Antonio *et al.*, 2023) and 'Smooth Cayenne' (Lakho *et al*., 2023), employing various explant types including shoot tips, nodal segments, and sucker buds (Reinhardt *et al.,* 2018). However, the ornamental dwarf pineapple variety *microstachys* (Fig.1) has received limited attention in micropropagation research despite its growing demand in floriculture. In the present study, a simple protocol was developed to propagate dwarf pineapple through tissue culture methods from the crown explants to ensure an abundant supply of this plant material for commercial cultivation.

Fig. 1. Dwarf pineapple *Ananas comosus* var. *microstachys*

MATERIAL AND METHODS

The mother plants were obtained from a nursery in Karjat, Maharashtra. The fruit stalks were harvested from the plants, and subsequently, the crowns were bilaterally excised from them and were used as explants (Zulkarnain *et al.*, 2018). These crowns were then washed under running water to remove all the traces of soil present on them and were further used to establish an aseptic culture.

The explants underwent a thorough washing process with tap water, followed by the addition of 1% of Bacillocid special. Subsequently, they were surface sterilised using 70% ethanol followed by 0.1% mercuric chloride solution for 15 minutes and rinsed four times with sterile double-distilled water within the Laminar Air flow chamber. Small crown segments (Fig.2) measuring 0.5-1.0 cm were placed on a modified MS medium supplemented with specific concentrations of growth regulators (BAP, KN) either individually or in combination, along with 3000 $mg \cdot L^{-1}$of sucrose and 0.7% agar. The pH of the medium was set to 5.7 using 0.1N HCl before autoclaving at 121°C for 20 minutes. The cultures were then kept at 25 ± 2°C with a 16-hour photoperiod. Subculturing was performed at 21-day intervals. The proliferated shoots were sub-cultured again to induce multiple

Fig. 2. Crown explant

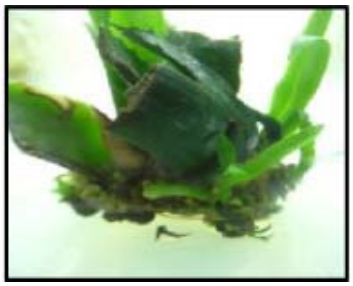

Fig. 3. Shoot bud proliferation

Fig. 4. *In vitro* rooting

shoot bud formation (Fig 3). The regenerated multiple shoots were divided, and individual shoots were transferred to a modified MS medium with varying concentrations of IBA and IAA for root induction (Fig 4) (Siposova *et al.*, 2021). Controls consisting of hormone-free MS basal medium were included in all experiments to verify that explants remained viable but did not exhibit callus induction, shoot proliferation, or rooting in the absence of exogenous growth regulators.

Requirements of cytokinin for *in vitro* shoot induction

The effect of cytokinin on explants for shoot induction was studied by inoculating them on a modified Murashige and Skoog medium supplemented with BAP and KN at concentrations ranging from 1.0 to 5.0 $mg.L^{-1}$. The crowns thus sterilised were transferred into the medium with various concentrations of cytokinin for the production of *in vitro* shoots.

The cytokinin (0.5–2.0 $mg.L^{-1}$ BAP and KN) and auxin (0.5-3.0 $mg.L^{-1}$ IBA and IAA) concentration ranges were selected based on previous reports demonstrating optimal *in vitro* responses in pineapple. BAP at 2.0 $mg.L^{-1}$ has repeatedly produced high shoot multiplication, including 16.7 shoots per explant in cv. Smooth Cayenne (Lakho *et al*., 2023).and 6.85 shoots per explant in cv. Josapine, when combined with 0.5 $mg.L^{-1}$ NAA (Sriskanda *et al*., 2025). For rooting, IBA (1.0–2.0 $mg.L^{-1}$) is consistently superior to other auxins, with 1.0 $mg.L^{-1}$ IBA yielding more roots and greater root length than other auxins (Lakho *et al*., 2023).

Requirement of auxin for *in vitro* callus induction

Explants were inoculated on the modified Murashige and Skoog's medium supplemented with auxins like NAA and 2,4-D. Each of them was tested with concentrations, viz- 0.5, 1.0, 1.5, 2.0 $mg.L^{-1}$. The responses of the explants were recorded at an interval of 7 days.

Synergistic effect of auxin and cytokinin for callus induction

The optimum concentration of cytokinins like BAP, Kinetin and auxins like NAA, 2,4-D was combined to test the synergistic effects of these on the explants' response for callus induction and further regeneration.

Rooting of *in vitro-derived* plants

The *in vitro* regenerated shoots were separated individually and sub cultured on full-strength and half-strength modified MS medium supplemented with 1 $gm.L^{-1}$ activated charcoal and 0.5 to 2.0 $mg.L^{-1}$ of IBA, NAA and IAA, respectively.

Vertically cut crowns callused approximately three weeks after the explants were placed on callus induction medium. The explants callused on MS medium supplemented with 0.5 $mg.L^{-1}$ NAA + 1.0 $mg.L^{-1}$ BAP gave the best result. The callus, initiated on media supplemented with the above hormonal combinations, was compact. The proliferated

Table 1. Synergistic effect of cytokinin + auxin on the callus-generating ability of the crown of *A. comosus* var *microstachys*

Concentration of plant Growth regulator BAP + NAA (mg.L^{-1})	Number of explants tested	Callus response expressed in percentage	Duration in days for callus initiation
0.0+0.0	12	-	-
0.5+0.0	12	10	26
0.5+0.5	12	25	26
1.0+0.5	12	92	18
1.5+1	12	33	22
2.0+1	12	66	23
0.0+0.5	12	-	-

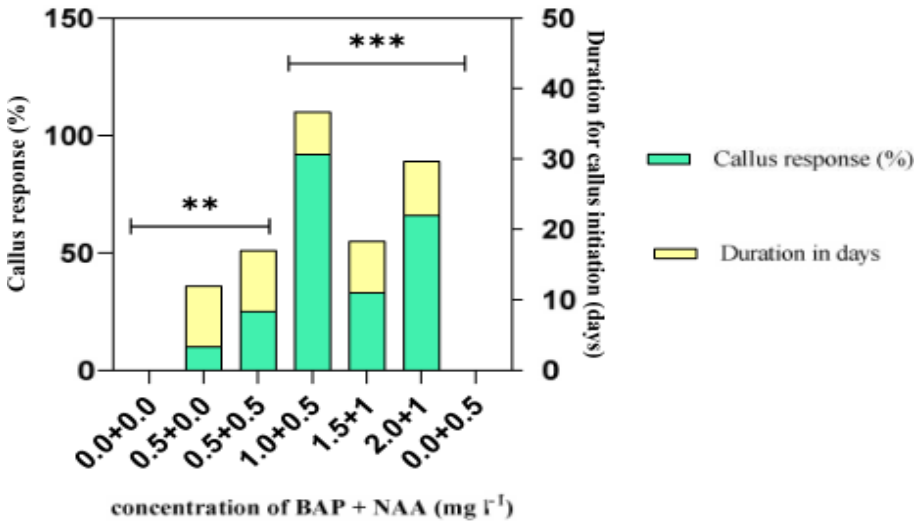

Fig 5. Synergistic effects of different concentrations of BAP and NAA on callus-generating ability of the crown of *A. comosus* var *microstachys*.

Callus response (%) (green bars, left y axis) and duration required for callus initiation (days) (yellow bars, right y axis) are shown for explants cultured on media supplemented with the indicated combinations of BAP and NAA (x axis). Data were analyzed using two way ANOVA followed by post hoc multiple comparison tests. The relationship between callus response and induction time was evaluated using Spearman correlation. Error bars represent 95% confidence intervals calculated from 12 replicates per treatment, and statistical significance is indicated by asterisks (**p < 0.01; ***p < 0.001).

Calli were sub-cultured into cytokinin-containing medium for shoot initiation.

For shoot induction callus, it was subcultured on the regeneration medium. The results show that the highest number of shoots was found to regenerate in the medium fortified with 2.0 mg.L^{-1} BAP alone. The BAP-NAA combination was not so efficient in initiating shoot regeneration from callus.

Table 2.Effect of BAP cytokinin on the shoot-generating ability of the callus.

Concentration of plant Growth regulator BAP (mg.L^{-1})	Number of explants tested	Shoot response in percentage	Number of shoots/explants.		
			7Days	14 Days	21Days
0.0	7	0	-	-	-
0.5	7	20	1	3	3
1.0	7	40	3	6	8
1.5	7	60	15	22	30
2.0	7	60	25	32	38

For rooting of excised shoots, either a single or a combination of two or three auxins was used routinely. In the present experiment, 1.0 mg.L^{-1} IBA was found to be the optimal concentration for root induction. Root formation was not observed when shoots were cultured on a medium lacking auxin. Other auxins tested were IAA and NAA, whose results were insignificant, as the roots developed were very few and not healthy.

RESULTS AND DISCUSSION

Establishment of explants

Establishment of aseptic culture was the most crucial stage of the *in vitro* culture of ornamental pineapple. The primary issue encountered was contamination, which was attributed to the presence of both endogenous and exogenous microflora inherited from the explants. To overcome this problem, a severe

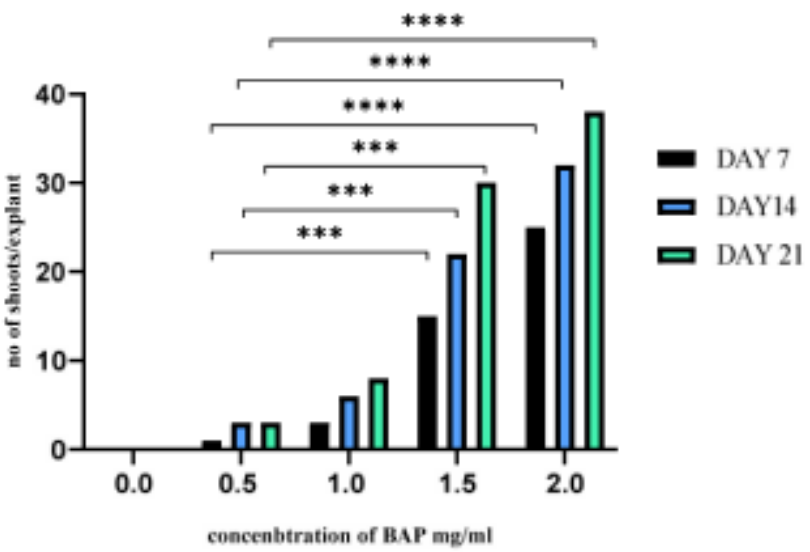

Fig 6. Effect of BAP concentration and culture duration on shoot proliferation.

The number of shoots per explant was recorded on day 7 (black bars), day 14 (blue bars), and day 21 (green bars) for explants cultured on media containing the indicated BAP concentrations (mg/ml) along the x axis. Data were analysed using two way ANOVA followed by Dunnett's multiple comparison test. Statistical significance is indicated by asterisks (***p < 0.001; ****p < 0.0001).

Table 3. Effect of auxin on root generating ability on the shoot of *Ananas comosus* var *microstachys.*Observation on 20 days after subculture.

Concentration of plant Growth regulator IBA (mg.L^{-1})	Number of shoots tested for rooting	Percentage root response	Average number of roots	Average length of roots(cm)
0.0	7	-	-	-
0.5	7	-	-	-
1.0	7	100	10	7
1.5	7	40	4	3
2.0	7	60	3	4

sterilisation protocol had to be followed. Even then, with the best of the technique applied, it was found that the survival rate of the explants in the laboratory condition was 80 per cent.

Another problem was browning of the media due to the abundance of polyphenols and their oxidation; this could be controlled by immersing the explants in water containing 1% (w/v) ascorbic acid or citric acid. Alternatively, in the initial stages of the culture, the explants were sub cultured more frequently to prevent the browning of the explants.

Synergistic effect of auxin and cytokinin

BAP and NAA in various combinations were added to Murashige and Skoog's medium for their ability to induce callus and shoots. These combinations of BAP and NAA gave good results for callus induction in crowns as compared to auxin 2,4-D, which was also used for the same purpose. Although all the combinations tried gave results but vertically cut crowns callused approximately three weeks after the explants were placed on callus induction medium. The explants callused on MS

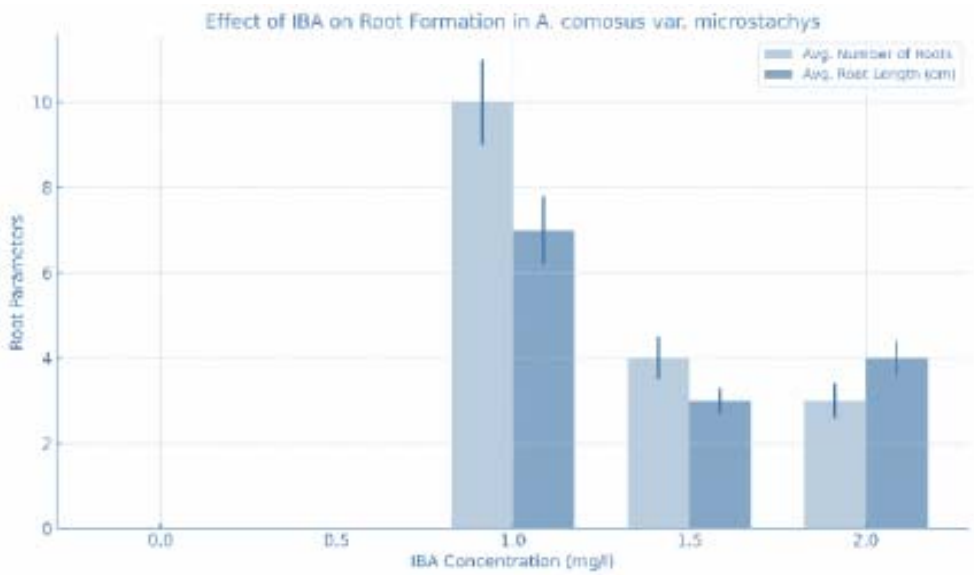

Fig 7. Effect of auxin on root generating ability on the shoot of *A. comosus var microstachys.* Observation on 20 days after subculture.

medium supplemented with 1.0 mg.L^{-1} BAP+0.5 mg.L^{-1} NAA gave the best result. The callus initiated on media supplemented with the above hormonal combinations was compact. The proliferated calli were sub-cultured into cytokinin-containing medium for shoot initiation. To check that it was only in combination of BAP and NAA that resulted in callus induction, the singular effect of BAP and NAA was also tried for callus induction, but neither of them gave results. Though only NAA was found to be necrotic, BAP did induce shoots in some explants at concentrations higher than that of NAA.

Effect of cytokinin on shoot regeneration

Benzyl amino purine was the most effective cytokinin in terms of multiple shoot induction. Percentage responses of the explants were also high compared to other cytokinins. BAP concentrations ranging from 1.0mg.L^{-1} to 5.0mg.L^{-1} were tested; almost all concentrations showed multiple shoot formation, but at a concentration of 2.0mg.L^{-1}, the shoot formation rate was maximum; it was around 25 shoots per explant within a week's incubation. Moreover, the plants obtained were also healthy. It was concluded that a concentration of 2.0mg.L^{-1} BAP was best; therefore, further experiments were continued with the same concentration. Kinetin was also used for the induction of shoots, but was not found to be as effective as compared to BAP.

Effect of 2,4-D on callus induction

Effects of various concentrations of 2,4-D were observed on ornamental pineapple, although most of the concentrations were found to be necrotic, callusing was observed in some explants inoculated in media containing 1.0 mg.L^{-1} 2,4-D after 30 days of subculture. This callus became brown later and did not proliferate.

Effect of various concentrations of IBA, IAA and NAA on root regeneration

For rooting of excised shoots, several concentrations of IBA, IAA and NAA were used. In the rooting experiment, Murashige and Skoog's medium with 1.0 mg.L^{-1} IBA was found to be the best for root induction. This concentration of IBA resulted in the greatest average number of roots, which was 10 andthe average length was found to be 7 cm. Root formation was not observed when shoots were cultured on a medium lacking auxin. Compared to IBA, IAA and NAA were also supplemented respectively into MS medium to check their effect on root initiation in the *in vitro* grown shoots. But IBA gave a better response to root initiation.

Hardening of *in vitro* derived plants

Acclimatisation is the final but necessary step in all plant propagation schemes. Here, plants have to adapt to new environmental conditions such as low relative humidity, higher light intensity and fluctuations of temperature and stress (Rambabu *et al.*, 2021). Hardening of the *in vitro-derived* plantlets was done in a greenhouse in small pots. It was found that in the primary hardening, 1:1 vermiculite and coco peat were very effective. The survival rate of the plantlets was 98%. In the secondary hardening, soil and sand were used in the ratio of 1:1, which also proved to be a good medium for hardening.

CONCLUSION

The present study successfully established a simple, reproducible, and efficient in vitro micropropagation protocol for dwarf ornamental pineapple using crown explants. The combination of 1.0 mg.L^{-1} BAP and 0.5 mg.L^{-1} NAA produced the best callus induction, while 2.0 mg.L^{-1}BAP proved most effective for shoot multiplication. Rooting was optimally achieved with 1.0 mg.L^{-1} IBA, and the survival rate of hardened plantlets reached 98 per cent. This protocol can serve as a reliable tool for mass multiplication of *Ananas comosus var.microstachys* to meet commercial floriculture demands.

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EVALUATION OF FUNGICIDES FOR THE MANAGEMENT OF POWDERY MILDEW CAUSED BY *ERYSIPHE POLYGONI* IN FENUGREEK (*TRIGONELLA FOENUM-GRAECUM*)

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ABSTRACT

A field study was conducted at Sardarkrushinagar Dantiwada Agricultural University, Jagudan, Gujarat, over four consecutive Rabi seasons (2018-19, 2019-20, 2020-21 and 2021-22) using a randomized block design with three replications to assess the efficacy of two fungicides against powdery mildew in fenugreek (cv. Gujarat Methi-2). Among all treatments, hexaconazole 5 SC at 0.0063% (T$_f$) consistently recorded the lowest disease intensity (pooled mean:11.34%) and the highest seed yield (2309 kg/ha), being at par with hexaconazole 0.005% and wettable sulphur 0.25%. The untreated control showed the highest disease intensity (38.82%) and the lowest yield (1596 kg/ha). Residue analysis confirmed hexaconazole residues well below permissible limits, while economic evaluation revealed the highest ICBR (13.82) with T$_f$. Thus, foliar application of hexaconazole 5 SC at 0.0063% proved most effective, safe, and economical for managing powdery mildew in fenugreek.

Keywords:*Erysiphe polygoni*, Economics, Fenugreek, Fungicides, Powdery mildew, Residues

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is an annual leguminous crop belonging to the family Fabaceae, cultivated worldwide as a multipurpose plant valued for its leaves and seeds. Globally, it is grown across Asia, Africa, the Mediterranean region and parts of Europe for its culinary, medicinal and industrial applications. The seeds are a rich source of protein, fibre, saponins and alkaloids and are widely used in functional foods and traditional medicine for their hypoglycaemic and hypocholesterolemic properties. Major fenugreek-producing countries include India, Egypt, Morocco and China, together contributing significantly to global spice trade and pharmaceutical industries.

In India, fenugreek holds a prominent position as the third-largest seed spice crop, extensively cultivated in Rajasthan, Gujarat, Madhya Pradesh and Uttar Pradesh. It serves as an important component of smallholder farming systems, contributing to household income and nutritional security. However, fenugreek productivity is severely constrained by several fungal, bacterial and viral diseases that adversely affect yield and quality. Among the fungal diseases, powdery mildew, downy mildew, root rot and wilt are predominant, with powdery mildew caused by *Erysiphe polygoni*

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being one of the most widespread and destructive. The disease typically appears during the late vegetative to pod formation stages, covering leaves, stems and pods with white powdery growth, leading to premature leaf senescence, reduced photosynthetic efficiency and yield losses up to 25-70 per cent under severe infection.

Although several management approaches, including cultural and biological methods, have been explored, their effectiveness remains inconsistent under field conditions. Hence, optimizing fungicidal management using safe and economical formulations suited to local agro-climatic conditions is essential. Therefore, the present investigation was undertaken to evaluate the efficacy of different concentrations of hexaconazole and wettable sulphur for sustainable management of powdery mildew in fenugreek under field conditions at the Seed Spices Research Station, SDAU, Jagudan.

MATERIAL AND METHODS

Experiment site and Duration

A comprehensive field experiment was undertaken in a randomized block design with three replications during the Rabi seasons of 2018-19, 2019-20, 2020-21 and 2021-22 at Seed Spices Research Station, Jagudan.

Crop and Variety

The Fenugreek cv. Gujarat Methi-2 (GM-2) was meticulously sown in the month of November, with a well-maintained row spacing of 45 cm and a seed rate of 15 kg per hectare.

Treatments and Fungicidal applications

To ascertain the effectiveness of disease management, two distinct fungicides, hexaconazole 5 SC (0.0050%) and wettable sulphur 80 WP (0.20%), each with three prefixed concentrations, were systematically compared to an untreated control group. The efficacy of these fungicides was meticulously evaluated against the untreated control through the application of two sprays, adhering to the predetermined concentrations. The first spray was diligently administered at the onset of the disease, followed by a second spray after a lapse of 15 days from the initial application.

Calculation of Percent Disease Index

Intricate observations on the intensity of the powdery mildew disease were meticulously recorded from 20 randomly selected plants from each plot, employing a precise 0-4 scale, as elaborated below:

0.0: No incidence/Healthy

1.0: Whitish small spots on the leaf

2.0: Whitish growth covering the entire leaf

3.0: Whitish growth on leaf and stem

4.0: Whitish growth on leaf, stem, and pod

The percent disease index (PDI) was meticulously calculated based on the observations, employing the well-established formula. Additionally, the percent disease intensity (PDI) was further evaluated using the formula proposed by Datar and Mayee (1981) to provide a comprehensive assessment of the disease management strategies employed in the study.

PDI = [(Total grade / (Maximum grade) × 100] / No. of plants scored

Pesticide Residue Analysis method

Modified QuEChERS multiresidue method was adopted for the extraction and clean-up of various pesticide residues from seed spices. A representative portion ground seed (20 g) was moistened with water followed by addition of acetonitrile. The extract was treated with sodium chloride for separation of acetonitrile layer which was then subjected to dispersive SPE clean-up using PSA, $MgSO_4$

Treatment details

Sr.No.	Treatments	Conc. (%)	Dose(ml or g/ 10 L)
T_1	Hexaconazole 5 SC	0.0038	7.6
T_2	Hexaconazole 5 SC	0.0050	10.0
T_3	Hexaconazole 5 SC	0.0063	12.6
T_4	Wettablesulphur80 WP	0.15	18.75
T_5	Wettablesulphur80 WP	0.20	25.0
T_6	Wettablesulphur80 WP	0.25	31.25
T_7	Untreated control	-	-

Note: First spray at initiation of disease and second spray after 15 days of first spray

and C18. The residues were determined using GC-MS/MS and/or LC-MS/MS.

RESULTS AND DISCUSSION

Percent disease intensity (PDI)

Upon examining the data, it evident that there was a noteworthy disparity in the percent disease intensity throughout all the experimental years, as well as in the overall pooled results (refer to Table 1). The application of T_3, specifically hexaconazole at a concentration of 0.0063%, resulted in the lowest percent disease intensity values across all the years of experimentation (2018-19, 2019-20, 2020-21, and 2021-22), as well as in the pooled results, exhibiting values of 12.78, 8.97, 10.42, 13.47, and 11.34, respectively. In the *Rabi* season of 2018-19, the treatment T_3, which utilized hexaconazole at a concentration of 0.0063%, exhibited at par results with T_2 (hexaconazole 0.005%) and T_6 (wettable sulphur 0.25%) treatments. Similarly, during the Rabi season of 2019-20, T_3 remained on par with T_6 (wettable sulphur 0.25%), T_5 (wettable sulphur 0.2%), and T_2 (hexaconazole 0.005%) treatments.

Furthermore, in the *Rabi* season of 2020-21, the superior treatment T_3 (hexaconazole 0.0063%) demonstrated comparable efficacy with T_6 (wettable sulphur 0.25%) and T_2 (hexaconazole 0.005%) treatments. In the Rabi season of 2021-22, the most effective treatment, T_3 (hexaconazole 0.0063%), exhibited at par results with T_6 (wettable sulphur 0.25%) and T_2 (hexaconazole 0.005%) treatments.

Similarly, in the pooled results, T_3 demonstrated similar efficacy when compared to T_6 (wettable sulphur 0.25%), T_2 (hexaconazole 0.005%), and T_5 (wettable sulphur 0.2%) treatments.However, it is noteworthy that the untreated control exhibited the highest percent disease intensity values of 40.80, 47.63, 28.51, 38.80, and 38.82 during all four years of experimentation, as well as in the pooled results.

Seed yield

The analysis of the data has unveiled a significant variation in fenugreek seed yield across all the years of experimentation (Table 2). Remarkably high seed yields of 2770, 2017, 1927, 2521, and 2309 kg/ha were consistently observed with T_3, employing hexaconazole at 0.0063% concentration, during the entirety of the experimental period (2018-19, 2019-20, 2020-21, and 2021-22), as well as in the pooled results.

In the *Rabi* season of 2018-19, T_3, utilizing hexaconazole at 0.0063%

Table 1. Effect of different treatments on Percent disease intensity of Powdery mildew

Sr.No.	Treatments	Percent disease intensity				
		2018-19	2019-20	2020-21	52021-22	Pooled
T_1	Hexaconazole 5 SC 0.0038 %	*23.30^{bc} (15.65)	*22.48^{b} (14.62)	*22.41^{bc} (14.53)	*24.01^{bc} (16.56)	*23.05^{b} (15.33)
T_2	Hexaconazole 5 SC 0.0050 %	21.88^{cd} (13.89)	19.35^{cd} (10.98)	20.30^{de} (12.04	22.35^{cd} (14.46)	20.97^{bc} (12.81)
T_3	Hexaconazole 5 SC 0.0063 %	20.95^{d} (12.78)	17.43^{d} (8.97)	18.83^{e} (10.42)	21.53^{d} (13.47)	19.68^{c} (11.34)
T_4	Wettable sulphur 80 WP 0.15 %	24.96^{b} (17.81)	20.55^{bc} (12.32)	23.33^{b} (15.68)	25.64^{b} (18.72)	23.62^{b} (16.05)
T_5	Wettable sulphur 80 WP 0.20 %	23.17^{bcd} (15.48)	19.02^{cd} (10.62)	21.00^{cd} (12.84)	23.69^{bcd} (16.14)	21.72^{bc} (13.70)
T_6	Wettable sulphur 80 WP 0.25 %	22.09^{cd} (14.14)	17.78^{d} (9.32)	19.26^{de} (10.88)	22.77^{cd} (14.98)	20.47^{bc} (12.23)
T_7	Untreated control	39.70^{a} (40.80)	43.64^{a} (47.63)	32.27^{a} (28.51)	38.53^{a} (38.80)	38.54^{a} (38.82)
	S.Em	0.67	0.66	0.65	0.65	1.061
	C.D at 5%	2.08	2.03	2.01	2.01	3.15
	C.V%	4.64	4.98	5.01	4.42	4.75
	Y X T					1.87

Figures in the parenthesis are retransformed values

Treatments means with the letter (s) in common are not significant by DNMRT at 5% level of significance

concentration, exhibited comparable seed yields when compared to several treatments, namely T_2 (hexaconazole 0.005%), T_6 (wettable sulphur 0.25%), T_5 (wettable sulphur 0.2%), T_1 (hexaconazole 0.0038%) and T_4 (wettable sulphur 0.15%). These treatments yielded 2667, 2657, 2570, 2526, and 2505 kg/ha of seeds, respectively.

The results suggest that the application of T_3, utilizing hexaconazole at a concentration of 0.0063%, exhibited superior efficacy in significantly enhancing fenugreek seed yield over multiple years of experimentation. These findings offer valuable insights into the potential of this treatment for optimizing seed production in fenugreek cultivation.

During the *Rabi* season of 2019-20, T_3 displayed comparable seed yields with treatments T_6 (wettable sulphur 0.25%), T_5 (wettable sulphur 0.2%), and T_2 (hexaconazole 0.005%), which recorded seed yields of 1963 kg/ha and 1910 kg/ha, respectively. Similarly, in the *Rabi* season of 2020-21, the superior treatment T_3 (hexaconazole 0.0063%) showed comparable performance with T_2 (hexaconazole 0.005%), T_6 (wettable sulphur 0.25%), and T_5 (wettable sulphur 0.2%), which recorded seed yields of 1894 kg/ha, 1862 kg/ha, and 1790 kg/ha, respectively.

Table 2. Effect of different treatments on seed yield

		Seed yield (Kg/ha)				
Sr.No.	**Treatments**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**Pooled**
T_1	Hexaconazole 5 SC 0.0038 %	2526[a]	1724[a]	1773[a]	2250[a]	2068[b]
T_2	Hexaconazole 5 SC 0.0050 %	2667[a]	1910[a]	1894[a]	2390[a]	2215[ab]
T_3	Hexaconazole 5 SC 0.0063 %	2770[a]	2017[a]	1927[a]	2521[a]	2309[a]
T_4	Wettable sulphur 80 WP 0.15 %	2505[a]	1869[a]	1761[a]	2229[a]	2091[b]
T_5	Wettable sulphur 80 WP 0.20 %	2570[a]	1910[a]	1790[a]	2292[a]	2141[ab]
T_6	Wettable sulphur 80 WP 0.25 %	2657[a]	1963[a]	1862[a]	2381[a]	2216[ab]
T_7	Untreated control	1943[b]	1339[b]	1440[b]	1663[b]	1596[c]
	S.Em	145	107	83	159	56
	C.D at 5%	446	331	255	489	159
	C.V%	9.94	10.22	8.06	12.24	10.52
	Y X T					NS

Treatments means with the letter (s) in common are not significant by DNMRT at 5% level of significance

Table 3. Effect of different treatments on 1000 seed wt.(g)

SrNo.	Treatments	Mean 1000 seed weight (g)
T_1	Hexaconazole 5 SC 0.0038 %	15.3
T_2	Hexaconazole 5 SC 0.0050 %	15.7
T_3	Hexaconazole 5 SC 0.0063 %	16.1
T_4	Wettable sulphur 80 WP 0.15 %	15.4
T_5	Wettable sulphur 80 WP 0.20 %	15.6
T_6	Wettable sulphur 80 WP 0.25 %	16.1
T_7	Untreated control	14.9

Notably, in the pooled results, the differences between treatments were non-significant. However, T_3 consistently exhibited the maximum seed yield of 2309 kg/ha and was at par with T_6 (wettable sulphur 0.25%), T_2 (hexaconazole 0.005%), and T_5 (wettable sulphur 0.2%).

In contrast, the untreated control consistently showed the lowest seed yields of 1943 kg/ha, 1339 kg/ha, 1440 kg/ha, 1663 kg/ha, and 1596 kg/ha during all four years of experimentation, as well as in the pooled results.

These findings contribute valuable knowledge for practitioners aiming to improve fenugreek seed production and underscore the effectiveness of T_3 with hexaconazole 0.0063% for achieving optimal yields in fenugreek cultivation.

1000 seed weight

The maximum seed weight was observed in T_3, utilizing hexaconazole at a concentration of 0.0063%, and T6, employing wettable sulphur 80 WP at a concentration of 0.25%. The decline in percent disease intensity (PDI) could potentially augment plant growth and development, consequently influencing seed size and weight (Table 3).

These findings suggest that treatments T_3 and T_6 hold promise for promoting favourable seed weight in thecontext of disease management, thereby contributing to improved crop yield and quality.

Pesticide Residue Analysis

In this investigation, the residue levels of the crop treated with hexaconazole 5 SC at a concentration of 0.0063%, administered both at the disease onset and 15 days after the first application, were determined to be well below the critical limit set by various regulatory agencies (Table 5).

These results indicate that the application of hexaconazole at the specified concentration and timing adheres to the established safety guidelines, ensuring that the residue levels remain within acceptable limits. This finding holds significance for the safe and responsible use of the fungicide, minimizing potential risks to human health and the environment while effectively managing the target disease.

Economics

Based on the economic evaluation of various treatments, plots treated with hexaconazole 5 SC at a concentration of 0.0063% demonstrated the highest additional income, net realization, and Incremental Cost-Benefit Ratio (ICBR: 13.82). Following closely, hexaconazole 5 SC at 0.0050% concentration exhibited a favourable ICBR of 12.60.

The findings are well supported by the result of Kumawat and Shekhawat (2015) evaluated different nine fungicides against powdery mildew of fenugreek under field condition. Among these fungicides, hexaconazole at 0.005per cent recorded (9.60%) per cent disease intensity with maximum (84.68%) per cent disease control.

The results are in closed agreement with the study conducted by Dhruj *et al.*(2000) conducted field experiments to determine the efficacy of eight fungicides for the control of powdery mildew of fenugreek in Gujarat. The test fungicides included propiconazole at 0.025 percent, penconazole at 0.01 percent, hexaconazole at 0.005 percent, triadimefon at 0.025 per cent, tridemorph at 0.08 per cent, dinocap at 0.048 percent, sulphur WP at 0.2 percent and sulfur dust at 20 kg/ha. All the fungicides significantly reduced disease incidence in comparison with the control and increased seed yield. The minimum disease intensity (19.38%) and the highest yield (2132

Table 4. Protection Cost Benefit Ratio (PCBR)

Trt. No.	Quantity of materials (Kg or L/ha)	Cost of materials (₹ /ha)	Labour charges (₹ /ha)	Total cost of treatment (₹ /ha)	Yield (Kg/ha)	Gross realization (₹ /ha)	Net realization (₹ /ha)	Net gain (₹ /ha)	PCBR
T_1	0.760	304.00	1420.00	1724.00	2068	82720.00	18880.00	17156.00	9.95
T_2	1.000	400.00	1420.00	1820.00	2215	88600.00	24760.00	22940.00	12.60
T_3	1.260	504.00	1420.00	1924.00	2309	92360.00	28520.00	26596.00	13.82
T_4	1.875	468.75	1420.00	1888.75	2091	83640.00	19800.00	17911.25	9.48
T_5	2.500	625.00	1420.00	2045.00	2141	85640.00	21800.00	19755.00	9.66
T_6	3.125	781.25	1420.00	2201.25	2216	88640.00	24800.00	22598.75	10.27
T_7	0.000	0.00	0	0.00	1596	63840.00	0.00	0.00	

Cost of Inputs

Particular	Price (₹ /kg or L.)
Average Fenugreek Seed	40.00
Hexaconazole 5 SC	400.00
Wettablesulphur 80 WP	250.00
Labour/spray/ha	355.00

Table 5. Pesticide residue analysis

TrNo	Treatments	Results (ppm)	LoD (ppm)	LoQ (ppm)	Maximum ResidueLimit (ppm)		
					EU	CODEX	Japan
T_2	Hexaconazole 5 SC0.0050 %	0.067	0.2	0.5	0.1	0.2	0.1
T_7	Untreated Control	BDL					

BDL-Below detection limit

kg/ha) were recorded with penconazole but this fungicide treatment did not differ significantly from hexaconazole, which recorded 21.34 percent disease intensity and 2023 kg/ha seed yield.

These findings are well supported by the result of Kumawat *et al.*(2016) evaluated different nine fungicides against powdery mildew of fenugreek under field condition. Among these fungicides, hexaconazole recorded seed yield (24.61 q/ha) by increasing 63.08 percent seed yield.

According to Singh (2006) six fungicides were evaluated for control of powdery mildew disease of coriander (*Coriandrum-sativum*), caused by *Erysiphe polygoni*. All the fungicides reduced the disease severity significantly, over control, with maximum reduction in hexaconazole (0.1%) that was on par with propiconazole (0.1%) and wettable sulphur (0.3%).Yield of coriander was higher 2.54, 2.00 and 2.20 times, over control, in hexaconazole (0.1%),propiconazole (0.1%) and wettable sulphur (0.3%), respectively.

The present research findings corroborate well with the results of Patel *et al*. (2017), who reported that two sprays of hexaconazole 5 EC (0.05%) were most effective in managing powdery mildew of coriander caused by *Erysiphe polygoni* DC, recording a disease intensity of 22.53 and a 67.01 per cent reduction over control. The treatment was found statistically at par with wettable sulphur 80 WP (0.30%) and dinocap 48 EC (0.10%), which recorded 24.17 and 29.83 per cent disease intensity, respectively.

The present research aligns with the findings of Pawar *et al*. (2020), who studied the effect of fungicide sprays on powdery mildew of cowpea incited by *Erysiphe polygoni* (DC) and reported that hexaconazole 5 EC (0.05%) and triadimefon 25 WP (0.1%) were significantly effective and statistically at par, recording disease intensities of 18.18 and 19.33 per cent, respectively. These results are comparable to the present investigation, where hexaconazole effectively reduced disease intensity and improved seed yield and quality parameters in fenugreek.

Similarly, Undhad *et al*. (2022) evaluated different fungicides against *Erysiphe cichoracearum* causing powdery mildew of sesame and concluded that propiconazole 25 EC (0.025%) was the most effective, recording the minimum disease intensity (6.48%) with higher seed yield (699 kg/ha), followed by azoxystrobin 18.2 + difenoconazole 11.4 SC (0.030%) with 10.92 per cent disease intensity and 688 kg/ha seed yield.

The present research findings corroborate with the findings of Pansuriya (2022), who reported that among various fungicides evaluated under field conditions, hexaconazole 5 EC (0.05%) was the most effective treatment in reducing powdery mildew intensity (21.67%), resulting in the highest seed yield (1534 kg/ha), 1000-seed weight (13.73 g) and volatile oil content (0.41%) in fenugreek. Similar trends were observed in the present investigation, where hexaconazole significantly minimized disease severity and enhanced yield and quality parameters.

The study showed that hexaconazole 0.005% was highly effective in managing fenugreek powdery mildew, consistently recording the lowest disease intensity and higher seed yield across all seasons. These results align with finding by Patel *et al.* (2024) who reported that total six fungicides, along with treated and untreated control were evaluated for their efficacy to control the powdery mildew disease of fenugreek. All the fungicides were significantly effective in reducing the powdery mildew disease intensity over control. Among these fungicides, at maturity the minimum per cent disease intensity 29.25 was recorded with the spray ofhexaconazole (0.005%) @ 1 ml/l.The highest net returns were recorded with hexaconazole 5% EC (Rs. 20,198/ha) and an ICBR of 1:6.23.

CONCLUSION

This multi-season field evaluation, conducted over four consecutive Rabi seasons at SDAU, Jagudan, represents the first comprehensive study combining yield, economic and residue analyses for the management of powdery mildew in fenugreek. Foliar application of hexaconazole 5 SC at 0.0063% consistently recorded the lowest disease intensity (pooled mean 11.34%) and the highest seed yield (2309 kg/ha), while maintaining residue levels well below permissible limits and the highest benefit–cost ratio (ICBR 13.82). These results establish hexaconazole 5 SC at 0.0063% as an effective, safe, and economically viable option for sustainable management of powdery mildew in fenugreek under Gujarat conditions.

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ELUCIDATION OF RICE ADVANCED BREEDING LINES (F_6 GENERATION) FOR GENETIC DIVERSITY THROUGH PRINCIPAL COMPONENT AND HIERARCHICAL CLUSTERING ANALYSIS

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ABSTRACT

The current study aimed to evaluate 200 advanced breeding lines along with three checks during *kharif,*2024 to delineate the extent of genetic diversity for yield and its component traits using multivariate techniques using Principal Component Analysis (PCA), Hierarchical clustering and correlation. In PCA, the principal components having eigen values greater than one *viz.,* PC1, PC2, PC3,PC4 and PC5 detailing 20.3%, 16.7%, 14%, 12.8% and 12.7% respectively with a cumulative effect of 76.7% of the total variation. Based upon Wards method of hierarchical clustering, 200 rice advanced breeding lines along with three checks were divulged into 14 clusters based on different traits studied, in which cluster I topped with 30 advanced breeding lines followed by cluster XIII and VI with 29 and 25 advanced breeding lines, respectively. The advanced breeding linesconfined to cluster X registered higher cluster mean values for grain yield. Besides, cluster XIV showed highest values for panicle length, ear bearing tillers/m^2 and grains per panicle. The trait grain yield registered positive association with days to 50 % flowering, days to maturity, ear bearing tillers/m^2, grains per panicle and test weight through correlation analysis. From the present study, the advanced breeding lines *viz*., NDRA 78, NDRA 225, NDRA 226, NDRA 227 and NDRA 50 were identified as genetically potential advanced breeding lines for commercial exploitation for enhancing yield and component traits in rice.

Keywords: Correlation, Genetic diversity, Hierarchical cluster analysis, Principal component analysis, Rice**.**

INTRODUCTION

Rice (*Oryza sativa* L.) is foremost food crop feeding over half of the world's population (Ricepedia, 2025**).**Globally, India ranks second in rice production next to China. Despite, India produces 22% of the world's rice supply, population growth in the country is predicted to threaten food security by 2050 and increase demand for rice (Fathima *et al.*,2021).In India, during 2024-25 rice crop reported a production of 226.5 million tonnes from 51 million ha with average productivity of 4441 Kg/ha. In Andhra Pradesh, the crop is cultivated in total area of 1.92 million ha with production of 11.26 million tonnes and productivity of 5861 million tonnes (Season and Crop Report, 2023-24, Directorate of Economics and Statistics, Govt. of Andhra Pradesh).Even though the green revolution

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significantly increased rice production and productivity, a yield plateau prevented future advancement mainly due to various biotic and abiotic stresses.Hence, guaranteeing food security in future is a big challenging task, particularly, for rice breeders in India as rice is pivotal for food and nutritional security in the country. Despite this,options for breeders are very limited. Hence, breeders need to identify genetically diverse and potential advanced breeding lines for their inclusion in crop improvement programme by divergence studies for yield and its attributing traits.

Among various multivariate analysis tools *viz*., Principal Component Analysis (PCA) and cluster analysis have been reported to be effective for evaluating the phenotypic diversity in addition to identifying genetically distant clusters of genotypes and selecting important traits contributing to the total variation in the genotypes (Sudeepthi *et al*., 2020a). PCA has an edge over the other as it eliminates multicollinearity among the independent variables and shows the relevance of the largest contributor to the total variance at each differentiation axis and it comprehends non-parametric strategy from a complicated set of data.Hierarchical cluster analysis of quantitative traits is used to measure the genetic divergence and to classify the genetic stock into distinct groups (Pavan Kumar *et al.*,2019). Genetic divergence analysis using PCA and hierarchical cluster analysis isproductive in determining potential advanced breeding lines useful for hybridization.The prime objective of this examination was to delineate/elucidate genetic diversity and identify the superior advanced breeding lines for their inclusion in the commercial rice improvement programme.

MATERIAL AND METHODS

The prevailing examination was laid out with 200 advanced breeding linesof rice in F_6 generation together with three checks (NDLR 7 (tolerant to BPH and Blast with potential yield of 6.5-7 (t/ha), NDLR 8 (tolerant to BPH, leaf folder and moderately tolerant to Blast with potential yield of 6 – 7.5 (t/ha) and BPT 5204 (tolerant to BLB and Blast with potential yield of 6 (t/ha) during *kharif*, 2024 at Regional Agricultural Research Station (RARS), Nandyal, Andhra Pradesh, India during *kharif*, 2024. All the advanced breeding lines were evaluated in an Augmented Block Design with plot size of 10 m^2per line with a spacing of 20 x 15 cm. All the standard cultural and agronomic practices recommended by Acharya N.G. Ranga Agricultural University were adopted to achieve good crop growth. Data was gathered from five competitive and randomly selected plants for recording yield and yield attributes *viz*., Plant height (PH), Ear bearing tillers/m^2 (EBT/m^2), Panicle length (PL), Grains per panicle (GP), Test weight (TW) and Grain yield (Kg/ha)(GY) however data on days to 50% flowering (DFF) and days to maturity (DM) data was measured on plot basis. To assess genetic diversity among advanced breeding lines, PCA and cluster analysis wereused to identify the most contributing traits for variation and diversity among advanced breeding lines, respectively. The obtained data through evaluation of advanced breeding lines is subjected to statistical analysis to delineate genetic diversity through hierarchical clustering and PCA using JMP 18.0 statistical software (SAS Institute Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

The descriptive statistics of eight studied traits in 200 advanced breeding lines along with three checks is documented in Table 1.The advanced breeding lines,NDRA 3,NDRA 7,NDRA 20,NDRA 25,NDRA 30, NDRA 47, NDRA 62 and NDRA 94 (97 days) was observed to be early flowering, while NDRA 225 was late flowering (111 days). The line NDRA 94 (129)

Table 1. Descriptive statistics of eight yield and yield component characters in rice advanced breeding lines

S.No	Characters	Mean	Minimum	Maximum	SD	SE
1	DFF	105.06	97	112	1.91	0.13
2	DM	135.31	125	142	2.65	0.19
3	PH (cm)	89.53	70.42	109.34	6.78	0.48
4	PL	22.90	20.5	25.28	0.89	0.06
5	EBT/m2	521.80	336.6	778.8	91.09	6.39
6	GP	280.99	160.8	530.6	60.80	4.27
7	TW (G)	12.86	9.07	15.3	1.29	0.09
8	GY(Kg/ Ha)	6473.02	4650	8760	888.67	62.37

noticed early maturity while NDRA 58 and NDRA 80 (142) matured late than other advanced breeding lines. The PH ranged from 70.42 cm (NDRA 86) to 109.34 cm (NDRA164) with an average plant height of 89.53 cm. The mean value of PL was found to be 22.90 cm with range from 20.5 cm (NDRA 101) to 25.28 cm (NDRA 135). The hybrid NDRA 98 was found to bear a greater number of ear bearing tillers (778 / m^2), while least number of ear bearing tillers (336 / m^2) was displayed by hybrid, NDRA 150.The trait GP varied from 160 (NDRA 191) to 530 (NDRA 81) with mean value of 280. The advanced breeding lines NDRA 50 (9.07) and NDRA 001 (15.3) recorded minimum and maximum TW among all the advanced breeding lines. The mean GY (Kg/ha) was recorded as 6473 Kg with range from 4650 Kg (NDRA79) to 8760 Kg (NDRA 45) among the studied advanced breeding lines. The presence of significant variability among the advanced breeding lines for yield and yield component traits is the key for success in crop improvement programme. Vasudeva Reddy *et al.,* 2023 and Vijay Kumar *et al*., 2024 reported the similar experimental results while evaluating advanced breeding lines for yield and its component traits in rice.

The PCA is an authentic tool utilized for successful selection of divergent genotypesin crop improvement programme. The results of PCA revealed the significance of first five PCs in discriminating 200 advanced breeding lines along with three checks. The first five PCs *viz*. PC1, PC2 PC3, PC4 and PC5 exhibited eigen value greater than one explaining 76.7% of total variation. The eigen values and total cumulative percentage of variances explained by PCs is furnished in Table 2. PC1 with eigen value of 1.63 contributes 20.3% of the total variability, PC2, PC3, PC4 and PC5 with eigen value of 1.33, 1.12, 1.02 and 1.02 attributed 16.7%, 14.0%, 12.8%, and 12.7% of the total variability, respectively. The first PC displayed high positive weight to DFF (0.686), and DM (0.634). The second PC displayed highest positive loading to TW (0.734) and GY (0.364). Thethird PC displayed highest positive loading toEBT/m^2(0.643). Likewise, the fourth and fifth PCs gave positive loading to PL (0.753) and PH (0.709), respectively(Table 3).

The greater portion of the variance (20.3%) was noticed in PC1and was strongly convinced by DFF, DM, EBT/$m^2$and GY. PC2 was influenced by DM, PL, TW and GY. Similarly, PC3 was influenced by EBT/m^2, GY GP and TW. Likewise, PC4 and PC5 are primarily influenced by PL, PHand PH, GY respectively. Similar kind of results are in agreement with findings of Sudeepthi *et al.*

Table 2. Total variances explained by different principal components in rice advanced breeding lines

Components	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Eigen values	1.63	1.33	1.12	1.02	1.02	0.85	0.68	0.32
Proportion variance %	20.3	16.7	14.0	12.8	12.7	10.6	8.58	4.01
Cumulative variance %	20.3	37.1	51.1	63.9	76.7	87.4	95.9	100

Table 3. Factor loading of different characters with respect to different principal factors in rice advanced breeding lines

Principal Components	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
DFF	0.686	-0.155	-0.110	0.101	-0.745	-0.064	-0.194	0.659
DM	0.634	0.194	-0.114	0.279	-0.132	0.048	0.305	-0.596
PH (cm)	-0.044	-0.202	-0.156	0.456	0.709	0.459	0.079	0.051
PL	-0.247	0.354	-0.005	0.753	-0.113	-0.591	-0.003	0.077
EBT/m2	0.117	-0.399	0.643	-0.87	0.160	-0.215	0.573	20.070
GP	-0.098	-0.253	0.370	0.343	-0.570	0.569	-0.146	0.000
TW (G)	-0.083	0.734	0.134	0.078	-0.050	0.239	0.441	0.418
GY (Kg/ Ha)	0.181	0.364	0.617	0.059	0.326	-0.615	-0.563	-0.144

Bold figures indicate maximum and minimum values in each character.

2020a, Venkata Ratnam *et al.,* 2022, Edukondalu *et al.,* 2024 and Paramanik *et al.,* 2025 in rice.

The biplot depicted the relationship of 200 advanced breeding lines along with three checks for eight traits (Fig. 1). From the biplots, the eight yield and yield attributing traits were divulged into four groups. GY and DM were grouped in same cluster. DFF and EBT/m^2 were grouped in same cluster. The traits PL and TW were grouped in another cluster. Whereas, PH and GP together grouped as one cluster. The selection of advanced breeding lines with highest score (0.617) in PC3 will be desirable for developing high grain yielders in rice.The study showed that NDRA 78, NDRA 225 (NDLR 7 check), NDRA 226 (NDLR 8 check), NDRA 227 (BPT 5204 check) and NDRA 50 were located at extreme ends of distinct quadrants of the plot. Hence, these advanced breeding lines and checks were recognized as highly divergent and found to be potential for exploitation in hybridization programme to enhance heterotic potential in rice crop.

Hierarchical cluster analysis was conducted with 200 advanced breeding lines along with three checks using Wards method which provides the best result to get the finest possible classification. The cluster analysis revealed the aggregation of advanced breeding lines into fourteen clusters (Table 4 and Fig.2).The cluster means computed for eight major yield attributing characters revealed the existence of ample amount of variation among the clusters (Table 5).The highest and lowest cluster means were recorded for the traits GY (7902.86) and TW (11.44), respectively. Maximum cluster mean of overall traits was noticed in cluster X (7902.86) followed by cluster XIV (673.20). In contrast, the least

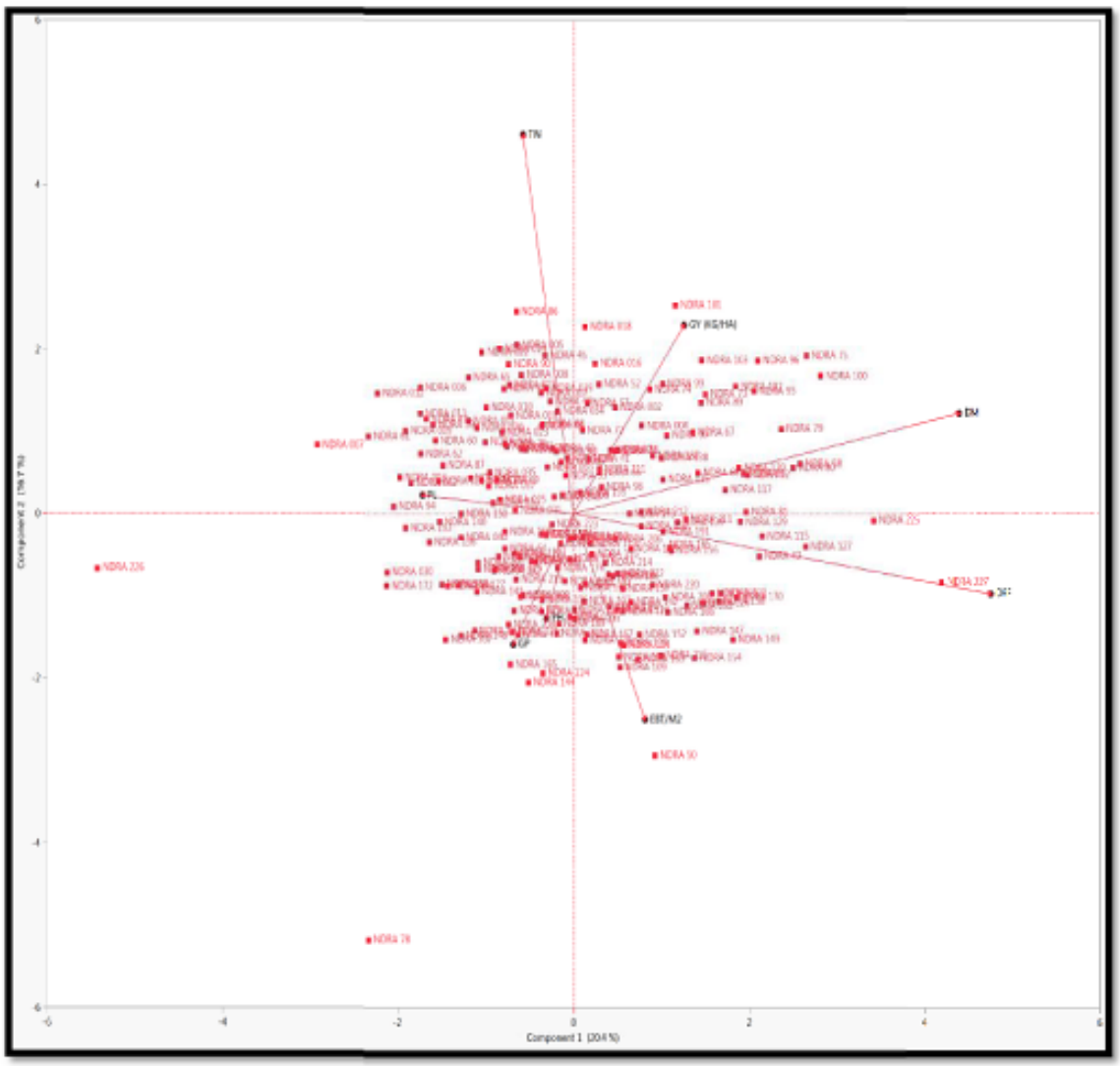

Fig 1. Biplot comprising of 200 rice advanced breeding lines along with three checks for eight yield and yield attributing traits

cluster mean was displayed by cluster XIV(11.44). This clearly infers the existence of ample amount of genetic divergence in the advanced breeding lines of these clusters. Further, among the fourteen divergent clusters, the highest numbers of advanced breeding lines were grouped in cluster I with 30 advanced breeding lines followed by 29 advanced breeding lines in cluster XIII and 25 advanced breeding lines in cluster VI. The advanced breeding lines in cluster XI showed highest mean values for DFF and DM. Similarly, the advanced breeding linesof cluster XIV showed maximum values for PL, EBT/m^2 and GP. The advanced breeding lines in cluster X displayed maximum cluster value for GY. Ravi Kumar *et al*.,2015, Kusuma Kumari *et al.*, 2021, Mondal *et al*., 2024 and Howlader *et al*., 2025 also documented same kind of clustering of accessions into distinct clusters.

The constellation plot based on Wards method (Fig. 3) depictsrelationship among the 200 advanced breeding lines along with three checks. The advanced breeding lines are grouped as end points and every cluster join as a new point with lines drawn will act as membership in constellation plot.The plot divided the total advanced breeding lines into

Table 4. Grouping of different advanced breeding lines into different clusters

Cluster	No. of advanced breeding lines	Advanced breeding lines
I	30	NDRA 001, NDRA 002, NDRA 74, NDRA 016, NDRA 41, NDRA 97, NDRA 017, NDRA 019, NDRA 77, NDRA 53, NDRA 93, NDRA 003, NDRA 69, NDRA 71, NDRA 87, NDRA 020, NDRA 025, NDRA 031, NDRA 64, NDRA 036, NDRA 037, NDRA 181, NDRA 42, NDRA 49, NDRA 040, NDRA 201, NDRA 023, NDRA 035, NDRA 032, NDRA 61
II	15	NDRA 018, NDRA 88, NDRA 022, NDRA 90, NDRA 47, NDRA 62, NDRA 59, NDRA 65, NDRA 60, NDRA 76, NDRA 029, NDRA 45, NDRA 66, NDRA 111, NDRA 72
III	16	NDRA 005, NDRA 008, NDRA 011, NDRA 014, NDRA 91, NDRA 015, NDRA 024, NDRA 021, NDRA 033, NDRA 63, NDRA 006, NDRA 010, NDRA 012, NDRA 013, NDRA 007, NDRA 009
IV	7	NDRA 034, NDRA 48, NDRA 44, NDRA 039, NDRA 46, NDRA 51, NDRA 52
V	15	NDRA 030, NDRA 172, NDRA 110, NDRA 159, NDRA 150, NDRA 136, NDRA 146, NDRA 177, NDRA 219, NDRA 209, NDRA 164, NDRA 205, NDRA 204, NDRA 206, NDRA 223
VI	25	NDRA 108, NDRA 151, NDRA 157, NDRA 176, NDRA 128, NDRA 152, NDRA 113, NDRA 143, NDRA 185, NDRA 174, NDRA 183, NDRA 214, NDRA 199, NDRA 109, NDRA 112, NDRA 203, NDRA 213, NDRA 119, NDRA 142, NDRA 122, NDRA 169, NDRA 125, NDRA 163, NDRA 198, NDRA 167
VII	10	NDRA 94, NDRA 144, NDRA 165, NDRA 224, NDRA 148, NDRA 175, NDRA 197, NDRA 207, NDRA 221, NDRA 226
VIII	16	NDRA 114, NDRA 130, NDRA 140, NDRA 193, NDRA 116, NDRA 182, NDRA 141, NDRA 179, NDRA 194, NDRA 208, NDRA 168, NDRA 171, NDRA 196, NDRA 178, NDRA 180, NDRA 210
IX	15	NDRA 004, NDRA 95, NDRA 81, NDRA 79, NDRA 80, NDRA 038, NDRA 57, NDRA 70, NDRA 58, NDRA 103, NDRA 73, NDRA 96, NDRA 89, NDRA 99, NDRA 102
X	7	NDRA 67, NDRA 75, NDRA 85, NDRA 100, NDRA 68, NDRA 127, NDRA 101
XI	7	NDRA 43, NDRA 115, NDRA 139, NDRA 166, NDRA 135, NDRA 225, NDRA 227
XII	10	NDRA 86, NDRA 145, NDRA 195, NDRA 117, NDRA 129, NDRA 120, NDRA 138, NDRA 212, NDRA 211, NDRA 156
XIII	29	NDRA 50, NDRA 124, NDRA 202, NDRA 131, NDRA 92, NDRA 118, NDRA 173, NDRA 191, NDRA 107, NDRA 186, NDRA 220, NDRA 184, NDRA 192, NDRA 222, NDRA 187, NDRA 98, NDRA 137, NDRA 153, NDRA 155, NDRA 121, NDRA 147, NDRA 123, NDRA 200, NDRA 149, NDRA 126, NDRA 170, NDRA 158, NDRA 154, NDRA 215
XIV	1	NDRA 78

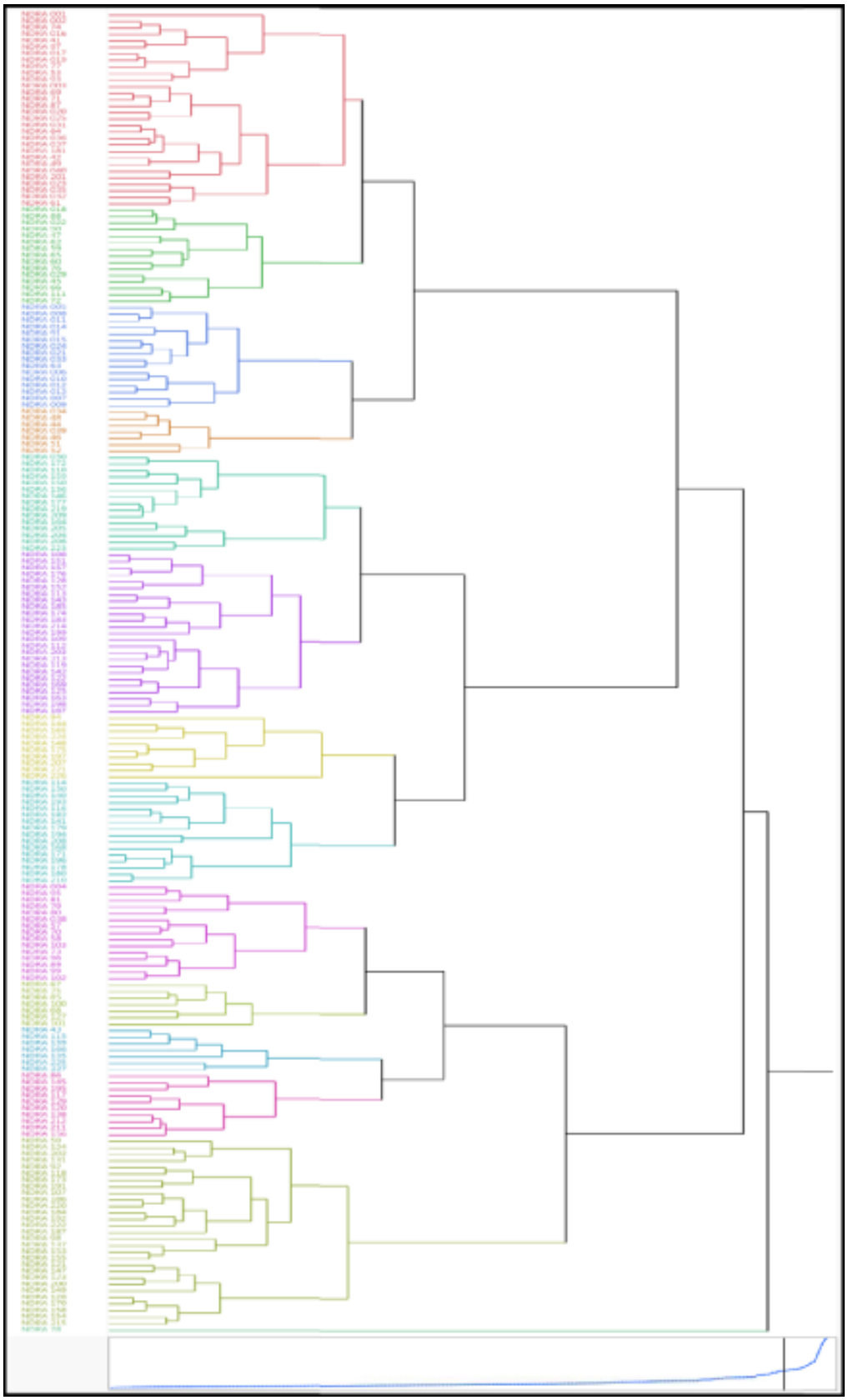

Fig 2. Dendrogram showing clustering by Wards method

Table 5. Cluster means of various characters of rice advanced breeding lines under study

Cluster No.	DFF	DM	PH	PL	EBT/m2	GP	TW	GY(Kg/ha	Mean
Cluster I	103.73	135.23	89.88	23.48	566.28	279.12	13.95	6616.00	978.46
Cluster II	103.67	134.20	90.10	23.25	481.80	292.35	13.73	7820.00	1119.89
Cluster III	103.50	134.06	86.47	23.14	438.90	298.80	**14.56**	5923.13	877.82
Cluster IV	103.29	137.57	94.80	21.96	485.57	265.63	14.13	6300.00	927.87
Cluster V	104.60	133.40	**96.53**	23.40	428.12	274.05	11.93	5912.00	873.00
Cluster VI	105.72	135.56	93.91	23.27	553.87	279.26	11.79	5914.80	889.77
Cluster VII	103.10	131.50	96.14	22.44	613.15	294.57	12.02	6131.60	925.56
Cluster VIII	104.44	132.88	85.18	22.04	469.43	259.94	11.84	6073.13	894.86
Cluster IX	107.33	138.87	90.34	22.59	439.56	308.05	14.19	6458.00	947.37
Cluster X	107.00	137.71	89.91	21.18	521.40	258.23	13.79	**7902.86**	1131.51
Cluster XI	**108.38**	**139.04**	93.22	23.53	565.85	275.81	12.06	7280.98	1062.36
Cluster XII	106.40	137.60	79.81	23.48	432.96	293.50	12.05	6447.00	941.60
Cluster XIII	106.28	135.52	84.04	22.48	626.54	267.28	11.87	6580.34	979.30
Cluster XIV	104.00	133.00	86.86	**23.66**	**673.20**	**400.38**	11.44	5880.00	1364.50
Mean values	105.10	135.44	89.80	22.85	521.19	546.46	12.81	6517.13	

Bold figures indicate maximum and minimum values in each character.

14 clusters with membership of 30, 15, 16, 7, 15, 25, 10, 16, 15, 7, 7, 10, 29 and 1.The Clustering pattern divulged that majority of advanced breeding lines congregated in cluster I (30), followed by Cluster XIII (29) and Cluster VI (25). The advanced breeding lines with longer vector line represent greater genetic distance between the clusters.Further, the identified advanced breeding lines with maximum genetic distance are considered as superior and exploited commercially in yield improvement programme in rice.

The correlation analysis of eight traits (Fig 4**)** revealed that PH was positively correlated with PL and PL was positively associated with PH, GP and TW. Similarly, GP was positively associated with DM, PL and TW. Likewise, TW was associated with DM, GP and GY. Furthermore, GY was positively associated with DFF, DM, EBT/m2, GP and TW and negatively associated with PH and PL. Similar kind of association results were also in congruence with Sudeepthi *et al*., 2020b, Roy *et al*., 2024 and Howlader *et al*., 2025.

CONCLUSION

PCA concluded that the first five PCs with eigen values more than one describing 24.76%, 23.26%, 14.54 and 13.22% respectively attributed 75.80% of total variation. The cluster analysis revealed high genetic diversity, suggesting a significant opportunity for crop improvement by utilizing advanced breeding lines from other clusters and recognized advanced breeding lines *viz.*, NDRA 78, NDRA 225, NDRA 226, NDRA 227 and NDRA 50 as superior and divergent advanced breeding lines for commercial exploitation. Furthermore, the advanced breeding lines *viz.*, NDRA 45, NDRA 90, NDRA

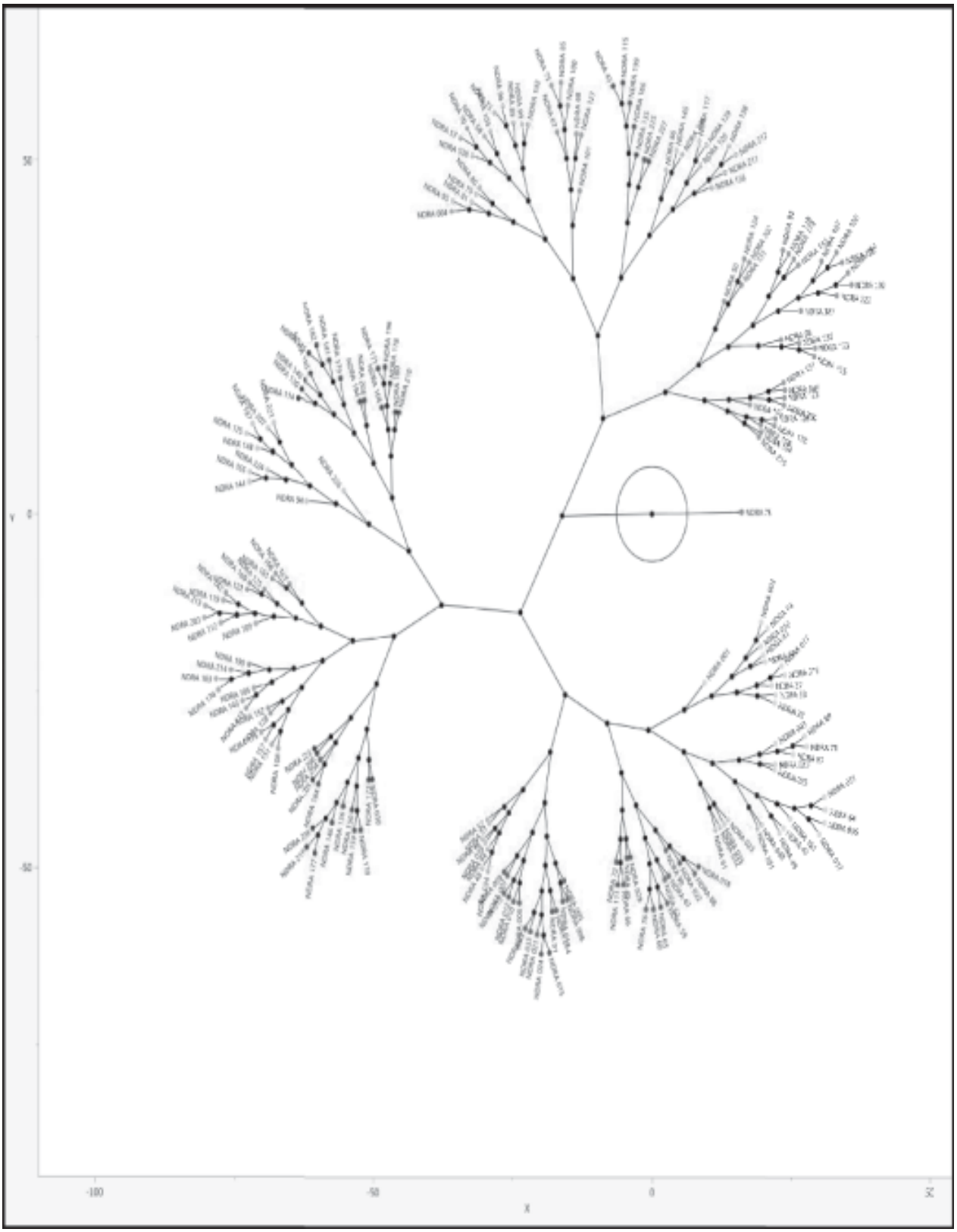

Fig 3. Constellation plot of 200 advanced breeding lines along with three checks into 14 clusters based on Euclidean distance

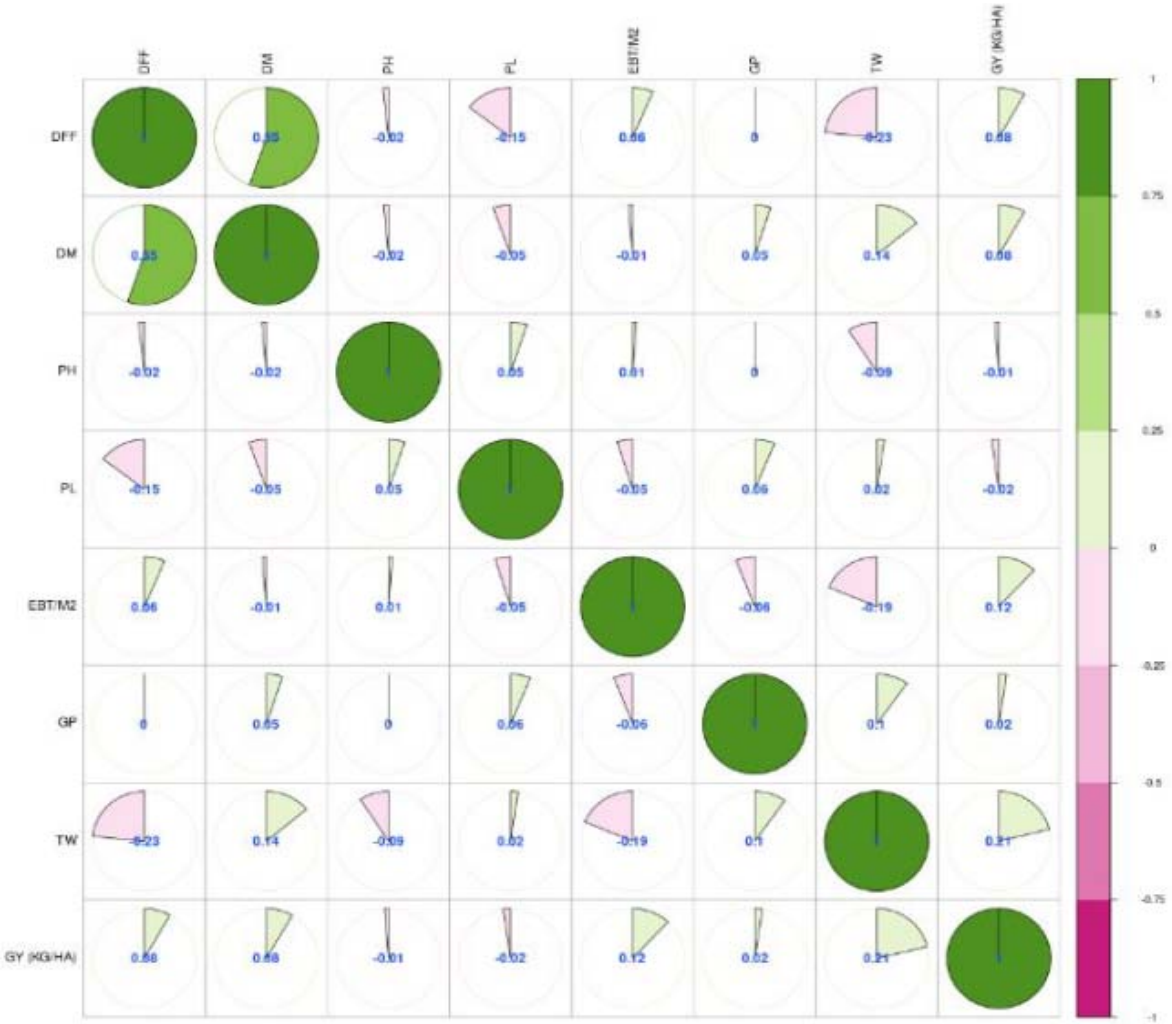

Fig 4. Correlation for yield and its components in rice advanced breeding lines

029 and NDRA 131 were identified as top grain yielders which can be exploited in crop improvement programme. Based on correlation analysis, GY was positively associated with DFF, DM, EBT/m2, GP and TW and negatively associated with PH and PL.

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EFFECT OF POST-EMERGENCE HERBICIDES ON WEED GROWTH AND PRODUCTIVITY OF HORSEGRAM (*MACROTYLOMA UNIFLORUM* L.)

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ABSTRACT

A field experiment was conducted during *kharif 2022* at the Agricultural Research Station, Ananthapuram, Andhra Pradesh, to evaluate the efficacy of different post-emergence herbicides on weed control, growth, yield, and economics of horse gram (*Macrotyloma uniflorum* L.) under rainfed conditions. The experiment was laid out in a randomized block design with eight treatments and three replications. The treatments were consisting of T1: Imazethapyr + imazamox @ 50 g/ha as PoE at 15 – 20 DAS, T2: Imazethapyr + imazamox @ 75 g/haas PoE at 15 – 20 DAS, T3: Propaquizafop 2.5% + imazethapyr 3.75% @ 1000 ml /ha as PoE at 15 – 20 DAS, T4: Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha as PoE at 15 – 20 DAS, T5: Clodinofop propargyl 8% + aciflourfen sodium 16.5 @ 500 ml /ha as PoE at 15 – 20 DAS, T6: Clodinofop propargyl 8% + aciflourfen sodium 16.5 @ 750 ml /ha as PoE at 15 – 20 DAS, T7: Hand weeding at 15-20 DAS and 35-40 DAS and T8: Weedy check. Results revealed that hand weeding twice at 15–20 and 35–40 days after sowing recorded the lowest weed density, highest weed control efficiency (WCE), and superior growth and yield attributes. Among herbicidal treatments, Propaquizafop 2.5% + Imazethapyr 3.75% @ 1500 ml/ha as PoE at 15–20 DAS recorded significantly lower weed density and higher WCE, followed by Propaquizafop + Imazethapyr @ 1000 ml/ha, due to their complementary control of both grassy and broadleaf weeds. The highest seed yield (1116 kg/ha) and bhusa yield (1942 kg/ha) were obtained in hand weeding twice, while Propaquizafop + Imazethapyr @ 1500 ml/ha achieved 908 kg/ha seed yield with a higher benefit-cost ratio (2.41), indicating its economic advantage.

Keywords: Economics, Horse gram, Post Emergence Herbicide, Seed yield, Weed Control Efficiency

INTRODUCTION

Horse gram is an arid, drought resistant and climate resilient legume crop in India (Kiran Kumar *et al*., 2023**).** In Andhra Pradesh, horse gram is cultivated on approximately 1.5 lakh hectares with annual production of around 90,000 metric tons and average productivity of about 600 kg/ha (Indiastat, 2024). It is mainly cultivated as contingent crop in scarce rainfall zone with poor management practices. Under these conditions, weeds pose a serious threat to the productivity of horsegram due to greater

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competition for nutrients, water, space and sunlight. The critical period of weed competition in horsegram is during first 30 days of sowing. Being a short duration crop, care should be taken on proper weed management to improve the productivity of horsegram. If sufficient labour is available, hand weeding at 20 and 40 DAS helps in effective weed control and conserves moisture, especially in rainfed agriculture. The traditional method of weed control, such as hand weeding and mechanical weeding, may be effective but expensive and time-consuming.

Unpredictable rainfall and labour scarcity during critical stage are posing problems for effective weed management. In such situation, use of herbicides offers a viable alternative for weed management in horsegram cultivation. Herbicides can effectively control weeds, improve crop yield by minimizing competition for essential resources like water, nutrients and sunlight. Application of pendimethalin and imazethapyr as pre-emergence (PE) and post-emergence (PoE), respectively, have shown promising results in greengram (Singh *et al*. ,2017). However, narrow time window of application often makes the PE herbicides less preferred choice among the farmers. Also, application of a single herbicide is often ineffective in controlling diverse weed flora. On the contrary, either ready or tank mixes of compatible herbicides with varying modes of action may ensure effective control of diverse weed flora and check shifting of weed flora complex and herbicide resistance (Banerjee *et al.*, 2018). In general, there is paucity of information on the impact of new herbicide ready mixes available in Indian market on the performance of horsegram.

Considering this, the present study was formulated to evaluate the effect of different post-emergence herbicides on weed density, growth, yield attributes, yield and economics of horsegram.

MATERIAL AND METHODS

Field experiment was conducted at Agricultural Research Station, Ananthapuram under AINP on Arid legumes during kharif, 2022. The experimentalsite was located in scarce rainfall zone of Andhra Pradesh with average annual rainfall of 520 mm and geographical coordinates of the site are approximately 14.68° N latitude and 77.60° E longitude.The soil atthe experimental site is red sandy loam. Soils were slightly alkaline with pH of 7.84, EC of 0.07 with low organic carbon (0.07%), low nitrogen (242.9 kg/ha) low phosphorus (25.7 kg/ha), medium inpotassium (281 kg/ha) and low micronutrients(Copper-0.08 ppm, Manganese-0.59 ppm, iron-0.43 ppm, zinc-0.50 ppm). Experiment was laid in RBD with three replications and eight treatments comprised of T1: Imazethapyr + imazamox @ 50 g/haas PoE at 15 – 20 DAS, T2: Imazethapyr + imazamox @ 75 g/haas PoE at 15 – 20 DAS, T3: Propaquizafop 2.5% + imazethapyr 3.75% @ 1000 ml /ha as PoE at 15 – 20 DAS, T4: Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha as PoE at 15 – 20 DAS, T5: Clodinofop propargyl 8% + aciflourfen sodium 16.5 @ 500 ml /ha as PoE at 15 – 20 DAS, T6: Clodinofop propargyl 8% + aciflourfen sodium 16.5 @ 750 ml /ha as PoE at 15 – 20 DAS, T7: Hand weeding at 15-20 DAS and 35-40 DAS and T8: Weedy check. ATPHG 11 was taken as test variety and sowing was done with seed drill. 4 kg of Nitrogen,10 kg of Phosphorus and 8 kg potash supplying fertilizers were broadcasted per ha. before sowing.The average maximum temperature over the recorded period was 34.9°C, and the average minimum temperature was 21.3°C. The average morning relative humidity was 85.4 per cent, while the average evening relative humidity was 45.8 per cent.The average wind speed was 7.50 kmph. The total rainfall received during crop growth period was 293 mm.*Commelina diffusa, Commelina*

benghalensis, Celosia argentea, Andrographis spp, Leucas aspera, Cyperus rotundus, Digitaria sanguinalis, were the major weeds observed in horsegram. Harvesting was done with sickles to ground level and dried. Threshing was done by trampling with tractor and seed and bhusa yield was recorded separately. Economics were calculated by taking prevailing labour wages and market prices of inputs and outputs into consideration. The collected data were subjected to statistical analysis using SPSS. Analysis of variance (ANOVA) was performed to determine the significance of treatment effects. Means were compared using the Least Significant Difference (LSD) test at a 5 percent probability level.

RESULTS AND DISCUSSION

Lowest weed density and highest weed control efficiency were recorded in hand weeding at 15-20 DAS and 35-40 DAS (Table2& Fig. 1). The reduction in weed density in hand weeding at 15-20 DAS and 35-40 DAS(T7)indicating its superiority over all herbicidal treatments. Manual weeding effectively uproots weeds and desiccates the weeds thereby preventing their regeneration and reducing subsequent weed competition. Similar observations were made by Taku *et al.* (2023), who reported that hand weeding significantly reduces weed population and enhances crop growth through the complete removal of weeds at critical growth stages. Among herbicidal treatments, Propaquizafop 2.5% + Imazethapyr 3.75% @ 1500 ml/ha (T4) recorded the lowest weed density and higher WCE, followed by Propaquizafop 2.5% + Imazethapyr 3.75% @ 1000 ml/ha (T3). The superior performance of these treatments might be attributed to the synergistic action of the grass killer (Propaquizafop) and broadleaf herbicide (Imazethapyr), providing broad-spectrum control over both monocot and dicot weeds. Similar findings were reported by *Patel et al.* (2021) and Kumar *et al.* (2022), who found that the combination of post-emergence herbicides was more effective than single herbicide applications in achieving higher weed control efficiency and yield advantage. In contrast, Imazethapyr + Imazamox @ 50 g/ha (T_1) and 75 g/ha (T_2) recorded the lowest WCE, indicating their limited efficacy in controlling mixed weed flora at the given doses. The highest weed density in the weedy check (T_8) was due to the absence of weed control measures, leading to higher weed biomass accumulation and greater crop–weed competition. These results are in agreement with Choudhary *et al.* (2020) and Singh *et al.*(2021), who reported that unchecked weed growth significantly suppresses crop growth and yield through competition for moisture, nutrients and light.

The data on plant height, number of branches/plant, no. of pods/plant, number of seeds/pod, pod length, seed and bhusa are presented in Table 1. Plant height, no. of pods/plant, seed and bhusa yield were significantly influenced by post emergence herbicides. Whereas, these herbicides did not exert significant influence onnumber of branches/plant, number of seeds/pod and pod length. Plant height, no. of pods/plant, seed and bhusa yield were significantly higher with hand weeding twice at 15-20 DAS and 35-40 DAS (T7) followed by Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha as PoE at 15 – 20 DAS (T4) and Propaquizafop 2.5% + imazethapyr 3.75% @ 1000 ml /ha as PoE at 15 – 20 DAS (T3) with significant parity between these two treatments.Significantly taller plantswere observed in hand weeding twice at 15-20 DAS and 35-40 DAS (T7) (79.6 cm). Among herbicide treatments, the tallest plants were observed in Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha as PoE at 15 – 20 DAS (T4) (66.2 cm) and Propaquizafop

2.5% + imazethapyr 3.75% @ 1000 ml /ha as PoE at 15 – 20 DAS (T3) (64.2 cm). The number of branches per plant varied from 6.13 to 10.1. Hand weeding twice at 15-20 DAS and 35-40 DAS(T7) had the highest number of branches (10.1), followed by Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha as PoE at 15 – 20 DAS(T4) (9.45) and Propaquizafop 2.5% + imazethapyr 3.75% @ 1000 ml /ha as PoE at 15 – 20 DAS (T3) (8.91). Treatments hand weeding twice at 15-20 DAS and 35-40 DAS (T7), Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha as PoE at 15 – 20 DAS (T4) and Propaquizafop 2.5% + imazethapyr 3.75% @ 1000 ml /ha as PoE at 15 – 20 DAS (T3), which had higher numbers of branches per plant, likely benefited from reduced weed pressure, which otherwise competes for nutrients and space. It suggests that this treatment provided optimal conditions for horsegram growth by effectively reducing weed competition. This observation aligns with findings from Kumar *et al*. (2017), who reported that effective weed management practices can enhance plant growth by minimizing competition for light, nutrients and water.Pod length ranged from 4.14 cm in weedy check(T8) to 5.30 cmin hand weeding twice at 15-20 DAS and 35-40 DAS (T7). Among herbicide treatments, Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha as PoE at 15 – 20 DAS (T4) recorded higher pod length (5.22 cm) followed by Propaquizafop 2.5% + imazethapyr 3.75% @ 1000 ml /ha as PoE at 15 – 20 DAS (T3) (5.11). The number of pods per plant was highest in hand weeding twice at 15-20 DAS and 35-40 DAS (T7) (113.3) and lowest in weedy check (T8) (37.3). Among herbicide treatments, Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha as PoE at 15 – 20 DAS (T4) recorded higher no. of pods/plant (94.4) followed by Propaquizafop 2.5% + imazethapyr 3.75% @ 1000 ml /ha as PoE at 15 – 20 DAS (T3) (87.1) and Clodinofop propargyl 8% + aciflourfen sodium 16.5 @ 500 ml /ha as PoE at 15 – 20 DAS (T5) (72.8). Less weed density in hand weeding twice at 15-20 DAS and 35-40 DAS (T7), resulting in higher WCE, increased plant height, branches/plant and pods/plant in horsegram. Higher growth and yield attributes were observed in hand weeding twice at 15-20 DAS and 35-40 DAS (T7) which can be attributed to reduced weed density and higher weed control efficiency (WCE) resulted less competitiveness of weeds with the crop, creating a more favorable environment for crop growth and development.The better performance of combination of herbicides was due to its synergistic effect in controlling population as well as dry matter accumulation of different weed flora complex. These results are in tune with the findings of Katoch *et al*. (2023) and Poornima *et al*. (2018) .

Seed yield ranged from 648 kg/ha in weedy check (T8) to 1116 kg/ha in hand weeding twice at 15-20 DAS and 35-40 DAS (T7). Higher seed yield was recorded in hand weeding twice at 15-20 DAS and 35-40 DAS (T7) with 1116 kg/ha followed by Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha as PoE at 15 – 20 DAS (T4) with 908 kg/ha. Bhusa yield followed a similar trend, with hand weeding twice at 15-20 DAS and 35-40 DAS (T7) having the highest yield (1942 kg/ha) and weedy check (T8) has the lowest (1036 kg/ha). Among the herbicide treatments Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha as PoE at 15 – 20 DAS (T4) recorded higher bhusa yield of 1563 kg/ha followed by Propaquizafop 2.5% + imazethapyr 3.75% @ 1000 ml /ha as PoE at 15 – 20 DAS (T3) with 1544 kg/ha. The superior performance of hand weeding twice at 15-20 DAS and 35-40 DAS(T7) can be attributed to the effective and continuous suppression of weeds, which minimized competition for essential growth resources such as light, nutrients, moisture, and space, allowing the crop to utilize these resources

Table 1. Effect of post-emergence herbicides on growth and yield of horsegram

Treatments	Plant height at harvest (cm)	No. branches /plant	Pod length (cm)	No. pods/ plant	No.of seeds /Pod	Seed yield (kg/ha)	Bhusa yield (kg/ha)
T1: Imazethapyr + imazamox @ 50 g/ha as PoE at 15-20 DAS	38.1	8.33	4.44	41.3	4.64	691	1146
T2: Imazethapyr + imazamox @ 75 g/ha as PoE at 15-20 DAS	38.6	8.03	5.05	44.0	4.77	658	1061
T3: Propaquizafop 2.5% + imazethapyr 3.75% @ 1000 ml /ha as PoE at 15 – 20 DAS	64.2	8.91	5.11	87.1	4.67	846	1544
T4: Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha as PoE at 15 – 20 DAS	66.2	9.45	5.22	94.4	4.78	908	1563
T5: Clodinofop propargyl 8% + aciflourfen sodium 16.5 @ 500 ml /ha as PoE at 15-20 DAS	57.7	8.31	5.03	72.8	4.77	792	1447
T6: Clodinofop propargyl 8% + aciflourfen sodium 16.5 @ 750 ml /ha as PoE at 15-20 DAS	51.2	8.28	4.94	70.8	4.55	781	1351
T7: Hand weeding at 15-20 DAS and 35-40 DAS	79.6	10.1	5.30	113.3	5.11	1116	1942
T8: Weedy check	36.2	6.13	4.14	37.3	4.43	648	1036
S.Em+	2.63	0.35	0.52	4.72	0.41	49.6	96.7
CD @ 5 %	7.13	NS	NS	12.7	NS	138	269

more efficiently for better vegetative and reproductive growth. Similar findings were reported by Poornima *et al*. (2018) and Katoch *et al.* (2023), who observed that timely and effective weed removal enhances crop growth, photosynthetic activity and yield potential.

The enhanced seed and bhusa yields under Propaquizafop + Imazethapyr combinations (T4 and T3) may be due to their broad-spectrum control over both grassy and broadleaf weeds and their residual activity, which ensured prolonged weed suppression during the crop's critical growth stages. Singh *et al*. (2022) and Meena *et al*. (2021) also reported that herbicide mixtures with complementary modes of action improve weed control efficiency, nutrient use efficiency, and ultimately yield in pulse and oilseed crops. Higher yields in effective weed control treatments can also be linked to improved crop canopy structure, higher photosynthetic rate, and better assimilate partitioning toward reproductive organs. According to Kumar *et al*. (2019) and Reddy *et al*. (2020), maintaining a weed-free environment

Table 2. Weed density, weed control efficiency and economics of horsegram as influenced by application of post emergence herbicides

Treatments	Weed density (no./m2)	WCE (%)	Cost of cultivation (Rs/ha)	Gross Returns (Rs/ha)	Net Returns (Rs/ha)	B:C ratio
T1: Imazethapyr + imazamox @ 50 g/ha as PoE at 15-20 DAS	36.7	43.2	11432	22123	10691	1.94
T2: Imazethapyr + imazamox @ 75 g/ha as PoE at 15-20 DAS	36.0	44.3	11900	21045	9145	1.77
T3: Propaquizafop 2.5% + imazethapyr 3.75% @ 1000 ml /ha as PoE at 15-20 DAS	23.3	63.9	11550	27061	15511	2.34
T4: Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml / ha as PoE at 15 – 20 DAS	22.7	64.9	12075	29056	16981	2.41
T5: Clodinofop propargyl 8% + aciflourfensodium 16.5 @ 500 ml / ha as PoE at 15 – 20 DAS	30.7	52.5	11615	25344	13729	2.18
T6: Clodinofop propargyl 8% + aciflourfensodium 16.5 @ 750 ml / ha as PoE at 15 – 20 DAS	29.3	54.7	12170	25003	12833	2.05
T7: Hand weeding at 15-20 DAS and 35-40 DAS	4.2	93.5	16600	35701	19101	2.15
T8: Weedy check	64.7	-	10150	20725	10575	2.04

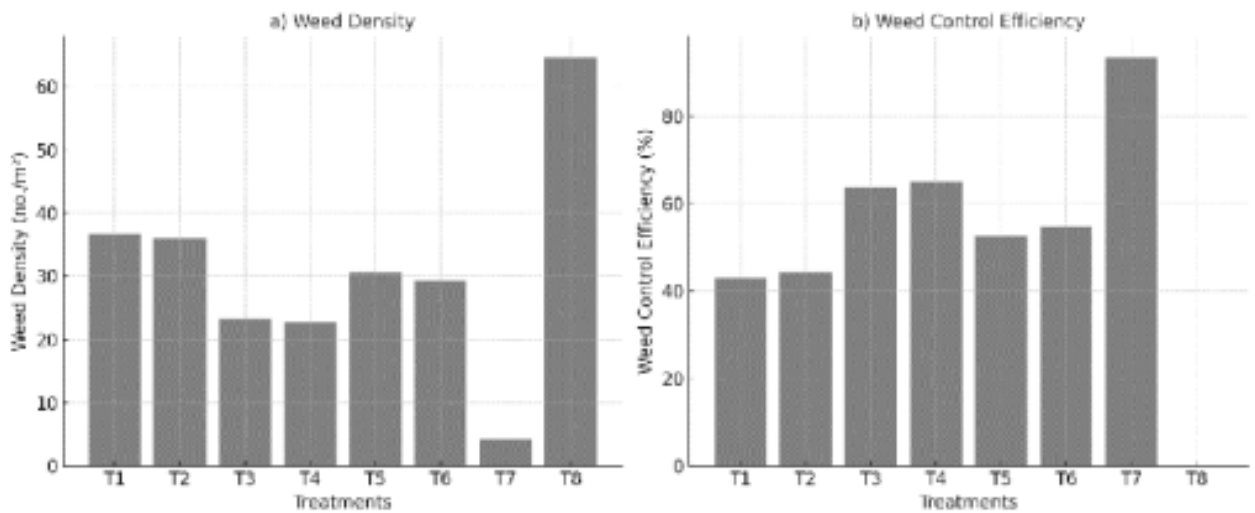

Fig 1. Effect of Post Emergence Herbicide on Weed Density and WCE in Horse gram

during early crop establishment plays a critical role in enhancing yield attributes and final productivity in pulses. Moreover, early weed removal helps reduce competition for soil moisture, particularly under rainfed conditions, which is crucial for optimizing productivity in dryland crops like horsegram. The lowest seed and bhusa yields in the weedy check (T8) were due to severe weed infestation, which led to intense competition for growth resources and substantial depletion of soil nutrients and moisture. This finding corroborates the reports of Choudhary *et al.* (2020) and Bairwa *et al*. (2023), who emphasized that unchecked weed growth drastically reduces crop productivity through higher weed biomass accumulation and greater crop–weed competition.

Economics revealed the cost of cultivation ranged from Rs.10,150/ha in weedy check (T8) to Rs. 16,600/hain hand weeding twice at 15-20 DAS and 35-40 DAS(T7), indicating that some weed management practices are more cost-intensive than others. Hand weeding twice at 15-20 DAS and 35-40 DAS (T7) had the highest gross returns (Rs. 35,701/ha) and net returns (Rs. 19,101/ha), while weedy check (T8) had the lowest gross returns (Rs. 20,725/ha) and lowest net returns were with Imazethapyr + imazamox @ 75 g/ haas PoE at 15 – 20 DAS (T2) (Rs. 9,145/ha). This shows that despite the higher cost of cultivation, the returns in hand weeding twice at 15-20 DAS and 35-40 DAS are substantially higher, making it economically beneficial. Among herbicide treatments, higher gross returns and net returns were recorded in Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha as PoE at 15 – 20 DAS (T4) with Rs. 29,056 and 16,981 /ha, respectively. The B:C ratio was highest in Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha as PoE at 15 – 20 DAS (T4) (2.41) followed by Propaquizafop 2.5% + imazethapyr 3.75% @ 1000 ml /ha as PoE at 15 – 20 DAS (T3) (2.34) and Clodinofop propargyl 8% + aciflourfen sodium 16.5 @ 500 ml /ha as PoE at 15 – 20 DAS (T5) (2.18), suggesting that these treatments are more profitable.Even though hand weeding at 15-20 DAS and 35-40 DAS produced a higher gross and net returns, the B:C ratio was lower because two hand weedings incurred more expenditure to maintain the weed free condition.

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EFFECT OF STRUCTURED INTERVENTION ON THE MENTAL HEALTH OF NEET AND JEE ASPIRANTS IN VISAKHAPATNAM DISTRICT OF ANDHRA PRADESH

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ABSTRACT

Adolescence is a critical stage of growth marked by emotional, psychological, and social changes. During this period, many adolescents face mental health issues, often triggered by academic stress and parental pressure. Building resilience helps them manage stress effectively and maintain better mental well-being.With the aim to assess the effectiveness of a structured intervention program in enhancing the mental health of NEET and JEE aspirants aged 16–19 years, an experimental study was conducted on 200 students.Results showed that one third of the experimental group of both NEET and JEE aspirants who had low levels of mental health were reduced to zero percent after intervention, also a drastic increase in the percentage of experimental groups of NEET and JEE aspirants with high mental health was observed from before intervention (6 % of NEET and 18 % of JEE) to after intervention (68 % of NEET and 62 % of JEE) which evidently shows the positive impact of the intervention programme. Findings also revealed significant mean differences between experimental and control groups of both NEET and JEE aspirants after intervention at p value 0.01 level of significance. These findings support the inclusion of structured intervention programs in academic settings to foster emotional well-being and psychological coping among students facing high-stakes competitive examinations.

Keywords: Academic pressure,Emotional Regulation, JEE aspirants,NEET aspirants, Psychological Well-being, Resilience based intervention.

INTRODUCTION

Adolescence, especially between the ages of 16 to 19 years, is an important stage where young people go through emotional changes, form their identity and face academic challenges. For students preparing for competitive exams like NEET and JEE, this phase becomes even more stressful. They often spend long hours in studying, stay away from social activities and face constant pressure from parents and coaching centers. All these factors can affect their mental health, leading to stress, anxiety and even depression.

Many studies have shown that students who are in coaching centres for preparing competitive exams, often go through a lot of mental pressure due to strict schedules and lack

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of emotional support. In such situations, building resiliencei.e., the ability to handle stress and bounce back from problems can help students stay mentally healthy.School-based resilience interventions such as emotional regulation training, stress-management techniques, and problem-solving & skill-building significantly enhance the resilience and psychological well being in adolescents (Llistosella *et al.,* 2023)

Structured intervention programs teach students how to cope up with stress, manage their emotions, solve problems, and build confidence. Indian students preparing for competitive undergraduate entrance exams demonstrated that greater resilience serves as a protective factor against stress, fostering improved emotional control and time management (Sarkar, 2024).These programs can be included in schools and coaching centres without making students feel uncomfortable or judged. Although past research has shown that these programs help teenagers feel better, very few studies have focused on NEET and JEE students. This study tried to fill that gap by studying how well a resilience-based intervention program works for NEET and JEE aspirants. A mental health tool developed by Dr. Khan Zeenat Muzaffar (2021) was used to measure their mental health before and after the program. The objective of the study was to improve the mental health status of aspirants through structured intervention program.

MATERIAL AND METHODS

Based upon the nature of the research problem and objectives of the present study, Experimental research design was opted for the study.The sample size was 200 adolescents (100 experimental group and 100 control group) who were selected purposively from the NEET & JEE colleges located in Vishakhapatnam district of Andhra Pradesh. Prior to collection of data, official consent was acquired from the respective college authorities and respondents.General Information Schedule and SES Scale developed by Kuppuswamy (2019) were used to collect basic background information from the participants. Mental Health Battery developed by Dr. Khan Zeenat Muzaffar (2021) was used to obtain the respondents Mental health.This scale consisted of 34 statements which assesses well-being of individuals in four domains which are psychological well-being, Physical well-being, Emotional well-being and social well-being.An intervention programme focussed on improving mental health was developed and implemented for a period of 4 months. After 4 months, post test was conducted to study the effectiveness of the intervention programme.

The researcher developed resilience-based intervention module for experimental groups from urban areas. The developed module was reviewed and validated by five subject experts from the fields of Human Development and Family Studies (HDFS) and Psychiatry. The experts included Dr. K. Mayuri, Professor of HDFS (Retd.) and Emeritus Scientist, ICAR; Dr. Bilquis, Professor of HDFS, College of Community Science; Dr. S. Jaiganesh, Associate Professor of Psychiatry, AIIMS Mangalagiri; Dr. V. Sravan Reddy, Associate Professor and Head of the Department of Psychiatry, NIEPID Secunderabad; and Dr. S. Prasanthi, Subject Matter Specialist, KVK–ANGRAU, Utukur, Kadapa. The experts critically evaluated the content for its relevance, age appropriateness and cultural sensitivity, and their valuable suggestions were incorporated into the final version of the module. Thus, the module was content validated by qualified experts prior to its implementation.

The program covered resilience building, mental health awareness, and management of stress, anxiety, depression and time through structured sessions lasting 60 minutes per day over three consecutive days for each topic. Sessions were conducted individually and in groups in the regional language (Telugu) &

Table 1. Contents of intervention module

Sr.no	Area	Topic& Sub Topics		Duration	Materials used
1	Resilience	Orientation on Resilience and importance		1 hour/ day	Power point presentation Videos, Lecture method, Poster
		• Building and strengthening Resilience in Adolescents • Characteristics of resilient person • Personal counselling			
2	Mental Health	Orientation on Mental Health and importance of well being		1 hour/ day	Power Point presentation and Lecture Method, poster
		➢ Signs and Symptoms ➢ Government Schemes for Mental Health			
		Stress Management	• Importance • Strategies • Activities to manage stress		Power point presentation Videos, Lecture method, poster
		Anxiety Management	• Importance • Strategies • Activities to manage Anxiety	1 hour/ day	Power point presentation Videos, Lecture method
		Depression Management	• Importance • Strategies • Activities to manage Depression	1 hour/ day	Videos, Lecture method, Poster
		Time Management	• Importance • Strategies • Activities for time management	1 hour/ day	Power point presentation Videos, Lecture method

English using Power Point presentations, videos, posters, and discussions. Verbal consent was obtained, and participation was voluntary. Interactive lectures, activities, and counselling were used to enhance coping skills, resilience, and emotional regulation.

RESULTS AND DISCUSSION

The pre and post test data results related to the levels of mental health among the aspirants are presented in Figures 1& 2.

Figure 1 depicts the levels of mental health of NEET aspirants before intervention, classified into Poor(Low), Moderate (Medium), and Good (High) mental health across the experimental and control groups. It is evident that before intervention, the majority of NEET aspirants, across both experimental and control groups, were in the moderate mental health category, followed by a significantpercentagewho showed poor mental health. Only a negligible percent

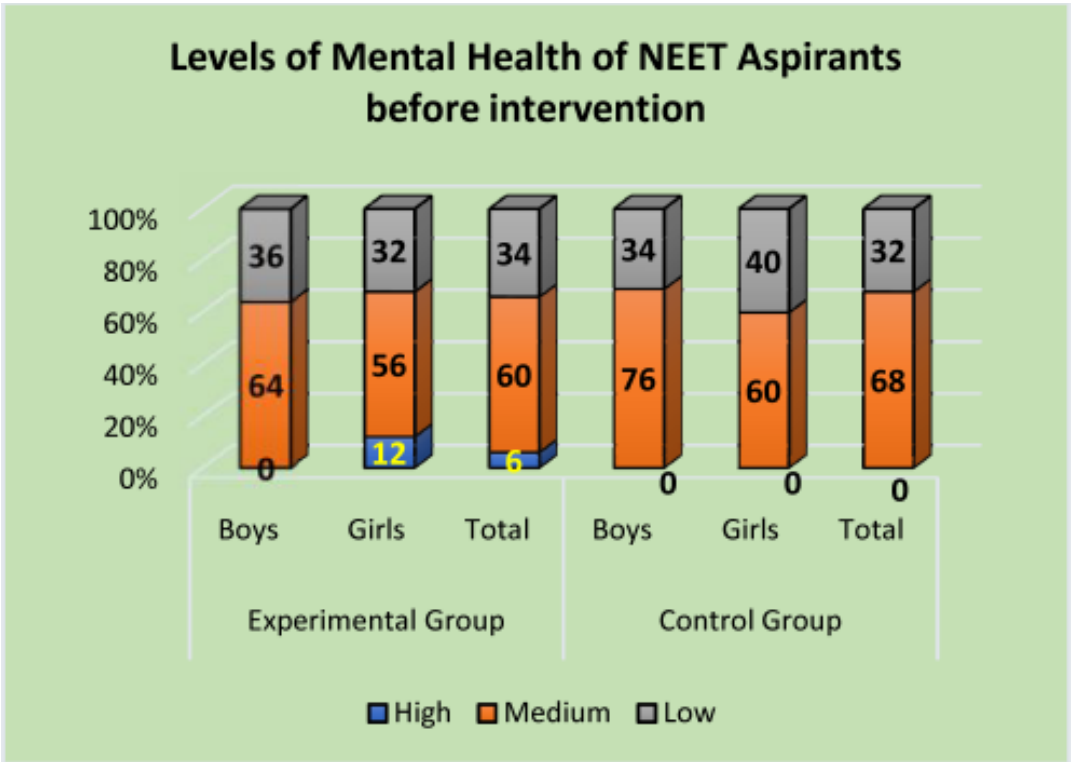

Fig. 1. Distribution of NEET aspirants based on their Levels of Mental Health before Intervention

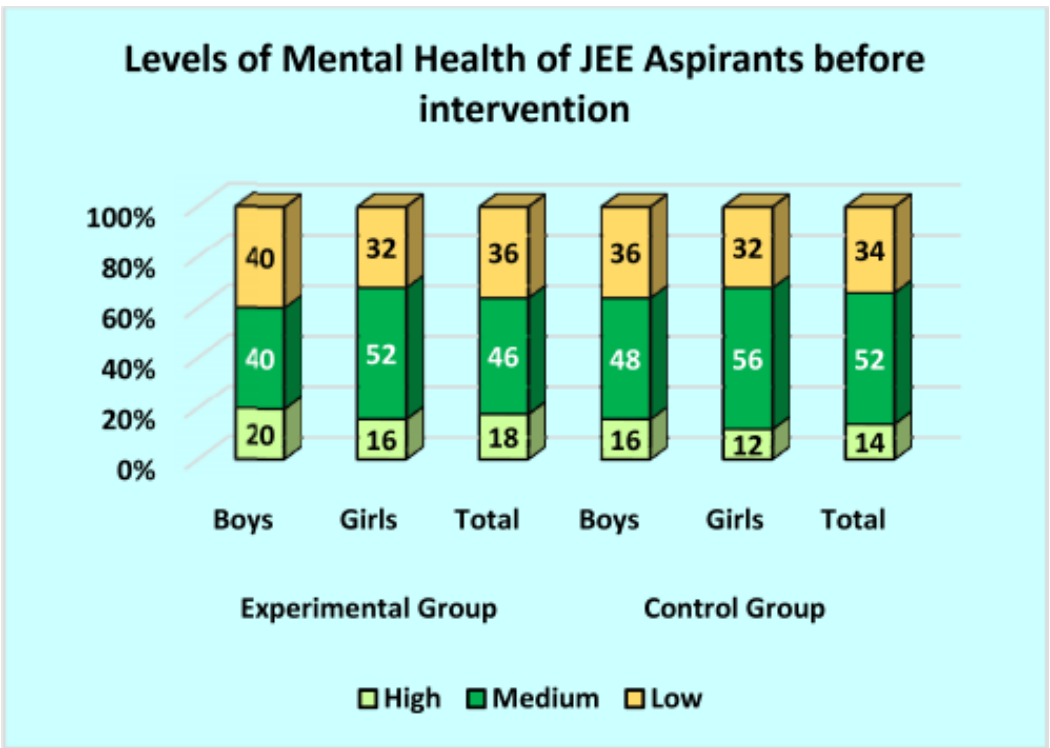

Fig.2.Distribution of JEE aspirantsbasedon Levels of Mental Health before Intervention

Table 2. Mean Differences in Mental Health Dimensions of NEET and JEE Aspirants before intervention **n=200**

Sr. no	Mental Health Dimension	Groups	NEET			JEE		
			Mean ± SD	t value	p value	Mean ± SD	t value	p value
1	Psychological well being	Experimental boys	25.76 ± 4.35	1.69^{NS}	0.096	24.88 ± 6.66	0.37^{NS}	0.708
		Control boys	28 ± 4.97			25.56 ± 6.11		
		Experimental girls	26 ± 4.4	1.33^{NS}	0.186	25.56 ± 6.11	0.29^{NS}	0.771
		Control girls	24.4 ± 4.03			26 ± 4.4		
		Over all Experimental	25.88 ± 4.33	0.34^{NS}	0.728	25.22 ± 6.34	0.47^{NS}	0.632
		Overall Control	26.2 ± 4.83			25.78 ± 5.28		
2	Emotional well being	Experimental boys	22.8 ± 8.99	0.23^{NS}	0.817	24.16 ± 9.3	0.42^{NS}	0.674
		Control boys	22.24 ± 8			25.36 ± 10.72		
		Experimental girls	24.96 ± 9.93	0.12^{NS}	0.898	25.36 ± 10.72	0.13^{NS}	0.891
		Control girls	24.64 ± 7.46			24.96 ± 9.93		
		Over all Experimental	23.88 ± 9.44	0.25^{NS}	0.799	24.76 ± 9.95	0.19^{NS}	0.843
		Overall Control	23.44 ± 7.75			25.16 ± 10.23		
3	Physical well being	Experimental boys	23 ± 5.41	0.78^{NS}	0.433	22.72 ± 4.73	1.14^{NS}	0.259
		Control boys	24.32 ± 6.36			24.44 ± 5.87		
		Experimental girls	23.2 ± 3.67	0.69^{NS}	0.490	24.44 ± 5.87	0.89^{NS}	0.375
		Control girls	23.96 ± 4.05			23.2 ± 3.67		
		Over all Experimental	23.1 ± 4.58	1.05^{NS}	0.295	23.58 ± 5.34	0.23^{NS}	0.815
		Overall Control	24.14 ± 5.28			23.82 ± 4.88		
4	Social well being	Experimental boys	15.6 ± 7.27	0.78^{NS}	0.434	18.76 ± 9.3	0.14^{NS}	0.886
		Control boys	17.24 ± 7.44			18.36 ± 10.3		
		Experimental girls	19.52 ± 9.5	1.66^{NS}	0.102	18.36 ± 10.3	0.41^{NS}	0.680
		Control girls	15.68 ± 6.5			19.52 ± 9.5		
		Over all Experimental	17.56 ± 8.6	0.7^{NS}	0.484	18.56 ± 9.71	0.19^{NS}	0.846
		Overall Control	16.46 ± 6.96			18.94 ± 9.83		
5	Overall well being	Experimental boys	87 ± 14.17	1.57^{NS}	0.121	88.52 ± 27.59	0.69^{NS}	0.490
		Control boys	93.12 ± 13.22			93.72 ± 25.3		
		Experimental girls	93.68 ± 19.52	1.13^{NS}	0.262	94.88 ± 24.38	0.19^{NS}	0.848
		Control girls	88.52 ± 11.71			93.68 ± 19.52		
		Over all Experimental	90.34 ± 17.22	0.15^{NS}	0.873	91.7 ± 25.97	0.41^{NS}	0.680
		Overall Control	90.82 ± 12.58			93.7 ± 22.36		

***p 0.05 level of significance, **p 0.01 level of significance**

(limited to girls inthe experimental group) exhibited good mental health.

Figure 2 explains that before intervention, the majority of JEE aspirants, across both experimental and control groups, were in the moderate mental health category, followed by a poor mental health. Only a small percentage of adolescents in both groups fell under good mental health.

The dominance of medium levels of mental health before the intervention in both groups might be attributed to multiple factors such as academic stress, family pressure, competitive examination anxiety, and limited engagement in structured mental well-being practices. These factors may have restricted the participants ability to attain higher levels of mental health. The above results indicate a strong presence of mental health challenges across both groups. These findings are consistent with those of Joshi and Sagar (2015), who reported that among adolescents, over half (51.2%) exhibited moderate levels of mental health, thereby supporting the observation that medium levels of mental health were prevalent prior to any intervention.

Table 2 presents the mean differences in various dimensions of mental health including psychological, emotional, physical, social, and overall well-being among NEET and JEE aspirants across experimental and control groups, before intervention. The results indicated that,among NEET aspirants, emotional and social well-being appeared slightly higher among girls in the experimental group compared to those in the control group. However, these differences were not statistically significant. A similar trend was noted in physical well-being, where boys in the control group showed slightly better scores but the difference was marginal. When overall well-being was considered, both experimental and control groups reported almost equal scores, showing that their mental health was at a similar level before the intervention program started.The results are in line with the study of NEET aspirants by Verma and Kumar (2023) who found that, the majority were clustered in the moderate mental health category, while nearly one-third showed poor levels of well-being, indicating vulnerability prior to intervention.

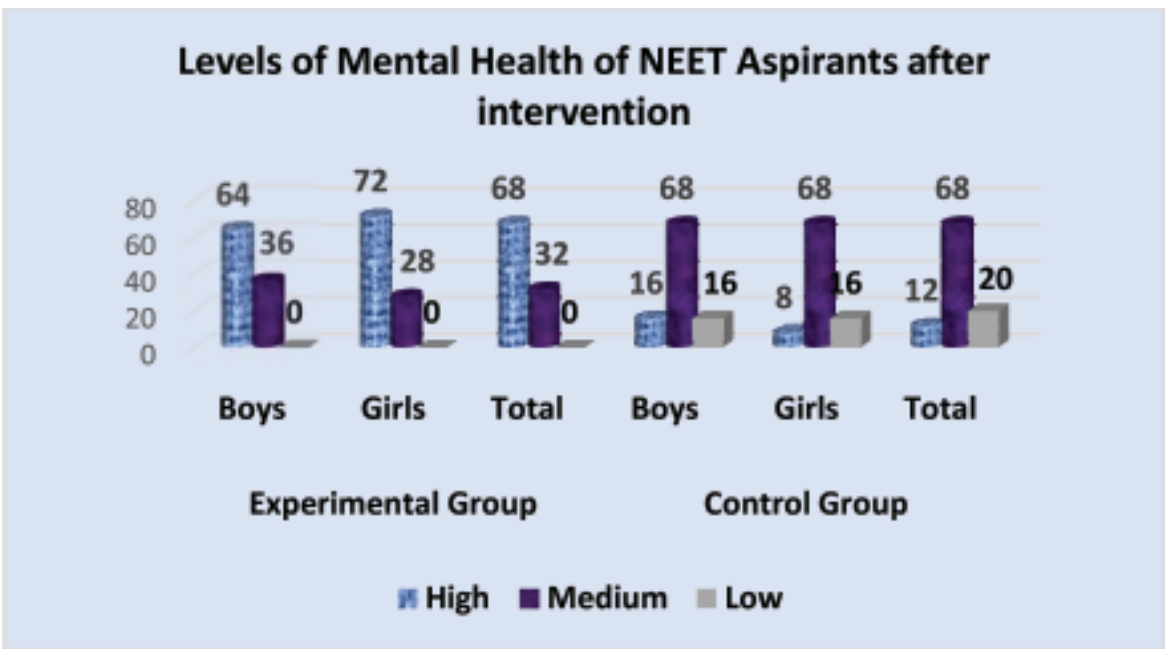

Fig.3. Distribution of NEET aspirants according to Levels of Mental Health after Intervention

With respect to JEE aspirants, a similar trend was observed. Control group boys showed slightly better scores across most dimensions, particularly in emotional and physical well-being, however, these differences were not statistically significant. Girls in both the experimental and control groups recorded nearly identical scores across all domains, indicating a consistent mental health status across genders and groups. (NEET & JEE).These findings align with earlier studies such as those by Khan and Qasim (2025) which concluded that, while aspirants face extreme academic stress, personal variables like gender did not have a statistically significant impact.

From the figure 3, it is evident that after intervention, the majority of NEET aspirants in the experimental group fell in the good mental health category, with more than two-thirds of adolescents showing improvement. Followed by less than one-third remained in the moderate category and none of the adolescents were in the poor category. These results are highlighting the effectiveness of the intervention program. With regard to the control group, the majority of adolescents continued to remain in the moderate category, followed by poor category and only a negligible percentage had good mental health.

This clear difference between the experimental and control groups emphasizes the positive impact of the intervention in significantly strengthening the psychological well-being of NEET aspirants. This can also be attributed to the positive impact of the program in enhancing coping skills, resilience, and emotional regulation. In contrast, the prevalence of medium levels in the control group suggests that, without intervention, adolescents may struggle to achieve optimal mental health outcomes.The above findings are in line with the study by Heizomi *et al.,* (2020), which demonstrated improvements in mental health dimensions through a school-based program, suggesting that such interventions can elevate mental health levels beyond those observed in control groups.

Figure 4 showed that after intervention, the majority of JEE aspirants in the experimental

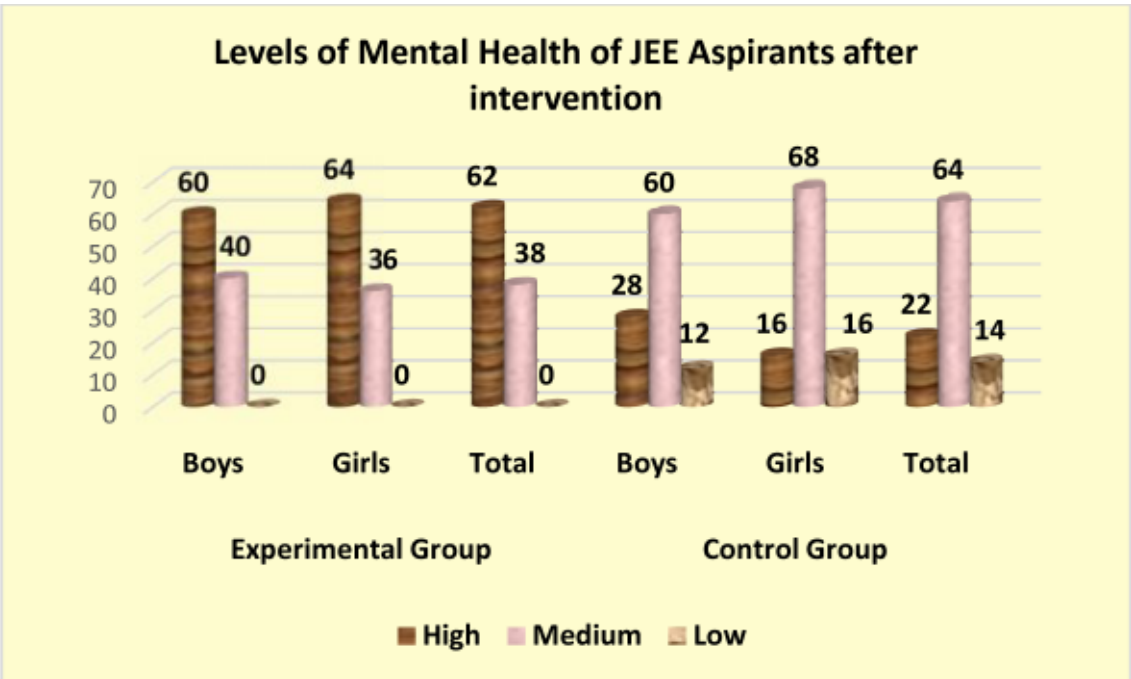

Fig.4. Distribution of JEE aspirantsaccording to Levels of Mental Health after intervention

Table 3. Mean Differences in Mental Health Dimensions between Experimental and Control Groups after intervention (NEET and JEE Aspirants) n=200

Sr.no	Mental Health Dimension	Groups	NEET			JEE		
			Mean ± SD	t value	P value	Mean ± SD	t value	P value
1	Psychological Well Being	Experimental boys	34.92 ± 4.08	4.58 **	0.000	33.56 ± 6.65	3.86 **	0.000
		Control boys	29.32 ± 4.53			26.88 ± 5.53		
		Experimental girls	34.76 ± 4.1	7.93 **	0.000	34.36 ± 6.25	4.45 **	0.000
		Control girls	25.44 ± 4.19			27.68 ± 4.13		
		Over all Experimental	34.84 ± 4.05	8.45 **	0.000	33.96 ± 6.4	5.88 **	0.000
		Overall Control	27.38 ± 4.74			27.28 ± 4.84		
2	Emotional Well Being	Experimental boys	29.16 ± 7.67	2.04 *	0.046	33 ± 8.95	2.06 *	0.044
		Control boys	23.88 ± 10.36			27.96 ± 8.3		
		Experimental girls	33.36 ± 9.58	3.59 **	0.000	33.16 ± 10.58	2.55 *	0.013
		Control girls	24.64 ± 7.46			26.44 ± 7.82		
		Over all Experimental	31.26 ± 8.84	3.93 **	0.000	33.08 ± 9.7	3.3 **	0.001
		Overall Control	24.26 ± 8.94			27.2 ± 8.02		
3	Physical Well Being	Experimental boys	30.8 ± 5.27	3.91 **	0.000	30.56 ± 4.68	3.61 **	0.000
		Control boys	24.32 ± 6.36			25 ± 6.1		
		Experimental girls	31.36 ± 3.61	6.8 **	0.000	32.2 ± 5.35	6.14 **	0.000
		Control girls	23.96 ± 4.05			24.12 ± 3.81		
		Over all Experimental	31.08 ± 4.48	7.07 **	0.000	31.38 ± 5.04	6.75 **	0.000
		Overall Control	24.14 ± 5.28			24.56 ± 5.05		
4	Social Well Being	Experimental boys	24.84 ± 7.18	2.28 *	0.027	27.28 ± 8.88	2.46 *	0.017
		Control boys	19.84 ± 8.28			21.48 ± 7.72		
		Experimental girls	28.28 ± 9.38	3.29 **	0.001	26.92 ± 10.09	2.51 *	0.015
		Control girls	20 ± 8.35			20.56 ± 7.6		
		Over all Experimental	26.56 ± 8.44	3.97 **	0.000	27.1 ± 9.4	3.55 **	0.000
		Overall Control	19.92 ± 8.23			21.02 ± 7.6		
5	Overall Well Being	Experimental boys	115.96 ± 15.36	3.81 **	0.000	124.4 ± 22.68	3.85 **	0.000
		Control boys	97.36 ± 18.96			103.04 ± 15.93		
		Experimental girls	127.76 ± 18.49	7.05 **	0.000	126.64 ± 24.77	5.13 **	0.000
		Control girls	94.04 ± 15.13			98.8 ± 10.99		
		Over all Experimental	121.86 ± 17.85	7.49 **	0.000	125.52 ± 23.53	6.38 **	0.000
		Overall Control	95.7 ± 17.06			100.92 ± 13.71		

group fell under the good mental health category, with more than three-fifths of students showing clear improvement from before intervention levels. This is followed by less than two-fifths in the moderate category and none of them remained in the poor mental health category. These results are indicating the effectiveness of the intervention program. With respect to the control group, the majority of students fell in the moderate category, followed by poor category and only a small percentage had good mental health.

The significant percentage of students showing high mental health in the experimental group after the program reflects the positive impact of the intervention in boosting resilience, concentration, and emotional stability. In contrast, the control group's higher numbers in the medium category indicate that without such support, aspirants may face difficulties in reaching their best possible mental health amidst intense exam pressure.

These findings clearly demonstrate the effectiveness of the intervention in significantly improving the mental health and overall well-being of both NEET and JEE aspirants. Compared to the control group, the experimental group reported higher levels of psychological wellness and a complete absence of low well-being, thereby supporting the impact of resilience-based interventions in promoting adolescent mental health during exam preparation phases.A study by Feiss *et al.* (2019) revealed that school-based interventions significantly reduced internalizing mental health problems compared to control conditions, indicating better mental health outcomes in experimental groups than in control group.

The above table presents the mean differences in various dimensions of mental health including psychological, emotional, physical, social, and overall well-being among NEET and JEE aspirants across experimental and control groups after intervention. The results indicated that among NEET aspirants, experimental girls showed particularly higher levels of psychological, emotional, and physical well-being compared to control girls. Similar trends were observed in boys, especially in psychological and social well-being, indicating that those in the experimental group had improved levels of mental health. Notably, the overall well-being of NEET experimental participants was significantly higher than that of their control counterparts. These results are supported by the study conducted by Barrass, Dodd, and Singh (2025),who found that resilience-based training improved psychological and emotional regulation among Indian high school students, with girls showing stronger gains in emotional well-being. Similarly, Sharma and Nair (2024) reported that mindfulness-based group interventions led to higher levels of self-esteem, social connectedness and overall well-being, with girls benefiting more than boys in physical and emotional health.

In the JEE group, the experimental group demonstrated improved levels of mental health across all domains. While both boys and girls in the experimental group showed better scores, girls consistently scored higher, particularly in physical and overall well-being. Singh and Thomas (2022) observed that adolescent girls showed greater improvement in physical and overall well-being after structured stress-management programs, underscoring gender variations in outcomes.

CONCLUSION

Adolescents preparing for competitive examinations such as NEET and JEE often experience high levels of stress, emotional instability and social disconnectedness, which adversely affect their overall mental health at a very prime age. The findings of the present study revealed that the structured intervention i.e., a mental health tool developed by Dr. Khan Zeenat Muzaffar (2021), was effective in enhancing

various dimensions of mental well-being, including psychological, emotional, physical and social health. The intervention included strategies like positive thinking, social support, group discussions, mindfulness and meditation that helped students develop stronger coping mechanisms, better emotional regulation and improved interpersonal skills, thereby contributing to higher levels of overall mental health. In light of these findings, it is recommended that wellness and mental health education classes be incorporated into the academic curriculum, particularly for students attending integrated coaching programs at the senior secondary level. Such initiatives would promote resilience, adaptability and emotional stability, equipping adolescents to manage the intense academic pressures associated with competitive examinations more effectively.

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FORMULATION AND OPTIMIZATION OF HERBAL GRANOLA BAR USING FACTORIAL DESIGN

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ABSTRACT

The experimental work was carried out in 2022-2023 in SVU college of sciences, Sri Venkateswara University, Tirupati. The main aim was to design a herbal granola bar and its optimization using factorial design. Factorial design was used to determine the significant factors and the optimal condition of the process variable. The factors considered for the study were gum acacia (stabilizer/Gum acacia) and dried herb powder, and the responses were mouth feel, colour and overall acceptability. In the study, increase in colour values of the product was observed with added levels of *Centella asiatica* herb powder up to 6 percent, although irreversible effect was observed at the level of 8 percent.The mouth feel values of the herbal granola bar formulations containing different levels of *Centella asiatica* herb powder and gum acacia reveals that the main effect plot shows that the addition of *Centella asiatica* herb powder up to 6 percent markedly increased the mouth feel values of product. Addition of *Centella asiatica* herb powder up to 6 percent did not affect the taste of the product, however at the level of 8 percent the formulated product perceived the specific medicinal herb taste and flavour in herbal granola bar. Finally, the sensory attributes in terms of overall acceptability of formulations containing 6 percent *Centella asiatica* herb powder and 1.5 percent level of gum acacia were best and well accepted.

Keywords: *Centella asiatica*, Granola bar, Herb, Optimization.

INTRODUCTION

In India, herbs/medicinal plants have been used under a medical system Ayurveda since 5000 years(Jamshidi-Kia *et al., 2017*). This system includes diet and herbal remedies specifically to the body, mind and spirit for disease prevention and treatment. In addition to the macro and micro nutrients such as proteins, fats, carbohydrates, vitamins or minerals necessary for normal metabolism, a plant based diet contains numerous non-nutritive phyto-constituents which may also play an important role in health enhancement. The utilization of herbs will encourage variety in food intake and support nutrient diversity by encouraging new food choices. The food products based on herbs/medicinal plants are quite limited. There are few constraints faced by the food industry to incorporate herbs/ medicinal plants as an ingredient into the food

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matrix. Because, each herb/medicinal plant has their characteristic aroma and taste that can easily change the product unique characteristics. Ultimately, it may show an impact on acceptability of the product. *Centella* herb, which has mild bitter taste and acceptability, can be incorporated into suitable food products.Medicinal plant sector has an important position in the socio-cultural, spiritual and medicinal arena of rural and tribal lives of India (Alamgir, 2017).

Demand is increasing rapidly for the processed and convenience foods because of the increasing awareness about the health, changing socio-economic needs, and insufficient time to cook food with the correct/ balanced amount of nutrition(Sushant *et al.,2021*). One such nutritionally balanced convenience food is the nutritious granola bars, which are acquiring popularity in the worldwide market. Granola bars are products obtained from the compression of grains, containing nuts, dried fruits, flavorings and binder ingredients. The bars contain wide range of nutrients as well as sufficient amount of carbohydrates, proteins and fats and are accessible in smaller packets or pouches, light in weight, very convenient to carry and can be eaten at any point of time(Sharma *et al.,*2014).According to a recently published report by TechSci Research - India Nutrition Bars Market Forecast and Opportunities, 2020, the nutrition bars market in India is anticipated to grow at a CAGR (Compound Annual Growth Rate) of more than 29% during 2015- 2020 on account of increasing working population, rising per capita expenditure, growing incidences of lifestyle diseases and surging youth population.

Centella asiatica comprises a broad spectrum of phytonutrients that provide a range of beneficial effects (Seevaratnam *et al.,* 2012). Generally, *Centella asiatica* contains various classes of phytonutrients such as triterpenes, carotenoids, glycosides, flavonoids, alkaloids, volatile oils and fatty oils (Chandrika and Kumara, 2015). Every research suggests that it is a “miracle herb” for all kind of treatment. It has a cosmic effect on different organs like brain, skin, heart, gastro intestinal system, collagenious tissues and also possesses strong antioxidant properties. Nutritionally, combining cereal grains with other ingredients are valuable to provide better nutrition(McKevith, 2004). By changing and adding additional ingredients, nutritional value of granola bars can be altered. Along these lines, granola bar was chosen to provide value addition with the herb/medicinal plant i.e., *Centella asiatica* in the current study. The food industry has been developing and launching cereal and millet based, fruit based and multi grain bars into the market. Herbs and products containing herb(s) have been in exchange and business and are presently utilized for an assortment of purposes (Awuchi, 2019).Herbal based food products particularly in granola bar market are almost absent. After reviewing the literature on herbal food products with reference to *Centella asiatica*, very limited research studies are available. By keeping in view of it, the research work was planned to design a herbal granola bar and its optimization interms of its composition and quality.

MATERIAL AND METHODS

Medicinal herbs/medicinal plants are gaining interest now a days because of its various health benefits. Granola bars are very adaptable products made from processed cereals mixed with a variety of ingredients. In this context, in development of herbal foods, granola bar was chosen with value addition by*Centella asiatica* in the current study.The methodology adopted for the research work is given as follows.

Processing of herb-*Centella asiatica*

The leaves and the aerial part of the *Centella asiatica* plants were used. The leaf tissues were found to have higher triterpenoids content than the callus and cell suspension. Fresh fully matured leaves of *Centella asiatica* were collected from Krishi Vignana Kendra, Tirupati. A voucher specimen was prepared and tested by the experts with a sample of *Centella asiatica* species from the Department of Botany, SVU,Tirupati. The collected leaves were washed thoroughly to remove the adherent dust particles and cleaned leaves were kept for shade drying about 2 hours. The Cabinet drier was used to decrease the moisture by maintaining the temperature about 40^0C (24 hrs) and to retain the maximum nutrients of *Centellaasiatica*. Then the dried herb/ medicinal plant leaves were ground into a coarse powder with the help of mixer and stored in an airtight container.

Procurement of ingredients

Good quality of selected ingredients (Table 4) were procured from local super market, Tirupati. These ingredients were selected based on the functional compounds present in them which will provide value addition to the product. Stabilizers and emulsifiers such as Gum Acacia and liquid glucose were purchased from online sources.

Table 1. Experiments conducted for optimization of herbal granola bar

S.No	*Centella asiatica* herbpowder (%)	Gum acacia (%)
Experiment 1		
1	2.0	0.5
2	2.0	1.0
3	2.0	1.5
4	2.0	2.0
Experiment 2		
5	4.0	0.5
6	4.0	1.0
7	4.0	1.5
8	4.0	2.0
Experiment 3		
9	6.0	0.5
10	6.0	1.0
11	6.0	1.5
12	6.0	2.0
Experiment 4		
13	8.0	0.5
14	8.0	1.0
15	8.0	1.5
16	8.0	2.0

Formulation and Optimization of Herbal Granola Bar

Demand for the processed and convenience foods is increasing rapidly due to the increasing awareness about the health, changing socio-economic needs, and insufficient time to cook food with the correct/ balanced amount of nutrition. For the formulation of highly acceptable granola bar, different proportions of ingredients were selected. The formulations were worked out to design and optimize the herbal granola baras follows.

Formulation

The primary objective of the current study is to design herbal granola bar. Hence, to get desirable characteristics, various trials were made with different formulations where major emphasis was given to herb powder at different compositions.Totally sixteen trials with four experiments were conducted for the optimization of herbal granola bar. The experiments conductedfor the optimization of herbal granola bar are given in table 1.

Weighing of ingredients

↓

Roasting of grains & other ingredients

↓

Mixing of all ingredients

↓

Preparation of binding syrup

↓

Addition of roasted ingredients to the syrup

↓

Addition of *Centella asiatica* herb powder

↓

Addition of gum acacia

↓

Blending

↓

Pourhotmixtureon bakingtray

↓

Light pressing

↓

Pre-heatingovento170^{0}C/15mins

↓

Baking (145p C,15minutes)

↓

Cooling

↓

Shaping

↓

Packaging

↓

Labelling

↓

Storing

Fig.1.Formulation of Herbal GranolaBar

Optimization

Herbal granola bar was optimized by using factorial research design. An experiment containing two factors, or even more than two, is considered a factorial experiment (related to treatment structure only). Factorial design was used to determine the significant factors and the optimal condition of the process variable. The factors considered for the study were Gum acacia (stabilizer) and dried herb powder, and the responses were mouth feel, colour and overall acceptability.

Table 2. Results subjected for optimization of herbal granola bar

S.No	*Centella asiatica* herb powder(g)	Gum acacia (g)	Responses		
			Mouthfeel	Colour	Overallac ceptability
		Experiment 1			
1	2.0	0.5	6	5	6
2	2.0	1.0	6	5	7
3	2.0	1.5	6	5	7
4	2.0	2.0	7	5	6
		Experiment 2			
5	4.0	0.5	7	6	7
6	4.0	1.0	7	6	7
7	4.0	1.5	7	6	7
8	4.0	2.0	6	5	7
		Experiment 3			
9	6.0	0.5	8	7	7
10	6.0	1.0	8	7	6
11	6.0	1.5	8	8	8
12	6.0	2.0	8	6	6
		Experiment 4			
13	8.0	0.5	4	5	4
14	8.0	1.0	5	4	5
15	8.0	1.5	4	5	5
16	8.0	2.0	4	4	4

Herbal Granola Bar

Table 3. Optimization of herbal granola bar using factorial research design

Experimental Run	*Centella asiatica* herb powder(g)	Gum acacia (g)	Responses		
			Mouthfeel	Colour	Overall acceptability
1	2	0.5	6	5	6
2	2	1	6	5	7
3	2	1.5	6	5	7
4	2	2	7	5	6
5	4.0	0.5	7	6	7
6	4.0	1	7	6	7
7	4.0	1.5	7	6	7
8	4.0	2	6	5	7
9	6.0	0.5	8	7	7
10	6.0	1	8	7	6
11	6.0	1.5	8	8	8
12	6.0	2	8	6	6
13	8.0	0.5	4	5	4
14	8.0	1	5	4	5
15	8.0	1.5	4	5	5
16	8.0	2	4	4	4

Minitab statistical software was used to create the full factorial design with four levels of two factors. Sixteen combinations of two variables were replicated twice and the results were averaged and used for the statistical analysis (table 2). The main and interaction effects of added ingredients on the colour, mouthfeel and OAA were analysed through general linear model regression analysis with analysis of variance (ANOVA). The data was subjected to analysis of variance by using the statistical analysis system (Co Stat version 6.204, CoHort Software, Monterey, California, USA). Student- NewmanKeuls test ($p< 0.05$).

RESULTS AND DISCUSSION

The results obtained were subjected to statistical analysis and are presented as follows.Optimization of herbal granola bar Minitab statistical software was used to create the full factorial design with four levels of two factors.

Sixteen combinations of two variables were replicated twice and the results were averaged and used for the statistical analysis (Table 3). The main and interaction effects of added ingredients on the colour, mouth feel and overall acceptability were analyzed through general linear model regression analysis with analysis of variance (ANOVA). The data was subjected to analysis of variance by using the statistical analysis system (Co Stat version 6.204, CoHort Software, Monterey, California, USA). Student- NewmanKeuls test ($p< 0.05$) was used to resolve the difference among the samples.

Colour

The results of sensory evaluation are very prominent with different herbal granola

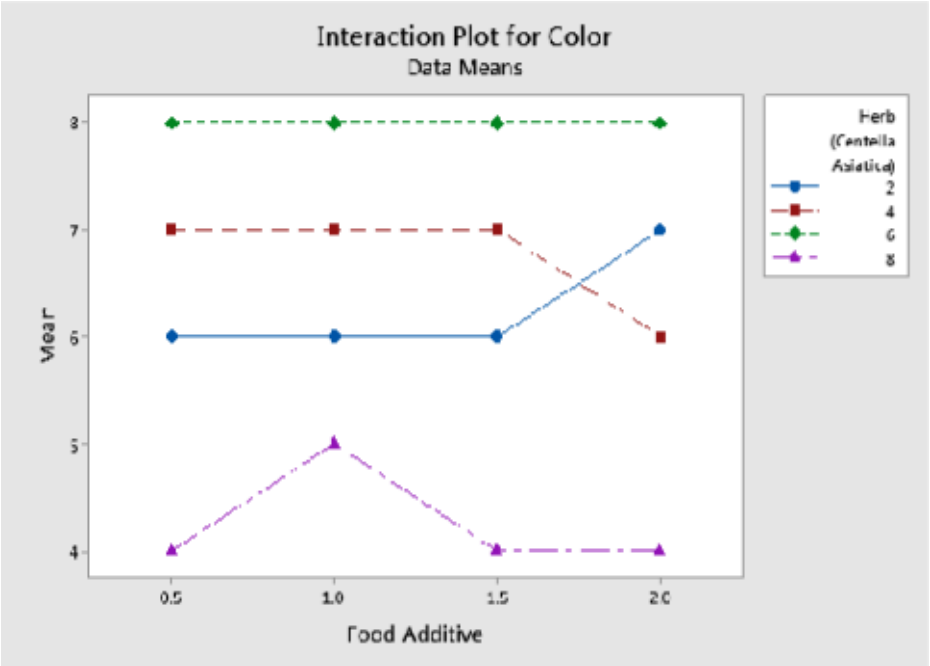

Fig.2.Effect of factors on colour of herbal granola bar

bar formulations prepared with varying levels of Gum acacia and *Centella asiatica* herb powder combinations. The influence of the selected factors i.e. *Centella asiatica* powder and Gum acacia on the colour of herbal granola bar is presented fig 2.

In the current study, increase in colour values of the product was observed with added levels of *Centella asiatica* herb powder up to 6 percent, although irreversible effect was observed at the level of 8 percent. The addition of gum acacia did not much affect the colour of the product. The changes in colour values might be due to the pigments which were present in *Centella asiatica*. In the current study results, theformulations seemed to be highly influenced by the levels of *Centella asiatica* herb powder and their interactions. Overall, the results revealed that the colour of formulation which contains 6 percent *Centella asiatica* herb powder and 1.5 percent of gum acacia was best among all samples.Mrudula *et al.* (2017) conducted a study on development, quality evaluation and shelf life studies of extruded herbal snack foods with fortified herb (*Ocimum basilicum*). The herbal snack was developed by incorporating different proportions of *Ocimum basilicum* paste. According to these results, during the storage period of 60 days of prepared samples, it was observed that the sensory attributes of the samples both control and experiment, were slightly decreased respectively. But the sample which is having ocimum paste has more palatability i.e., the acceptability of this sample was a way more acceptable compared with other samples.

Mouth feel

The mouth feel values of the herbal granola bar formulations containing different levels of *Centella asiatica* herb powder and gum acacia are shown in table 3. The main effect plot shows that the addition of *Centella asiatica* herb powder up to 6 percent markedly increased mouth feel values of product. But with the addition of 8 percent *Centella asiatica* herb powder, the values for mouth feel were decreased. It might be due to the specific taste

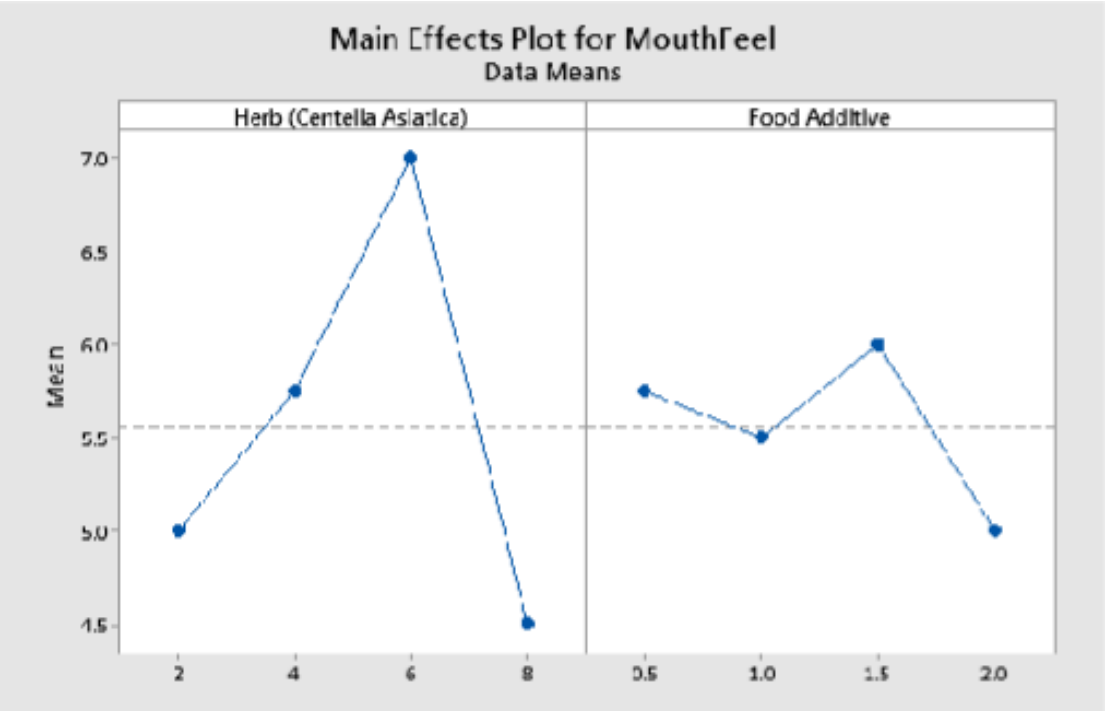

Fig.3.Effect of factors on mouthfeel of herbal granola bar

and flavour of particular medicinal herb. The effect of the selected factors i.e. *Centella asiatica* herb powder and gum acacia on the mouth feel of herbal granola bar was presented in fig 3.

Overall acceptability (OAA)

Overall acceptability is a measure which generally influenced by all sensory properties of food. The influence of the selected factors i.e. *Centella asiatica* herb powder and gum acacia on the overall acceptability of herbal granola bar was presented in fig 4. The increase in overall acceptability (OAA) of the product was observed with added levels of *Centella asiatica* herb powder, although irreversible effects were observed at the level of 8 percent addition. Addition of *Centella asiatica* herb powder up to 6 percent did not affect the taste of the product, however at the level of 8 percent the formulated product perceived the specific medicinal herb taste and flavour in herbal granola bar. Finally, the sensory attributes of formulations containing 6 percent *Centella asiatica* herb powder and 1.5 percent level of gum acacia were best and rated upper part and well accepted. Ramakrishna *et al.* (2015) developed a product labeled Nutraceutical enriched Indian traditional chikki. They formulated and standardized chikki with added herbs like ashwagandha (*Withania somenifera*),tulasi (*Ocimum sanctum* L.) and ajwain (*Trachyspermum ammi* S.). Storage studies were carried out for the developed products up to 90 days. Their results revealed that, sensory analysis of chikki prepared with the addition of herbs showed high acceptance. Significant differences were also observed for colour, flavour and crunchiness among the samples.

Standardization of herbal granola bar

Herbal granola bar was standardized with optimized ingredient composition obtained in full factorial design with four levels of two factors. The table 4 shows the ingredient composition used to design the herbal granola bar. The factors which were optimized were

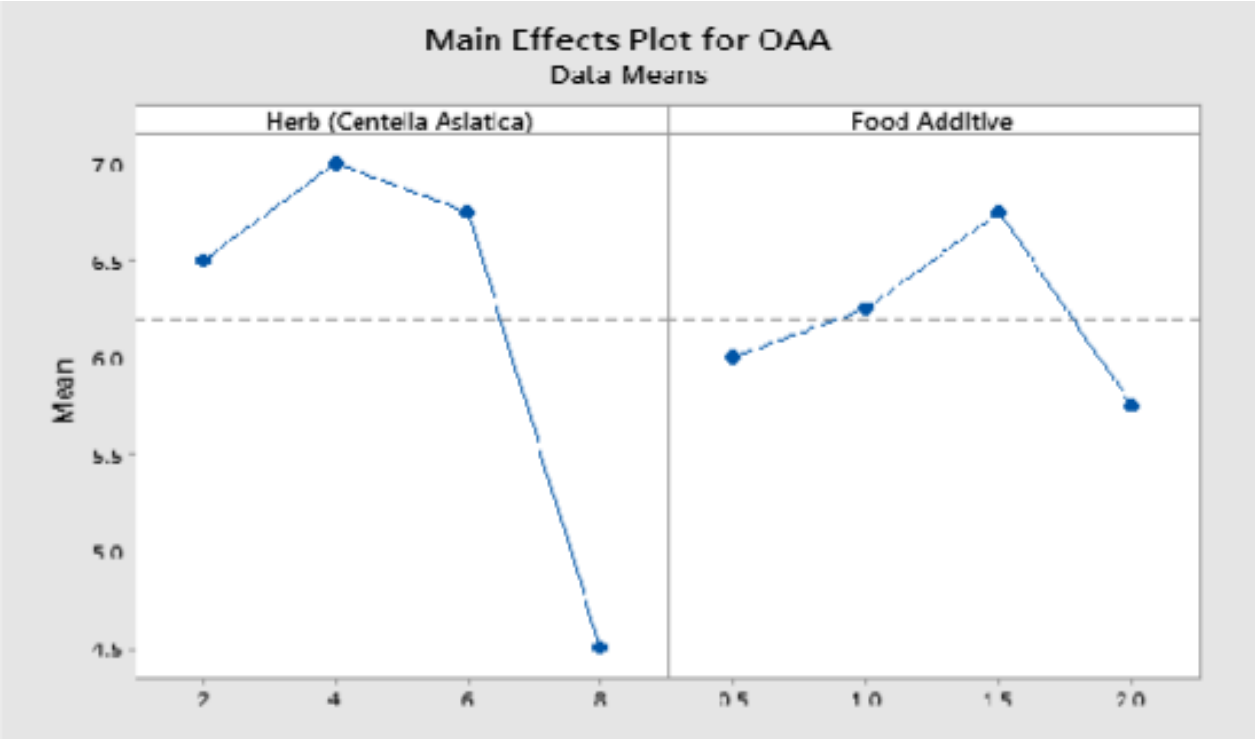

Fig.4.Effect of factors on OAA of herbal granola bar

Table 4. Standardized and optimized composition of Herbal Granola Bar

S. No.	Ingredents	Quantity (g)
1	Foxtail millet flakes	8.0
2	Bajra flakes	8.0
3	Soychunks	8.0
4	Organic rolled oats	8.0
5	Pumpkin seeds	4.5
6	Flax seeds	4.5
7	Sesame seeds	4.5
8	Chia seeds	4.5
9	Raisins	5.0
10	Fresh dates	5.0
11	Sugar	25
12	Honey	5.0
13	Glucose syrup	3.0
14	Gum acacia	1.5
15	Cocoa powder	2.5
16	Skimmed Milk Powder	3.0
17	*Centella asiatica* powder	6.0

taken as optimal composition for designing the final herbal granola bar.

Many herbs have been proven for its bioactive components and their potential to decrease many risk factors. Therefore addition of medicinal herbs into granola bars could help to provide value added herbal granola bars with enhanced nutritional and medicinal values. The present study results revealed that the nutritional properties of *Centella asiatica* and binding properties of gum acacia brought conspicuous changes in the product quality. The important interactions between the appropriate levels of *Centella asiatica* herb powder and gum acacia are eventually important for a highly acceptable product. The combination of 6% *Centella asiatica* herb powder and 1.5 % of gum acacia was found to be the best combination for the development of herbal granola bar with optimum quality characteristics.Kamalesh *et al.* (2021) conducted a study on the influence of chocolate fortification with C*entella asiatica,* A*belmoschus esculentus* and P*sidium guajava* on the content of biologically active substances. Their research examined the combination of *Centella asiatica,Abelmoschus esculentus*, and *Psidium guajava* in the process of chocolate formulation. The concentration of the product was optimized based on taste, flavour, texture, and stability. The optimized concentration was subjected to Nutritional, Stability, Sensory, Antioxidant, Antimicrobial and Shelf life analysis.

The demand for healthy, nutritious and safe food is growing worldwide and consumers are taking the forward step towards natural healthy food products. The use of *Centella asiatica* in the formulation of the herbal granola bar has provided higher nutritional values and it will suitable to the current consumers due to its high levels of antioxidants and phytochemicals. Herbal granola bar developed by using a variety of functional ingredients can be introduced into the commercial market for various segments of consumers concerned about nutritious and healthy foods. Herbal granola bar could meet this trend with their rich source of phytonutrients.

The cost of production of one kg herbal granola bar was about Rs. 434.64/- and each bar (approximately of 30 gm) is Rs. 14.48/-. This was comparatively very less than any commercial bars that are available in market. By the incorporation of medicinal herb powder, this will provide nutritional and therapeutic benefits to the consumer. This herbal granola bars can be prepared / manufactured at home, cottage and industrial scale to meet the consumer demands, nutritional security and healthy life to population.

CONCLUSION

The sensory attributes of formulations containing 6 percent *Centella asiatica* herb powder and 1.5 percent level of gum acacia were best and and well accepted.The current study thus concludes that nutrifoods such as herbal granola bars are intended to not only provide essential macro and micronutrients to the body but also to supply it with bioactive ingredients that aid to decrease nutrition-related diseases and ensure physical and mental well-being. With rapid advances in food technological research, active ingredients from herbs/medicinal plants served as key ingredients for the development of novel food products. Granola bars have been a good choice to test the novelty in the products because of increasing demand in global convenience health/functional food product market. Combination of herbs/medicinal plants in formulating granola bars with gifted health benefits and to avoid any side effects with respect to quality testing, safety and price.

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ASSOCIATION BETWEEN ANTHROPOMETRIC INDICATORS AND GLYCEMIC STATUS AMONG DIABETIC ADULTS OF BHUBANESWAR, ODISHA

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ABSTRACT

Globally, type 2 *diabetes mellitus* (T2DM) has become a common chronic illness due to dietary changes, sedentary lifestyles and urbanisation.With the rising prevalence of diabetes, understanding the role of nutrition is crucial for effective management. A study was conducted in 2023 with 100 diabetic adults, to assess their dietary intake, anthropometric measurements and blood sugar levels. Nutritional status was evaluated using standard indices *viz.*, Body Mass Index (BMI),Waist circumference (WC) and Abdominal fat (AF). The association between nutritional status and blood sugar levels among diabetic adults was also statistically analyzed. The mean waist circumference was found to be 96.84±13.13 cm for males and 100.5±14.69 cm for females which is greater than the normal value. A large number of diabetic adults (50.0%) were found to have a higher FBS (>125mg/dl) and 49.0 percent of the respondents were seen to have higher PPBS levels (>200 mg/dl). The blood parameters of the respondents were found to be greater than the normal values. A positively significant association was found between Body Mass Index and Central Obesity with elevated blood sugar levels as the χ^2 observed value (19.035) was found to be less than the χ^2 calculated value (19.975). Participants with a balanced diet exhibited better glycemic control, while those with inadequate nutrient intake showed higher fasting blood sugar levels. These findings implicate that nutritional interventions are vital for good diabetes management and reducing complications.

Keywords: Blood sugar level, Diabetic, Nutritional status.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) has become a prevalent chronic disease globally, driven by urbanization, sedentary lifestyle and dietary changes. The global prevalence of diabetes has been steadily increasing, with approximately 537 million adults affected in 2021. This number is projected to rise significantly, reaching over 780 million by 2045 (Sun *et al*., 2022). Obesity, particularly central obesity, is a key risk factor for insulin resistance and the development of diabetes. Anthropometric measures like Body Mass Index (BMI) and Waist Circumference (WC) are vital for assessing obesity and fat distribution, with both strongly linked to glycemic control and diabetes complications.

Body Mass Index (BMI), calculated from weight and height, categorizes individuals into

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weight classes but does not account for fat distribution or distinguish between fat and lean mass. Despite these limitations, a higher BMI is consistently associated with a higher risk of T2DM, insulin resistance and poor glycemic control (World Health Organization, 2016).Waist circumference (WC), on the other hand, specifically indicates central obesity, which is strongly tied to insulin resistance and cardiovascular risks in diabetic adults due to release of pro-inflammatory cytokines by visceral fat. (Huang *et al*., 2023).

In addition to anthropometric measures, blood parameters such as Fasting blood glucose (FBG) and Hemoglobin A1c (HbA1c) are critical for assessing diabetes severity and management (Antwi-Baffour *et al*., 2023). Poor glycemic control, often accompanied by dyslipidemia, exacerbates the risk of cardiovascular complications. Clinical symptoms such as polyuria, polydipsia and peripheral neuropathy further underline the importance of effective diabetes management, particularly in individuals with higher WC and BMI (Alshammari *et al.,*2022).This study investigated the association between nutritional status and blood sugar levels among diabetic adults in Bhubaneswar, Odisha, with a focus on anthropometric and biochemical markers to enhance understanding of diabetes management.

MATERIAL AND METHODS

The present study conducted at different locations of Bhubaneswar, Odisha during 2023 (6 months).Adults (both male and female) aged 35 to 55 years were included as respondents in this study. The criteria adopted by Kuppuswamy, 2017 was followed.

Inclusion criteria

1. Adults with a blood sugar level above 100 mg/dL.
2. Individuals diagnosed with Type 2 Diabetes for more than six months.
3. Individuals aged 35 to 55 years.

Exclusion criteria

1. Individuals with Type1diabetes.
2. Patients with gestational diabetes (pregnant women).
3. Individuals not within the age range of 35-55 years.

Bhubaneswar, Odisha, was chosen as the study location for its diverse population and accessible healthcare facilities. A simple random sampling technique was employed to select 100 adults (50 males and 50 females), aged 35–55 years, with blood sugar levels >100 mg/dL from health care centers and local clinics. A pre-tested semi-structured questionnaire was used to gather data on socio- demographic profile and clinical symptoms of the patients.Ethical guidelines were followed, ensuring informed consent from participants, confidentiality, and adherence to ethical standards in data collection and analysis.

Blood sugar levels were recorded from respondents' recent medical reports. Anthropometric measurements including height, weight, waist circumference and hip circumference were taken following standard procedures. WHR (Waist-Hip Ratio) and BMI was calculated using the formula, {BMI=Weight (Kg) /Height^2 (m^2)} and the respondents were classified in different groups according to WHO guidelines. The respondents were placed under different socio-economic classes based on Kuppuswamy's scale.

Data were analyzed using SPSS software. Percentage, mean, standard deviation, and chi-square tests were applied to interpret the results.Chi square test was employed to establish statistical significant association between blood sugar levels with BMI and waist circumference of respondents.

RESULTS AND DISCUSSION

The demographic data of the subjects in table 1 indicated that the majority of diabetic adults were aged 46–55 years (58.0%), followed by 42.0 percent in the age group of

Table 1. Distribution of samples according to socio demographic characteristics

n=100

S.No.	Specifications	Categories	Frequency (%)	
			Male(n=50) No. (%)	Female (n=50)No. (%)
1	Age	35-45 years	13 (26.0)	29 (58.0)
		45-55 years	37(74.0)	21 (42.0)
2	Educational Status	Post-Graduation	18(36.0)	8(16.0)
		Graduation	28(56.0)	25(50.0)
		Higher Secondary	3(6.0)	7(14.0)
		High School	1(2.0)	5(10.0)
		Primary School	-	5(10.0)
3	Occupation	Govt. Job	29(58.0)	12 (24.0)
		Private Job	11(22.0)	5 (10.0)
		Self-Employed	10 (20.0)	01 (2.0)
4	Family type	Nuclear	48 (96.0)	49 (98.0)
		Joint	02(4.0)	01 (2.0)
5	Socio-economic status	Upper	22(44.0)	31 (62.0)
		Upper middle	25 (50.0)	14 (28.0)
		Lower middle	03 (6.0)	02 (4.0)

*Figures in parenthesis indicates percentages

35–45 years. Majority of the participants (97.0%) belonged to nuclear families. It was observed that the male participants had higher representation at postgraduate and graduate levels, while females were more prominent at the higher secondary level. Similarly, a larger number of male participants were employed in Government sectors in comparison to their female counterparts.Socioeconomic analysis showed that 53.0 percent were from the upper group, 39.0 percent from the upper middle group, and 5.0 percent from the lower middle group.

Majority (38.0%) of the male subjects were in the pre-obese BMI category, while 44.0 percent of female subjects were classified as obese. Under normal category, 18.0 percent of the male subjects were in the normal category, whereas only 6.0 percent female participants were found to be in normal category. Similarly, 12.0 percent males and 8.0 percent females were underweight. Higher prevalence of obesity indicates excess weight gain and is a major issue among the diabetic adults.

Similarly, in majority of the participants, waist circumference exceeded the normal values, 92.0 percent of females and 82.0 percent of males showed higher abdominal fat. Central obesity i.e. excess waist circumference is considered as a risk factor for the development of diabetes. Abdominal obesity, defined by Waist-to-Hip ratio (WHR), was observed in 56.0 percent of males (WHR >1.0) and 62.0 percent of females (WHR >0.8). Among males, 26.0 percent had normal WHR and 18.0 percent had low WHR, while among females, these values were 30.0 percent and 8.0 percent, respectively.Body Mass Index (BMI) and Waist Circumference (WC) are widely recognized anthropometric measures for evaluating obesity and abdominal fat, both of which are critical indicators of metabolic health. These measures are strongly associated with insulin resistance, a central factor in the

Table 2. Distribution of samples according to BMI **n=100**

S.No.	Body weight category	BMI (kg/m²)	
		Male(n=50)	Female (n=50)
1	Underweight(<18.5)	6 (12.0)	4 (8.0)
2	Normal(18.5-22.9)	9 (18.0)	3 (6.0)
3	Overweight (23-24.9)	10 (20.0)	3 (6.0)
4	Pre-obese(25-29.9)	19 (38.0)	10 (20.0)
5	Obese(e”30)	13 (26.0)	22 (44.0)
Central obesity (Waist circumference in cm)			
6	Ideal value	94	80
7	Observed value(Mean±SD)	96.84±13.13	100.5±14.69
WHR(Abdominal fat)			
8	Excess(male : >1 female: >0.8)	28 (56.0)	31 (62.0)
9	Normal(male : 1 female: 0.8)	13 (26.0)	15 (30.0)
10	Low(male : <1 female:<0.8)	09 (18.0)	04 (08.0)

*Figures in parenthesis indicate percentages

pathophysiology of Type 2 diabetes (T2D) (Wondmkun, 2020).

Elevated BMI contributes to insulin resistance by promoting the secretion of adipokines and inflammatory markers that impair insulin signaling, leading to hyperglycemia (Zatterale *et al*., 2020). The findings of the present study indicates that a significant proportion of participants exceeded the normal BMI range, reflecting a shift toward excessive weight gain. This aligns with findings by Patel *et al*. (2023), which reported significantly higher BMI values in diabetic patients compared to healthy control population. Additionally, WC measurements indicated a high prevalence of central obesity, particularly among females, consistent with gender-specific fat distribution patterns. Elevated WHR further highlighted the prevalence of abdominal obesity, with higher risks of metabolic complications such as T2D and cardiovascular diseases (Huang *et al.,* 2012). Studies carried out by Aghaei *et al*., (2024) also reported similar trends, confirming WC and WHR as stronger predictors of insulin resistance than BMI.

The biochemical parameters of both male and female participants were recorded and compared to the reference value. The findings were displayed in Table 3. The Z values ($p<0.01$) indicate a significantly higher hemoglobin, PPBS, total cholesterol, HbA1c, HDL, HbA1c and blood pressure were observed indiabetic males than in their female counterparts.Whereas LDL, TG levels were significantly higher ($p<0.01$) in females as compared to the males. The level of FBS, did not vary significantly between male and female diabetic patients.

The comparative study indicated that diabetic males had significantly higher levels ($p<0.01$) of hemoglobin, blood PPBS, total cholesterol, HbA1c, HDL, and blood pressure than females. In contrast, diabetic females exhibited significantly higher ($p<0.01$) levels of LDL and triglycerides (TG) than males. The fasting blood sugar (FBS) levels did not show a significant difference between sexes among diabetic patients. Findings of the study

Table 3. Distribution of samples according to Biochemical parameters n=100

S.No.	Parameters		Male (mean ± SD)	Female (mean ± SD)	Reference value	Z-Value
1	Haemoglobin		12.0±1.25	10.0±1.26	13(M)12.5(F)	8.28**
2	FBS (mg/dl)		132.8±28.99	124.34±15.40	100	1.836(NS)
3	PPBS (mg/dl)		184.5±46.17	158.92±28.16	140	3.336**
4	Cholesterol (mg/dl)		225.9±24.36	203.82±29.88	200	3.953**
5	HDL (mg/dl)		41.8±13.46	40.94±19.03	40	1.077**
6	LDL (mg/dl)		103.0±17.30	108.38±15.42	100	1.712**
7	TG (mg/dl)		154.0±17.01	158.36±16.89	150	1.203**
8	HbA1c (%)		11.0±2.36	9.0±1.79	08	2.2688**
9	SystolicB.P (mmHg)		130.22±10.09	125.06±7.91	120	0.004**
10	DiastolicB.P (mmHg)		84.52±4.904	82.28±5.07	80	2.24**
11	FBS (mg/dl)	<110	11 (22.0)	13 (26.0)	-	-
		110-125	14 (28.0)	25 (50.0)	- -	-
		>125	17 (34.0)	20 (40.0)		
12	PPBS (mg/dl)	<140	13 (26.0)	16 (32.0)	-	
		140-199	12 (24.0)	14 (28.0)	-	
		>200	29 (58.0)	20 (40.0)	-	

FBS: Fasting blood sugar, PPBS: Postprandial Blood sugar, HDL: High Density Lipoprotein, LDL: Low Density Lipoprotein,TG:Triglyceride,HbA1c: Glycosylated Haemoglobin, B.P:Blood Pressure (Parenthesis"**"denotes significant variation(p<0.01)NS:Non-significant)

revealed that blood parameters have a significant relationship with the gender of the participants. Higher HbA1c levels among the males,shows poorer long-term glycemic control, potentially due to differences in treatment adherence or insulin sensitivity. Lipid profile analysis showed that females had elevated LDL and triglycerides, key risk factors for aterosclerosis and cardiovascular disease (CVD), while males exhibited higher total cholesterol and HDL levels (p<0.01). These findings echo the concerns raised by Zheng *et al*. (2019) and Hyassat *et al.* (2022), emphasizing the need for improved lipid management in diabetic patients. Hypertension was also prevalent among diabetic participants, with blood pressure exceeding 130/80 mmHg. Proper food management, including lifestyle changes and antihypertensive medications such as ACE inhibitors or ARBs, is crucial for mitigating cardiovascular risks (Zhen *et al*., 2022).

The observed values of blood sugar of the subjects under differentranges were presented in Table4.The analysis of fasting blood sugar (FBS) levels revealed that 45.0 percent of participants had FBS >125 mg/dL, indicating poor glycemic control, with a higher proportion of males (50.0%) compared to females (40.0%). In the prediabetic range (110–125 mg/dL), 28.0 percent males and 34.0 percent females, while 24.0 percent had normal FBS levels (<110 mg/dL).

Postprandial blood sugar (PPBS) levels showed that 49.0 percent of participants had

Table 4. Distribution of samples according to blood sugar level **n=100**

S.No.	Categories		Total	Male(n=50) No.(%)	Female(n=50) No.(%)
1	FBS(mg/dl)	<110	24	11 (22.0)	13 (26.0)
		110-125	31	14 (28.0)	17 (34.0)
		>125	45	25 (50.0)	20 (40.0)
2	PPBS(mg/dl)	<140	29	13 (26.0)	16 (32.0)
		140-199	26	12 (24.0)	14 (28.0)
		>200	49	29 (58.0)	20 (40.0)

values >200 mg/dL, with males (58.0%) outnumbering females (40.0%). In the intermediate range (140–199 mg/dL), 26.0 percent of participants were recorded, including 24.0 percent males and 28.0 percent females. Only 29.0 percent of participants had PPBS <140 mg/dL, with slightly more females (32.0%) than males (26.0%).

The findings highlight that a significant proportion of the sample had poor glycemic control, particularly among males. This underscores the need for targeted interventions to improve blood sugar management in diabetic adults. Blood sugar analysis revealed significant differences between diabetic males and females. Males showed higher fasting blood sugar (FBS) levels, indicating poorer glycemic control, while females had a higher prevalence in the prediabetic range, reflecting an elevated risk of diabetes progression. This finding aligns with studies by Patel *et al*., (2023), which reported poor glycemic control among diabetic patients.

The clinical signs of the subjects were recorded, and the frequency percentages distribution were shown in Figure 1. It is evident from the figure that, the frequency for observing fatigue was more in males (70.0%) than in females (64.0%) but, that of blurred vision was calculated less for males (22.0%) than in females (18.0%). Further, 42.0 percent males and 46.0 percent females were found to have polyuria. Similarly, polydipsia was seen in 56.0 percent of the males and 58.0 percent females, loss of weight without any heavy physical activity is seen in 24.0 percent males and 22.0 percent females. Slow wound healing is seen in 46.0 percent males and 32.0 percent females.

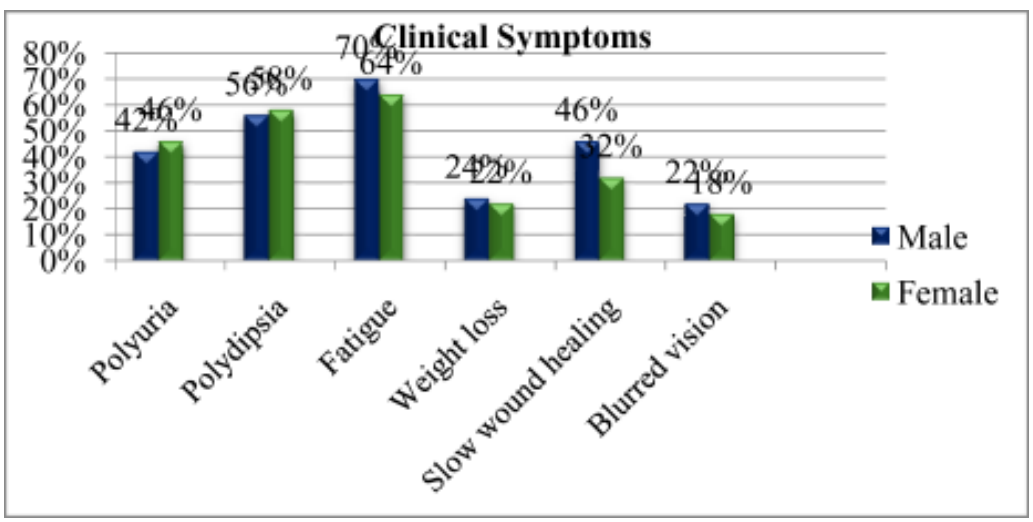

Fig. 1 Clinical signs among diabetic adults in Bhubaneswar

Table 5. Association of blood sugar level with BMI of samples **n=100**

S.No.	BMI	FBS (mg/dl)			PPBS (mg/dl)		
		<110	110-125	>125	<140	140-200	>200
1	Underweight (10)	6	4	0	8	2	0
2	Normal (26)	2	3	7	2	3	7
3	Overweight (29)	3	3	8	3	4	7
4	Pre-obese (29)	4	7	18	4	10	15
5	Obese (35)	3	11	21	8	10	17
6	Total (100)	18	28	54	25	29	46
7	χ^2(Table):15.51d.f:8 at 5%level of significance	χ^2**(Calculated)** =19.035			χ^2 **(Calculated)** = 19.975		

The ranges of the fasting blood sugar value increased with the increasing BMI as shown in Table 5. As the BMI falls, the fasting blood sugar level among there spondents were found to be less. A positive correlation was observed between the BMI and fasting blood sugar of the respondents. The PPBS was significantly increasing with the increasing BMI. The χ^2 calculated (19.975) value was greater than the χ^2 table value (15.51). The findings highlight association of BMI with the PPBS range. Table 6 also illustrates that fasting blood sugar values tended to rise with increasing BMI. Conversely, as BMI decreased, fasting blood sugar levels among respondents were also lower, indicating a positive correlation between BMI and fasting blood sugar. Similarly, postprandial blood sugar (PPBS) levels significantly increased with higher BMI values. The calculated chi-square (χ^2) value of 19.975 exceeded the table value of 15.51, confirming an association between BMI and PPBS range.Agrawal *et al.* (2017) also observed a positive correlation between BMI and FBS, and is consistent with the present study.

It has been observed from the Table 6 that, the male respondents having larger waist circumference showed a higher range of fasting blood sugar level as well as PPBS. The FBS was found to increase with increasing waist circumference of female respondents. The χ^2 calculated value (9.65) was greater than the χ^2 table (9.49) value.The table shows that the respondents having normal waist circumference possessed a lower range of PPBS range. The χ^2 calculated value was found to be greater than the χ^2 table value in both male and female respondents. So, it is supposed that there may be a direct relation between the Waist Circumference and the PPBS range of the respondents(Table 6).

It was further observed that male respondents with larger waist circumferences exhibited higher fasting blood sugar (FBS) and postprandial blood sugar (PPBS) levels. Among female respondents, FBS also increased with waist circumference. The chi-square (χ^2) calculated value of 9.65 exceeded the table value of 9.49, confirming a significant association.The table also shows that respondents with normal waist circumference had lower PPBS levels. In both male and female respondents, the calculated χ^2 values exceeded the table values, suggesting a potential direct relationship between waist circumference and PPBS levels.

CONCLUSION

The present study highlights a positively significant association between anthropometric indicators and glycaemic control among diabetic adults in Bhubaneswar, Odisha. A gradual increase in fasting and postprandial blood sugar values was recorded as the BMI increased from normal to obese category.The chi-square results for both fasting (χ^2 = 19.035) and postprandial (χ^2 = 19.975) glucose levels were greater than the table

Table 7. Association between Waist Circumference and Blood sugar level n=100

S.No.	Waist circumference	FBS(Male) mg/dl				PPBS(Male)mg/dl		
		<110	110-125	>125	Total	<140	140-200	>200
1	<94	6	2	1	9	5	4	0
2	94-102	2	4	7	13	2	4	7
3	>102	5	9	14	28	4	10	14
4	Total	13	15	22	50	11	18	21
5	χ^2Calculated value:9.95					χ^2Calculated value:10.54		
6	FBS (Female) mg/dl					PPBS (Female) mg/dl		
7	<80	3	1	0	4	3	1	0
8	80-88	1	6	8	15	0	6	9
9	>88	6	11	14	31	5	11	15
10	Total	10	18	22	50			
11	χ^2 Calculated value:9.65					χ^2Calculated value:17.19		
	χ^2 Table value:9.49, df:4 a t5% level of significance							

value (χ^2 = 15.51 at 5% level), confirming a positively significant association between BMI and blood sugar status.Similarly, waist circumference has an interrelationship with blood sugar levels in both male and female participants. Those with a waist circumference above the standard cut-off (>102 cm for males and >88 cm for females) had consistently higher fasting and postprandial glucose levels.These findings emphasize that excessive body weight and central obesity are important determinants of diabetes management outcomes. Routine assessment of anthropometric parameters should therefore be integrated into diabetes care to identify at-risk individuals and guide personalized dietary, lifestyle, and therapeutic interventions.Regular physical exercise, adherence to a balanced and portion-controlled diet, periodic monitoring of anthropometric indices,health education and community awareness programmes should form an integral part of diabetes management.

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SOCIAL MEDIA UTILIZATION AMONG TRIBAL YOUTH OF NORTH COASTAL ZONE IN ANDHRA PRADESH

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ABSTRACT

The present study was conducted to assess the social media utilization patterns among tribal youth of Parvathipuram Manyam district of Andhra Pradesh. A sample of 120 tribal youth were selected using a purposive sampling technique and data were collected through a structured interview schedule and analysed using appropriate statistical tools. The findings revealed that majority of the tribal youth were in the age group of 22-26 years, belonged to joint families, currently pursuing graduation and majority of them possessed medium to high social participation and information-seeking behaviour. With regard to social media utilization, majority of the tribal youth possessed android smartphones, depended on BSNL network and were mostly using platforms such as WhatsApp, YouTube and Instagram for communication, entertainment and social interaction. Usage of professional networks like LinkedIn and Twitter remained negligible. With regard to the purpose of use of social media, majority expressed entertainment and communication as the need. The study highlights the growing digital engagement among tribal youth while also indicating gaps in educational and professional use of social media. These insights can guide educators and extension professionals in designing targeted digital literacy and inclusion programs for tribal communities.

Keywords: Social Media, Tribal Youth, Utilization Patterns

INTRODUCTION

Social media is undeniably widespread, with billions of users of all ages and backgrounds globally. This platform facilitates community-based communication, teamwork and feedback by enabling users to engage through comments, likes, shares, conversations and images. It is a technological means of sending information, ideas opinions etc. through the communication device to a diverse audience using online platforms that enable users to create, share and exchange information and content, fostering virtual communities and networks. The platforms, such as Facebook, Instagram, Blogs, TikTok and YouTube, Myspace, Twitter, YouTube and some Gaming sites facilitate communication, collaboration and content sharing in various mediaformats like text, images, videos and more.

The pattern of social media use varies between regions and groups of individuals and

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it is highly influenced by characteristics such as age, education level, gender, technological accessibility and information seeking behaviour.that can impact how individuals utilize social media in multiple communities and situations. Utilization patterns describe how frequently and for what purpose users utilise social media platforms, such as communication, education, entertainment, news consumption and commercial activity. Young individuals are especially likely to use social media because of more mobile availability, peer influence and curiosity-driven behaviour (Kovanen *et al*., 2019).

In tribal communities, particularly in remote regions like Parvathipuram Manyam district of Andhra Pradesh, the influence of digital technology is gradually expanding. Tribal youth, who were once distanced from mainstream digital exposure, are increasingly becoming active users of social media due to improved mobile connectivity and smartphone penetration. However, the pattern and purpose of their social media usage often differs from their urban counterparts, influenced by socio-cultural, economic and educational backgrounds.

MATERIAL AND METHODS

A descriptive research study design was adopted to conduct the study on Social media utilisation patterns among Tribal Youth of Parvathipuram Manyam district. of Andhra Pradesh. The study was carried out with 120 tribal youth respondents covering Kurupam and Gummalaxmipuram tribal dense mandals for the study. These two mandals are also educational centers for tribal youth of manyam district due to proximity to ITDA. Purposive sampling technique was adopted in selection of respondents from six villages. The respondents with minimum three years of mobile experience were selected purposively to study the impact and utilization patterns. A structured interview schedule was prepared to collect data. Frequency, percentage, Mean, Standard Deviation,Interquartile range (IQR)and correlation were used for statistical analysis and drawing inferences.

RESULTS AND DISCUSSION

An effort has been made to carefully examine the results derived from the empirical data collected during the course of the study. For the purpose of clarity and brevity, with reference to the objectives, the data collected during the study was coded, analysed, interpreted

Data from Table 1 revealed that majority of the tribal youth fell under the category of 22-26 years (48.33 %) category followed by 18-22 years (27.50%) and 26-30 years (24.17%). The reason might be that during Covid period, Government supported children with digital devices for online education purpose.With regard to education, nearly half of the tribal youth have completed Graduation (49.17%) followed by Intermediate (25.83%) and High school (20.00%). Only five percent of the youth were illiterates. This is might be due to strong policy and institutional support from Government towards development of educational infrastructure and institutions in tribal areas through ITDA.

Data on Family type indicated that majority of the tribal youth were from joint families (60.83%) followed by nuclear family (23.33%) extended families (15.83%). The results clearly indicated the strong societal interactions and structures existed in tribal community. The other reason for the prominence of the joint family structure in the tribal society might be due to combined landholdings and strong bondages. With regard to respondents' occupation the data indicated that majority of the tribal youth of the study were students (36.67%) followed by daily labour (23.33%) and Agriculture

Table 1. Profile characteristics of the respondents **n=120**

S.No	Category	Frequency	Percentage
	Age		
1.	18 -22 years	33	27.50
2.	>22 – 26 years	58	48.33
3.	>26 – 30 years	29	24.17
		120	100.00
	Education		
1.	Illiterate	06	5.00
2.	High school	24	20.00
3.	Intermediate	31	25.83
4.	Graduation	59	49.17
		120	100.00
	Family Type		
1.	Nuclear Family	28	23.33
2.	Joint Family	73	60.83
3.	Extended Family	19	15.83
		120	100.00
	Occupation		
1.	Student	44	36.67
2.	Unemployed	18	15.00
3.	Agriculture	26	21.67
4.	Daily Labour	28	23.33
5.	Business	01	0.83
6.	Government job	03	2.50
		120	100.00
	Social participation		
1.	Low	16	13.33
2.	Medium	63	52.50
3.	High	41	34.17
		120	100.00
		Mean: 16.33 ; SD:1.06	
	Information seeking behaviour		
A	Formal sources		
1.	Low	04	3.33
2.	Medium	74	61.67
3.	High	42	35.00
	Total	120	100.00
		Mean 8.033, SD:1.22	
B	Informal sources		
1.	Low	14	11.67
2.	Medium	72	60.00
3.	High	34	28.33
		120	100.00
		Mean : 12.75 ,SD:1.57	

Table 2. Distribution of the respondents on the basis of ICT Possession n=120

S.No.	Type of Mobile	Frequency	Percentage
1.	iPhone	02	1.67
2.	Android	88	73.33
3.	Tablet	12	10.00
4.	Non android	18	15.00
		120	**100.00**

(21.67%) The reason for dependency on agriculture might be due to low or no employment opportunities in public and private sectors as these villages are located in remote areas.

Most of the tribal youth had medium (52.50%) to high (34.17%) social participation because of their involvement in community activities, government youth programmes and active participation in educational institutions and student clubs. Majority had medium to high information seeking behaviour from both formal and Informal sources. This might be due to their curiosity and use of easily accessible sources like government websites, institutions, friends, and relatives.

Social Media utilization patterns by the tribal youth.

Mobile Possession

Results in Table 2 showed the possession of mobile devices and indicated that majority of the tribal youth are using android devices (73.33%) followed by non-android phones (15.00%), Touch screen Tablet (10.00%) and only 1.67 per cent respondents were using iPhone.The reason for possessing and using ICT devices by all tribal youth might be due to online education imposed during COVID 19 pandemic and digital initiatives taken up by Government of India for e-Governance in all developmental areas. Also, the penetration of android devices even in the remote areas may be accounted to the affordability and accessibility, especially due to the digital explosion in the entertainment industry. This could be a great achievement for technology transfer in reaching the unreached especially the disadvantaged sections of the society. The findings of the present study were similar with the studies of Naresh and Kumari (2019), Ramya and Gopal (2022) and Mohanty *et al.,* 2023.

Type of Network usage

Network is operationally defined as the Telecommunication networks subscribed and used by the respondents.

Presented data in the Table 3 showed that the similar trend was observed in total sample data, forty-three percent of tribal youth preferred BSNL network (55.84 %) followed by Jio

Table 3. Distribution of the respondents on the basis of Network usage n=120

S.No.	Telecommunication networks	Frequency	Percentage
1.	Airtel	01	0.83
2.	Jio	52	43.33
3.	BSNL	67	55.84
	120	**100.00**	

Table 4. Distribution of the respondents on the basis of daily mobile data usage n=120

S.No.	Mobile data	Frequency	Percentage
1.	1GB	10	8.33
2.	1.5 GB	78	65.00
3.	2 GB	32	26.67
		120	**100/00**

Table 5. Distribution of the respondents on the basis of Monthly Recharge n=120

S.No.	Monthly Recharge	Frequency	Percentage
1.	Below Rs.200	01	0.83
2.	Rs 201 - 400	106	88.33
3.	Rs 401 - 800	05	4.17
4.	Above Rs 800	08	6.67
		120	**100.00**

(43.33%) and only 0.83 percent respondents were using Airtel network.

The reason for the above results might be the limited availability of private network operators in the tribal and remote areas. Majority of the tribal youth depended on Govt. telecommunication network BSNL due to non-availability of mobile towers and broadband networks.

Mobile data usage

As per the Table 4, tribal youth showed that most of them were using 1.5 GB (65.00%) data daily followed by 2 GB (26.67%) and 1GB (8.33%). The reason might be easy access to the technology with nominal prices from the network companies and affordability of the customers.

Monthly mobile recharge

An overview of the Table 5 shows that a great majority of the tribal youth were spending Rs.200 - 400 for monthly recharge (88.33%) followed by Rs. 400 – 800 (6.67%), above Rs.800 (4.17 %) and Below Rs.200 (0.83 %). The monthly mobile data recharge for majority of tribal youth is Rs.200-400 which is quite affordable by them.

Daily time spent on social media

Results presented in the Table 6 revealed that 61.67 per cent of the respondents were spending 5-6 hours followed by 7-8 Hours

Table 6. Distribution of the respondents on the basis of Time spent on social media. n=120

S.No.	Time spend	Frequency	Percentage
1.	2-4 Hours	08	6.67
2.	>4-6 Hours	74	61.67
3.	> 6 – 8 Hours	31	25.83
4.	More than 8 Hours	07	5.85
		120	**100.00**

Table 7. Distribution of the respondents on the basis of Usage of Social Media platforms

n=120

S.No.	Social Media platforms	Yes		No	
		Frequency	Percentage	Frequency	Percentage
1.	Facebook (2004)	41	34.17	79	65.84
2.	Instagram (2010)	103	85.83	17	14.16
3.	YouTube (2005)	120	100.00	0	0.00
4.	WhatsApp (2009)	120	100.00	0	0.00
5.	Snapchat (2011)	62	51.67	58	48.34
6.	Telegram (2013)	21	17.50	99	82.50
7.	Pinterest (2010)	1	0.83	119	99.17

* Multiple responses were recorded on this aspect

(25.83 %), More than 8 Hours (5.85%) and 2-4 Hours daily on social media (6.67%) The findings of the present study were similar with the studies of Pandey and Singhal (2017) and Victory and Priya (2024) indicating a considerable use of social media.

Social Media platforms usage

An overview of the table 7 indicated that YouTube and WhatsApp (100.00%) were used by cent percent followed by Instagram (85.83%), Snapchat (51.66%), Facebook (34.17%), Telegram (17.50%) and Pinterest (0.83%) were using. The professional social media platforms like Twitter, LinkedIn are not utilised by tribal youth. The reason might be most of them were students and were more inclined towards entertainment and communication media tools like You Tube and WhatsApp. In both girls and boys, YouTube

Table 8. Distribution of the respondents on the basis of Extent of Social Media Utilization

n=120

S.No.	Social Media Platforms	Total				
		Frequency of Usage				
		Daily f (%)	Weekly f (%)	Fortnightly f (%)	Monthly f (%)	Never f (%)
1.	Facebook	24(20.00)	6(5.00)	4(3.33)	4(3.33)	82(68.33)
2.	Instagram	104(86.67)	0(0.00)	0(0.00)	0(0.00)	16(13.33)
3.	YouTube	107(89.17)	13(10.83)	0(0.00)	0(0.00)	00(0.00)
5.	WhatsApp	120(100)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
8.	Snapchat	28(23.33)	31(25.83)	1(0.83)	4(3.33)	56(46.67)
9.	Telegram	7(5.83)	10(8.33)	2(1.67)	1(0.83)	100(83.34)
10.	Pinterest	0(0.00)	01(0.83)	0(0.00)	1(0.83)	118(98.33)

Figures in parenthesis indicate percentages

Table 9. Distribution of the respondents on the basis of Purpose of social media utilization

n=120

S.No	Social media utilization	Frequency	Percentage
1.	Carrier guidance	2	1.67
2..	Doom scrolling	9	7.50
3.	Educational Information	13	10.83
4.	Market information	0	0.00
5	Health Information	8	6.67
6.	Connecting With experts	1	0.83
7.	Connecting With Friends	81	67.50
8.	Entertainment	105	87.50

* Multiple responses were recorded on this aspect

and WhatsApp are used by cent percent for interaction and entertainment. The findings of the present study were similar to the studies of Deepak and Ramya (2023).

Extent of Social Media Utilization

It is evident from table 8 that cent percent of tribal youth respondents were using WhatsApp on a daily basis (100.00%) while majority of them were using YouTube (89.17%), Instagram (86.67%), Snapchat (23.33%) and Facebook (20.00) on a daily basis. This implies the extent of social media influence on the daily behavioural pattern of the tribal youth.

Purpose of social media utilization

The similar trend is observed among total tribal youth where majority of the respondents were using social media for entertainment purpose (87.50%) followed by connecting with friends (67.50%), Educational information (10.83%), Health information (6.67%), Doom scrolling (7.50%) and only few 1.67 per cent are using for career guidance and connecting with experts (0.83%.).The results from Table 8 indicated that the girl respondents used various social media platforms for the purpose of Entertainment followed by connecting with friends, educational information, health information, doom scrolling and connecting with experts.The results are in line with the findings of Priya and Latha (2019).

Data on over all social media utilization indicate that majority of the tribal youth fell under medium category in overall social media utilization followed by high utilization and low categories. The reason for medium to high

Table 10. Overall social media utilization pattern of Tribal youth **n=120**

S.No	Utilization pattern	Frequency	Cumulative Frequency (CF)
1.	Low Utilization	20	20
2.	Medium Utilization	62	82
3.	High Utilization	38	120
	Total	**120**	
		Mean: 98.667; **SD: 9.869**	

Table 11. Class Intervals and Lower Boundaries for Utilization Pattern of Social Media

Class Category	Class Interval	Lower Boundary (L)
Low Utilization	0–1	0.5
Medium Utilization	1–2	1.5
High Utilization	2–3	2.5

social media utilisation patterns among tribal youth might be due to tribal youth inquisitiveness and curiosity to explore and learn new things from the social media. Further it is also observed and revealed through the study conducted by Kiran and Babu (2020) that the kind of content consumption influence the behaviour of individuals especially youth as they are in intermittent and transformative stage of the life cycle. Hence, proper care need to be taken to create awareness regarding Do's and Don'ts while using social media to prevent digital addiction and complications.

Interquartile range (IQR)

Q1 = 30

Q3 = 90

Q1 (30th value) lies in the Medium Utilization category (since CF of Low = 20, and CF of Medium = 82, 30 lies in this range).

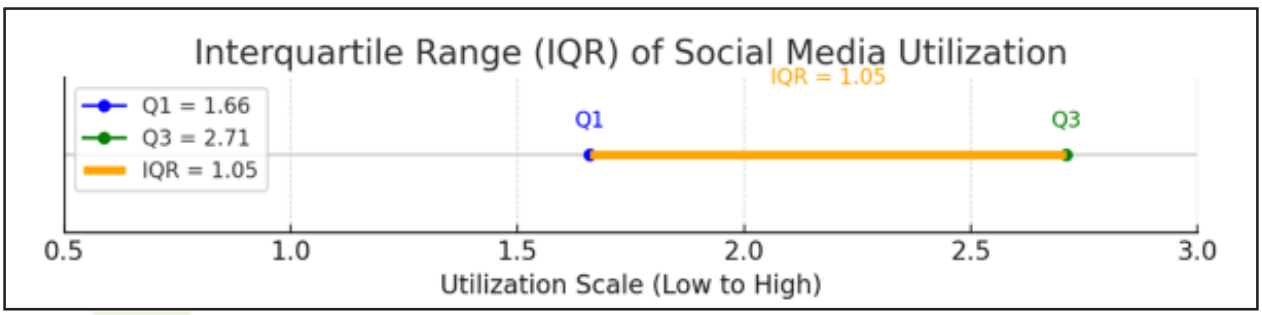

Table 12. Relationship between respondents profile characteristics with Utilization pattern

n=120

S.No	Independent variable	'r' Value
X_1	Age	0.008**
X2	Education	0.019*
X3	Family Type	0.091^{NS}
X4	Occupation	0.352**
X5	Social Participation	0.019^{NS}
X6	Leisure time activity	0.179*
X7	Motivation for social media use	0.063^{NS}
X8	Information Seeking Behaviour	0.209^{*}

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

NS : Non Significant.

Q3 (90th value) lies in the High Utilization category (since CF of Medium = 82, and CF of High = 120, 90 lies in this range).

Interquartile range (IQR)

Q1 =1.66

Q2 = 2.71

IQR=Q3"Q1= 2.71"1.66=1.05

The Interquartile Range (IQR) for the utilization pattern was calculated to be 1.05, indicating that the middle 50 per cent of the respondents fell under a moderate on the utilization scale. The first quartile (Q1) was found to be 1.66, while the third quartile (Q3) was 2.71, showing a concentration of social media use between medium and high categories.

Relationship between Independent and Dependent variables

In order to study the relationship between the selected profile characteristics of tribal youth with their social media Utilization pattern, coefficients (r) were computed and the values are presented in Table 12.

It could be inferred from Table 12 that the independent variables Age, Occupation and Education were significant at 0.01 level of probability; Leisure time activity and Information Seeking behaviour were significant at 0.05 level of probability. Other independent variables viz., Family Type, Social participation, Motivation for social media use, level of aspiration were found to be non-significant with social media utilisation patterns.Fatima and Hussain(2020) reported similar findings in their study on social media exploration among Muslim youth.

CONCLUSION

The present study revealed that overall social media utilisation pattern was in the moderate range in the tribal youth of the area as indicated by the Interquartile Range (IQR). YouTube, WhatsApp and Instagram were used by regularly by majority of the respondents when compared to other tools. These media tools can be further explored for educational and empowerment interventions in these areas. Half of the tribal youth (52%) fell under medium category in overall social media utilization followed by high utilization and low categories. The reason for medium to high social media utilisation patterns among tribal youth might be due to tribal youth inquisitiveness to explore and learn new things from the social media and also penetration of social media tools into the rural fabric. However, social media was majorly used for entertainment purpose (87.50%) followed by connecting with friends (67.50%) and meagre 10.83 percent for educational information. The findings underscore the need for targeted digital literacy programs utilising these tools that are widely prevalent among the youth of the region, infrastructure improvement and capacity-building interventions that encourage more productive use of social media among tribal youth, there by inclusive growth and social integration in these communities.

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FUNCTIONAL PROPERTIES OF UNRIPE BANANA (*MUSA PARADISIACA)* FLOUR OF PEYAN AND MONTHAN CULTIVARS

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ABSTRACT

This research, carried out during the year 2022-2023, comprehensively investigated the physicochemical and functional properties of unripe banana flours derived from the *Musa paradisiaca* cv Peyan and Monthan (genome ABB). Stage-1 unripe bananas were processed into flour using tray drying at 55 °C.Standard protocols were employed to evaluate the functional properties of the unripe banana flours. The bulk density of the unripe banana flour ranged from 0.68 to 0.69 g/mL. The Peyan and Monthan varieties exhibited emulsion activities of 6.45 ± 0.97% and 8.15 ± 1.35%, respectively. The hydration properties of the flour were highest at 70 °C and 90 °C for both varieties. Storage at 4 °C during a five-day period resulted in decreased light transmittance and increased syneresis, with significant differences between cultivars. Partial gelation occurred at 10% starch concentration, while complete gel formation was observed at 12%.These results add to the limited literature on the underexplored Peyan and Monthan cultivars, highlighting their potential as functional ingredients in healthy, value-added food products.

Keywords: Functional properties, Physicochemical properties, Unripe banana flour

INTRODUCTION

Banana (Musa spp.) ranks among the major cultivated tropical fruits globally, encompassing more than 1,000 varieties. The *Musa cavendish* variety is particularly significant, accounting for approximately 45% of the global banana market. Its dominance is largely due to high per-hectare yields and resilience to environmental fluctuations (FAO, 2022). Another notable group within the banana family is *Musa paradisiaca*, which includes over 100 cultivars.Edible bananas are typically categorized into dessert (AA, AAA, AAB) and cooking types (AAB, ABB, BBB). Cooking bananas, consumed at various ripeness stages, are less sweet when raw due to their firm and granular texture. They are recognized for their rich nutritional composition, providing significant amounts of dietary fiber, essential vitamins, and minerals (Pereira and Maraschin, 2015).

Bananas are usually harvested at developmental maturity while unripe, leading to significant post-harvest losses during transportation, handling, and storage (Al-Dairi *et al.,* 2022). Available method for reducing post-harvest losses is the dehydration of unripe bananas, followed by processing them

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into banana flour for use in various innovative products. This strategy promotes increased banana consumption andcontributes significantly tohealth, nutrition, and sustainable food supply.

Banana flour is a promising alternative to conventional flours used in bakery and cereal-based products (Marta *et al*., 2022). Its high content of bioactive compounds, particularly resistant starch, supports its use in functional and gluten-free food formulations (Khoozani*et al*., 2019). To effectively utilize unripe banana flour in the formulation of novel foods and translate them into marketable products, a thorough understanding of its functional properties is essential, given the substantial variation across different banana varieties.

The *Musa paradisiaca* cultivar Peyan (ABB), native to South India, holds medicinal significance in the indigenous food practices of Tamil Nadu. *Musa paradisiaca* cultivar Monthan (ABB), a commercially important cultivar in India, is primarily used for cooking but also serves both dessert and culinary purposes in north-eastern states. Despite their importance, little research has been conducted on thefunctional properties of these cultivars.The present study examined *Musa paradisiaca* cultivars Peyan and Monthan to address potential differences in functional properties among banana varieties. Specifically, it aimed to evaluate the physicochemical properties, as well as the hydration and gelation characteristics, of unripe banana flours derived from these cultivars.

MATERIAL AND METHODS

Procurement and Processing of Unripe Banana Flour

The *Musa paradisiaca*cv. Peyan and Monthan (genome ABB) were sourced from a local market in Chennai, Tamil Nadu. Authentication of the fruits was obtained from the Siddha Central Research Institute, Chennai (Form No. PCOG002-ACF).Stage-1 unripe bananas (fully green) were selected using the Von Loesecke scale, with ripening status confirmed by total soluble solids (TSS) analysis (Campuzano *et al*., 2018). The unripe pulp showed TSS values of 1.13–1.20 °Brix, consistent with early ripening. Peyan (PUBF) and Monthan (MUBF) flours were processed by the Campuzano *et al*. (2018) method.

Functional Properties of Unripe Banana Flour

Physicochemical properties

The physicochemical characteristics of the UBFwere evaluated following the methodology described by Wani *et al*. (2015).

Density and Flowability Parameters: A sample weighing 50 g was carefully added to a 100 mL graduated cylinder and softly tapped on a laboratory table until a stable volume was reached. Bulk density was expressed in g/mL. Tapped density was measured by gently tapping the cylinder with a glass rod on a stable surface until the sample volume stabilized, after which the sample mass was divided by the final tapped volume. Flowability of the powders was evaluated through the Carr Index and Hausner ratio, with interpretations made using standard charts (Alam *et al*., 2023).

$$\text{Carr index \%} = \frac{\text{Tapped density - Bulk density}}{\text{Tapped density}} \text{ X } 100$$

$$\text{Hausner ratio} = \frac{\text{Tapped density}}{\text{Bulk density}}$$

Foaming Capacity: UBF weighing one gram was mixed with 50 mL of distilled water in a graduated cylinder. The mixture was then vigorously shaken for 5 minutes to produce foam. The volume of foam 30 seconds after whipping was expressed as foam capacity using the equation given.

$$\text{Foaming capacity \%} = \frac{\text{Volume of foam after whipping - Volume of foam before whipping}}{\text{Volume of foam before whipping}} \times 100$$

Emulsion Activity and Stability: In a calibrated centrifuge tube, an emulsion was created by combining a 1 g sample, 10 mL of distilled water, and 10 mL of refined sunflower oil. The emulsion was then subjected to centrifugation at 2000 × g for 5 minutes. Emulsion Activity (%) was calculated as the height of the emulsified layer divided by the total height of the mixture multiplied by 100. To assess the stability, the emulsion was heated at 80°C for 30 minutes in a water bath. Afterward, it was cooled for 15 minutes under running tap water and centrifuged again at 2000 × g for 15 minutes.

Oil Absorption Capacity (OAC): One gram of the sample mixed with 10 mL sunflower oil was allowed to stand at room temperature for 30 minutes, and then centrifuged for 30 minutes at 2000 × g. OAC was calculated as the weight of sediment after draining oil divided by the sample weight.

Flour Hydration Properties:

To determine the gelling properties of the flour, a method described by Cornejo and Rosell (2015) was employed. Firstly, 0.2 grams of UBF was dispersed in 20 mL of distilled water and subjected to heating at various temperatures (50- 90°C) for 15 minutes in a shaking water bath. After cooking, the resulting paste was allowed to cool down to room temperature and centrifuged at 3000 × g for 10 minutes. The supernatant was carefully poured off, and its solid content was determined by evaporating it overnight at 110°C. The sediment obtained from centrifugation was weighed.

Water Solubility Index (WSI), Water Absorption Index (WAI), and Water Holding Capacity (WHC), were calculated using the respective equations. For determining the swelling volume, 0.5 g of UBF was combined with 30 mL of distilled water and left at room temperature for 24 hours.

$$\text{Water Solubility Index (\%)} = \frac{\text{Weight of dry supernatant}}{\text{Weight of sample}} \times 100$$

$$\text{Water Absorption Index (g/g)} = \frac{\text{Weight of wet sediment}}{\text{Weight of sample}} \times 100$$

$$\text{Water Holding Capacity (g/g)} = \frac{\text{Weight of wet sediment - Weight of dry sediment}}{\text{Weight of sample}} \times 100$$

$$\text{Swelling Volume (ml/g)} = \frac{\text{Total volume of swollen sample}}{\text{Weight of sample}} \times 100$$

Flour Gelling Properties

Least Gelation Concentration:In 5 mL of distilled water, flour dispersions ranging from 2% to 30% (w/v) were prepared and heated at 90°C for 1 hour in a water bath. After cooling under tap water and keeping them at 10 ± 2°C for 2 hours, the gelation capacity was determined by visually observing the sample slipped in inverted tubes (Chandra*et al.,* 2015).

Light Transmittance:To evaluate the light transmittance, an aqueous suspension of UBF (1%) was prepared and heated in a shaking water bath at 90ºC for 30 minutes. The suspension was then cooled for 1 hour at room temperature. Samples were stored in a refrigerator at 4ºC for 5 days, and transmittance was recorded each day by determining the absorbance at 640 nm (Wani *et al.,* 2015).

Syneresis: For measuring syneresis, unripe banana flour suspensions (2% w/w) were heated at 90 °C for 30 minutes in a water bath with constant stirring. The suspensions

were stored at 4 °C for a period ranging from 1 to 5 days. Syneresis was quantified as the percentage of water released after centrifugation at 3000 × g for 10 minutes (Wani *et al.,* 2015).

Statistical Analysis

Analyses were done in triplicate on a dry weight basis. To assess significant differences between the PUBF and MUBF, an independent t-test (two-tailed) was carried out. Data were analyzed using Microsoft Excel 2019.

RESULTS AND DISCUSSION

The unripe banana flours (UBFs) exhibited a creamy-yellow color, with moisture contents of 3.95 ± 0.75% for PUBF, while MUBF had a higher moisture content of 8.67 ± 0.67%.Around 10% moisture content is generally regarded as optimal for maintaining shelf stability (Zambrano *et al.,* 2019). The higher moisture in Monthan may reflect cultivar-specific differences in fruit moisture content.

Physicochemical Properties

Table 1depicts the physicochemical properties of unripe banana flour.

Density and Flowability Parameters

The bulk and tapped density values were comparable between cultivars, indicating no significant cultivar-dependent variation. These moderate values support good packing efficiency and handling in dry mixes. A bulk density range of 0.72 to 0.77 g/cm^{3}was recorded for green banana flours (Anajekwu*et al.*, 2020).The Carr Index of PUBF was 3.17 ± 0.71%, while MUBF showed 2.74 ± 0.03%. The Hausner Ratio for both flours ranged from 1.02 to 1.03. These values indicate that both flours are “excellent” or “very free-flowing”. Such flow properties are beneficial for industrial applications involving automated blending and packaging.

Foaming Capacity, Emulsion Activity and Stability: Foaming capacities were low for both cultivars, confirming that UBFs lack the protein quality required for interfacial film formation. The marginal cultivar difference has limited technological relevance. Poor foaming ability restricts their utility in aerated food systems but is typical for starch-dominant plant flours with low surface-active protein fractions.

Emulsion activities were low for both cultivars (6.45 ± 0.97% for PUBF; 8.15 ± 1.35% for MUBF), and complete destabilization occurred during stability testing. The limited emulsifying ability, likely due to low protein and surface-active components, makes UBFs unsuitable as primary emulsifiers but useful as supplementary ingredients for viscosity, fiber enrichment, or when blended with hydrocolloids.Qadir and Wani (2023) reported emulsion capacities of 9.52% and 2.32% in brown and polished rice flour, stating low emulsion stability. The emulsion activity of banana flours was relatively low compared to values reported for cereal and legumeflours (Chandra *et al.,* 2015).

Oil Absorption Capacity: The OAC of UBFs was 1.71 to 1.75 g/g, indicating good potential for enhancing flavor retention and mouthfeel in bakery products and reconstituted mixes. In a research, banana starch had an OAC of 1.16–1.22 g/g (Thanyapanich*et al*., 2021).

Flour Hydration and Gelling Properties

Flour hydration is influenced by the interaction between amylopectin and amylose, as well as by the granular structure of the starch. In UBF, this property is particularly important, as it affects product consistency, bulk, and performance, especially in baking and other processed foods. Gelation properties govern the texture, structural

Table 1. Physicochemical Properties of Unripe Banana Flours

Physicochemical properties	Peyan (PUBF)	Monthan (MUBF)	*p-value*
Bulk Density (g/ mL)	0.69 ±0.01	0.68±0.01^{NS}	.671242
Tapped Density (g/ mL)	0.71±0.01	0.70±0.01^{NS}	.370414
Carr Index %	3.17±0.71	2.74±0.03^{NS}	.355687
Hausner ratio	1.03±0.00	1.02±0.01^{NS}	.355914
Foaming capacity (%)	0.73±0.12	0.67±0.12 ^{NS}	.518519
Emulsion Activity (%)	6.45±0.97	8.15±1.35 ^{NS}	.151714
Emulsion Stability (%)	0	0	-
Oil absorption capacity (g/g)	1.71±0.02	1.75±0.02 ^{NS}	.113523
Swelling volume ml/g	3.49 ±0.21	6.20± 0.87*	.006426

Values areMean ± SD (n = 3),*p-value* <0.05, significant independent t-test (two-tailed)

integrity, and stability, making them pivotal for food product development.

Water Solubility Index: WSI is one of the parameters used to evaluate the integrity of starch granules (Paramasivam *et al.,* 2021). The water solubility indexincreased with temperature, reflecting progressive leaching of soluble amylose as starch granules hydrated and lost structural integrity. PUBF showed a WSI of 9.78% at 70°C, while MUBF reached 12.7% at 90°C, likely due to differences in granule crystallinity and amylose–amylopectin distribution. For reference, WSI values of 5.58–6.71% have been reported for other banana varieties (Anajekwu*et al*., 2020).

Water Absorption Index:WAI is a parameter used to evaluate the water absorption capacity of flour. MUBF exhibited a linear increase in WAI from 50°C to 90°C, reaching 3.47 g/g at 90°C. In contrast, PUBF showed peak hydration and gelling capacities at 70°C. For comparison, Campuzano *et al*. (2018) reported WAI values of 3.39–3.52 g/g dry weight for green banana flour.

Water Holding Capacity:UBF exhibited good water-holding capacity, which increased with temperature from 50°C to 90°C, ranging from 4.00 to 4.31 g/g. Adequate WHC supports its application in moisture-retentive formulations such as baked goods and meat analogues.

Swelling volume: The swelling volume of PUBF was 3.49 ± 0.21 mL/g, whereas MUBF exhibited a higher value of 6.20 ± 0.87 mL/g. Elevated starch content, especially with a higher proportion of branched amylopectin, contributes to increased swelling capacity in flours and food products (Awuchi*et al*., 2019).

Least Gelation Concentration: Partial gelation of PUBF and MUBF was observed at 10% starch concentration, with complete gelation at 12%. The gelation capacity is affected by water competition between protein gelation and starch gelatinization. Thanyapanich *et al*. (2021) reported complete gelationat 10–14% w/v for banana starch. These findings indicate that UBF can form gels at moderate starch concentrations, supporting its potential application in structured foods such as puddings and gluten-free doughs.

Paste Clarity and Syneresis: Storing unripe banana flour at 4°C for 120 hours led to decreased light transmittance and increased syneresis (Table 2), with significant

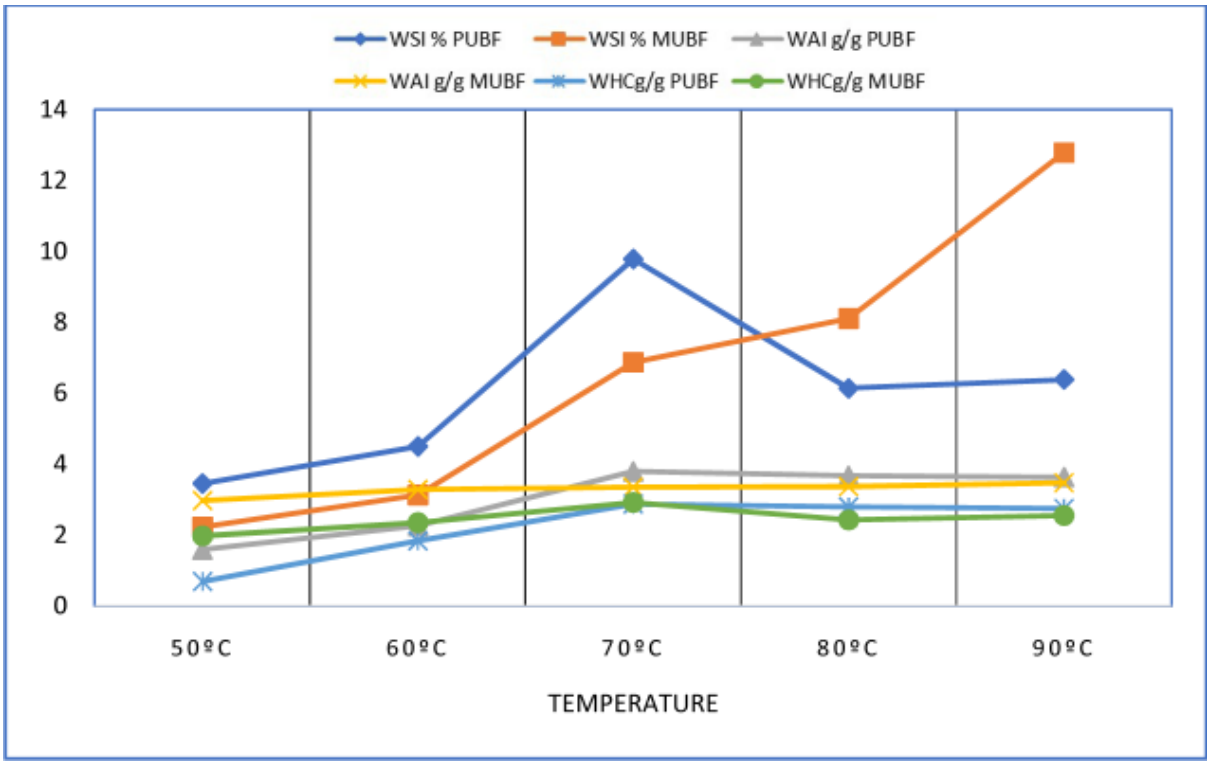

Fig. 1. Flour Hydration Properties of UBFs

differences between Peyan and Monthan flours. The reduced clarity is attributed to starch retrogradation and amylopectin recrystallization. Monthan and Saba (ABB) starches have shown syneresis of 70–77%, which increased to 80–85% after 5 days of storage (Paramasivam *et al*., 2021).High syneresis restricts use in refrigerated gels but indicates potential suitability in freeze-thaw-stable applications where controlled retrogradation is desirable.

CONCLUSION

This study investigated the functional properties of unripe banana flours from Musa cv. Peyan and Monthan to emphasize their potential as valuable additives in various food products. Based on the compressibility index and Hausner Ratio, both PUBF and MUBF were classified as excellent or very free-flowing, indicating their suitability for efficient industrial handling, blending, and packaging. The water-holding capacity of the flours increased with temperature (4–4.31 g/g between 50ºC and 90ºC), supporting their use in moisture retention and texture improvement in baked goods, meat analogues, and ready-to-cook products. Peyan and Monthan flours showed notable water solubility, enhancing their applicability in beverages, soups, sauces, and instant mixes. Their hydration and gelling abilities further position them as effective natural thickeners, stabilizers, and binding agents for gluten-free foods, extruded snacks, confectionery, and dairy/plant-based formulations. Refrigerated storage (4ºC for 120 hours) resulted in decreased light transmittance and increased syneresis, reflecting typical retrogradation behaviour of high-amylose flours. The functional attributes of Peyan and Monthan unripe banana flour demonstrate strong potential for product development, particularly in ready-to-eat and ready-to-cook foods.

Table 2. Light Transmittance and Syneresis of Unripe Banana Flour

Light Transmittance			
Storage in hours	**Peyan (PUBF)**	**Monthan (MUBF)**	***p value***
24	3.25 ± 0.02	1.49 ±0.05*	.000555
48	3.01 ± 0.33	1.38 ±0.04*	.0206
72	2.55 ±0.34	1.27 ±0.07*	.035842
96	1.83 ±0.25	1.04 ±0.08^{NS}	.053128
120	1.61 ± 0.01	0.76 ±0.22*	.033312
Syneresis			
24	71.68± 2.23	65.56±2.87^{NS}	.140525
48	83.66± 1.47	70.23±1.78*	.00973
72	85.76 ±0.734	74.36± 2.77*	.030152
96	87.94±2.35	75.99±1.65*	.027714
120	89.23 ±0.69	84.14±2.09^{NS}	.082604

Values are mean ± standard deviation (n = 3), *p-value* <0.05,
significant independent t-test (two-tailed)

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SYNERGISTIC ANTIMICROBIAL EFFECTS OF PLANT EXTRACTS ON TENCEL FABRICS TREATED WITH NATURAL FINISH

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ABSTRACT

Plant extracts are rich sources of bioactive compounds with anti-microbial properties. Tencel is a regenerated fibre derived from wood pulp of eucalyptus, spruce and beech trees. The present study was conductedin 2024 to investigate the synergistic effect of antimicrobial properties of Tencel fabrics treated with natural finish developed from a combination of plant extracts. *Chrysopogon zizanioides* (L.) Roberty (CZ), or vetiver, is a fragrant grass which has been used in the treatment of various skin infections due to its antimicrobial properties. Extracts from *Kaempferia galanga* L., *Cassia fistula* L. and *Chrysopogon zizanioides* (L.) Roberty in different proportions were used for developing the natural finish. Aqueous plant extracts were used to apply natural finish on to the Tencel fabric. The antimicrobial properties of treated Tencel fabrics were evaluated against both gram-positive and gram-negative bacteria using AATCC TM90 method and compared with the untreated fabric. The study revealed that fabric sample treated with a combination of CZ, KG and CF extracts produced the largest zones of inhibition for both bacterial strains. Thus, it is inferred that plant extract combination can be used as textile finish to enhance the antimicrobial properties of the fabrics since a synergistic effect is observed.

Key words: Antimicrobial, *Cassia fistula, Chrysopogon zizanioides, Kaempferia galanga*, Natural finish, Plant extracts, Tencel

INTRODUCTION

Tencel is a regenerated fibre derived from wood pulp of eucalyptus, spruce and beech trees. It is a fibre that is considered to be eco-friendly since it can be manufactured using recycled solvent. It is a cellulosic fibre which is used to replace cotton in several applications.(Afroz and Islam, 2021). Tencel is the trade mark recorded by Courtaulds Fibres Ltd. Company and the generic term for Tencel is Lyocell(Chen, 2015). Studies showed that the fabrics made from 100 percent Tencel showed high water vapor permeability and air permeability than the fabrics made from cotton and cotton blends (Afroz *et al.*, 2022). Any finish that is applied to Tencel fabrics will be better absorbed. As there is an emphasis on pollution control and biological protection in the current scenario, developing some natural finishes will be more beneficial to improve the quality of human life. To avoid the fabric borne infections, development of antimicrobial textiles

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can be a better choice. However, the Tencel fabric itself lacks the intrinsic antimicrobial properties. Still the properties can be imparted to the fabric by means of special finishes or dyes. Tencel fabrics that were dyed with pomegranate peel showed antibacterial properties (Rehman *et al.*, 2018).

There were several findings that illustrate the use of natural plant extracts in different solvents as potential antimicrobial agents. The effectiveness of different plant extracts in inhibiting microbial growth depends on the species of plant, the part of the plant used, and the solvent used for extraction (Banu *et al.*, 2024) have been studied. A study conducted using the alcoholic extracts of *Cassia fistula* leaves showed that the gram-negative bacteria were more sensitive to the finish applied using the extracts than gram-positive ones (Seyyednejad *et al.*, 2014).Oil extracted from Vetiver [*Chrysopogon zizanioides* (L.) Roberty syn. *Vetiveria zizanioides* (L.) Nash] commonly known as khas-khas, khas, khus-khus or khus grass exhibited a moderate ability against gram-positive bacteria, especially *Staphylococcus aureus (S.aureus)* in the antimicrobial assay (David *et al.*, 2019). The biological activities of *C. zizanioides* showed that they can act as a natural remedy for different conditions like cancer, diabetes, convulsions, inflammation, depression and bacterial infections (Grover *et al.*, 2021).Several studies demonstrated the traditional use of *Kaempferia galanga* L. in treating bacterial and fungal diseases like skin, diarrhoea and dandruff (Kumar, 2020). Extracts of *K.galanga* in different solvents showed good in-vitro antibacterial and antifungal effects. The present study focused on analysing the antibacterial activity of the Tencel fabric treated with aqueous extracts from *Kaempferia galanga* L., *Cassia fistula* L., and *Chrysopogon zizanioides* (L.) Roberty. The study also investigated synergistic effect of antibacterial properties of Tencel fabric treated with plant extracts,by treating with both isolated form and in combination, which acted as natural finishes.

Table 1.Specification of Tencel fabric

Features	Description
Fibre	100% Tencel
EPI (Ends Per Inch)	124
PPI (Picks Per Inch)	64
Weave	2 X 1 Twill
GSM	130
Count	30 X 30

MATERIAL AND METHODS

Fabric used for the study was desized and bleached Tencel fabric with the specifications shown in table 1. Different parts of three different plants *Kaempferia galanga* L., *Cassia fistula* L., and *Chrysopogon zizanioides* (L.) Roberty were used for the study and are shown infigure 1. *Kaempferia galanga* L. is a rhizomatous herb which finds its application in medicines, perfumes, food etc. *Cassia fistula* L. is a tree found throughout Kerala and has both ornamental and medicinal value. *Chrysopogon zizanioides* (L.) Roberty syn. *Vetiveria zizanioides* (L.) Nash is also found throughout Kerala and used in medicines, basket making, perfumes etc. The sources were identified by Dr.Sreekumar V.B., Principal Scientist of Forest Botany Department, Kerala Forest Research Instititute (KFRI), Peechi, Thrissur, Kerala and voucher specimens are deposited at KFRI herbarium. Table 2 shows the parts of these sources used for conducting this study.

Preparation of extract

The rhizomes, leaves and roots from the sources were washed thoroughly and dried in shade. The dried rhizomes, leaves, and roots were shredded into small pieces and then ground to fine powder. Aqueous extracts of the

Kaempferia galanga L.

Cassia fistula L.

Chrysopogon zizanioides (L.) Roberty

Fig. 1. Plant sources used for study

powdered samples were prepared by the following procedures. Figure 2 shows the powdered form of the plant sources.

Kaempferia galanga L.: 20g of shade dried powder of rhizomes was simmered with 600ml of water for a period of 20 mins and filtered. The filtered liquor was concentrated to 200ml by boiling.

Cassia fistula L.: 20g of shade dried powder of leaves was simmered with 400ml of water for a period of 20 mins and filtered. The filtered liquor was concentrated to 200ml by boiling.

Chrysopogon zizanioides (L.) Roberty: 20g of shade dried powder of roots was simmered with 400ml of water for a period of 20 mins and filtered. The filtered liquor was concentrated to 200ml by boiling.

The rhizome powder of *Kaempferia galanga* produced a viscous extract. It required a higher solvent volume of 600ml for greater dilution to maintain effective simmering and prevent scorching during the simmering process. The leaf powder of *Cassia fistula* and root powder of *Chrysopogon zizanioides* yielded extracts that were less viscous and manageable with 400ml of solvent. All filtrates were reduced to 200ml, which ensured comparable extract strengths for further applications. The concentrated extracts were stored under refrigeration.

Application of natural finish

Plant extracts were used to prepare the finishing bath at a concentration of 50g/L. The material liquor ratio was taken as 1:20. 20 ml solution was taken from the 50 g/l aqueous extract of the natural sources. The fabric was immersed in the aqueous solution with plant extractsfor one hour duration. Different proportions of the extracts were used to study the effect of combining extracts from different sources. Table 3 shows the samples that are used for the study treated with different proportions of extracts

Antibacterial assay

The AATCC TM90 Antibacterial Assay was used to evaluate the effectiveness of the natural finishes given to the fabrics.For

Table 2.Specification of Sources

Common Name	Plant Name	Part Used
Sand ginger	*Kaempferia galanga* L.	Rhizomes
Golden Shower Tree	*Cassia fistula* L.	Leaves
Vetiver grass	*Chrysopogon zizanioides* (L.) Roberty	Roots

Kaempferia galanga L.
Rhizomes powder

Cassia fistula L.
Leaves powder

Chrysopogon zizanioides
(L.) RobertyRoots powder

Fig. 2. Powdered form of plant sources used for the study

qualitative testing of antimicrobial activity of textile and leather materials AATCC TM90 agar diffusion method is used.(Nguyen *et al.*, 2023)

Maintenance of Bacterial Culture: The growth method is performed as follows: At least three to five well-isolated colonies of the same morphological type were selected from an agar plate culture. The top of each colony is touched with a loop, and the growth was transferred into a tube containing 4 to 5 ml of a suitable broth medium, such as Nutrient broth. The broth culture was incubated at 35^0C until it achieves or exceeds the turbidity (usually 2 to 6 hours). The turbidity of the actively growing broth culture was adjusted with sterile saline or broth to obtain turbidity. This results in a suspension containing approximately 1 to 2 x 108 CFU/ml for *S.aureus* and *Escherichia coli (E.coli)*

Inoculation of Test Plates:Optimally, within 15 minutes after adjusting the turbidity of the inoculum suspension, a sterile cotton swab was dipped into the adjusted suspension. The swab should be rotated several times and pressed firmly on the inside wall of the tube above the fluid level. This will remove excess inoculum from the swab.The dried surface of a Nutrient agar plate was inoculated by streaking the swab over the entire sterile agar surface. This procedure was repeated by streaking two more times, rotating the plate approximately 60^0 each time to ensure an even distribution of inoculum. As a final step, the rim of the agar was swabbed.The lid was left ajar for 3 to

Table 3. Samples treated with different proportions of extracts

Proportion of extracts used*	Sample
Untreated Sample	Sample 1
100% CZ	Sample 2
100% CF	Sample 3
100% KG	Sample 4
50% CF+ 50% CZ	Sample 5
50% CF + 50% KG	Sample 6
50% CZ+50% KG	Sample 7
33.3% CZ+33.3% KG+33.3% CF	Sample 8

*KG: *Kaempferia galanga* L., CF: *Cassia fistula* L., CZ: *Chrysopogon zizanioides* (L.) Roberty

5 minutes, but no more than 15 minutes, to allow for any excess surface moisture to be absorbed before placing the sample.The fabric of 2.2cm diameter is placed over the agar. Further, the petriplates were placed inversely for complete diffusion and inhibition zones were examined by measuring the diameter (mm) formed around the well after 24 hrs incubation at 37°C. The zones were measured by using standard (Hi-Media) scale. Agar diffusion method was used to study zone of inhibition of Tencel fabric dyed with pomegranate peel. (Rehman *et al.,* 2018)

RESULTS AND DISCUSSION

A comparison of antibacterial activity against gram negative bacteria -*E.coli* and gram positive bacteria –*S.aureus* is shown in Table 4 and Figure 3.

The antibacterial activity of Tencel fabrics that were given natural finishes, were assessed against the gram positive bacteria –*S. aureus* and gram negative bacteria –*E. coli* using the zone of inhibition method. The results, represented in table 4 and figure 3, show that:

Sample 1, the untreated fabric exhibited no antibacterial activity, showing a 0 mm zone of inhibition for both *S. aureus* and *E. coli*.

Sample 2 and Sample 3 fabrics that are treated with single source CZ and CF respectively did not show any zone of inhibition for either bacterial strain, indicating no antibacterial activity in the given concentration.

Sample 4, the Tencel fabric treated with KG demonstrated moderate antibacterial activity, with a 5 mm zone of inhibition against *S.aureus* and a 16 mm zone against *E. coli*, indicating a better efficacy against E. coli.

Fabric sample 5, treated with a combination of CF and CZ showed some anti-bacterial activity. It showed a 5 mm and 19 mm zone of inhibition against *S.aureus* and *E. coli* respectively. The hydro-alcohol extracts of *Cassia fistula* L. leaves was reported to show prominent antimicrobial activity against bacteria and fungi (Singh *et.al,* 2023).Five compounds present in *Chrysopogon zizaniodes* (L.) Roberty root were identified to be responsible for the antibacterial activity (Ramírez-Rueda *et al.*, 2019).

Fabric sample 6, treated with CF and KG also exhibited antibacterial activity, with a 10 mm inhibition zone for *S.aureus* and 26 mm zone for *E. coli*. The antibacterial property of *Kaempferia galanga* may be attributed to the presence of polar compounds such as genetic

Table 4. Assessment of antibacterial activity of treated Tencel fabrics

Samples	Zone of Inhibition (mm)	
	Staphylococcus aureus	***Escherichia coli***
Sample1: Untreated	0mm	0mm
Sample 2: CZ	0mm	0mm
Sample 3:CF	0mm	0mm
Sample 4: KG	5mm*	16mm*
Sample 5: CF+CZ	5mm*	19mm*
Sample 6: CF +KG	10mm*	26mm
Sample 7: CZ+KG	20mm*	5mm*
Sample 8: CZ+KG+CF	26mm	22mm

*Beneath the fabric there is a zone of inhibition or there is no bacterial growth

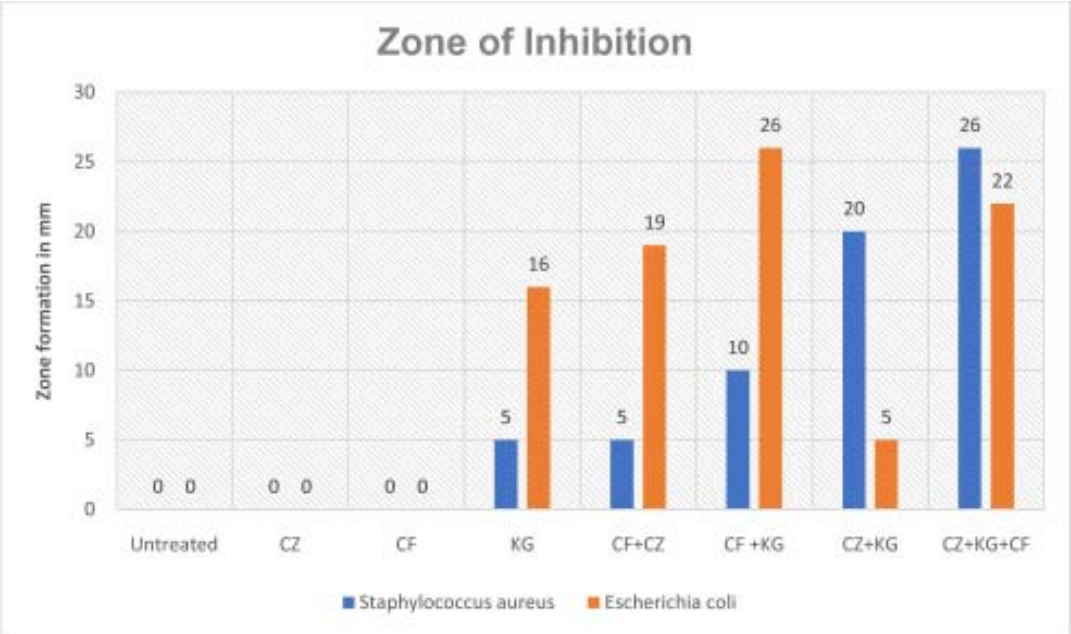


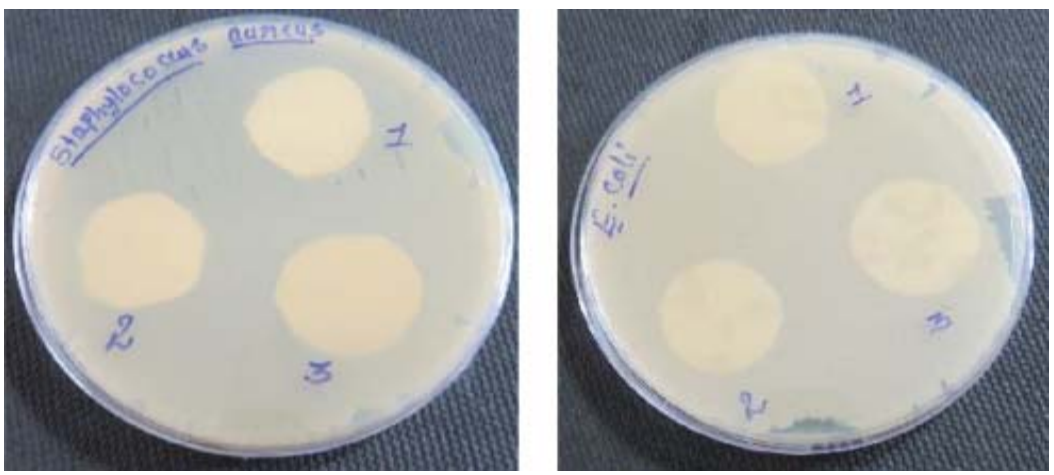
Fig. 3. Zone of inhibition formed by treated Tencel fabrics

acid, syringic acid, apigenin and cinnamic acid (Men *et al.*, 2024).

Sample 7 which is treated with the combination of CZ and KG displayed the highest inhibition against *S.aureus* with a 20 mm zone of inhibition but was found less effective against *E. coli*, with only a 5 mm zone.

Fabric sample 8 treated with a combination of CZ, KG and CF produced the largest zones of inhibition for both bacterial strains, with 26 mm against *S.aureus* and 22 mm against *E. coli* which suggests a strong synergistic effect of all three extracts.

The antibacterial assessment shows that the untreated Tencel fabric (Sample 1) and those treated with plant extracts of *Chrysopogon zizanioides*(Sample 2) and *Cassia fistula* (Sample 3) did not exhibit any zones of inhibition. This indicates minimal antibacterial effect at the given concentration. Higher concentrations may be necessary to achieve greater activity.*Kaempferia galanga*



1- Untreated, **2**- 100% CZ, **3**-100% CF

4- 100% KG, **5**- 50% CF+ 50% CZ, **6**-50% CF + 50% KG

7- 50% CZ+50% KG, **8**- 33.3% CZ+33.3% KG+33.3% CF

Fig.4. Antibacterial activity of Tencel fabric treated with natural finishes

(Sample 4) exhibited moderate antibacterial activity, especially against *E.coli*. Improved activity was observed in the combined treatments (Samples 5 to 8). The combination of extracts demonstrates the potential for synergistic effects in antibacterial applications, with sample 8 (CZ+KG+CF) demonstrating the highest efficacy against both the bacterial strains.(Wijayawardhana *et al.*, 2021)

CONCLUSION

The combination of the extracts of *Kaempferia galanga*, *Chrysopogon zizanioides*, and *Cassia fistula* exhibited maximum antibacterial activity although individual plant extracts did not exhibit prominent antibacterial properties. This makes them suitable for treating the fabric as a natural finish aimed at reducing bacterial growth on fabrics.A synergistic effect of the extracts was observed on the Tencel fabric treated with the plant extracts.

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FACTORS INFLUENCING WOMEN ENTREPRENEURSHIP IN PALNADU DISTRICT OF ANDHRA PRADESH

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ABSTRACT

The present study was conducted in 2023-24 in Palnadu district of Andhra Pradesh where active participation of self-help groups in various economic and social development programs is prevalent. The data were collected from randomly selected 90 women agripreneurs with the help of well-structured interview schedule to assess the perceived factors that influence entrepreneurial success of the women engaged in varied enterprises.Dairy farming (41.11 %) found to be the most common enterprise followed by vegetable production (23.33%), poultry farming (20%), agro-processing (6.67%), nursery management (5.56%) and aquaculture (3.33%). The findings revealed decision-making ability and planned resource allocation as the significant predictors of entrepreneurial success of women in Palnadu. In addition to these factors, human management, account keeping, planned marketing, expertise and knowledge on enterprise significantly contributed to the growth of enterprise.Socio-cultural constraints were perceived as the major constraints affecting 96.67 percent of women followed closely by marketing constraints (94.44%) and financial constraints (87.78%). Interventions such as workshops, mentorship and experiential learning opportunities that enhance the skills of planned resource allocation, decision-making ability and risk-taking behaviour among women could be highly beneficial.

Key words: Agripreneurship, Challenges, Entrepreneurial success, Perceived factors

INTRODUCTION

The National Sample Survey Office (NSSO) reports that women constitute nearly 46 percent of agricultural workforce in India.Women agripreneurship in rural areas comprehends the significant role of women in agricultural value chains, type of agricultural enterprise, success factors impacting their ventures, their drive for economic independence and empowerment and the challenges they encounter. The significant contributions of women in agriculture, from working as labourers to becoming entrepreneurs, excelling in every aspect of income generation are remarkable. It is evidenced that entrepreneurship for women is mostly a necessity driven activity with limited scope for innovation providing scope for strengthening potentially new emerging activities through appropriate training for innovation apart from easy access to finance (Samantroy and Tomar, 2018).Vuciterna *et al.*

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(2024) revealed the significant contributions of women entrepreneurs to agricultural innovation, sustainability and rural development while facing systemic biases, limited access to resources and societal beliefs that hamper their entrepreneurial growth.

Women not only cultivate different crops but are also engaged in dairy farming, poultry and other agro-processing activities supported by various government schemes. With regard to dairy farming, women are involved in milking domestic animals daily, selling products like milk, ghee, curd and paneer in market and also directly to consumers.Rural women take care of animals, clean the sheds, prepare farm yard manure and cow dung, collect animal feed, prepare value-added food products, especially those derived from perishable vegetables and fruits.

Women engaged in agribusinesses are influenced by the economic, social, technological and environmental factors.The economic factors include market demand, access to finance and infrastructure.Social factors comprise entrepreneurial traits, social networks, cultural practices and family support. Technological advancements and environmental conditions also significantly determine entrepreneurial success. Studying the factors behind the success of women-led agrienterprises in Andhra Pradesh, is critical due to the state's heavy reliance on agriculture.Keeping this in view, the study made an attempt to explore the perceived factors that influence the entrepreneurial success of women in Palnadu district of Andhra Pradesh.

MATERIAL AND METHODS

The study was purposively conducted in Palnadu district during the year 2023-2024 where there is the significant presence of self-help groups actively participating in various economic and social initiatives. Three mandals with highest number of women entrepreneurs were purposively selected. From each mandal, two villages with highest number of women entrepreneurs were purposively selected. From a verified list of all women entrepreneurs in each selected village, 15 respondentswere chosen using simple random sampling without replacement making a total sample of 90 respondents for the study. Based on the insights from the reviewed literature and expert's opinion, a pre-structured interview schedule was developed and used tocollect the data from selected women agripreneurs.

The perceptions of the 90 respondents pertaining to the factors influencing agri-preneurial success of women were recorded. The data were analysed using a three-point rating scale assigning scores of 3, 2 and 1 against high, medium and low respectively. Multiple regression analysis was employed to assess the key factors which effect the entrepreneurial success as per the perception of respondents.

$$Y = \beta 0 + \beta 1 X_i + \varepsilon$$

where:

- Y is the dependent variable (Entrepreneurial success)

- X_i is the independent variable (Factors affecting the entrepreneurial success)

- $\beta 0$ is the intercept,

- $\beta 1$ is the slope (coefficient),

- ε is the error term representing unexplained variation

The dependent variable i.e., Entrepreneurial success was measured in terms of growth rate of the enterprise i.e., percentage increase in revenue over the previous year. This reflects the ability of the enterprise to expand its market presence and improve financial performance over time. Information on growth rate of the enterprises

Table 1. Profile characteristics of the sample respondents **n=90**

S.No.	Particulars	Frequency	%
1.	**Age group**		
	<30 Years	0	0.00
	30-40 Years	37	41.11
	40-50 Years	50	55.56
	>50 Years	3	3.33
2.	**Size of agricultural land holdings**		
	<1 acre	0	0.00
	1-3 acres	36	40.00
	3-5 acres	33	36.67
	>5 acres	21	23.33
3.	**Education Level**		
	Illiterate	23	25.56
	Primary Education	28	31.11
	Secondary Education	27	30.00
	Higher Secondary Education	11	12.22
	Graduation	1	1.11
	Higher than Graduation	0	0.00
4.	**Marital status**		
	Married	76	84.44
	Unmarried	0	0.00
	Widowed	8	8.89
	Divorced	3	3.33
5.	**Family size**		
	<3	0	0
	3 to 5	64	71.11
	>5	26	28.89
6.	**Family type**		
	Nuclear	79	87.78
	Joint	11	12.22

was obtained by comparing current and previous year revenue. Based on this comparison, enterprise performance was categorized into growth rate more than, same as and less than the previous year to capture directional changes in enterprise growth. The data pertaining to the factors affecting the entrepreneurial success such as planned resource allocation, planned production, planned marketing, human management,

money management, account keeping, commitment, personal efficacy, leadership ability, expertise and knowledge in enterprise, economic motivation, good networking ability, innovative behaviour, risk taking behaviour and decision-making ability were collected from 90 sample respondents in the study area. For each factor, statements were prepared and respondents were asked to rate it on a three-point likert scale (low, medium and high). The frequency distributions of these perceptions were analysed to understand how many respondents chose each level for each factor and to know the factors that are most strongly perceived and that are less perceived.

RESULTS AND DISCUSSION

Table 1 presents the profile characteristic attributes of the sample women agripreneurs such as age, gender, education, marital status, family size, family type and size of land holding to gain insights into their entrepreneurial behaviour, perceptions and preferences. Understanding these characteristics is crucial as they can greatly impact entrepreneurial decisions. Therefore, information on the general characteristics of the sample participants was collected, analysed, and the results were discussed and presented in the subsequent section.

It can be inferred from Table 1 that majority (55.56%) of the respondents belong to age group of 40-50 years, followed by 41.11 percent of respondents in 30-40 years age group, 3.33 percent of respondents were in the age group of above 50 years and there were no respondents under the age of 30 years.

About 40.00 percent of the sample women hold 1-3 acres, 36.67 percent with 3-5 acres and 23.33 percent more than 5 acres indicating that women in Palnadu hold relatively small land parcels, with a smaller portion holding larger farms. The distribution of family size shows that about 71 percent of women were having a family of more than 5 while 29 percentwith 3 to 5 members in their family and none of them belong to less than 3 members category. About 31.11 percent of women had primary education, 30.00 percent secondary education, 25.56 percenthad no formal education, 12.22 percent had higher secondary education, 1.11 percent fell under graduation category and no respondents at higher than graduation level. Marital status revealed that majority (84.44 %) of them were married, 8.89 percent were widowed, 3.33 percent were divorced and none of them belonged to unmarried category. Furthermore, the study revealed that 88 percent and 12 percent of them lived in nuclear and joint families respectively.

The women agripreneurs in Palnadu were involved in different types of Agri-entrepreneurial activities such as Dairy Farming, Poultry Farming, Agro-Processing, Crop Cultivation, Nursery Management and Aquaculture. The agribusiness activities adopted by women is depicted in table 2. It is evidenced that 41.11 percent of womenwere involved in dairy farming highlighting it as a significant source of income for both households and local economy.Women managed small to medium-sized dairy farms, primarily focusing on milk production. They played a multifaceted role in livestock management involving feeding, milking, and ensuring animal health through proper nutrition and veterinary attention, managing economic aspects by marketing milk to consumers.Thus, women contributed to a great extent to both animal husbandry sector and their family income. They demonstrated strong resilience facing challenges like fluctuating milk prices and limited access to advanced technology.

About 23.33 percent of respondents were engaged in vegetable production,

Table 2. Type of Agri-business activity adopted by sample respondents

n=90

S.No.	Type of Enterprise	Frequency	%	Major perceived challenges
1.	Dairy Farming	37	41.11	· fluctuating milk prices · limited access to advanced technology
2.	Poultry Farming	18	20.00	· fluctuating market prices · unpredictable weather conditions
3.	Agro-Processing	6	6.67	· limited access to modern machinery · fluctuating market demand
4.	Vegetable production	21	23.33	· fluctuating market prices · unpredictable weather conditions
5.	Nursery Management	5	5.56	
6.	Aquaculture	3	3.33	

highlighting its prominence in rural agricultural entrepreneurship. Despite market fluctuations and weather risk, women play a major role in agricultural sector. They cultivate vegetables like chilli, brinjal, okra, gourds and others on small plots and sell their produce at local markets to middlemen or directly through stalls or cooperatives

Twenty percent of women were engaged in poultry. It is observed that women managed all the activities like procurement of chicks, feeding, caring, selling, day-to-day management, and monitoring the flock health with regular veterinary check-ups. They also sell eggs and poultry meat, either directly to local markets or through cooperatives. They were trained on modern poultry farming techniques, credit, feed and vaccines through SHGs. Despite price fluctuations and disease outbreaks, these women could manage their farm and contribute to their household income and local economy.

Only 6.67 percentof women were involved in agro-processing which involves cleaning, drying, grinding, and packaging spices, or preserving fruits and vegetables,making pickles, sweets and jellies. Women sell their products at local markets, fairs, and through direct orders. Despite limited access to modern machinery and unstable demand, women are leveraging their skills and local resources to create sustainable livelihoods.

Women were also engaged in nursery management (5.56 %) and aquaculture (3.33%).They manage nurseries that produce a variety of seedlings, including vegetables, fruits, flowers, and ornamental plants. The women are involved in sowing, potting, watering, and maintaining optimal growing conditions within greenhouses or under shade nets. Women engaged in aquaculture,cultivate fish species such as carp, catla, and rohu, manage all aspects of the aquaculture operation, from feeding to harvesting, packaging, and sale of the produce either directly in local markets or through intermediaries. Overall, a wide variety of agricultural activities were practiced, with crop cultivation and dairy farming standing out as the primary enterprises of rural women agripreneurs.

Ezilda María Cabrera and David Mauricio (2017) highlighted that internally, human capital, education and experience while at

micro environment level, access to resources, acquiring resources and entrepreneurial performance were the major factors affecting success of female entrepreneurship. Dhanya *et al.* (2022) in their study on socio-economic profile with respect to women agripreneurs in Western agro-climatic zone of Tamil Nadu found that women agripreneurs (47.14 %) received support from family and friends which acted as a key factor in their business success and 19.28 percent of respondents indicated that their sense of responsibility and sacrifices contributed to their entrepreneurial success. Yoganandan *et al.* (2022) demonstrated that age, education level and farming experience significantly influence agripreneurs' satisfaction. Based on the critical reflections of prior research, an attempt was made to explore the factors affecting the success of women agripreneurs in Palnadu district of Andhra Pradesh.

The responses on perceived factors were collected using a three-point scale. For each factor, how many respondents rated it as low, medium and high were counted and the frequency distribution of the perceptions across the respondents was analysed. Table 3 presents the distribution of frequencies and percentages for various factors categorized as high, medium and low, reflecting their perceived impact on rural women agri-preneurial success. About 38.89 percent of respondents rated decision-making ability and risk-taking behaviour to have immense impact on their entrepreneurial success while 36.67 percent of them reported expertise and knowledge in enterprise and money management to have a significant

Table 3. Perceived factors influencing the success rate of women agripreneurs

n=90

S.No	Factors	High		Medium		Low	
		Frequency	%	Frequency	%	Frequency	%
1	Planned resource allocation	32	35.56	30	33.33	28	31.11
2	Planned production	29	32.22	40	44.44	21	23.33
3	Planned marketing	29	32.22	39	43.33	22	24.44
4	Human management	29	32.22	31	34.44	30	33.33
5	Money management	33	36.67	32	35.56	25	27.78
6	Account keeping	31	34.44	31	34.44	28	31.11
7	Commitment	32	35.56	31	34.44	27	30.00
8	Personal efficacy	32	35.56	33	36.67	25	27.78
9	Leadership ability	32	35.56	28	31.11	30	33.33
10	Expertise and knowledge in enterprise	33	36.67	39	43.33	18	20.00
11	Economic motivation	29	32.22	33	36.67	28	31.11
12	Good networking ability	30	33.33	40	44.44	20	22.22
13	Innovative behavior	28	31.11	35	38.89	27	30.00
14	Risk taking behavior	35	38.89	35	38.89	20	22.22
15	Decision making ability	35	38.89	40	44.44	15	16.67

influence. This suggests that technical knowledge and financial management are critical for achieving success in agricultural entrepreneurship.

Innovative behaviour and planned marketing have high impact ratings (31.11% and 32.22%, respectively) and medium impact ratings (38.89% and 43.33%, respectively) as perceived by the respondents. Good networking ability and leadership ability were also perceived as critical, with 44.44 percent and 31.11 percent of women rating their impact as medium. This reinforces the importance of these factors in sustaining success but suggests that other factors like decision-making and risk-taking behavior may be more immediately impactful. Account keeping and commitment were perceived as lower in impact, with substantial percentage of respondents (34.44% and 35.56%) rated them in medium category, demonstrating their role in driving entrepreneurial success.

Table 4 revealed that planned resource allocation had the strongest positive correlation with enterprise growth rate (r = 0.773). Decision-making ability (r = 0.745) and human management (r = 0.592) also exhibited strong association with growth rate. Moderate positive correlation observed between planned resource allocation and decision-making ability (r = 0.648), as well as between planned resource allocation and human management (r = 0.383). This suggests that effective resource allocation not only directly influences enterprise success but also improves decision-making and management capabilities, further contributing to the growth and success of the enterprise. On the other hand, innovative behaviour displayed weak and, in some cases, negative correlations with other variables showing that innovation might be more intricate, potentially depending on other moderating factors.These findings underscore the need for targeted interventions such as training programs, workshops, and mentorship opportunities that foster the entrepreneurial attributes. Enhancing women's decision-making capabilities and resource allocation could directly impact the growth and sustainability of their businesses.

Overall, the correlation analysis highlights the close linkage between personal attributes and business outcomes in the context of rural women agripreneurs. Recognizing and strengthening these linkages can be pivotal in promoting the growth and sustainability of women-led agricultural enterprises.

Table 5 depicts the multiple regression analysis, with the adjusted R Square value of 0.793 highlighting a very good model fit with F-statistic value of 38.95 and an extremely significant p-value.Results in table 5 indicates that decision-making ability (p=<0.001) and planned resource allocation (p=<0.001)are the strongest significant predictors of entrepreneurial success of women agripreneurs in Palnadu. This implies that women with strong decision-making skills and planned resource allocation are more likely to achieve higher levels of success in their agricultural enterprises. Additionally, human management (p=<0.001), account keeping (p=0.013), planned marketing (p=0.047), expertise and knowledge in enterprise (p=0.013) significantly contributed to success, emphasizing the importance of maintaining records, networking and efficiency in planning the marketing activities.The innovative behaviour (p=0.168), money management (p=0.262) and leadership ability (p=0.139) were the least significant variables with p-values above 0.05. This suggests that these factors may be important but they do not play a critical role in determining success of rural women in agri-entrepreneurship in the area under study.Thus, the study aligns well with systematic reviews

Table 4. Association between perceived factors affecting the entrepreneurial success

S.No	Variable	1	2	3	4	5	6	7	8	9
1	Planned Resource Allocation	1.000								
2	Planned Marketing	0.122	1.000							
3	Human Management	0.383	0.038	1.000						
4	Accounting	0.234	0.001	0.026	1.000					
5	Leadership Ability	0.454	0.065	0.370	0.118	1.000				
6	Expertise and Knowledge in Enterprise	0.254	-0.156	0.279	0.078	0.220	1.000			
7	Innovative Behaviour	-0.077	-0.040	0.238	0.038	-0.110	0.097	1.000		
8	Decision Making Ability	0.648	0.022	0.412	0.274	0.258	0.162	0.105	1.000	
9	Growth Rate	0.773	0.131	0.592	0.339	0.462	0.357	0.131	0.745	1.000

and empirical study of Suraj (2023), about creativity, adaptability, networking, mentorship, resilience, planning and personal traits. Hence, success depends not only on formal inputs such as education, capital, experience but also on mindset, continuous learning, adaptability of rural women agripreneurs. The findings of Díaz-Santamaría and Bulchand-Gidumal (2021), Kurczewska *et al.* (2020), Madhumitha *et al.* (2020) and Saghaian *et al.* (2022) give empirical weightage to the influence of entrepreneur skills/training, educational status, work experience, knowledge, resource management skills on entrepreneurial success. The results are also in consistent with the findings of Nida Hussain and Baoming Li (2022) supporting the positive influence of entrepreneurial leadership style on success.

There is a need to build competencies of rural women through structured training programs in core areas such as finance, marketing, production, leadership and managerial skills to enhance their ability to run an entrepreneurial business.The agripreneurship offers numerous opportunities for rural women leading to economic empowerment, allowing them to diversify their income sources and invest for their family. Conversely, rural women face challenges that are diversified and interconnected creating a complex environment that requires targeted policy interventions, awareness programs and community support networks.

Sehrawat *et al.*(2025) in their study highlighted the status, importance and constraints of women agri-entrepreneurs with a view to improve their contribution to the economy and for true inclusive growth.Selvam (2024) in his study discussed the challenges and sustainable development opportunities available to women in agri-entrepreneurship.By identifying and addressing the problems of rural women in agripreneurship, it is possible to unlock these opportunities, leading to more resilient and prosperous rural communities.

Table 6 depicts the constraints faced by women entrepreneurs. Among the constraints, socio-cultural constraints were identified as more prominent, as perceived by 96.67percent of respondents. The socio-cultural factors include tradition / culture prevent women from taking up business, gender discriminated socialization, lack of support from family and society, multiple workload and related conflicts and criticism/ ridicule of the society.This was

followed by marketing constraints (94.44%) and financial constraints (87.78%) indicating that limited market access and inadequate capital are major barriers.Marketing challenges include exploitation of middlemen, lack of transportation facilities, low prices, lack of market information, frequent price fluctuations, insufficient demand for products and competition from other units.Financial constraints were also critical, i.e., shortage of in-hand finance for fixed and working capital, high interest rates, low benefit–cost ratio, lack of financial assistance from banks and government agencies and limited knowledge of financial schemes.

Constraints related to raw materials (82.22%) and power supply (68.89%), further hindered business operations, while entrepreneurial constraints (64.44%) and labour related constraints (53.33%) also contributed to a considerable extent.Uncertainty in power supply, high cost of electricity, and absenteeism of power personnel, created major operational challenges. These power related issues intensify marketing and raw material challenges, by limiting production consistency and increasing operational costs. These findings stressed the need for reliable and affordable power infrastructure for supporting entrepreneurial activities of rural women. Limited awareness of entrepreneurial development agencies, absence of consultancy support, inadequate technical expertise, insufficient management training and weak linkages with developmental organizations are the entrepreneurial challenges perceived.

Labour-related challenges include high labour cost, non-availability of skilled labour, scarcity of labour and absenteeism.These findings highlight the problems related to market access, infrastructure, finance, skill

Table 5. Multiple Regression Analysis showing relation between perceived factors and the entrepreneurial success

Variable	B	*t*	p value
Constant	-1.308	-4.612	< .001***
Planned Resource Allocation	0.405	5.165	< .001***
Planned Marketing	0.115	2.021	.047**
Human Management	0.234	3.793	< .001***
Money Management	0.064	1.128	.262
Account Keeping	0.141	2.533	.013**
Leadership Ability	0.095	1.495	.139
Expertise and Knowledge	0.140	2.545	.013**
Innovative Behavior	0.079	1.391	.168
Decision Making Ability	0.369	4.808	< .001***
R = 0.902			
R^2 = 0.814Adj.			
R^2 = 0.793			
F = 38.95			

Note: *** denotes significance at 1% level and ** denotes significance at 5% level

Table 6. Distribution of constraints perceived by women agripreneurs n = 90

S.No.	Constraints	Frequency	Percentage
1.	Socio-cultural constraints	87	96.67
2.	Marketing constraints	85	94.44
3.	Financial constraints	79	87.78
4.	Challenges in raw materials	74	82.22
5.	Challenges in power supply	62	68.89
6.	Entrepreneurial challenges	58	64.44
7.	Labour constraints	48	53.33

development and labour availability that hinder the growth and sustainability of rural women-led enterprises.Thus community-level interventions including awareness campaigns and advocacy are required to challenge the restrictions limiting women's participation in agripreneurship.Enhancing the access to markets by providing the required infrastructure, information, technology and marketing strategies is critical for success of women.Improved financial literacy and easier access to credit along with tailored products specifically for women agripreneurs from microfinance institutions, banks, and cooperatives are needed.These findings were in line with previous research findings of Siddeswari (2018); Devi *et al*.(2023) and Roy *et al*., 2025 wherein marketing, technical, economic, and social constraints were identified as the primary constraints of rural women entrepreneurs.

CONCLUSION

The study shows that a diverse range of activities such as dairy, crop cultivation and poultry were practised by the rural women in Palnadu. Planned resource allocation followed by decision-making ability and human management displayed strong positive correlation with the enterprise growth rate. The most influencing factors of success of women entrepreneurs comprise planned resource allocation, decision-making ability, human management, account keeping, planned marketing and expertise and knowledge in enterprise. Therefore, enhancing these skills among women through workshops, mentorship and experiential learning opportunities could lead to high success rate. Innovative behaviour, money management and leadership ability also showed a significant impact on entrepreneurial success. Socio-cultural constraints followed by marketing and financial constraints were found to be more prominent among the women entrepreneurs. The interventions that promote creativity, confidence, and leadership skills among women support them to scale up and sustain their enterprises.

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HOLT'S EXPONENTIAL SMOOTHING AND ARIMA MODELS FOR FORECASTING COCONUT PRODUCTION TRENDS IN INDIA

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ABSTRACT

This study forecasts coconut production in India for the next decade using two time series forecasting models: Holt's Exponential Smoothing and ARIMA. By analysing historical production data from 1956 to 2021, both models indicate a consistent upward trend in coconut production. The study compares model performance using accuracy measures such as MAE, MAPE, and AIC. Results show that while both models forecast similar trends, ARIMA outperforms Holt's Exponential Smoothing in terms of accuracy, as reflected by lower MAPE values. Although Holt's method fitted the values slightly better, ARIMA produced more reliable predictions. The models did not perform well based on RMSE criteria, but residual analysis suggests that Holt's method produces more random, white noise residuals compared to ARIMA. The findings underscore ARIMA's superior predictive accuracy in forecasting coconut production, despite both models having potential for long-term forecasting.

Keywords: ARIMA,Coconut Production, Forecast, Holt Exponential Smoothing.

INTRODUCTION

India occupies a prominent position in the global coconut economy, contributing 31.45% of the world's production in 2021–22 with an output of 19,247 million nuts (India Trade Portal, 2025). The coconut sector plays a crucial socio-economic role by generating nearly 30,748 crore for the national GDP and supporting the livelihoods of around 12 million people. Approximately 600,000 workers are engaged directly in processing industries such as copra production, oil extraction and coir manufacturing (India Brand Equity Foundation). With an average productivity of 9,123 nuts per hectare - among the highest globally (Kalidas *et al*., 2014). India continues to be a key player in the international market.

Coconut cultivation in India is regionally concentrated, with Karnataka, Tamil Nadu, Kerala and Andhra Pradesh contributing nearly 89.13% of the national cultivated area and 90.04% of total production (Jayasekhar and Jacob, 2021; Narmada *et al*., 2022). Karnataka leads the country with 4,210.87 million nuts annually, followed by Tamil Nadu and Kerala (Narmada *et al.*, 2022). At the global level, India ranks third in production after Indonesia and the Philippines, with a cultivated area of

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approximately 2.19 million hectares (International Coconut Community, 2021).

However, production trends in the coconut sector are influenced by a combination of internal factors-such as cultivation techniques, labour availability, and management efficiency and external influences including climate change, natural disasters, pests and diseases, and volatile market conditions (Muyengi *et al*., 2015; Gurbuz and Manaros, 2019). These uncertainties highlight the necessity for accurate forecasting to support strategic decision-making. Reliable production forecasts play a vital role in planning resource allocation, stabilizing prices, ensuring livelihood security, guiding trade and export policies, and fostering value-added industries. Previous research has emphasized that fluctuations in production, area, and yield significantly affect long-term sectoral sustainability (Narmada and Karunakaran, 2022).

In this context, the present study aims to evaluate and compare the forecasting accuracy of two widely used timeseries models Holt's Exponential Smoothing and ARIMA using historical production data spanning 1956–2021. By analysing their performance and selecting the most reliable model, the study provides a scientific basis for forecasting coconut production in India for the next decade. The findings are expected to assist policymakers, agricultural planners, processing industries, and other stakeholders in adopting informed strategies to promote sustainability and growth in the coconut sector.

MATERIAL AND METHODS

This study focused on forecasting coconut production in India for the next ten years using historical production data from 1956 to 2021 (66 observations). Two time series models—Holt's Exponential Smoothing and ARIMA (Auto Regressive Integrated Moving Average)—were applied to capture trends, seasonality, and variations in the data. Both models relied on past values to predict future outcomes, but they approached the time series characteristics differently. Holt's method was suited for capturing trends and seasonality, whereas ARIMA addressed autocorrelation and more complex patterns.

Data analysis was carried out in RStudio. For Holt's Exponential Method, no differencing was required since the model inherently captured level and trend. In contrast, the ARIMA model required the series to be stationary, and the best fit was selected based on the Akaike Information Criterion (AIC). For Holt's method, model selection was guided by the values of the smoothing parameters Alpha (á) and Beta (β).

Holt's Exponential Smoothing Method

Holt's method, developed in 1957 as an extension of simple exponential smoothing, used weighted averages of past observations to forecast series with linear trends. It involved two main equations - level and trend - combined to generate forecasts.

Forecast equation is $y_{t+h} = l_t + hb_t$

Level equation is $l_t = \alpha y_t + (1-\alpha)(l_{t-1} + b_{t-1})$

Trend equation is $b_t = \beta(l_t - l_{t-1}) + (1-\beta) b_{t-1}$

Here, l_t denoted the level of the series, b_t denoted the trend, á was the level smoothing parameter, α was the trend smoothing parameter, and *h* represented the forecast horizon.

Auto Regressive Integrated Moving Average (ARIMA)

The ARIMA model predicted future values from past observations and error terms and effectively handled autocorrelation. It combined three components: autoregression (AR), differencing (I), and moving average (MA). The model was denoted as ARIMA(p,d,q), where *p* was the order of the AR part, *d* was the degree

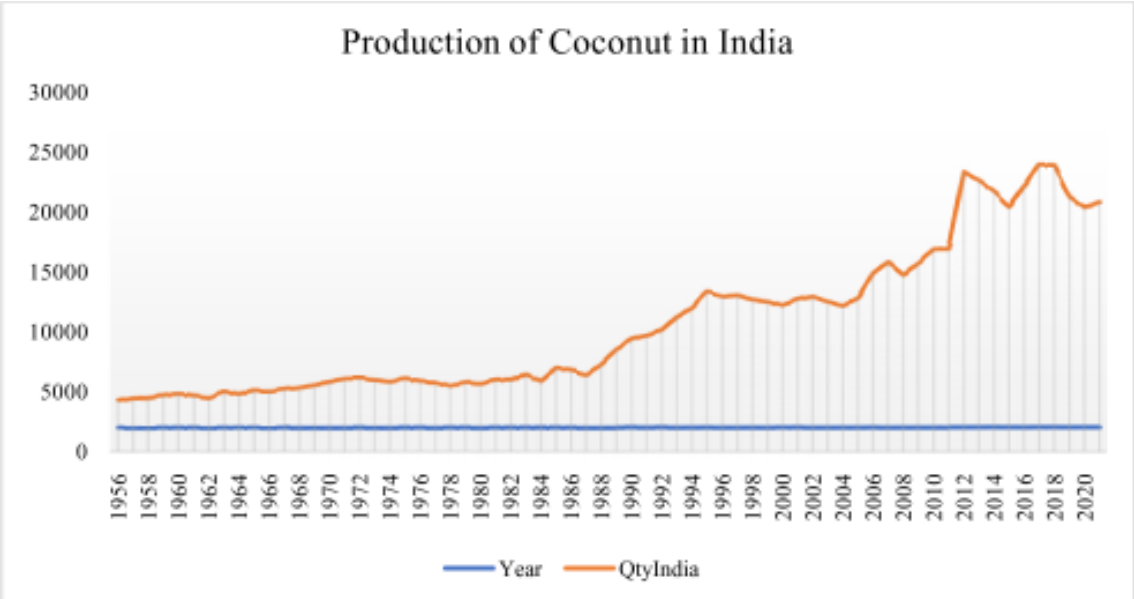

Fig 1. Coconut production in India.

of differencing, and *q* was the order of the MA part. The general form was:

$$y_t = c + \phi_1 y_{t-1} + \ldots + \phi_p y_{t-p} + \theta_1 \varepsilon_{t-1} + \ldots + \theta_q \varepsilon_{t-q} + \varepsilon_t$$

where, y_t was the differenced series, ϕ represented the AR parameters, θ the MA parameters, and εt the error term.

RESULTS AND DISCUSSION

Before fitting a model to time series data, visualizing the data was essential to help reveal any underlying trends, seasonality, and other significant characteristics. Plotting allowed researchers to visually assess these elements, which were crucial for selecting and tuning an effective forecasting model. In this study, two univariate time series were examined: coconut production in India, aiming to forecast production over the next 10 years. Using statistical software to plot these time series provided insights into trends, seasonality, and stationarity, guiding the

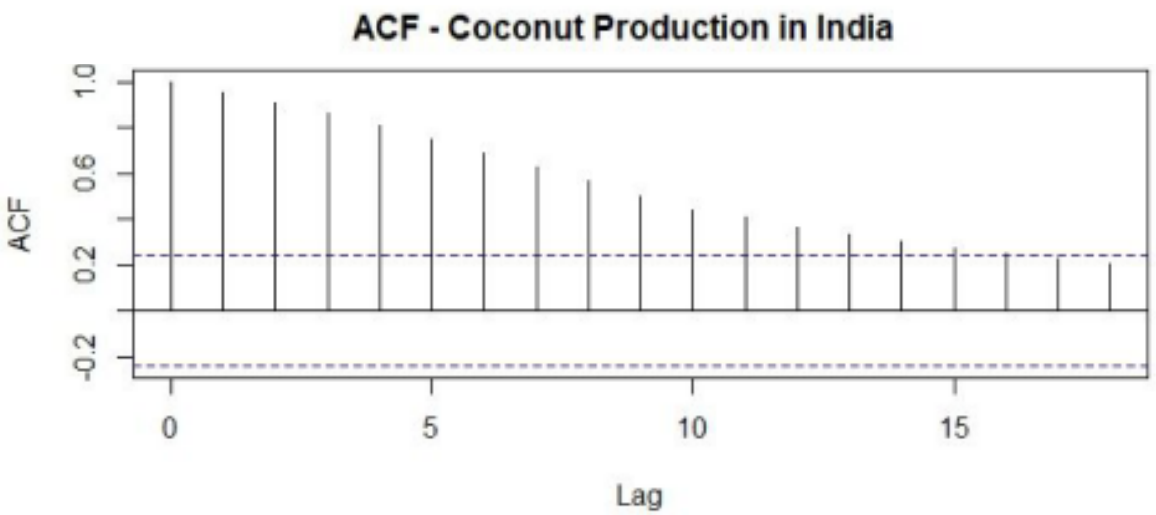

Fig 2. ACF – Coconut Production in India.

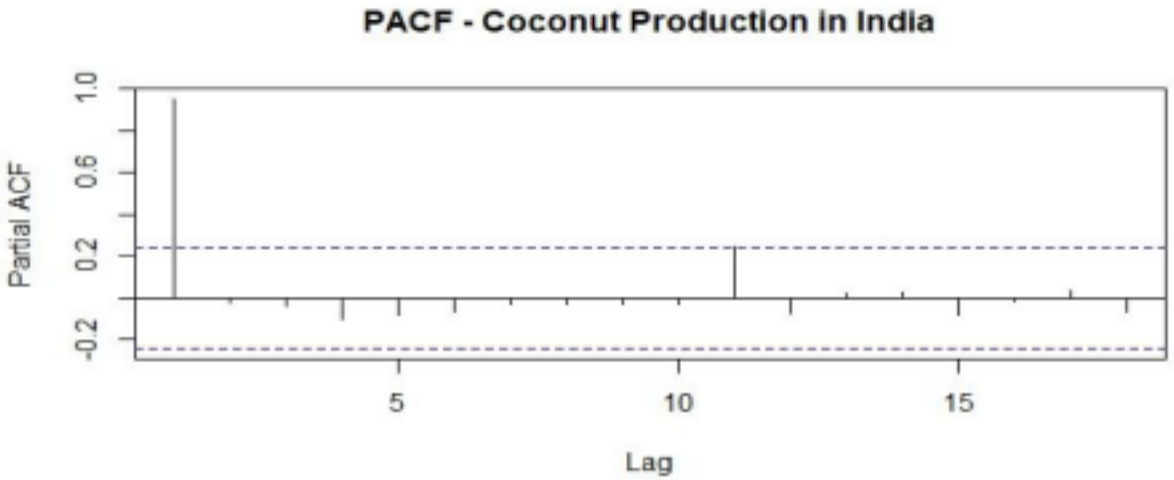

Fig 3. PACF – Coconut Production inIndia.

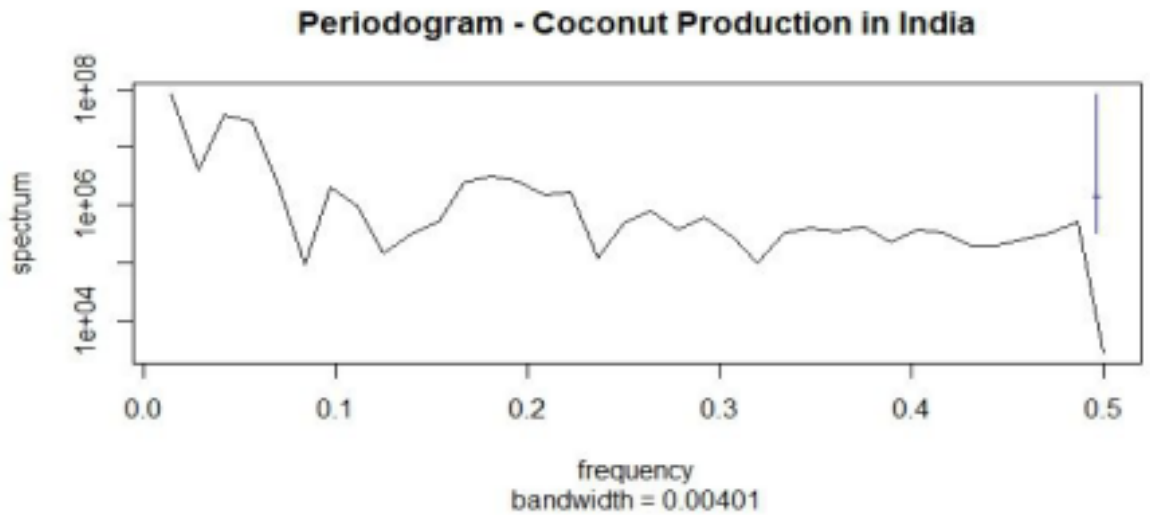

Fig 4. Periodogram – Coconut Production in India and Kerala.

identification of the most suitable approach for accurate prediction based on the observed patterns in the historical data.

The graph of the series (Fig. 1) clearly showed an upward trend in coconut production in India. To examine the presence of seasonality in the series, the Auto Correlation Function (ACF), Partial Auto Correlation Function (PACF), and the Periodogram were used.

The ACF, PACF, and periodogram analyses indicated the absence of seasonality in the series. Specifically, the ACF did not show strong lags at 1 or 12, and there were no prominent peaks in the periodogram, suggesting a non-seasonal nature. Additionally, the ACF lags and the general upward/downward trend suggested that the series was likely non-stationary. To confirm non-stationarity, the Augmented Dickey-Fuller test or the Phillips-Perron test was applied. If these tests confirmed non-stationarity, differencing the series helped achieve stationarity.

Table 1. ADF Test Results Before and After Differencing

Stationarity Test Results		
Remark	ADF Test	Phillips-Perron Test
Test Static	-1.8118	-7.3322
P-value	0.6514	0.6825
Result	Non-stationary	Non-stationary
Stationarity Test Results (after differencing)		
Remark	ADF Test	Phillips-Perron Test
Test Static	-4.2334	-54.742
P-value	0.01	0.01
Result	Stationary	Stationary

Table 2. Forecast of Coconut Production for Next Ten Years

Holt's		ARIMA	
Year	**Forecast**	**Year**	**Forecast**
2022	20969.72	2022	20990.15
2023	21203.32	2023	21244.17
2024	21436.92	2024	21498.2
2025	21670.52	2025	21752.23
2026	21904.12	2026	22006.25
2027	22137.72	2027	22260.28
2028	22371.32	2028	22514.31
2029	22604.92	2029	22768.33
2030	22838.52	2030	23022.36
2031	23072.12	2031	23276.38

The test results are presented below.

Table 1 presents the results of stationarity tests conducted using the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron test, both before and after differencing the data. Initially, the test statistics for both the ADF (-1.8118) and Phillips-Perron (-7.3322) tests, along with their respective p-values (0.6514 and 0.6825), indicate non-stationarity as they fail to reject the null hypothesis of a unit root. However, after differencing the data, the test statistics significantly improve (ADF: -4.2334, Phillips-Perron: -54.742), with p-values dropping to 0.01 for both tests. This confirms stationarity, as the null hypothesis is now rejected at the 1% significance level. These results suggest that differencing the data was necessary to achieve stationarity, a critical assumption for time series modelling.

Comparison of the Performance of the Two Methods

Table 2 compared the forecasts of coconut production in India for the next ten

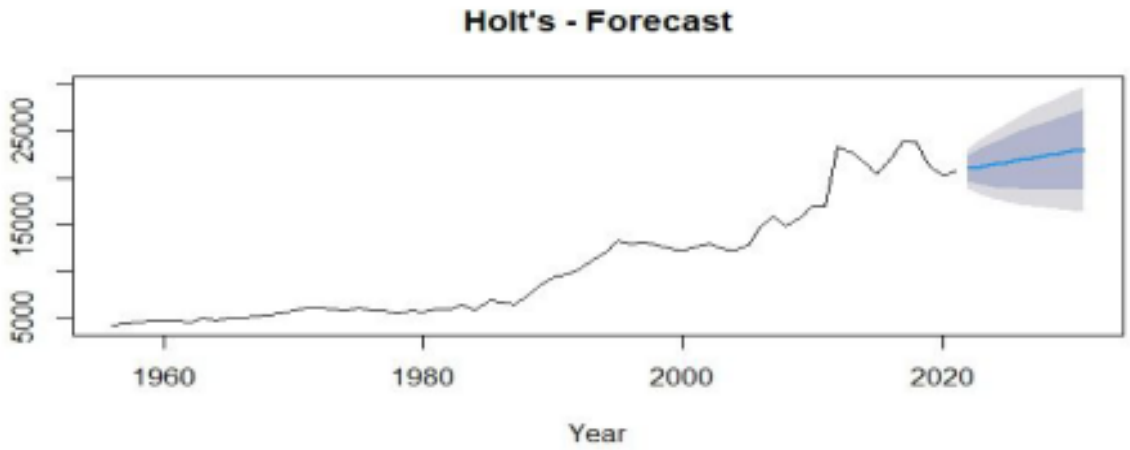

Fig.5. Forecast of Coconut Production in India: Holt's Method.

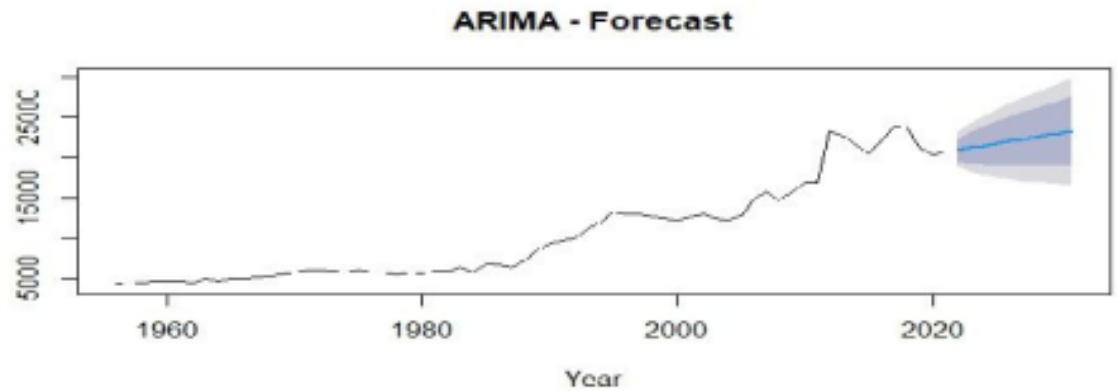

Fig 6. Forecast of Coconut Production in India: ARIMA.

years (2022–2031) using Holt's Exponential Smoothing method and the ARIMA model. Both models projected an increasing trend in production over the forecast period, but there were subtle differences in their predictions in specific years. Holt's method, an extension of simple exponential smoothing, focused on capturing trends and seasonality. On the other hand, the ARIMA model accounted for past values and errors in the time series, emphasizing autocorrelation and modelling complex seasonal patterns.

Holt's Exponential Smoothing provided slightly lower forecasts for most years compared to ARIMA. In 2022, Holt's predicted a production of 20,969.72 units, which was slightly lower than ARIMA's 20,990.15 units. This trend continued in subsequent years, with both models gradually increasing their estimates. By 2026, Holt's forecast reached 21,904.12 units, compared to ARIMA's slightly higher 22,006.25 units, indicating a difference of about 102 units. Similarly, by 2030, Holt's predicted 22,838.52 units, while ARIMA estimated 23,022.36 units, maintaining a consistent gap. Overall, while the forecasts were closely aligned, ARIMA's projections consistently edged higher than those of Holt's, suggesting a marginally more optimistic outlook for coconut production. This comparison underscored the reliability of both methods in capturing growth trends, with ARIMA offering a nuanced advantage in accounting for historical patterns.

Table 3. Fitted Vs Actual Values

Year	Actual Value	Fitted Values	
		Holt's	ARIMA
2016	22167	20673	20693
2017	23904	22401	22421
2018	23798	24137	24158
2019	21288	24031	24052
2020	20308	21521	21542
2021	20736	20542	20562

Fig. 5 indicates a general upward trend in production, with some fluctuations over the years.

Fig. 6 illustrates the forecast of India's coconut production using the ARIMA, an upward trend with notable fluctuations over time.

Table 3 compared the actual coconut production values from 2016 to 2021 with the fitted values from Holt's Exponential Smoothing and ARIMA. In 2016, the actual production was 22,167 units, and both models underpredicted the value, with Holt's at 20,673 and ARIMA at 20,693. In 2017, the actual production of 23,904 units was closely estimated by both models, with Holt's predicting 22,401 and ARIMA 22,421. In 2018, the actual value was 23,798, and both models slightly overestimated, with Holt's at 24,137 and ARIMA at 24,158. The actual production dropped to 21,288 in 2019, but both models overestimated again, with Holt's at 24,031 and ARIMA at 24,052. In 2020, the actual value of 20,308 was overestimated by both models, with Holt's at 21,521 and ARIMA at 21,542. Similarly, in 2021, the actual value of 20,736 was predicted by Holt's as 20,542 and ARIMA as 20,562. It was evident from the above table that both models fitted the data as well as the trend while comparing the actual values to fitted values. Overall, while both models followed a similar pattern, ARIMA generally provided slightly more accurate predictions, especially in matching the actual values more closely in most years.

Table 4. Residual Analysis – Ljung Box Test

Ljung-Box Test		
Remarks	**Holt's**	**ARIMA**
Test Statistic	20.311	20.857
P-Value	0.2211	0.02645
Total Lags used	10	10

Residual Analysis

We further analysed the residuals and measures of accuracy of the model to support the above statement. Residual analysis and accuracy measures were essential for evaluating model performance and selecting the most suitable model. In residual analysis, plotting residuals over time allowed us to visually assess whether they maintained a constant mean and variance. Additionally, a histogram of residuals revealed whether they followed a normal distribution. This step helped determine if the model effectively captured the data's underlying patterns. The Autocorrelation Function (ACF) plot further assisted in verifying the independence of residuals. If the ACF plot showed no significant spikes, it indicated a lack of correlation, suggesting that residuals were uncorrelated. For further validation, the Ljung-Box Pierce statistic was used to statistically

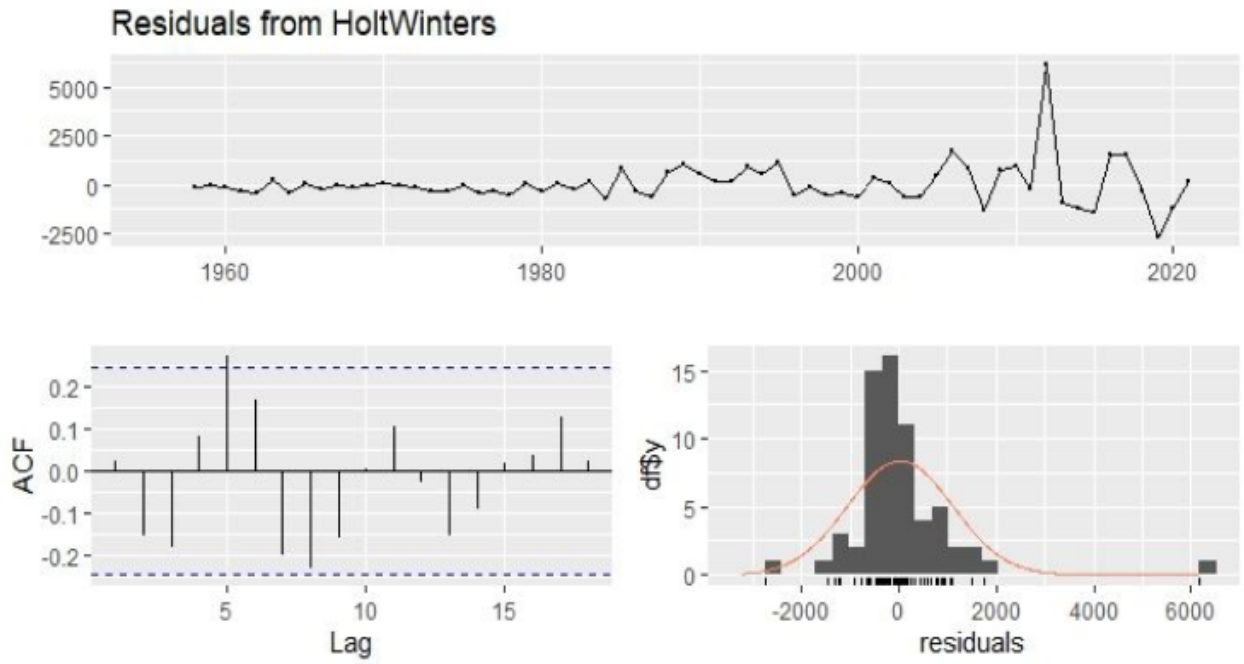

Fig7. Residuals from Holt's Exponential Model: Coconut Production in India

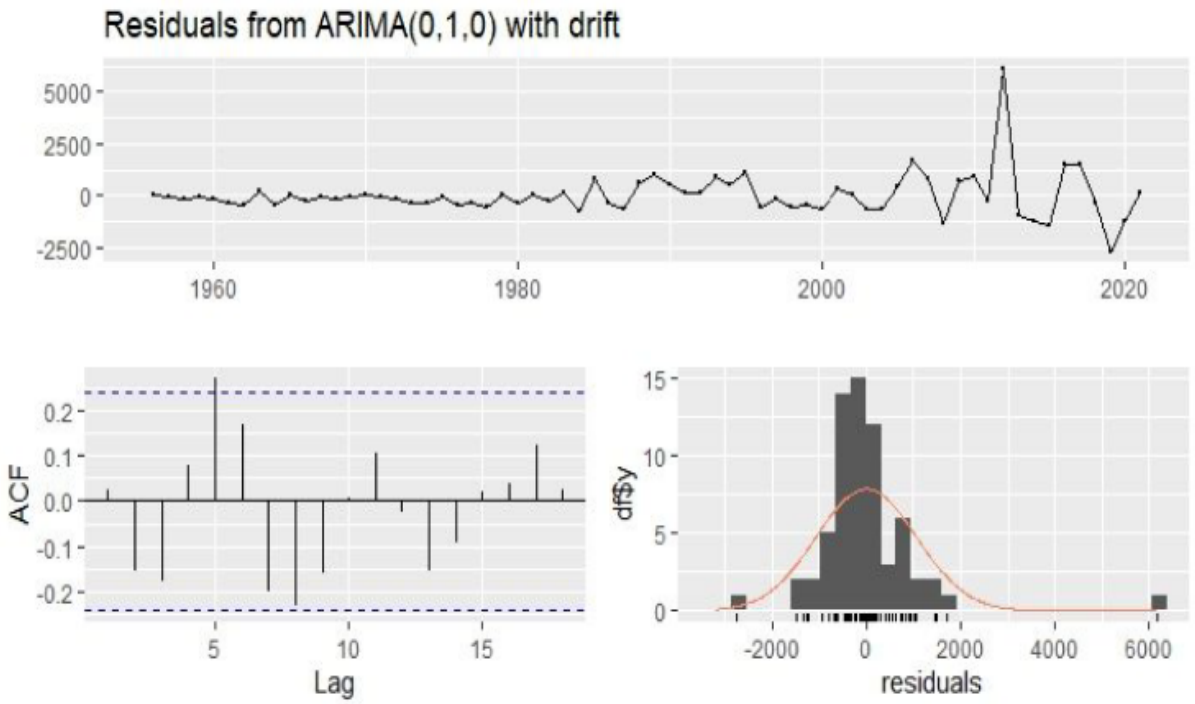

Fig 8. Residuals from ARIMA Model: Coconut Production in India

confirm residual independence. Together, these methods provided a comprehensive check, confirming that the model's assumptions held and that it had adequately captured the data structure.

The Ljung-Box test results presented in Table 4 assessed the autocorrelation of the

residuals from both Holt's Exponential Smoothing and ARIMA models. For both models, the test was applied to 10 lags, with the test statistic for Holt's being 20.311 and for ARIMA being 20.857. The p-value for Holt's was 0.2211, which was greater than the common significance level of 0.05, indicating that the residuals from Holt's did not exhibit significant autocorrelation and were likely random (i.e., the model had captured the underlying structure of the data well). However, for ARIMA, the p-value was 0.02645, which was less than 0.05, suggesting that there was significant autocorrelation in the residuals. This indicated that the ARIMA model had not fully captured all the patterns in the data, and further refinement might have been needed. In conclusion, Holt's appeared to have produced residuals that were more adequately white noise compared to ARIMA.

For both models, Holt's Exponential Smoothing and ARIMA, the time plot of the residuals (Fig. 7 and 8) showed that the variation of the residuals stayed within a range and remained consistent across the historical data, indicating that the variance could be treated as constant. The histogram suggested that the residuals might not have been normal — the left tail seemed a little too long. Consequently, forecasts from these methods were likely to be quite good, but prediction intervals computed assuming a normal distribution might have been inaccurate.

Table 5. Measures of Accuracy

Model Performance – Measures of Accuracy		
Remarks	**Holt's**	**ARIMA**
MAE	636.8156	621.6017
MAPE	5.431846	5.353232
MASE	1.010142	0.9860087
RMSE	1071.639	1055.082

Measures of Accuracy

Various model accuracy measures, such as Mean Absolute Error (MAE), Mean Absolute Scaled Error (MASE), Root Mean Squared Error (RMSE), Mean Absolute Percent Error (MAPE), and Akaike Information Criterion (AIC), provided insight into model performance using historical data. These metrics helped gauge how well the model fitted past data, though it was important to note that they might not have directly translated to future forecasting accuracy. MAE, which indicated the average absolute difference between actual and forecasted values, was straightforward and useful; a lower MAE suggested a more accurate model. MASE, when above 1, implied that the model performed worse than a naive forecasting approach, with lower values indicating better accuracy relative to this benchmark. RMSE was valuable for understanding the model's prediction error; an RMSE of 0 would have signified perfect alignment between expected and actual values, while lower RMSE values generally reflected a better-fitting model. MAPE, meanwhile, enabled comparison of forecast accuracy across models, with lower MAPE values indicating superior forecasting performance. Finally, the AIC assisted in model selection, balancing goodness of fit with model complexity. Collectively, these metrics offered a comprehensive approach to assessing model accuracy and comparing models effectively.

The model performance metrics presented in the table, including MAE, MAPE, MASE, and RMSE, provided a comparison of the accuracy of Holt's Exponential Smoothing and ARIMA models. The Mean Absolute Error (MAE) was slightly lower for ARIMA (621.60) compared to Holt's (636.82), indicating that ARIMA had a marginally smaller average

prediction error. Similarly, the Mean Absolute Percentage Error (MAPE) for ARIMA (5.35%) was also slightly better than Holt's (5.43%), suggesting that ARIMA's forecasts were more accurate in terms of percentage error. The Mean Absolute Scaled Error (MASE) was very close for both models, with Holt's at 1.01 and ARIMA at 0.99, indicating similar scaling of errors relative to the benchmark model. Lastly, the Root Mean Square Error (RMSE) was also lower for ARIMA (1055.08) compared to Holt's (1071.64), further highlighting that ARIMA offered slightly better performance in terms of reducing large errors. Overall, both models showed similar accuracy, but ARIMA marginally outperformed Holt's in most accuracy measures.

CONCLUSION

This study set out to analyse coconut production in India and to forecast future production using two univariate time series models: Holt's Exponential Smoothing and the ARIMA model. The visual examination of the data revealed a clear and consistent upward trend in coconut production from 1956 to 2021, supporting the historical data suggesting a consistent increase in demand. Forecasts for the period 2022–2031 from both methods indicated a continued rise in coconut production, with ARIMA consistently projecting slightly higher value, 23,022.36 units in 2030 compared to Holt's 22,838.52. When evaluated against the actual values from 2016 to 2021, both models broadly captured the underlying trend, though ARIMA provided marginally closer estimates in most years. Residual analysis offered an important contrast: Holt's model produced residuals that were uncorrelated and behaved more like white noise, as indicated by a statistically insignificant Ljung–Box p-value (0.2211). In contrast, the ARIMA model showed some residual autocorrelation (p = 0.02645), suggesting incomplete modelling of the underlying data structure. However, despite this limitation, the accuracy metrics: MAE, MAPE, MASE, and RMSE indicated that ARIMA performed slightly better than Holt's. ARIMA recorded a lower MAE (621.60 versus 636.82), lower MAPE (5.35% versus 5.43%), lower MASE (0.986 versus 1.01), and a lower RMSE (1055.08 versus 1071.64), confirming its marginally superior forecasting accuracy across all measures. Overall, the study concludes that both Holt's Exponential Smoothing and the ARIMA model are suitable for forecasting coconut production in India, effectively capturing the long-term growth trend observed in the historical data. While Holt's demonstrates stronger residual behaviour, ARIMA achieves marginally superior forecasting accuracy, making it the more reliable model for predicting future coconut production in this case. The forecasts from both models indicate a steady rise in coconut output over the next decade, offering valuable insights for policymakers, agricultural planners, and stakeholders in the coconut sector.

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TRADITIONAL CUISINES OF THE PARAJA TRIBAL COMMUNITY IN KORAPUT, ODISHA AND THEIR NUTRITIONAL SIGNIFICANCE

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Indigenous communities often inhabit the regions rich in biodiversity and collectively manage 22 percent of the earth's land and ecosystem. Their indigenous food system relies on natural ecosystems and encompasses a diverse range of local food resources, including cultivated crop varieties, wild plants, and domestic as well as wild animals.These foods are not only integral to the cultural identity and traditions of indigenous communities but also serve as a vital source of nutrition and sustenance. Unfortunately, modernization led to rapid erosion of the indigenous knowledge (IK) system. Additionally, oral transmission of their knowledge makes it vulnerable to loss. In the face of growing urbanization and unsustainable food practices causing climate change, hunger, and malnutrition; documenting and promoting indigenous culinary heritage is vital for achieving health, environmental sustainability and Sustainable Development Goals (SDGs).

The Paraja tribe, one of the distinct tribal groups of Odisha, is primarily concentrated in the Eastern Ghats, particularly in the Koraput district, which is a hub of tribal population (Census of India, 2011).A variety of wild foods have been documented as being utilized by the tribal communities of the district. More than 150 varieties of wild plant species comprising of cereals, millets, wild yam species, wild leafy plants and wild fruits & berries have been recorded as being used for food as well as medicinal purposes. Few studies have explored the indigenous food system of the Paraja community, which mostly focuses on their agricultural and biodiversity issues. However, limited literature exists on their age-old culinary practices and their significance in supporting health and ecological balance. Therefore, the present study was undertaken to document the traditional cuisines of the community including details on the ingredients, method of preparation and the socio-cultural aspects of their food system.

An ethnological field survey was conducted in Koraput district, located in the Southern part of Odisha, India (18.13°–19.10° N Latitude and 82.50°–83.23° E Longitude). The district comprises two administrative subdivisions, Koraput and Jeypore with a total of 14 blocks. For this study, five Paraja-dominated blocks namely Jeypore, Kundura, Baipariguda, Laxmipur, and Semiliguda were selected using purposive sampling. From each block, five villages with a predominant Paraja population were randomly chosen, yielding a total of 25 villages.A qualitative ethnographic approach was adopted to document the indigenous culinary knowledge of the Paraja community. Elder women (>40 years), recognized by the community as custodians of traditional food knowledge, were selected as

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Table 1. Commonly used foodstuffs in the traditional preparations of Paraja community

Sl.No.	Common Name	Local Name	Scientific Name
Cereals and Millets			
01	Rice	*Chaula*	*Oryza sativa*
02	Corn	*Janna*	*Zea mays*
03	Finger millet	*Mandia* (Ragi)	*Eleusine coracana*
04	Little millet	*Suan*	*Panicum sumatrense*
05	Foxtail millet	*Kangu*	*Setaria italic*
06	Sorghum	*Khed Janna*	*Sorghum bicolour*
Legumes and Dry beans			
01	Red gram	*Kandula*	*Cajanus cajan*
02	Horse gram	*Kulathi*	*Macrotyloma uniflorum*
03	Black gram	*Biri*	*Vigna mungo*
04	Cowpea seeds	*Jhudunga*	*Vigna unguiculata*
05	Moth bean	*Dangar rani*	*Vigna aconitifolia*
06	Broad bean	*Bilo jhata*	*Vicia faba*
Roots & Tubers			
01	Wild tuber	*Sorenda kanda*	*Dioscorea pentaphylla*
02	Wild tuber	*Targia kanda*	*Discorea remotiflora*
03	Wild tuber	*Pita kanda*	*D. oppositifolia*
04	Wild tuber	*Cherenga kanda*	*D. wallichi*
05	Wild tuber	*Pit kanda*	*D. oppositifolia*
06	Yam	*Langal kanda*	*Dioscorea alata*
Greens, Vegetables and Shoots			
01	Sunsunia	*Tuntunia*	*Marsilea quadrifolia*
02	Spined Amaranth	*Kanta Bhaji*	*Amaranthus spinosus*
03	Wild greens	*Celery*	*Celosia argentea*
04	Wild greens		*Kainria Hibiscus sabdariffa*
05	Wild greens	*Chakunda*	*Cassia tora*
06	Winged bean	*Karamanga*	*Psophocarpus tetragonolobous*
07	Sword bean	*Semi*	*Carnavalia gladiate*
08	Bamboo shoot	*Karadi*	*Bambusa vulgaris*
09	Mahua flower	*Mahuala phul*	*Madhuca indica*
10	Tamarind	*Tentuli*	*Tamarindus indica*

key respondents through snowball sampling. Additional information was obtained from knowledgeable household members and village elders.Fieldwork was carried out between October 2024 and January 2025, using qualitative tools including Semi-structured interviews and Focus Group Discussions (FGDs) to collect information regarding indigenous knowledge on food sourcing, culinary practices, nutrient perceptions, seasonal availability, and cultural significance.Participatory Observation was conducted to record and document step-wise preparation methods during household cooking sessions and food demonstrations. Audio, photographs and field notes were used for documentation, with participants' consent.

Traditional dishes were classified based on their nature and consumption patterns into four distinct categories:(a) cereal and millet based staple dishes, (b) festive and ceremonial dishes, (c) vegetable and pulse-based side dishes and (d) fermented alcoholic beverages.The nutritional composition (energy, carbohydrate, protein, fat, dietary fibre and mineral content (iron and calcium) of the documented dishes were estimated using standard reference values from the Indian Food Composition Tables *(*Longvah *et al*., 2017*).* Nutrient values per 100 g edible portion were used for computation based on ingredient proportions and yield factors, wherever applicable.

Commonly used foodstuffs in traditional preparations

The Paraja community of Koraput district incorporates a variety of foodstuffs including cereals and millets, legumes and dried beans, wild roots and tubers, greens, vegetables and shoots in their traditional preparations.A detailed list of the traditional foodstuffs under each of the above groups has been furnished in Table 1 along with their common name, local name and scientific name.

Traditional cuisines and their method of preparation

A total of sixteen unique traditional cuisines and beverages prepared using simple traditional processing methods such as soaking, fermentation, boiling, steaming and roasting were documented. Based on the ingredients used, these have been classified into three categories: Cereal and millet-based staple dishes, Festive and Ceremonial dishes, Vegetable and Pulse-based dishes and Fermented Alcoholic beverages. The detailed descriptions of the dishes are provided below:

A. Cereal and Millet based staple dishes

i. Bhata

Bhata is the most common staple dish of the community that is prepared by boiling rice. Often, a variety of pulses and millets are boiled with rice to prepare different variations of *bhata.* Semi boiled pulses like black gram, horse gram or red gram are added to half cooked rice and cooking is completed to prepare the ricevariations like *Biri bhata, Kulatha bhata* or *Kandula bhata.* Similarly, a variety of millet bhatas, like *Suan bhata,Kangu bhata* and *Khedjanha bhata* are often prepared from little millet, foxtail millet and sorghum, respectively.

ii. Peja

Peja, a popular fermented and nutritious millet-based cuisine enjoyed by the Paraja community. *Mandia peja*, an extensively consumed dish is prepared from fermented ragi paste and broken rice. Sometimes to add a variation, broken rice is substituted by corn (*Janna*) or other millets such as foxtail millet (*Kangu*) or little millet (*Suan*) resulting in *Janna peja, Kangu peja* or *Suan peja*,respectively. During the periods of grain scarcity, only ragi flour is used as the sole ingredient to prepare *Lai peja*.

Table 2. Nutritive value (Per 100 g) of Traditional Cereal and Millet based Staple dishes

Name of the Traditional dish	Nutritive value (Per 100 g)						
	Energy (kcal)	Protein (g)	Fat (g)	Fibre (g)	Carbohy-drate(g)	Calcium (mg)	Iron (mg)
Rice Bhat	33.39	0.72	0.04	0.25	7.11	0.68	0.05
Suan Bhat	31.48	0.92	0.35	0.70	5.95	1.46	0.11
Kangu Bhat	30.15	0.81	0.23	0.58	6.01	1.38	0.21
Khed Jana Bhat	30.37	0.90	0.15	0.92	6.15	2.50	0.35
Biri Bhat	38.87	1.21	0.08	0.51	8.08	1.90	0.16
Kulathi Bhat	38.99	1.18	0.06	0.42	8.24	24.57	0.25
Kandula Bhat	39.02	1.18	0.08	0.45	8.18	2.25	0.14
Lai Peja	29.15	0.65	0.17	1.01	6.02	33.09	0.42
Mandia Peja	35.0	0.78	0.18	1.04	7.36	32.63	0.42
Mandia Jau	58.42	1.30	0.32	1.87	12.23	59.79	0.76
Janna Peja	34.60	0.79	0.18	1.21	7.12	32.65	0.45
Kangu Peja	34.56	0.79	0.21	1.11	7.14	32.77	0.45
Suan Peja	34.82	0.82	0.24	1.13	7.13	32.78	0.43

iii. Jau

Jau is another fermented ragi based dish consumed occasionally by the community.The preparation process resembles that of *Peja,* but has a thick consistency. During the periods of grain scarcity, *Aam takuajau* is prepared from mango kernel powder, prepared by pounding thoroughly cleaned and soaked mango kernel. Prior to the preparation, they detoxify the mango kernel by soaking overnight and draining the soaked water.

Nutritional and Health significance of staple dishes

The nutritive value analysis revealed notable variations in their nutrient composition (Table 2). The energy content ranged from 29.15 kcal in *Lai Peja* to 58.42 kcal in *Mandia Jau*. Protein values were generally low but comparatively higher in dishes prepared with pulses such as *Biri Bhat*, *Kulathi Bhat*, and *Kandula Bhat* (1.18–1.21 g/100 g), indicating the benefit of cereal–pulse combinations. Fat content remained low across all dishes, reflecting minimal oil use in traditional cooking, while fibre content was higher in millet preparations (around 1g /100g), enhancing their role in digestive health and glycaemic regulation. Carbohydrate levels were moderate, with *Mandia Jau* recording the highest value (12.23 g/100 g), offering sustained energy release. Mineral composition showed a striking advantage of millets over cereals; *Mandia Jau*, *Mandia Peja*, and other millet dishes contained substantially higher calcium (32–60 mg/100 g) and iron (0.42–0.76 mg/100 g) compared to rice-based dishes.

Being rich in minerals like calcium and iron, along with dietary fibre, essential amino acids, and phytochemicals like polyphenols, regular consumption of millet based dishes is associated with lower risk of non-communicable diseases like diabetes, atherosclerosis and hypertension (Jacob *et al.,* 2024). Further, the

traditional methods such as soaking, germination and fermentation, helps in reducing the anti-nutritional factors present in millets, thus enhancing nutrient bioavailability and digestibility of the dishes (Khan*et al.,* 2025).

B. Festive and Ceremonial Dishes

The Paraja community of Koraput district often considered food as a sacred offering and present it to please deities, honour ancestors and extend hospitality to guests. Several sweet delicacies are also prepared and served during festive occasions. A few prominent ones are discussed below:

i. Jam and Mencha

To prepare this festival delicacy,dough prepared by kneading ragi flour with water, jaggery and a pinch of salt. It is steam cooked by unique traditional methods using an earthen pot, half filled with water and placed over *chullaha* (wood-fired stove) to generate steam. A platform is made above the water level by arranging bamboo sticks and layered with sal (*saragi)* leaves. The dough is then formed into small round and/or elongated shaped dumplings and placed over the platform and covered well with an additional layer of leaves and a lid to retain the steam and evenly cooked to *Jam* and/or*Mencha*,respectively.

ii. *Manduru*

To prepare *Manduru*, a mixture is prepared by adding jaggery and a pinch of salt to ragi flour, placed in a bamboo basket and covered with a cloth. An earthen pot half-filled with water is placed over a traditional *chullah* (wood-fired stove) covered by a perforated lid to retain steam. The basket is placed over the pot and the mixture is allowed to cook evenly to get the desired dish *Manduru*. Often a freshly prepared blend of ginger, garlic, green chillies, and roasted sesame seed powder is added to the mixture to enrich the flavour and taste.

iii. *Anda*

Anda is a fermented festive dish. Ragi flour batter is prepared and allowed for overnight fermentation. The next day, the fermented batter is slowly added to the boiling water with continuous stirring to prevent lump formation. Jaggery and a pinch of salt is added to it and cooked to a smooth, uniform and thick consistency to get *Anda*.

iv. *Patrapoda pitha*

To prepare this dish, ragi flour dough is prepared by adding small amount of water, jaggery and a pinch of salt. The dough is divided into small parts and each part is wrapped between two sal (*sargi*) leaves and roasted by placing it directly over an open fire. The use of leaves (*patra*) and roasting gives the name *Patrapoda pitha* to the dish. The slow roasting process gives a smoky flavour, distinct aroma and a mildly caramelized texture to the *pitha.*

During food crisis periods, few uncommon cakes (*pitha***)** using *kunda* (rice polish) and *Aam takua* (mango kernel powder), are prepared as part of coping mechanism of the community. To obtain the rice polish, paddy is pounded and winnowed by traditional household methods. The finer husk particles (*kunda*) adhering to the *kullaha* (winnowing pan) are collected and used in the place of ragi in the above process for preparing *Kunda pitha*. Similarly, mango kernel powder, prepared as described above, is used in place of ragi to prepare *Aam takua pitha.*

v. Suan or Kangu Khir

Paraja community uses typical millets like little millet (*Suan*) or foxtail millet (*Kangu*) for the preparation of sweet delicacies called as Suan khir or Kangu khir respectively. The selected millet is boiled in enough water by the addition of jaggery and a pinch of salt and allowed to simmer till it attains a soft and semi-liquid consistency.

Table 3. Nutritive value (Per 100 g) of Traditional Festive and Ceremonial dishes

Name of the dish	Nutritive value (Per 100 g)						
	Energy (kcal)	Protein (g)	Fat (g)	Fiber (g)	Carbohydrate (g)	Calcium (mg)	Iron (mg)
Jam/Mencha	*218.09*	4.02	0.72	2.00	48.18	194.91	3.13
Manduru	237.48	4.90	3.92	2.64	45.71	242.37	3.82
Suan khir	*103.43*	*1.16*	*0.69*	0.85	*23.51*	*13.86*	2.90
Kangu khir	102.00	1.81	0.63	0.96	22.97	15.86	1.97
Anda	*141.12*	2.60	0.46	1.29	31.18	126.12	2.02
Patra poda pitha	*218.09*	4.02	0.72	2.00	48.18	194.91	3.13

Nutritional and health significance of Festive and Ceremonial dishes

It is observed from Table 3 that the energy values of ragi-based items such as *Manduru* and *Patra Poda Pitha* is high (approx. 218–237 kcal), which indicate their role as calorie-dense foods essential for meeting the energy demands for high intensity activities in tribal settings. The Protein (approx. 2.6 to 4.9 g/100 g) and fat value (approx. 0.4 to 0.7g/ 100g) shown to be modest across all dishes. While, the inclusion of sesame seeds in *Manduru* contributes the healthy fat (approx.4 g/100g) content. All the ragi-based recipes such as *Manduru*, *Mencha*, *Patra Poda Pitha* and *Anda* showed notably higher calcium (approx.125–242 mg/100 g) and iron content (approx.2 to 4 mg/100 g). Carbohydrate content was found to be moderate to high across all dishes (approx. 31 to 48 g/100 g), important in regions reliant on labor-intensive livelihoods. Dietary fiber, was observed across recipes (approx.1 to 3 g/100 g), contributing to improved gut health, satiety, and reduced risk of metabolic disorders. *Manduru* demonstrated comparatively superior nutritional density due to the inclusion of sesame seeds and spice pastes, contributing to higher protein, beneficial fats, and minerals. The porridges, *Suan Khiri* (little millet) and *Kangu Khiri* (foxtail millet) showed lower energy and nutrient density per 100 g, attributable to the higher proportion of water in preparation.

Jacob *et al.* (2024) also made similar observation with ragi based dishes, which were found to be rich in calcium, iron, dietary fibre and polyphenols. Gopalan *et al.* (1989) observed that inclusion of jaggery further enhances the iron and energy content of these dishes.Additionally, sesame seeds, is associated with lowering blood pressure and cholesterol levels and help prevent degenerative diseases (Govindasamy *et al.*, 2018).

C. Vegetable and pulse-based side dishes

Several side dishes are prepared by the Paraja community by boiling or stewing vegetables, tubers, pulses and wild greens with natural spices and minimal or no oil. Few important ones have been discussed below:

i. Ambilia sag

This dish is prepared using tubers, greens, vegetables and bamboo shoots (*karadi*) withpulses and tamarind paste. The selected ingredients are first boiled in sufficient water. A freshly prepared seasoning paste comprising of ginger, garlic, green chillies, turmeric and tamarind pulp is then added followed by rice

flour or ragi flour paste and simmered to get a thick consistency.

The community people follow the traditional age old practice of detoxifying the wild tubers and bamboo shoots prior to cooking by boiling or soaking overnight and discarding the water. The process removes bitterness present in these wild food.

ii. Atani sag

Preparation of this dish closely resembles that of *Ambilia sag***,** with the primary distinction being the exclusion of pulses, tamarind pulp and rice or ragi flour paste. *Atani sag* is a dry variation with a distinct texture and characteristic flavour.

iii. Tentuli jhola* and*Torani jhola

Tentuli jhola and *torani jhola* are prepared occasionally using ingredients like tamarind (*tentuli*) or fermented rice water i.e., drained cooked rice water that has been kept overnight for fermentation (*torani*)**.**The pulp extracted from tamarind or fermented rice water (*torani*) is thoroughly mixed with green chillies, garlic, and turmeric. The mixture is then boiled with a pinch of salt to enhance the taste and served as side dishes.

iv. Poiti

Poitiis a pulse-based stew prepared from selected sun-dried and coarsely ground pulses like red gram, black gram,broad bean or sword bean seeds. The pulse is boiled by adding freshly made paste of ginger, garlic, green chillies and turmeric to prepare the side dish. The spices infuse rich and aromatic flavour into the dish. Finally, a pinch of salt is added to enhance the taste. Occasionally, vegetables and tubers are cooked along with the pulses, providing texture and nutritional variety to the dish.

Nutritional and health significance of side dishes

Among the dishes listed in Table 4 it is observed that, *Atani sag* shows the highest nutritional profile, particularly in terms of protein (1.89 g/100 g), fibre (3.8 g/100 g), calcium (94.43 mg/100 g), and iron (2.29 mg/ 100 g). *Amblia sag* contains moderate calcium (24.39 mg/100 g). All three dishes are *low in energy and fat.* The higher fibre content may be attributed to the fibrous nature of the leaves and minimal processing techniques typically used by the Paraja households.

Talang *et al.,* (2023) also recorded wild plants and greens as notable sources of crude fibre, minerals like calcium and iron, vitamin C and flavanol compounds. Bamboo shoot also contributes dietary fibre, selenium, and potassiumand is beneficial in weight management, cardiovascular diseases and cancer (Basumatary *et al.* 2017). Tamarind, being used in many side dishes, is a good source of antioxidants, especially vitamin C, flavonoids, carotenoids, vitamin B complex and is known to boost immunity (Kumar *et al.* 2020).

D. Alcoholic Beverages

Table 4. Nutritive value (Per 100 g) of Vegetable and pulse-based side dishes

Name of the dish	Nutritive value (Per 100 g)						
	Energy (kcal)	Protein (g)	Fat (g)	Fibre (g)	Carbohydrate (g)	Calcium (mg)	Iron (mg)
Amblia sag	15.00	0.48	0.09	0.93	2.75	24.39	0.62
Atani sag	35.65	1.89	0.37	3.8	4.82	94.43	2.29
Poiti	19.24	1.10	0.05	0.53	0.4	13.40	0.64

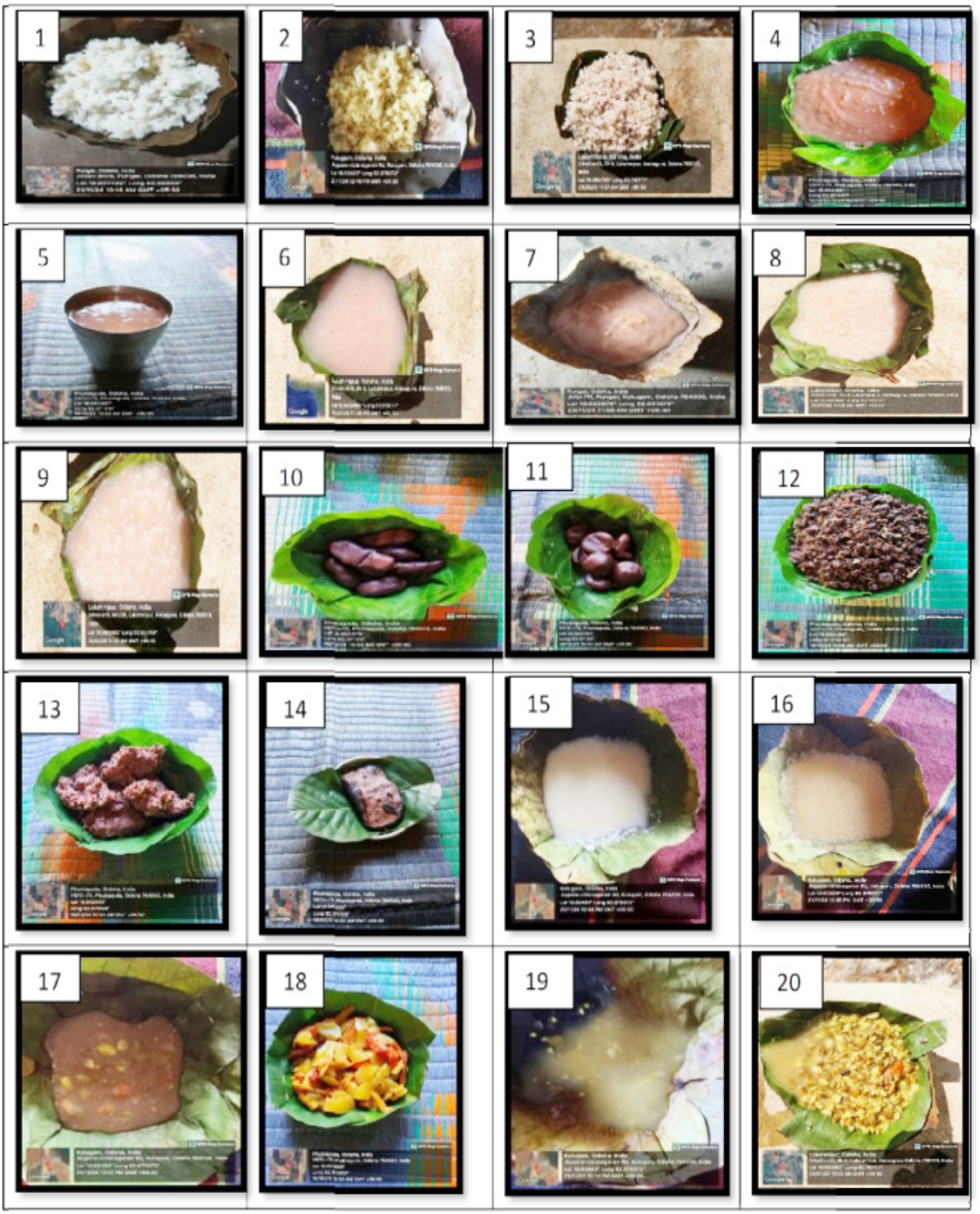

Fig. 1 to 20 -Traditional Dishes of Paraja community; 1- *Suan rice;*2- *Kangu rice;*3- *Khed Janha rice ;*4- *Mandia jau*5- *Mandia pej;* 6- *Lai pej;* 7-*Janna pej;* 8- *Kangu pej;* 9- *Suan pej;*10- *Manida jam;*11- *Mandia mencha;* 12- *Mandia Manduru*13- *Madia Anda;* 14- *Patra poda pitha;* 15- *Suan Khiri;* 16- *Kangu Khiri;* 17- *Ambilia sag;* 18-*Atani Sag;* 19- *Torani jhola;* 20- *Poiti*

Paraja community of Koraput district consumes a variety of alcoholic beverages that are either collected directly from a type of palm tree or prepared using cereals, millets or wildflowers using traditional fermentation and distillation methods. The details including the ingredients used as substrate materials and starters, preparation methods, cultural significances, etc. are presented below:

i. Mahuli mada

Mahuli mada ***(****wine****)*** is prepared by soaking sundried mahua flowers (*Mahula phula)* in aluminium or earthen pot (*handi)* tightly covered with a lid followed by adding a natural starter (prepared using rice flour and natural herbs) to initiate fermentation. When froth appears, the pot is placed over fire and another pot is reversely placed over it and sealed by pasting stickymud to construct a indigenous distillation assembly. The steam generated is passed through a metallic pipe fixed on the top pot, condensed and collected in a vessel kept underwater. The distillate (ethanol)is diluted and consumed as *Mahuli mada*.

ii. Landha

Preparation of *Landha* begins with the germination ofragi grains. One portion of the germinated grains is sundried and finely ground and the remaining portion is coarsely pounded and soaked overnight. *Peja* is prepared by cooking freshly prepared ragi flour using the excess water decanted after overnight soaking.The coarsely pounded part is then mixed to above Peja and allowed to rest for 2 to 3 days. Then the finely ground portion is added and kept undisturbed till the appearance of bubbles. The fermented liquid is then filtered to remove solids and the filtrate (*Landha****)*** **is** ready for consumption.

iii. Pendom

Pendom is another traditional fermented drink prepared by the community using rice as its base substrate. Rice is cooked to a soft consistency and spread on a bamboomat for cooling. Thestarter powder (about 2 - 4%), a dry mixture of herbs known as *Pendom Osho* (*Pendom* medicine), specially prepared from roots and barks of some wild plants, is uniformly mixed. The mixture is soaked in a vessel or earthen pot and capped tightly with clothes to provide the optimum incubation temperature to allow fermentation. The mixture is allowed to rest till the appearance of cream-like slurry and allowed for further fermentation. The resultant thick paste is consumed after adding water.

iv. Salap

The panicles/ inflorescence (*kenda*) of a matured *Salap* tree, a typical variety of palm tree (*Caryota urens* L.) is cut to allow for sap secretion. A container is fixed firmly to the *kenda* base and hung from the branches of the tree by a rope to accumulate the secreted sap. The accumulated sap is collected two to three times a day by climbing up the tree. The initially collected sap is a white liquid, which tends to be sweet and non-alcoholic. After the addition of the starter (mixture of natural herbs) fermentation begins and a mildly alcoholic beverage called *Salap*, is obtained.

Nutritional and health significance of alcoholic beverages

The alcoholic beverages usually serve as recreational or ceremonial agents**.**The ethnic beverages consumed by the communities involve fermentation of the key substrates like ragi and rice, which produces bioactive compounds like antioxidants and probiotics in *Landha* and *Pendom* that support gut health, metabolism, and immunity (Tomar, *et el*., 2025). Similarly, mahua flowers, used in the preparation of *mahuli*, is a good source of nutrients like, protein, vitamins, carbohydrate, minerals, enzymes & organic acids (Kumari, *et al.*, 2018Besides all these health benefits, it is well established that consumption of high level

of alcohol is injurious to health, especially it leads to liver cirrhosis, loss of productivity, family breakdown, accidental death and so on (Choudhury, 2018).

CONCLUSION

The rich culinary practices of Paraja community of Koraput district, Odisha reflect the inclusion of locally available natural ingredients as the key component in their traditional cuisines, which offer a model for both health and environmental sustainability. Their close association with nature, dependency on local biodiversity and use of low impact cooking methods form the foundation of a resilient and culturally rich food system. The findings underscore the significant nutritional merit of indigenous dishes prepared by the community. Millet- and ragi-based foods offer superior mineral content, dietary fibre, and sustained energy, while traditional leafy vegetable preparations supply vital micronutrients with minimal fat. Together, these dishes form a balanced, culturally rooted diet that supports health, resilience, and daily energy needs. Moreover, time-tested processing methods enhance nutrient availability and food safety, reinforcing the importance of preserving and promoting such indigenous culinary knowledge for improved nutritional well-being and sustainable food practices.However, the shifting lifestyle patterns, increased accessibility to processed and modern foods, and loss of interest among the younger generation pose a serious threat to their traditional food system.A well-formulated policy framework is urgently needed to document, preserve and promote the culinary knowledge of the Paraja community, so as to safeguard the rich cultural heritage and to promote national food security goals.

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KNOWLEDGE, ATTITUDE AND PRACTICES IN SUSTAINABLE NUTRITION AMONG WOMEN RESIDING IN JAIPUR

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Sustainable nutrition involves making food choices that nourish people while reducing environmental impact and promoting social equity. It encourages plant-forward diets, conscious food consumption, reduced food waste, and support for local and seasonal food systems. With the rise of global concerns such as climate change, environmental degradation and food scarcity, sustainable dietary patterns are now being recognized as integral to addressing multiple environmental and public health crises (Myers *et al.,* 2017). These diets, which emphasize the consumption of locally sourced, seasonaland minimally processed foods, can help lower greenhouse gas emissions, conserve water and soil resources, and support ecosystem balance (Toromade *et al.,* 2024).

In many households, especially in developing countries, women are the primary decision-makers in food-related activities. They typically oversee the procurement, preparation, and consumption of food, thus exerting a significant influence on family and community dietary patterns. Their engagement in sustainable nutrition practices can help steer communities toward healthier and more environmentally friendly dietary habits. (Chamhuri *et al.,* (2024)).In addition to these barriers, socio-economic disparities and marketing targeted by the food industry also pose challenges by increasing prevalence of processed and convenience foods in displacing traditional, home-cooked meals, thereby affecting the sustainability of food consumption patterns (Jereme *et al.,*2021).To explore and understand these dynamics, Knowledge, Attitude, and Practice (KAP) studies provide a robust framework. These studies assess what people know about a topic, how they feel about it, and how they act in practice. KAP assessments have been widely used to guide health and nutrition interventions, providing critical insights into behavioral gaps and areas for awareness enhancement (Baungaard *et al.,* 2023).

Given the strong links between dietary patterns, health outcomes and environmental impacts highlighted by global modelling studies (Springmann *et al.,* 2018), the research aimed to assess women's knowledge of sustainable nutrition, examine their attitudes and motivations toward sustainable diets, and identify the practices and barriers shaping their current food-related behaviors. A total of 250 women residing in urban areas of Jaipur were initially contacted for participation in the study. All prospective participants were screened based on the predefined eligibility criteria, which included: being within the age group of 30–45 years, residing in Jaipur for a minimum of three years, serving as the primary household food

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decision-maker, and being willing to provide informed consent for participation.

Out of the 250 women approached, 50 participants fulfilled all eligibility criteria and consented to participate in the study. Thus, the final sample size represents approximately 20 percent of the contacted individuals who met the inclusion requirements. These participants were selected through convenience sampling from various urban localities of Jaipur, including housing associations, self-help groups, and social clubs, ensuring representation from diverse urban settings within the city. Also looking at the time it took to gain consent of the subjects fulfilling the eligibility criteria and the subsequent time constraint, it was decided to limit the sample to 50 women. Data was collected using a structured interview schedule adapted from existing KAP assessment models. The tool was pre-tested in a small pilot study conducted with 10 women from the target group to check clarity and language suitability of the questionnaire consisting of four sections that include Demographic Information, Knowledge Assessment, Attitude Assessment and Practices and Barriers and reviewed by nutrition experts to ensure reliability and clarity. Descriptive statistics summarized the data, while Pearson correlation tested links between demographics (education, income) and knowledge/practice scores. Thematic analysis of open-ended responses highlighted key barriers.

Majority (80%)participants were aged 30–40 years, a group typically involved in household food decisions. Nearly half (47%) were postgraduates and 37% were undergraduates, indicating a generally well-educated sample that is likely to have better awareness of sustainability concepts. A large proportion (78.1%) were employed, suggesting possible time constraints that could influence their daily food choices. These demographic characteristics help explain later patterns in knowledge, attitudes and practices, especially the gap between awareness and actual adoption.

Table 1. Demographic characteristics of the respondents **n=50**

Characteristics	Categories	Percentage (%)
Age Group (years)	30-35	42
	36-40	38
	41-45	20
Educational Level	High School	16
	Undergraduate	37
	Postgraduate	47
Employment Status	Employed	78.1
	Homemaker	21.9
Family type	Nuclear	67.8
	Joint	32.2
Income	Low	24
	Medium	61
	High	15

Knowledge of the respondents with regard to Sustainable Nutrition

About half of the sample (52%) respondents showed moderate knowledge with fewer demonstrating high or low awareness. Understanding was stronger for general sustainability themes seasonal eating, meat-related environmental impact and food waste than for specific areas like local food systems and sustainable packaging. Women aged 30–35 years displayed slightly better awareness (36%), while those in the 41–45 group (12%)showed broader understanding but more gaps in detailed concepts. Income also influenced knowledge: medium-income women had more balanced awareness, low-income groups struggled with specialized topics like packaging and food-system impacts, and high-income respondents were more familiar with environmental issues than with local sourcing or packaging practices. Educational differences were clear, with postgraduates scoring highest. These trends mirror the observations of Weerasekara *et al.,* (2020), who reported uneven sustainability knowledge among women in South Asia. Sánchez-Sabate and Sabaté (2019) similarly noted that general sustainability ideas are commonly understood, whereas knowledge of specific components often remains limited.

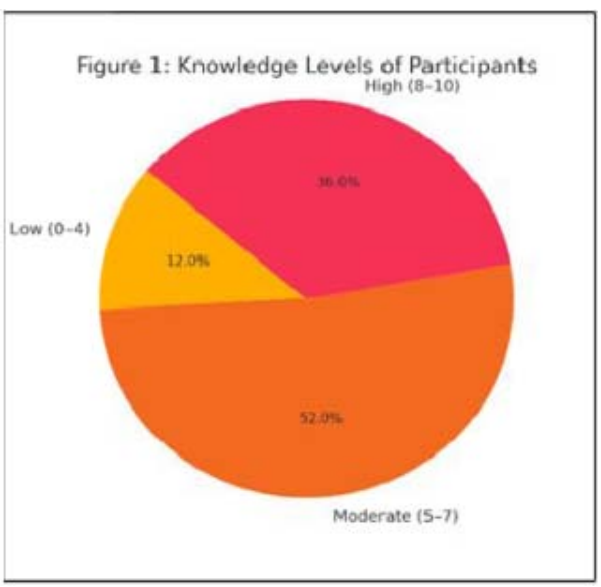

Fig. 1. Knowledge of the respondents with regard to Sustainable Nutrition

Attitude of the respondents with regard to Sustainable Nutrition

60% percent of the respondents displayed favorable attitudes toward sustainable nutrition, especially in relation to buying local foods and reducing household waste. Interest in organic products was comparatively lower, largely because of cost sensitivity. Age appeared to influence attitudes to some extent: women aged 30–35 years were generally more open to trying sustainable alternatives, whereas those in the 41–45 group expressed supportive views but were more cautious about higher-priced options due to greater household responsibilities. Income differences were also visible. Medium-income women tended to show balanced yet practical attitudes toward sustainability, while low-income participants were more hesitant about adopting costlier choices. In contrast, high-income respondents expressed enthusiasm but were selective about which sustainable behaviors they found convenient. Attitudes were strongest among postgraduate women, reinforcing the role of education in shaping perceptions of

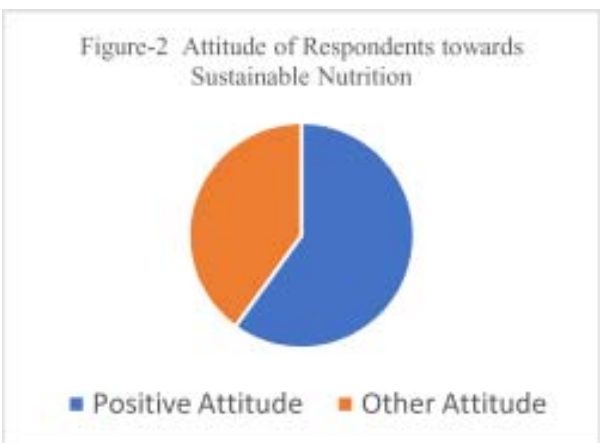

Fig.2.Attitude of the respondents with regard to Sustainable Nutrition

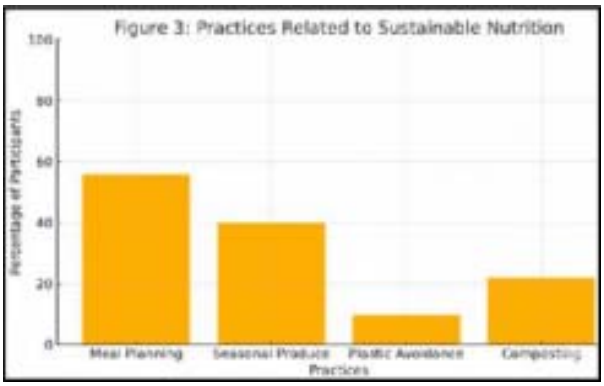

Fig.3.Practices followed by the respondents with regard to Sustainable Nutrition

sustainability. These trends are consistent with Rondoni & Grasso, (2021), who noted that consumers often value sustainable options but remain careful when such choices involve additional financial commitment.

Practices followed by the respondents with regard to Sustainable Nutrition

Despite supportive attitudes, actual sustainable practices were limited among respondents. While over half planned meals and 40% preferred seasonal or local foods, only a small number regularly composted or avoided plastic packaging. Younger women (30–35 years) were slightly more consistent in adopting such practices, whereas those aged 41–45 years reported lower adherence due to greater household responsibilities and time constraints. Income also played a role: medium-income women showed more steady engagement, low-income groups faced affordability barriers and high-income respondents often prioritized convenience. This intention–behavior gap reflects findings by Vermeir *et al.,* (2020), who noted that motivated consumers struggle to maintain sustainable habits because of limited time and accessibility. Hartmann and Siegrist (2017) similarly reported that practical constraints,especially cost and convenience, often prevent individuals from turning positive attitudes into regular sustainable behaviors.

Barriers to following practices related to Sustainable Nutrition

High cost emerged as the most common barrier (72%), suggesting that many women perceive sustainable options such as organic foods or eco-friendly product as financially burdensome. Limited availability of seasonal or local produce (58%) further restricted their choices, indicating that access, not just awareness, shapes daily food decisions. Time constraints (46%) were especially relevant among employed women, who may find sustainable cooking and waste-management practices harder to maintain. Additionally, limited household support (34%) suggests that responsibility for sustainable actions often falls solely on women, making consistent practice difficult. Together, these barriers explain why positive attitudes did not translate into regular sustainable behaviors and highlight the need for better affordability, availability and shared household responsibilities.

Significant correlations were found between education and knowledge (r = 0.48), knowledge and practices (r = 0.42), and attitudes and practices (r = 0.39). This shows that higher education improves awareness, and greater understanding or positive attitudes can support better practices. However, the strength

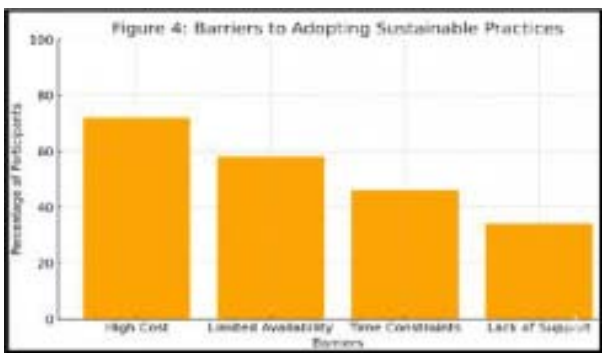

Fig.4.Barriers faced by the respondents to follow Sustainable Nutrition practices

Table 2. Relationship between Knowledge and Attitude with the practice of Sustainable Nutrition

Variables Compared	Correlation (r)	Significance (p-value)	Interpretation
Education & Knowledge	0.48	$p < 0.01$	Higher education is associated with better knowledge of sustainable nutrition.
Knowledge & Practices	0.42	$p < 0.05$	Greater understanding supports better practices, but not consistently.
Attitude & Practices	0.39	$p < 0.05$	Positive attitudes influence practice, though barriers still limit action.

of these relationships was moderate, suggesting that knowledge and attitude alone are not enough to ensure consistent sustainable behaviors. Socioeconomic factors, limited time and restricted market access continue to limit the translation of awareness into daily practice.

This study states that over two-thirds of participants possessed basic awareness of sustainable nutrition, yet this understanding rarely translated into consistent practice. Many continued relying on traditional or perceived "sustainable" habits rather than adopting evidence-based sustainable nutrition behaviors, revealing a clear gap between knowledge and action. These findings suggest that awareness alone is not enough; women require practical guidance, improved access to sustainable options and support to overcome everyday barriers. Targeted education, community programs and policy measures are needed to encourage the adoption of sustainable nutrition practices at a broader level.

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