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CONTENTS

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ISOLATION OF NATIVE ENTOMOPATHOGENIC FUNGI FROM NORTH COASTAL DISTRICTS OF ANDHRA PRADESH

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ABSTRACT

Entomopathogenic fungi (EPF) are a group of fungi that infect and kill insect pests making them valuable tools for biological pest control. These fungi occur naturally in the environment and can be used as biopesticides to manage insect pests in agriculture. Soil samples were collected from agricultural crops like Maize, Paddy, Sugarcane and wild tree soil samples like Cannon ball (Nagamalli), Peepal, Spanish cherry (*Mimusops elengi*), Anjeer, *Neolamarckia cadamba* from Srikakulam, Vizianagaram, Visakhapatnam and Anakapalle districts of Andhra Pradesh. The fungal isolates were isolated using soil serial dilution and inoculated on SDAY media. Microscopic observation of fungal isolates was done under NIKON Eclipse E200 at 40x magnification and images were captured using V-image 2013 software. Based on morphological features like white colony colour, branched conidiophore, hyaline oval conidia, one of the isolates was identified as Beauveria. Whereas the other isolate with olive green colony colour, whorls of round conidia was identified as *Metarhizium*.

KEYWORDS: Native entomopathogenic fungi, Isolation, Identification, *Beauveria*, *Metarhizium*.

INTRODUCTION

Biological control offers an environmentally sustainable approach for controlling insect pests. Among the key agents used are entomopathogenic fungi, which play a vital role in reducing pest populations and minimizing crop damage. The success of these fungi as biocontrol agents depends largely on the insect's susceptibility and the fungal virulence. Unlike other biological control organisms, entomopathogenic fungi do not require ingestion to infect; they penetrate the host directly through the cuticle. This unique infection pathway allows them to be used for regulating a broad range of insect pests. As a result, these fungi were widely recognized as integral components of integrated pest management strategies (Inglis *et al*., 2000). EPF are employed worldwide to combat several agricultural insect pests and are considered a promising strategy in insect pest management (Kumar *et al*., 2019; Liu *et al*., 2021).

Isolation of native entomopathogenic fungi is essential to identify locally adapted strains that can serve as effective, eco-friendly biocontrol agents against insect pests, particularly under the specific environmental conditions of the region.

Therefore, the present study is focused on the isolation and characterization of native entomopathogenic fungi from soils in the North Coastal districts of Andhra Pradesh, aiming to explore their potential for sustainable pest management.

MATERIAL AND METHODS

Collection of soil samples

A total of thirty-two soil samples were collected from agricultural ecosystems (Paddy, Sugarcane, Maize) and natural ecosystems like wild trees (Peepal, Spanish cherry (*Mimusops elengi*), *Neolamarckia cadamba*, Cannon ball (Nagamalli), Anjeer) from North coastal districts of Andhra Pradesh: Srikakulam, Vizianagaram, Visakhapatnam and Anakapalle. Soil samples were collected at the root zone of 5-10 cm depth with the help of shovel. About 400 g of soil sample was collected, cleaned and mixed homogenously and placed in a sterilized plastic polythene bags and labelled the soil samples with date, place of collection, crop or tree name. The isolation of native EPF was done using soil serial dilution method and from insect cadavers. Among the soil samples collected two entomofungal isolates were identified.

Isolation of soil samples by serial dilution method

Serial dilution is a fundamental microbiological technique employed to progressively reduce the

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concentration of microorganisms in a sample by a specific factor, typically tenfold at each step. This method is particularly useful for estimating the population of viable fungal spores or propagules present in a given sample. Serial dilution process involves a known quantity (0.1 g) of the soil suspension added to 9 ml of sterile diluent in a test tube and mixed thoroughly. Using a micropipette, 1 ml of this mixture is transferred to another tube containing 9 ml of fresh diluent, achieving a 10-fold dilution (10^{-1}). This step is repeated to obtain a series of dilutions (e.g.,10^{-2} to 10^{-8}) for the isolation of individual fungal colonies in subsequent steps. An aliquot of 100 µl from each dilution (10^{-4} to 10^{-8}) was aseptically spread onto petri dishes containing Sabouraud Dextrose Agar supplemented with Yeast Extract (SDAY). The distribution of entomopathogenic fungi in Central Brazilian soils and reported Metarhizium isolates from soil samples that were isolated through serial dilution method (Rocha *et al*., 2012). Each dilution is plated in triplicate to ensure accuracy and reproducibility. The inoculum is uniformly spread across the agar surface using a sterile L-shaped glass spreader.

Isolation of fungi by natural infection of insect cadaver

Insect cadaver collected from the agricultural ecosystem (Maize crop) was surface sterilized with 4% solution of sodium hypochlorite for one minute followed by rinsing in sterile distilled water to remove the external contaminants. Larva was placed on SDAY media and incubated under controlled conditions. Fungal growth was monitored from the larvae and sub culturing was done to obtain pure fungal isolates at regular interval. The fungal spores were serially diluted from 104 to 108 and inoculated on to the SDAY media.

Morphological identification of entomopathogenic fungi

Slide was prepared by placing a drop of sterile distilled water using a sterilized loop and fungal spore was transferred onto the drop of water and coverslip was placed. The slide prepared was examined under the microscope at 10x and 40x magnification using compound microscope (NIKON Eclipse E200) and at 40x magnification the images were captured digitally using V-image 2013 software. The morphological features like shape of the conidia, size, colour of spores, length and width ratio of spores were observed under compound microscope.

RESULTS AND DISCUSSION

The soil samples were collected from agricultural and natural ecosystems from North coastal districts of Andhra Pradesh. The native isolates of Beauveria bassiana and *Metarhizium rileyi* were identified in the present study. The isolate which appeared white in colour was identified as B. bassiana and white cadaver collected from maize crop showed white colony colour initially and upon incubation, turned to olive green colour was identified as M. rileyi (Norjmaa *et al*., 2019).

The fungal isolates were designated with a code AKP Bb-cd for B. *bassiana* and AKP Mr-2m for M. *rileyi*.

The native fungal isolates AKP Bb-cd and AKP Mr-2m showed round shaped colonies at 12 days after incubation on the petri plates that indicates uniform growth on the surface of SDAY media (Table 2). The growth pattern was circular for both the isolates. The colony diameter for AKP Bb-cd isolate was 6 cm and for AKP Mr-2m isolate the diameter was recorded as 4 cm. Fast radial growth was observed for B. *bassiana* AKP Bb-cd isolate and slow radial growth was observed for M. *rileyi* AKP Mr-2m isolate. The B. *bassiana* AKP Bb-cd isolate showed raised elevation initially and gradually become flatten (Figure 1) and M. rileyi AKP Mr-2m showed flat elevation (Figure 2). The shape of the conidia of AKP Bb-cd was globose and AKP Mr-2m showed whorls of round spores when identified under the microscope. The length and width ratio of the isolate AKP Bb-cd strain is 2.0 µm and AKP Mr-2m strain is 2.34 µm (Table 1).

Vimala *et al*. (2003) isolated M. *rileyi* from infected larvae of Helicoverpa armigera and *Spodoptera litura* collected from different geographic locations of South India. During the investigations it was found that a relative humidity of 90.8% and rainfall of 84 mm and a temperature of 23.67°C were found conducive for the natural mycosis of M. *rileyi*. Similar studies were conducted by Manjula and Krishna Murthy (2005) on H. *armigera* and S. *litura*.

Spore shape can vary within the same fungal strain depending on the type of substrate as demonstrated by Townsend *et al*. (1995). In their study, *Beauveria* isolates produced ellipsoidal spores when grown on insect hosts,

Table 1. Morphological characteristics of native fungal isolates

Isolates	Colony Colour	Colony elevation	Shape of the conidia	Spore size (µm) (40X)		L/W ratio
				Length	Width	
B. bassiana AKP Bb-cd	White	Initially raised and then flat	Globose	7.26	3.63	2.0
M. rileyi AKP Mr-2m	Olive green	Flat	Round to oval conidia	6.83	2.91	2.34

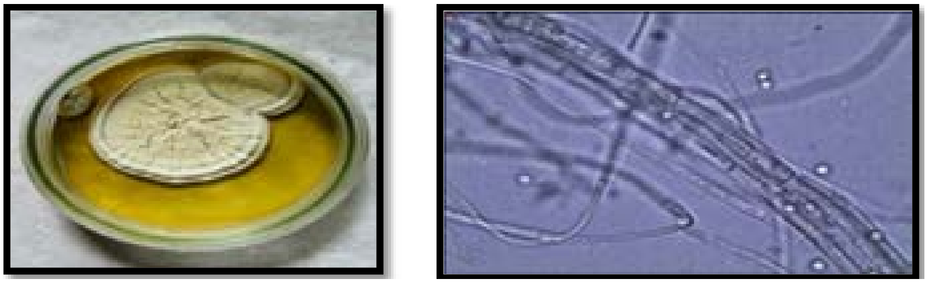

Figure 1. Morphological identification of B. bassiana AKP Bb-cd

Table 2. Growth characters of the isolated native entomopathogenic fungal isolates

Fungal isolate	Colony shape	Radial growth	Growth pattern	Colony diameter (cm)
AKP Bb-cd	Round shaped colony	Fast	Circular in nature	6 cm
AKP Mr-2m	Round shaped colony	slow	Circular	4 cm

Figure 2. Insect cadaver collected from maize crop and Morphological identification of M. rileyi AKP Mr-2m under compound microscope

whereas spherical spores were observed when cultured on artificial media.

Visalakshi *et al*. (2020) isolated an entomopathogenic fungus *Nomuraea rileyi* from the infected larval instars. The fungus produced septate hyaline mycelium with erect conidiophores produced on short conidiogenous cells, whorls of aseptate round to ovoid conidia are formed on phialides produced on smooth, erect, single/ synnematous conidiophore.

Two entomofungal isolates B. *bassiana* and M. *rileyi* were obtained from the isolation process. Morphological characteristics played a significant role for distinguishing variations for both entomofungal isolates. Differences were noticed in colony morphology, along with distinct variations in conidial size and shape, aiding in the identification and comparison of the entomofungal isolates and furthermore, molecular characterization will help in understanding genetic diversity between the two isolates and assessment of phylogenetic relationships, which is critical for selecting effective biocontrol agents and understanding their ecological adaptability and host specificity (Santos *et al*., 2022). Integrating morphological and molecular data ensures robust identification, enhancing the efficacy and safety of using entomopathogenic fungi in biological control programs.

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ASSESSMENT OF GENETIC VARIABILITY IN CASTOR (*Ricinus communis* L.) GENOTYPES UNDER RAINFED CONDITIONS

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ABSTRACT

Forty diverse genotypes of castor (*Ricinus communis* L.) were evaluated during *kharif*, 2024 to estimate genetic variability, broad sense heritability, and genetic advance for 12 metric traits. The analysis of variance revealed significant amount of variation among the genotypes for all the traits studied. It was noted that the estimates of phenotypic coefficient of variation (PCV) were higher than the genotypic coefficient of variation (GCV), indicating role of environment in governing the traits. Notably, traits like number of capsules on primary spike and total seed yield have high PCV and GCV implying the wide spectrum of variability for these traits. High heritability coupled with high genetic advance as a percentage of the mean was recorded for effective primary spike length, number of capsules on primary spike, number of effective spikes per plant, 100 seed weight and total seed yield. This indicates a predominant additive gene action in the expression of these traits, suggesting that direct selection for them would be rewarding towards genetic improvement of castor.

KEYWORDS: PCV, GCV, Genetic advance, Heritability.

INTRODUCTION

Castor (*Ricinus communis* L., 2n=2x=20), a premier non-edible commercial oilseed crop, belongs to spurge family, commonly known as Euphorbiaceae. India is the global supplier of castor oil and its by-products. India alone produces 18.79 Lakh metric tonnes of castor bean from 10.30 lakh ha cultivated area with an average productivity of 1824 kg ha^{-1} (INDIASTAT, 2023-24). In India, castor is chiefly grown in the states of Gujarat followed by Rajasthan, Andhra Pradesh, Telangana, Tamil Nadu, Karnataka and Madhya Pradesh. Castor oil contains substantial quantity of the unusual hydroxylated fatty acid "ricinolate" which enhances its consumption as a lubricant in power engines. It can readily be dissolved in alcohol and transformed into biodiesel even at low temperatures. It is also used to manufacture soaps, printing inks, linoleum, varnishes and plasticizers. Castor oil is a potent laxative and is also a curing agent for skin problems *viz.,* sunburn, crinkles and stretch symbols, etc. The by-product of castor oil expeller is the cake which contains vital organic nitrogen (6.4%), P_2O_5 (2.5%) and K_2O (1%) including micronutrients for organic farming. The plant stems are used as firewood and to prepare paper pulp by the paper mills. Beyond this, fresh castor leaves are used to rear eri-silkworms, while desiccated leaves are used as an insecticide in agriculture.

The success of plant breeding hinges on the existing genetic variability within the crop (Zheng *et al*., 2010). Assessing and estimating genetic variability in the germplasm is crucial before initiating any crop improvement program or selecting appropriate breeding techniques. This analysis aids in developing high-yielding and high-quality cultivars, ultimately increasing production. Heritability plays a key role in determining the transmissibility of traits to future generations, which is vital for selecting component traits to improve yield. Heritability estimates, along with genetic advances, are more reliable in predicting the genetic gain achieved via selection compared to heritability estimates alone.

MATERIAL AND METHODS

The present investigation was carried out during kharif, 2024 at Agricultural Research Station, Ananthapuramu, Andhra Pradesh. The experimental material utilized for the present study comprised of 40 castor genotypes sown under rainfed alfisols in alpha lattice design replicated twice. Each genotype was planted in two rows of 6 m length adopting a spacing of 90 cm × 60 cm. All the recommended package of practices were adopted to raise a healthy crop. Observations on five randomly selected plants in each genotype for 12 metric traits *viz.,* days to 50% flowering of primary spike, days to maturity of primary spike, plant height

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up to primary spike (cm), number of nodes to primary raceme, effective primary spike length (cm), number of capsules per primary spike, number of effective spikes per plant, volume weight (g/100ml), hundred seed weight (g), total seed yield (kg/ha), final plant stand (no./plot) and oil content (%) were studied. Oil content in castor genotypes were estimated by Nuclear Magnetic Resonance Spectrometry (NMR) at Indian Institute of Oilseeds Research (IIOR), Hyderabad. The statistical analysis for various traits was computed using R statistical package.

RESULTS AND DISCUSSIONS

High magnitude of variability enhances the likelihood of developing desirable genotypes in crop plants. The primary objective of germplasm conservation is to collect and preserve the genetic diversity of native crop species, ensuring its availability for both present and future generations. In this study, significant differences among the castor genotypes were observed for all the traits examined, indicating the presence of considerable genetic variability. Such variability provides a valuable resource for crop improvement programs, enabling breeders to select and combine favourable traits effectively.

Traits with high heritability are generally easier to improve through selection, as their expression is less influenced by environmental factors and are more controlled by genetic makeup. Consequently, the selection process becomes more efficient, and the response to selection is greater. These findings underscore the importance of evaluating and conserving diverse germplasm to sustain long-term agricultural productivity and adaptability to changing environmental conditions.

The analysis of variance, along with estimates of genetic variability, heritability, and genetic advance as a percentage of the mean, are presented in Tables 1 and 2. In addition, the graphical representation of PCV, GCV, heritability, and genetic advance as a percentage of the mean for various traits is illustrated in Figure 1. Highly significant differences were observed among the genotypes for all the traits under study, indicating the presence of substantial genetic variability within the population. This variation provides ample scope for selection and genetic improvement. The character days to 50% flowering of primary spike recorded a mean of 55.60 days, while days to maturity of primary spike averaged at 105.80 days. The final plant stand had a mean of 17.40 plants per plot, and plant height up to the primary spike averaged 47.04 cm. The number of nodes to the primary raceme showed a mean of 13.27, whereas the effective primary spike length had a mean of 24.71 cm. The number of capsules per primary spike averaged 51.14, and the number of effective spikes per plant showed a mean of 3.42. Volume weight recorded a mean value of 64.53 g/100 ml, while hundred seed weight had an average of 29.09 g. The total seed yield had a mean of 807.32 kg/ha, and oil content averaged 47.69 %.

Range of variation for days to 50% flowering ranged from 50.00 (ACI-16) to 64.00 (ACI-25) days, and days to maturity varied between 99.50 (ACI-16) and 114.50 (ACI-25) days. Final plant stand ranged from 15.00 (ACI-11) to 20.00 (ACI-16)plants per plot, while plant height up to the primary spike varied from 34.30 (DCS-9) to 55.30 (ACI-26) cm. The number of nodes to the primary raceme fluctuated between 10.50 (JC-24) and 15.50 (ACI-01), while effective primary spike length extended from 15.60 (ACI-30) to 39.90 (ACI-01) cm. The number of capsules per primary spike ranged from 40.40 (ACI-21) to 83.10 (ACI-26), and the number of effective spikes per plant varied between 2.10 (ACI-27) and 5.10 (ACI-01). Volume weight ranged from 58.45 (ACI-05) to 71.55 (ACI-02) g/100 ml, and hundred seed weight varied from 22.45 (ACI-19) to 39.45 (ACI-26) g. Total seed yield showed a wide range of variation from 495.50 (ACI-05) to 1661.40 (ACI-28) kg/ha, whereas oil content ranged between 44.00 (ACI-11) and 51.85 (ACI-34) %.

High estimates of PCV and GCV were recorded for number of capsules per primary spike (20.10% and 21.34%) and total seed yield (20.10% and 21.34%). Moderate PCV and GCV were noticed for hundred seed weight (GCV 11.76%, PCV 13.12%). Moderate GCV and High PCV were noticed for the traits effective primary spike length (GCV 19.92%, PCV 21.35%) and number of effective spikes per plant (GCV 18.48%, PCV 20.10%). Low GCV and moderate PCV were noticed for plant height up to primary spike (9.04%, PCV 13.48%).

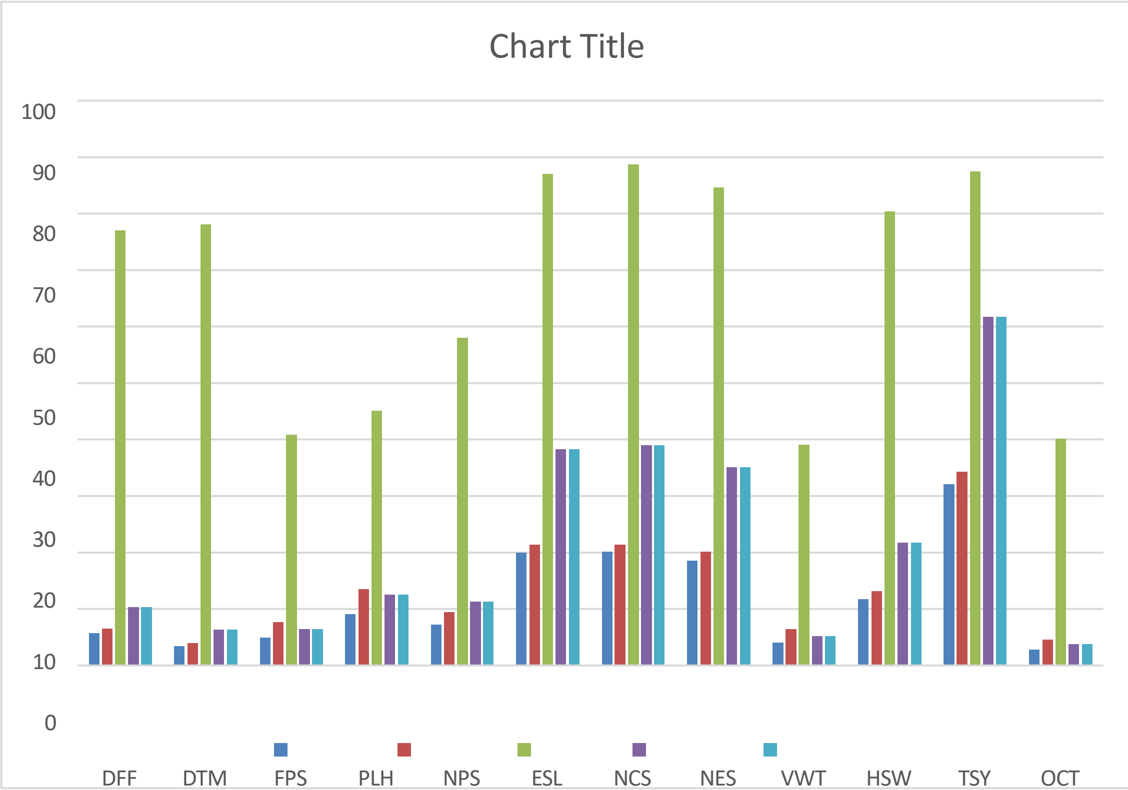
Low PCV and GCV were noted for number of nodes to primary raceme (GCV 7.16%, PCV 9.40%), and final plant stand (GCV 4.91%, PCV 7.68%) days to 50% flowering of primary spike (GCV 5.69%, PCV 6.48%), days to maturity of primary spike (GCV 3.47%, PCV 3.92%) and oil content (GCV 2.84%, PCV 4.49%).

Table 1. ANOVA for seed yield and its attributes in 40 castor genotypes

		Replication (df:1)	Genotypes (df:39)	Blocks (df:6)	Error (df:33)
1.	Days to 50% flowering of primary spike	5.51	23.04**	3.87	2.99
2.	Days to maturity of primary spike	6.05	30.66**	5.40	3.77
3.	Final plant stand	0.001	2.51**	1.35	1.06
4.	Plant height up to primary spike	9.11	58.27**	9.64	22.08
5.	Number of nodes to primary raceme	2.20	2.46**	0.36	0.65
6.	Effective primary spike length	1.98	52.06**	1.41	3.61
7.	Number of capsules per primary spike	3.36	224.65**	16.35	13.44
8.	Number of effective spikes per plant	0.002	0.872**	0.06	0.07
9.	Volume weight	1.13	23.84**	14.68	10.44
10.	Hundred seed weight	10.80	26.27**	1.84	2.85
11.	Oil content	3.87	6.42**	0.77	2.74
12.	Total seed yield	984.91	143416.12**	9813.12	9569.11

Table 2. Mean, variability, heritability (bs) and genetic advance as per cent of mean for 12 characters in 40 Castor genotypes

S. No.	Trait	Mean	Min	Max	GCV (%)	PCV (%)	$h^2_{(bs)}$ (%)	GA	GAM (%)
1.	DFF	55.66	50.00	64.00	5.69	6.48	77.01	5.72	10.28
2.	DTM	105.80	99.50	114.50	3.47	3.92	78.08	6.68	6.31
3.	FPS	17.40	15.00	20.00	4.91	7.68	40.84	1.12	6.47
4.	PLH	47.04	34.30	55.30	9.04	13.48	45.04	5.89	12.50
5.	NPS	13.27	10.50	15.50	7.16	9.40	58.02	1.49	11.24
6.	ESL	24.71	15.60	39.90	19.92	21.35	87.05	9.46	38.28
7.	NCS	51.14	40.40	83.10	20.10	21.34	88.71	19.93	38.99
8.	NES	3.42	2.10	5.10	18.48	20.10	84.60	1.19	35.02
9.	VWT	64.53	58.54	71.55	4.01	6.42	39.09	3.33	5.17
10.	HSW	29.09	22.45	39.45	11.76	13.12	80.40	6.31	21.73
11.	OCT	47.69	44.00	51.85	2.84	4.49	40.17	61.74	3.71
12.	TSY	807.32	495.50	1661.40	32.04	34.26	87.49	497.51	61.74



DFF-Days to 50% flowering of primary spike
NCS -Number of capsules per primary spike
DTM-Days to maturity of primary spike
NES -Number of effective spikes per plan
FPS - Final plant stand
VWT- Volume weight
PLH-Plant height up to primary spike
HSW- Test weight
NPS-Number of nodes to primary raceme
TSY- Total Seed yield
ESL- Effective primary spike length
OCT- Oil content

Fig.1. Genotypic and phenotypic coefficient of variability, Heritability and Genetic advance as per cent mean for 12 traits studied in castor genotypes.

The results are in consonance with the findings of Rukhsar *et al*. (2018) for days to 50% flowering of primary spike, Deepak *et al*. (2024) for Days to maturity of primary spike. Abimiku *et al*. (2012), Getinet *et al*. (2014) and Dapke *et al*. (2016) for plant height up to primary spike. Getinet *et al*. (2014) and Rukhsar *et al*. (2018) for number of nodes to primary spike. Dapke *et al*. (2016) for effective primary spike length. Deepak *et al*. (2024) for number of capsules per primary spike. Halilu *et al*. (2013) and Rukhsar *et al*. (2018) for number of effective spikes per plant. Yamanura and Kumar (2020) for hundred seed weight. Rajavardhan *et al*. (2023) and Deepak *et al*. (2024) for total seed yield. Yamanura and Kumar (2020) and Rajavardhan *et al*. (2023) for oil content.

High heritability accompanied by moderate genetic advance was observed for the days to 50% flowering of primary spike (77.01% and 10.28%). while high heritability coupled with low genetic advance was recorded for days to maturity of primary spike (78.08% and 6.31%). These patterns suggest the involvement of non-additive gene action in the inheritance of these traits. Similarly, moderate heritability combined with moderate genetic advance was found for plant height up to primary spike (45.04% and 12.50%) and number of nodes to primary spike (58.02% and 11.24%) while moderate heritability and low genetic advance (39.09% and 5.17%) for volume weight. This indicates limited scope for improvement of these traits.

High heritability associated with high genetic advance as a percentage of the mean was recorded for five traits *viz.,* effective primary spike length (87.05% and 38.28%), number of capsules per primary spike (88.71% and 38.99%), number of effective spikes per plant (84.60% and 35.02%) and 100 seed weight (80.40% and 21.73%) and total seed yield (87.49% and 61.74%) This indicates a predominant influence of additive gene action in the expression of these traits, suggesting that direct selection would be rewarding towards genetic improvement.

Similar results were reported by Udaya *et al*. (2013) and Dapke *et al*. (2016) for days to 50% flowering of primary spike. Rukhsar *et al*. (2018) for days to maturity of primary spike. Najan *et al*. (2010) and Patel and Patel (2014) for plant height up to primary spike. Rukhsar *et al*. (2018) for number of nodes to primary spike,. Rukhsar *et al*. (2018), Deepak *et al*. (2024) for effective primary spike length and number of capsules on primary spike. Udaya *et al*. (2013) for number of effective spikes per plant. Sadaiah *et al*. (2021) and Deepak *et al*. (2024) for hundred seed weight. Rajavardhan *et al*. (2023) and Deepak *et al*. (2024) for total seed yield.

Number of capsules on primary spike and total seed yield have high PCV and high GCV indicates the presence of high range of variability. High heritability coupled with high genetic advance as a percentage of the mean was recorded for effective primary spike length, number of capsules on primary spike, number of effective spikes per plant, 100 seed weight and total seed yield. This indicated a predominant influence of additive gene action in the expression of these traits, suggesting that direct selection would be rewarding towards their genetic improvement in castor.

Future scope: Future research should focus on selecting yield attributing traits like effective primary spike length, number of capsules on primary spike, number of effective spikes per plant, 100 seed weight and total seed yield aid in genetic improvement of castor.

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CHALLENGES FACED BY AGRI STARTUPS IN ANDHRA PRADESH

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ABSTRACT

Agristartups were recognized as key agents of transformation in India's agricultural sector, where supportive ecosystems had been fostered to promote innovation and entrepreneurship. However, despite their potential to revolutionize agri-business models and value chains, these startups were found to face challenges that hindered their growth and sustainability. The present article was aimed at identifying and analyzing the challenges encountered by agristartup founders across five key dimensions: financial, technological, operational, marketing, and personal. The findings were based on the study conducted with 40 agristartups followed an exploratory-cum-descriptive research design operating across various districts of Andhra Pradesh. It was revealed that high taxation, limited financial access, lack of scalable technologies, poor infrastructure, disrupted supply chains, and limited mentoring were among the most pressing issues. It was concluded that targeted policy interventions, improved support mechanisms, and ecosystem strengthening were crucial for addressing these multifaceted challenges and for fostering the long-term success of agristartups.

KEYWORDS: Entrepreneurship, Innovation, Policy interventions, Startups, Sustainability.

INTRODUCTION

The agriculture sector, which had been traditionally dependent on conventional methods and practices had undergone a significant transformation driven by innovation, technology, and entrepreneurial enthusiasm considered outcomes of ongoing transitions (Ganga and Roshni, 2022). At the forefront of this transformation, agristartups were identified as key catalysts for technological change. Unlike traditional enterprises, startups were characterized by their innovative approaches, high risk environments, and potential for rapid growth (Ekhande and Suradkar,2023). The limited success was taken to underscore the importance of understanding both the innovative practices employed and the challenges encountered (Dykha *et al.,* 2022).

Despite their growing impact, agristartups face multiple hurdles including fragmented landholdings, low technology adoption among smallholders, high upfront costs, uncertain returns on investment, and complex legal and policy frameworks. Upon examination, it was revealed that the majority of challenges faced by agristartups were structural, operational, and market-related rather than technological (Kumar *et al.,* 2024 and Pandey *et al.,* 2024). Therefore, this study was aimed to assess the core challenges faced by agristartups in Andhra Pradesh and offer practical insights for ecosystem enhancement.

MATERIAL AND METHODS

The study followed an exploratory-cum-descriptive research design to Identify and analyze the challenges faced by agristartups in Andhra Pradesh. A total of 40 startups were purposively selected, and data was collected through a semi-structured interview schedule. The identified challenges were categorized into five areas: financial, technological, operational, marketing, and personal. The responses of the agristartups were collected through interview method and were analyzed using Garett ranking Technique.

Garett ranking technique helped to identify and prioritize the most significant challenges faced by respondents based on individual rankings. Each respondent was asked to rank challenges, with the most significant challenge given the highest priority as Rank I. This ranking method helped in identifying and analyzing the major challenges systematically and these ranks were converted into scores using a specific formula to calculate present position. The converted scores were then averaged to determine the Garett mean score for each challenge. The challenge with the highest mean score was considered the most critical. This technique provides a systemic and quantitative way to analyze subjective opinions.

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Table 1. Challenges faced by Agristartups (n=40)

S. No.	Challenges	GMS	Rank
Financial challenges			
1.	High GST Taxes & compliances	61.50	I
2.	Inadequate financial support by the investors	57.00	II
3.	High rate of interest	55.30	III
4.	Inadequate incentives provided by government	55.00	IV
5.	Lack of collateral security	31.50	V
Technological challenges			
1.	Inadequate scalable technologies for commercialization	74.96	I
2.	High cost of technologies	59.92	II
3.	Lack of skills in handling and maintaining latest technologies	56.48	III
4.	Lack of technical know-how	46.64	IV
Operational and policy challenges			
1.	Difficulty sourcing raw materials at stable prices	58.40	I
2.	High cost of logistics and supply chain	56.28	II
3.	Poor rural infrastructure (roads, storage, cold chains etc)	55.70	III
4.	Seasonal risks and weather dependency	54.90	IV
5.	Difficulty in expanding operations or scaling the business	53.90	V
6.	Lack of awareness or inability to access government schemes	52.65	VI
7.	Weak enforcement or awareness of Intellectual Property Rights (IPR)	46.28	VII
Marketing challenges			
1.	Disrupted supply chain	62.50	I
2.	Inadequate market information	60.40	II
3.	Problems in procuring agri-commodities	59.05	III
4.	Low level of knowledge about marketing	53.05	IV
Personal challenges			
1.	Difficulty in attracting or retaining early customers	66.35	I
2.	Lack of mentoring and business guidance	60.40	II
3.	Non-availability of trained manpower	56.55	III
4.	Low level of innovation capability	52.70	IV

(Source: Primary survey data, 2025

The tool used for challenges analysis in this study was Garett Ranking Technique. The method involves calculating the percentage position for each rank using the formula:

Percent position = 100 * (Rij – 0.5)/Nj

Where,

Rij = rank given for ith constraint by jth individual

Nj = number of constraint ranked by jth individual

RESULTS AND DISCUSSION

The challenges were studied under five sub-headings which included financial, technological, operational and policy, marketing and personal challenges faced by the AgriStartup founders. The major challenges were identified and prioritized as follows;

Results from the Table 1 interfered that in financial challenges that High Goods and Service taxes and compliances emerged as the most critical issue (Rank I) with Garett mean score (61.50), Inadequate financial support by investors (Rank II), High rate of interest (Rank III), inadequate incentives provided by the government (Rank IV), and the Lack of collateral security was considered the least severe in this category (Rank V).

In technological challenges, the most significant barrier was Inadequate scalable technologies for commercialization (Rank I) with Garett mean score (74.96). This was followed by the high cost of technologies (Rank II), lack of skills in handling and maintaining latest technologies (Rank III), and lack of technical know-how (Rank IV).

Among operational and policy challenges it is revealed that, difficulty in sourcing raw materials at stable prices was ranked highest (Rank I) with Garett mean score (58.40), followed by high cost of logistics and supply chain (Rank II) poor rural infrastructure (roads, storage, cold chains etc) (Rank III). seasonal risks and weather dependency (Rank IV), difficulty in expanding operations or scaling the business was ranked fifth (Rank V). lack of awareness or inability to access government schemes came sixth (Rank VI), and the lowest-ranked issue was Weak enforcement or awareness of Intellectual Property Rights (Rank VII).

With regards to marketing challenges, the descending orders of the ranked challenges include: disrupted supply chain was the most pressing concern (Rank I) with Garett mean score (62.40), inadequate market information (Rank II), problems in procuring agri-commodities (Rank III), and low level of knowledge about marketing (Rank IV).

Regarding the personal challenges, difficulty in attracting or retaining early customers was ranked first (Rank I) with Garett mean score (66.35), followed by lack of mentoring and business guidance (Rank II), non-availability of trained manpower (Rank III), and low level of innovation capability (Rank IV).

The findings indicated that agristartups were constrained by financial hurdles, with high Goods and Service taxes, limited investor support, and lack of government incentives affecting their growth. Technological adoption was hindered by the absence of scalable solutions, high costs, and insufficient technical skills. Operational efficiency was impacted by raw material instability, high logistics costs, poor infrastructure, and limited access to government support. Marketing challenges were disrupted supply chains and inadequate market knowledge, while personal challenges included customer acquisition difficulties, lack of mentoring, and limited innovation. These challenges reflected systemic gaps requiring targeted policy, financial, and capacity-building interventions.

The study concluded that issues such as limited access to finance, inadequate infrastructure, lack of scalable technologies, high taxation, disrupted supply chains, and insufficient mentorship had significantly hindered their growth and sustainability. It was further emphasized that without targeted policy interventions, enhanced support systems, and a strengthened entrepreneurial ecosystem, the long-term viability of these startups could not be ensured.

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NANOTECHNOLOGY AND ITS ROLE IN SEED TECHNOLOGY

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ABSTRACT

Nanotechnology, an emerging field of material science, deals with materials smaller than 100 nanometres and has wide applications in plant and animal research. In agriculture, particularly in seed science, nanoparticles are used to enhance germination, seed vigour and tolerance to environmental stresses. Their effects, however, can be beneficial or harmful, depending on factors such as composition, size, shape, surface modification, concentration, plant species and environment. Studies highlight that nanoparticle size and concentration are crucial in determining their biological impact. This review discusses the role of nanoparticles in seed technology and their potential benefits for sustainable agriculture.

KEYWORDS: Nano particles, Seed technology, Seed germination, Seed vigour.

INTRODUCTION

Nanotechnology refers to the branch of science and engineering devoted to designing, producing and using structures, devices and systems by manipulating atoms and molecules at nanoscale. "Nano" means one-billionth (10-9), thus nanotechnology deals with materials measured in a billionth of a meter. Nanoparticles are atomic or molecular aggregates with at least one dimension between 1 and 100 nm (Roco, 2003). Nanoparticles have a small size and a high surface-to-volume ratio, which confer to them remarkable chemical and physical properties in comparison to their bulk counterparts (Roduner, 2006). Due to their unique properties nanoparticles are suitable for use in different fields, such as life science, electronics and chemical engineering (Jeevanandam *et al*., 2018).

National nanotechnology initiative is U.S government research and development initiative, has given the definition of nanotechnology as "Understanding and control of matter at dimensions between approx. 1 and 100 nanometers. Nanoparticles are widely used in different aspects of daily life activities and have a significant effect on society, economy and the environment (Nel et *al*., 2006). Nanotechnology has generated various types of nanoparticles (NPs) with differences in size, shape, surface charge and surface chemistry (Albanese *et al*., 2012).

Nanotechnology has recently attracted significant interest in plant science due to its potential to develop compact, efficient systems for enhancing seed germination, growth and protection against biotic and abiotic stresses. Seeds, often described as nature's nano-gift, can have their full potential harnessed through nanotechnology. Various seed quality enhancement techniques exist, each offering distinct benefits, but nanoparticle treatments are particularly promising. Such treatments can accelerate germination, increase seedling strength, vigour and improve overall seed quality. Metal-based nanoparticles are widely applied in these contexts (Zhu and Nguguna, 2014). Consequently, many researchers are exploring the use of metal oxide nanoparticles and carbon nanotubes to penetrate the seed coat and promote germination.

Composition of nanoparticle

Nanoparticles consist of three layers: the surface layer, the shell layer, and the core. The surface layer usually consists of a variety of molecules such as metal ion, surfactants and polymers. Nanoparticles may contain a single material or consist of a combination of several materials. Nanoparticles can exist as suspensions, colloids, or dispersed aerosols depending on their chemical and electromagnetic properties.

CLASSIFICATION OF NANOPARTICLES (NPs)

Nanoparticles are broadly divided into various categories depending on their morphology, size and chemical properties. Based on physical and chemical characteristics, some of the well-known classes of nanoparticles are given as below.

1.CARBON-BASED NANOPARTICLES

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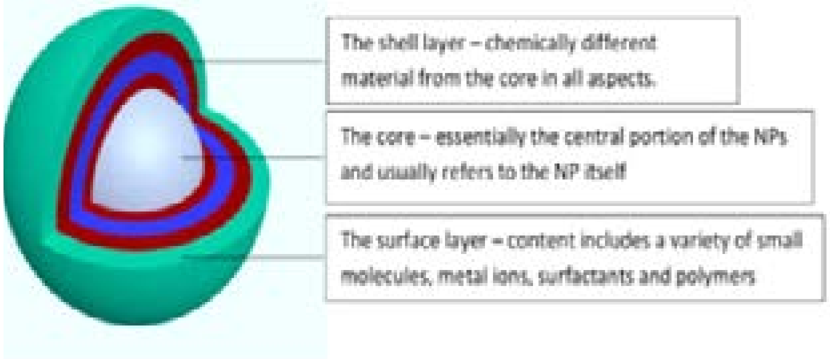


Fullerenes and carbon nanotubes (CNTs) represent two major classes of carbon-based NPs. Fullerenes contain nanomaterial that are made of allotropic forms of carbon. Carbon nano tubes (CNTs) are elongated, tubular structure, 1–2 nm in diameter (Ibrahim, 2013).

2. METAL NANOPARTICLES

Metal nanoparticles are usually defined as particles of metal atoms with diameters between 1 nm and about a few hundreds of nanometres. Purely made of metal precursors. Types of metal nanoparticles:

a)Metal organic Frameworks (MOF)

b)Metal Nanoparticle

c)Metal Sulfide Nanoparticle

d)Metal oxide Nanoparticle

e)Doped Metal/Metal Oxide Nanoparticle

3. CERAMICS NANOPARTICLES

These are inorganic, non-metallic solids that can exist in either amorphous or crystalline forms. They are widely used because of their favourable properties, including chemical inertness, high thermal stability and durability.

4. SEMICONDUCTOR NANOPARTICLES

Semiconductor materials have unique physical properties and possess properties between metals and non-metals. Semiconductor nanoparticles possess wide bandgaps and therefore showed significant alteration in their properties. These are the fluorescent materials.

5. POLYMERIC NANOPARTICLES

These nanomaterials (NMs) are primarily derived from organic matter, excluding carbon-based and inorganic nanomaterials. By leveraging non-covalent (weak) interactions for self-assembly and molecular design, organic nanomaterials can be structured into desired forms such as dendrimers, micelles, liposomes and polymer nanoparticles.

Eg: Chitosan nanoparticles

6. LIPID-BASED NANOPARTICLES

Generally, a lipid nanoparticles is characteristically spherical with diameter ranging from 10 to 1000 nm. Like polymeric nanoparticles, lipid nanoparticles possess a solid core made of lipid and a matrix contains soluble lipophilic molecules. Characteristically spherical and contain lipid moieties. Effectively used in many biomedical applications.

APPROACHES FOR SYNTHESIS OF NANOPARTICLES

a) Top-down approach

This method involves breaking down materials into their basic building blocks. It often relies on chemical or thermal techniques such as milling, grinding, or cutting. The process is energy-intensive and generally more expensive compared to bottom-up approaches.

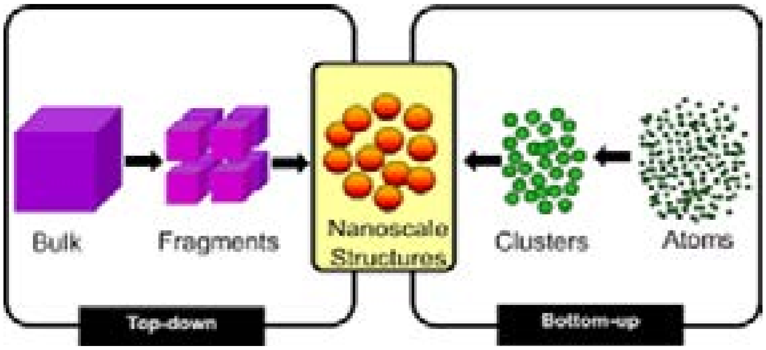
b) Bottom-up approach

This approach involves constructing complex systems by assembling simple, atomic-level components. It enables the production of nanostructures with fewer defects and a more uniform chemical composition, enhancing their performance and reliability.

SYNTHESIS OF NANOPARTICLES

1) Physical method

The synthesis of nanoparticles often requires



significant time and energy, typically involving high temperatures and pressures. Common techniques include laser ablation, ultrasonication, photoirradiation, radiolysis, solvated metal atom deposition and vaporization. These methods, while effective, can be resource-intensive and may limit large-scale or cost-effective production.

2) Chemical Synthesis Method

This is a straightforward method for synthesizing nanoparticles, based on a bottom-up approach. It requires relatively low energy, cost-effective and is suitable for both in vivo and in vitro applications, offering versatile uses. However, when performed at low temperatures, the use of toxic and stabilizing agents can pose environmental and health hazards, making the process potentially harmful.

3) Biological methods

Green synthesis techniques typically employ non-toxic chemicals, benign solvents, and biological extracts or systems. These approaches are considered safe, environmentally friendly and sustainable alternative to conventional physical and chemical methods for nanoparticle fabrication. They are particularly well-suited for in vivo applications, drug delivery and the development of bioactive agents. Additionally, green synthesis is easy to perform, efficient, eco-friendly and requires less energy, making it a preferred method for sustainable nanotechnology applications.

UPTAKE AND TRANSLOCATION OF NANOPARTICLES IN PLANTS THORUGH ROOTS AND LEAF SURFACE

The interaction between nanoparticles and plants is affected by factors such as particle size, shape, and surface characteristics. The way plants absorb nanoparticles depends largely on the method of exposure. In roots, nanoparticles are taken up primarily via two pathways: the apoplastic pathway, which involves movement through cell walls and intercellular spaces whereas symplastic pathway involves transport through the cytoplasm of connected cells via plasmodesmata. Many types of nanoparticles reach the endodermis, the symplastic pathway allowing the entry of nanoparticles through the plasma membrane, this pathway is more important than the apoplastic pathway (Qian *et al*., 2013). Different types of nanomaterials such as Au, Ag, Al_2O_3, CeO_2, Cu, CdS, Fe_2O_3, Fe, SiO_2, TiO_2, Zn, ZnO, ZnSe reports their impact on plant physiology and the development of plants (Singla *et al*., 2019). The cell wall of the plant is a complex matrix, where only a few materials pass through the plant cell (Deng *et al.,* 2014).

Most of the nanoparticles bind to the carrier protein via ion channels endocytosis, form new pores and enter plant cell. After entering they are transported from one cell to the other via plasmadesmata. Entry depends on the size of the nanoparticles. Small sized nanoparticles enters easily through the cell wall. Hydrophobicity and chemical inertness of the leaf cuticle prevents their entry. Newly grown leaves in plants and undeveloped cuticles in flowers may have a higher probability of nanoparticles entering the leaves and developing from its effects (Honour *et al*., 2009). There are two routes for the uptake of nanoparticle solution through the cuticle layers, non-polar solutes enter through lipophilic pathway and polar solutes through aqueous pores.

The stomatal pathway is a confirmed route for the uptake of foliar-applied nanoparticles (NPs), allowing them to move from leaf surfaces to other plant tissues (A. Avellan *et al*., 2021). Upon contact, nanoparticles adhere to the plant surface through electrostatic, hydrophobic, and van der waals interactions. Their uptake is influenced by particle polarity: both positively and negatively charged nanoparticles can be absorbed by leaves and translocated to roots, whereas root uptake occurs predominantly for negatively charged nanoparticles. The most direct evidence comes from Avellan *et al*. (2017), who exposed Arabidopsis to both positively and negatively charged gold nanoparticles (~12 nm) and found that "positively charged NPs induced a higher mucilage production and adsorbed to it, which prevented translocation into the root tissue," while negatively charged NPs "did not adsorb to the mucilage and were able to translocate into the apoplast".

IMPACT OF NANOTECHNOLOGY IN SEED TECHNOLOGY

Nanotechnology plays a significant role in advancing seed technology by enhancing germination and promoting vigorous seedling growth. The core claims about nano-priming enhancing germination and enzyme activation are well-supported. Mahakham *et al*. (2017) demonstrated that silver nanoparticles at 5-10 ppm significantly improved rice seed germination and enhanced α-amylase activity, directly confirming key mechanistic claims. Nano fertilizers enable precise and efficient delivery of essential nutrients, improving seedling nutrition and overall growth. Nano pesticides target specific pathogens and pests, reducing chemical use and environmental impact. Siddaiah *et al*. (2018) showed that the treatment of millet seeds with chitosan nano-particles resulted in alteration of the innate immune system of the plants and increased resistance against pathogens. Moreover, nanoparticles can serve as carriers for gene delivery, supporting crop improvement and stress tolerance. Collectively, these applications result in higher yields, enhanced resistance to biotic and abiotic stresses, and promote sustainable agricultural practices, positioning nanotechnology as a transformative tool in modern seed science.

NANOPARTICLES IN IMPROVING SEED GERMINATION, QUALITY AND YIELD

Nanoparticles can exert both stimulatory and inhibitory effects on seed germination. Their positive effects are primarily due to enhanced activities of α-amylase and protease enzymes, increased protein synthesis and improved water absorption within the seed all of which promote early and uniform germination. Conversely, nanoparticles can also trigger the formation of reactive oxygen species (ROS), leading to oxidative stress that damages DNA, proteins and cell membranes (Moore, 2006). The presence of nanoparticles in the growth medium can alter water balance through the seed coat, thereby affecting germination. Multiple studies confirm that size, concentration, and nanoparticle type significantly affect germination outcomes across various plant species (K. Adhikari *et al*., 2021). Furthermore, nanoparticles can help break seed dormancy, act as nano-fertilizers or pesticides, and enhance enzymatic activity. As they degrade in soil, nanoparticles release ions that plants absorb as nutrients, contributing to growth and productivity.

POTENTIAL RISKS/ BIOSAFETY CONCERNS

1. CYTOTOXICITY OF NANOPARTICLES

Pesticides and fertilizers in nano formulations, when air borne - deposit on above ground plant parts - plugging of the stomata which hinders the gaseous exchange and create toxic barrier on the stigma preventing the penetration of the pollen tube. It may also enter the vascular system and hinder the translocation process, preventing the fertilization and seed formation. M. Kumari *et al*., 2012 documented cellular-level effects including chromosomal aberrations and micronucleus formation. M. Thiruvengadam *et al*., 2024 confirms nanoparticles induce cytotoxicity through ROS generation leading to cell death.

2. POTENTIAL RISKS OF NANOTECHNOLOGY

Chemical hazards on edible plants after treatment with high concentration. Nanomaterial generated free radicals in living tissue leading to DNA damage. The nanotoxicity studies in agriculture are very limited and it causes a potential risk to plant, animal microbes and even humans. There are some negative effects of Nanomaterials on biological systems and the environment caused by nanoparticles. Nano materials are able to cross biological membranes and access cells tissues and organs that larger sized particles normally cannot. Therefore, nanotechnology should be carefully evaluated before increasing the use of the nano agro materials.

CHALLENGES IN NANOTECHNOLOGY

Despite its potential, nanotechnology in seed science faces several challenges. The major concern is the toxicity of nanoparticles, which can negatively affect seed germination, plant growth, and soil microorganisms.

Lack of standardized methods for nanoparticle synthesis, application and dosage limits consistent results. Environmental accumulation and bioaccumulation pose ecological risks. Limited understanding of nanoparticle interactions within plant systems further complicates their safe use. Additionally, high production costs, regulatory issues, and insufficient safety guidelines hinder large-scale application. Addressing these challenges through detailed risk assessment and sustainable practices is crucial for the safe integration of nanotechnology in seed science. Producing nanomaterials in large volumes while maintaining consistent quality and affordable cost remains a major challenge. The gap between basic research and application is another challenge in nanotechnology like several technologies.

The interaction between nanoparticles and plant cells plays a crucial role in advancing plant nanotechnology. Engineered nanoparticles are increasingly applied to improve crop productivity by enhancing seed germination, vigour, and resistance to both biotic and abiotic stresses. These particles can accumulate in various plant parts such as roots, stems, and leaves, influencing physiological processes like growth, respiration, transpiration, and biomass formation. Beneficial effects are generally observed at lower nanoparticles concentrations, which differ among crops. Nonetheless, careful consideration of biosafety and environmental impacts is essential, as nanomaterials and nano waste may pose future risks to agricultural ecosystems.

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A PROFILE STUDY OF FARMERS AFFECTED BY HUMAN WILDLIFE CONFLICT IN KURNOOL DISTRICT OF ANDHRA PRADESH

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ABSTRACT

The present study was carried out to know the profile of farmers affected by human-wildlife conflict in Kurnool district of Andhra Pradesh over a randomly drawn sample of 120 respondents. The results revealed that the majority of the farmers were in middle age (43.33%), illiterate (31.67%) and had marginal level of land holding (36.66%). Most of them had a medium level of annual income (75.83%), had not undergone any formal training (67.50%) and had medium levels of extension contact (66.66%), mass media exposure (71.66%). These socio-economic characteristics revealed that, sample population with moderate access to resources and limited exposure to advanced agricultural practices or mitigation strategies. The study emphasizes the importance of tailored awareness programs, extension services and policy interventions that consider the specific demographic and socio-economic background of these farmers to reduce vulnerability to human wildlife conflict and improve their adaptive capacity.

KEYWORDS: Human-wildlife conflict, Profile.

INTRODUCTION

The total forest cover in Andhra Pradesh is 37,258 square kilometres, which accounts for 23.00 per cent of the geographical area (FSI, 2023). In Kurnool district, forest cover was reported as 1,780 square kilometres, forming about 10.34 per cent of the district total area (Global Forest Watch, 2023). While these forested regions play a critical role in sustaining biodiversity and maintaining ecological balance, they have also become hotspots for Human-Wildlife Conflict (HWC). Species involved in HWC are leopards, wild boars and deer increasingly venture into human settlements in search of food and water. This often resulted in crop damage, livestock predation, property destruction and injuries to humans. The frequent interactions between humans and wildlife highlight the urgent need for sustainable forest management, community awareness programs and effective conflict mitigation strategies to ensure both wildlife conservation goals and human safety issues.

MATERIAL AND METHODS

The present study was conducted by following exploratory research design. Kurnool district of Andhra Pradesh was purposively selected based on its high incidence of human-wildlife conflict. From the selected district, two mandals were selected through simple random sampling method. From each of the selected mandal, three villages were selected through simple random sampling procedure thus making a total of six villages, 20 respondents were selected from each village using simple random sampling procedure thus making a total of 120 respondents. After a thorough review of literature and consultations with experts a set of nine variables were selected. The data was collected through a structured interview schedule and analysed using mean and standard deviation for drawing meaningful interpretations.

RESULTS AND DISCUSSION

The respondents were distributed based on their selected profile characteristics and the results were presented in the Table 1.

Age

From the Table 1, it was clear that majority (43.33%) of the respondents belonged to middle age category followed by young age (34.17%) and old age (22.50%) categories respectively. The reason behind this was middle aged respondents were actively engaged in farming and related livelihoods, making them more likely to have direct and frequent encounters with wildlife, which made their perceptions crucial for understanding conflict dynamics and assessing the effectiveness of

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mitigation measures. This finding was in conformity with the findings of Islam (2015) and Mukesh (2017).

Education

From the Table 1, it was evident that majority (31.67%) of the respondents were illiterate followed by high school (21.67%), primary school (20.83%), functionally literate (10.83%), intermediate (8.33%) and graduation and above (6.67%) level of education respectively. The key reasons for the trend was low awareness on education and schools were either unavailable or located far from villages, making access difficult. Additionally, economic hardship had forced many families to prioritize farm labour and household responsibilities over formal education, leading to early dropouts or complete avoidance of schooling. This finding was in conformity with the finding of Naveen (2023).

Land holding

It was implied from the Table 1, that a majority (36.66%) of the respondents were marginal followed by small (34.16%), medium (13.33%), semi-medium (9.16%) and large (6.66%) farmers respectively. This distribution may be attributed to overall landholding pattern in the region, where fragmented and small-sized holdings were more prevalent due to population pressure and generational division of land. In areas prone to human-wildlife conflict, marginal farmers were significant in number, as they tend to cultivate on the fringes of forests or reserve areas, which were more vulnerable to wildlife intrusion. This finding was in conformity with the finding of Singh (2023) and Deepak (2022).

Annual Income

It was noticed from Table 1, that majority (75.83%) of the respondents belonged to medium annual income level followed by those with high (13.34%) and low (10.83%) levels of annual income respectively. The majority of the respondents belonged to medium income, this may allowed them to use basic mitigation measures like scare devices or community monitoring, although they likely remained limited in accessing advanced or costly interventions such as electric fencing or insurance coverage which was occurred due to human wildlife conflict. This finding was in conformity with the finding of Jadhav (2020).

Training Undergone

It was evident from Table 1, that majority (67.50%) of the respondents were not undergone training and 32.50 per cent of the respondents have undergone training respectively. The majority of the respondents were not undergone training due to the reason that many farmers resided in remote and forest adjacent areas where poor infrastructure and logistical challenges had limited their access to formal training programs. Additionally, there appeared to had with low levels of awareness regarding the availability and importance of such training, largely due to inadequate outreach by government departments and agricultural extension services. This finding was in conformity with the finding of Venkatesan and Vijayalakshmi (2015).

Extension Contact

A desultory look at the Table 1 disclosed that more than half (66.66%) of the respondents have medium extension contact followed by 13.34 per cent of them with high extension contact and only 20.00 per cent of them with low extension contact respectively. This was because majority of the respondents have frequent interaction with extension agents which helped them to get aware of latest crop varieties, technologies, new mitigation measures and compensation schemes. This finding was in conformity with the finding of Mukesh (2017) and Singh (2023).

Mass media exposure

It was noticed from Table 1, that majority (71.66%) of the respondents had medium mass media exposure, followed by those with high (16.67%) and low (11.67%) of mass media exposure respectively. The findings indicated that, medium portion of farmers have access to information through media such as radio, television and mobile phone, their usage was often irregular or limited to general content. This finding was in conformity with the findings of Mukesh (2017) and Neha (2022).

The study concludes that a large proportion of the respondents affected by human-wildlife conflict in Kurnool district fall into the categories of middle-aged, illiterate, and marginal landholders. These characteristics suggest a group that may be more vulnerable to wildlife intrusions due to limited resources, education, and institutional support. Despite moderate levels of income and exposure to extension and mass media services,

Table 1. Distribution of farmers according to their profile (n=120)

S. No	Variables	Category	Frequency (f)	Percentage (%)	Mean	S.D.
1.	**Age**	Young (<35 years)	41	34.17		
		Middle (36-55) years	52	43.33	-	-
		Old (>56 years)	27	22.50		
		Total	**120**	**100**		
2.	**Education**	Illiterate	38	31.67		
		Functionally literate	13	10.83		
		Primary school	25	20.83	-	-
		High school	26	21.67		
		Intermediate	10	8.33		
		Graduation and above	8	6.67		
		Total	**120**	**100**		
3.	**Land holding**	Marginal (Up to 2.5 acres)	44	36.66		
		Small (2.5 to 5 acres)	41	34.16		
		Semi medium (5 to 7.5 acres)	11	9.16	-	-
		Medium (7.5 to 10 acres)	16	13.33		
		Large (> 10 acres)	8	6.66		
		Total	**120**	**100**		
4.	**Annual income**	Low annual income	13	10.83		
		Medium annual income	91	75.83	**169341.66**	**139281.19**
		High annual income	16	13.34		
		Total	**120**	**100**		
5.	**Training undergone**	Training undergone	39	32.50	**-**	**-**
		Training not undergone	81	67.50		
		Total	**120**	**100**		
6.	**Extension contact**	Low extension contact	24	20.00		
		Medium extension contact	80	66.66	**9.87**	**1.48**
		High extension contact	16	13.34		
		Total	**120**	**100**		
7.	**Mass media exposure**	Low mass media exposure	14	11.67		
		Medium mass media exposure	86	71.66	**11.38**	**1.69**
		High mass media exposure	20	16.67		
		Total	**120**	**100**		

the lack of formal training and educational attainment hinders the effective adoption of advanced conflict mitigation techniques. These findings underscore the urgent need for capacity-building initiatives such as location-specific training programs, community-based conflict management strategies, and better accessibility to extension and information services. Moreover, improved infrastructure and policy-level interventions should be designed to target the most affected segments of the farming population. Strengthening institutional support and ensuring participatory approaches in planning and implementation can enhance the resilience of these communities against recurring human-wildlife conflict.

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CHALLENGES FACED BY WOMEN AGRIPRENEURS IN SOUTHERN ANDHRA PRADESH

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ABSTRACT

The present study, titled "Business analysis of women agripreneurs in Southern Andhra Pradesh", specifically in the districts of Tirupati, Chittoor and SPSR Nellore. The study was conducted with an objective of identifying challenges faced by the women agripreneurs. Using purposive random sampling, primary data was collected from 30 women agripreneurs. The main challenges were multiple role conflicts, lack of training, poor market access, high interest rates and limited institutional support. Despite hurdles, women-led agribusinesses showed promise for rural development. The study emphasizes the need for targeted training, financial access and policy support to scale women-led agri-enterprises effectively.

KEYWORDS: Challenges; Agri-enterprises; Women agripreneurs.

INTRODUCTION

India, with its vast population and dynamic economic environment, had experienced a significant increase in women's participation in entrepreneurial activities, particularly in agriculture and allied sectors (Tiwari, 2022). This shift reflects broader social changes and policy support enabling women to overcome traditional barriers and assume leadership roles in enterprise development (Singh and Raghuvanshi, 2012). Women entrepreneurs, particularly in agripreneurship, have shown the ability to contribute meaningfully to rural livelihoods and national economic growth (Dhulipudi *et al.,* 2024). Agripreneurship, defined as entrepreneurship in agriculture and allied activities such as food processing, dairy and horticulture, has provided women with opportunities to enhance their income, independence, and community involvement (Bairwa *et al.,* 2012).

Despite these developments, women-led agri-enterprises continue to face persistent challenges including limited access to capital, inadequate technical training and institutional barriers. Against this backdrop, the present study was undertaken to identify the challenges that were encountered by women agripreneurs.

MATERIAL AND METHODS

The study was conducted in the state of Andhra Pradesh, selected for its strong agricultural base and supportive ecosystem for women entrepreneurs. The districts of Tirupati, Chittoor and SPSR Nellore were purposively chosen due to their active participation of women in various agricultural enterprises. A purposive random sampling design was used to select 30 women agripreneurs actively engaged in agri-based enterprises. Lists of potential respondents were obtained from Krishi Vigyan Kendras (KVKs), MSME departments and other supporting organizations. From these, women involved specifically in agri-related enterprises were shortlisted and randomly selected to ensure diverse representation.

Primary data was collected using a structured and pre-tested questionnaire interview schedule focused on various categories of challenges being faced by women *viz.,* personal challenges, technical, marketing, financial and institutional challenges. Garrett's Ranking Technique was used to analyse the identified challenges. Garrett ranking technique helped to identify and prioritize the most significant challenges faced by respondents based on their individual rankings. Each respondent was asked to rank challenges, with the most significant challenge given the highest priority as I. This ranking method helps in identifying and analyzing the major challenges systematically and these ranks were converted into scores using a specific formula to calculate percent position. The converted scores were then averaged to determine the Garrett mean score for each challenge. The challenge with the highest mean score was considered the most critical. This technique provides a systematic and quantitative way to analyze subjective opinions.

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The tool used for analysis of challenges was Garrett's Ranking Technique. The method involves calculating the percentage position for each rank using the formula:

$$\textbf{Percentage position} = \frac{100(Rij-0.5)}{Nj}$$

RESULTS AND DISCUSSION

The information related to the challenges faced by women agripreneurs was gathered through a survey using a well-structured and pre-tested schedule. Respondents were asked to rank the constraints, with the most significant challenge given the highest priority. This ranking method helped in identifying and analyzing the major challenges systematically.

Results from the Table 1 indicated that, among the personal challenges faced by women agripreneurs were: multiple role conflicts (Rank I), inability to manage time for business (Rank II), inadequate risk-taking ability (Rank III), poor decision-making (Rank IV), limited family support (Rank V) and low self-confidence (Rank VI). The results suggested that balancing multiple roles emerged as the most significant personal challenge, reflecting the burden of household and business responsibilities on women agripreneurs. Additionally, time constraints and limited confidence in decision-making and risk-taking highlight the need for targeted capacity-building and family support initiatives.

Results from Table 1 indicated that, among the technical challenges faced by women agripreneurs were: inadequate training (Rank I), non-availability of skilled labour (Rank II), lack of organizational guidance (Rank III), lack of consultancy and counselling facilities (Rank IV), less managerial experience (Rank V) and lack of awareness on new technologies (Rank VI).The findings highlighted that inadequate training was the most critical issue, suggesting the need for structured, hands-on capacity-building programs. Furthermore, the absence of skilled labour and limited organizational guidance point to a gap in external technical support, while the lack of awareness of new technologies and managerial experience further restricts innovation and operational efficiency in their enterprises.

Results from Table 1 indicated that, among the marketing challenges faced by women agripreneurs were: inadequate market information (Rank I), lack of diversification knowledge e on market sources (Rank II), more competition (Rank III) and low demand for produce (Rank IV). The findings suggested that insufficient access to timely and accurate market information severely impacted pricing and sales decisions. The lack of knowledge regarding diverse market outlets and stiff competition from established players hindered market penetration. Additionally, low consumer demand for certain agri-products further challenged the sustainability of these enterprises.

Results from Table 1 indicated that, among the financial challenges faced by women agripreneurs were: high rate of interest (Rank I), inadequate working capital (Rank II), lack of awareness of funding schemes and loan facilities (Rank III), lack of financial guidance (Rank IV) and unavailability of collateral security for getting loans (Rank V).

The high cost of borrowing and limited access to working capital emerged as the most pressing financial barriers. The lack of awareness and guidance regarding formal funding opportunities reflected a need for greater financial literacy. Additionally, the issue of not possessing collateral further limited access to institutional credit, especially for women from weaker economic backgrounds.

Results from Table 1 indicated that, among the institutional challenges faced by women agripreneurs were: poor access to institutional credit (Rank I), multiple approvals and licensing works (Rank II), heavy compliances (Rank III) and lack of exclusive instructions for providing timely guidance (Rank IV). Poor access to institutional credit ranked highest, reinforcing the earlier financial barriers faced by these women. The complexity and volume of licensing and regulatory approvals, combined with bureaucratic delays and lack of clear guidance, created hurdles in formalizing and scaling their enterprises. These institutional inefficiencies limited their ability to fully benefit from government schemes and formal sector linkages.

The above analysis clearly revealed that women agripreneurs faced a diverse set of challenges cutting across personal, technical, economic, financial and institutional domains. Among these, personal responsibilities and lack of technical training emerged as the most critical barriers, significantly affecting their efficiency and business performance. Economic limitations such as inadequate market information and stiff competition, combined with financial difficulties like high interest rates and limited

Table 1. Challenges faced by women agripreneurs (n=30)

S. No.	Category	Challenge	GMS	Rank
1.	**Personal challenges**	Multiple role conflicts	77.80	I
		Inability to manage time	73.20	II
		Inadequate risk taking ability	60.00	III
		Poor decision making	53.20	IV
		Limited family support	51.60	V
		Low self-confidence	50.33	VI
2.	**Technical challenges**	Inadequate training	73.15	I
		Non availability of skilled labour	68.65	II
		Lacks of organizational guidance	58.00	III
		Lack of consultancy and Counselling facilities	49.40	IV
		Less managerial experience	43.00	V
		Lack of awareness on new technologies	34.00	VI
3.	**Marketing challenges**	Inadequate market information	69.00	I
		Lack of diversification knowledge on market sources	64.00	II
		More competition	50.40	III
		Low demand for produce	41.80	IV
4.	**Financial challenges**	High rate of interest	74.00	I
		Inadequate working capital	71.00	II
		Lack of awareness of funding schemes and loan facilities	57.20	III
		Lack of financial guidance	45.80	IV
		Unavailability of collateral security for getting loans	33.80	V
5.	**Institutional challenges**	Poor access to institutional credit	74.85	I
		Multiple approvals and licencing works	60.65	II
		Heavy compliances	46.50	III
		Lack of exclusive instructions for providing timely guidance	20.00	IV

(SOURCE: Primary data survey 2025)

access to credit, further constrain their entrepreneurial potential. Additionally, institutional issues, including complex regulatory procedures and poor infrastructure, add to the burden. Addressing these ranked challenges through targeted interventions such as skill development programs, financial literacy, improved market access and gender-sensitive policies is essential to empower women agripreneurs and enhance the sustainability of their agri-enterprises.

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EVALUATION OF MORPHO-PHYSIOLOGICAL TRAITS IN GROUNDNUT (*Arachis hypogaea* L.) GENOTYPES

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ABSTRACT

The present study was conducted during rabi, 2024-25 at the dryland Farm of S.V. Agricultural College, Tirupati, under Acharya N.G. Ranga Agricultural University, Andhra Pradesh. Twenty groundnut genotypes were evaluated to assess variability in morpho-physiological traits. The field experiment was laid out in Randomized Block Design (RBD) with three replications. Significant differences were observed among genotypes for all studied traits. Among the twenty genotypes, TAG-24 was the earliest maturing genotype, while Dheeraj exhibited the greatest plant height. TCGS-1694 and Kadiri-9 showed the highest leaf area index and SCMR, respectively. The findings indicate considerable genetic variability, offering scope for selection and improvement in groundnut breeding programs.

KEYWORDS: Morpho-physiological traits, Genetic variability, Randomized Block Design.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop, belonging to the family Leguminosae. This self-pollinating plant species possesses a specific chromosome count of 2n = 40. Its introduction to India occurred in the first half of the sixteenth century. China is the world's leading producer of groundnut, followed by India, the United States and Argentina. Globally, India is the largest exporter of groundnut, which is grown in an area of 4.7 million hectares with a production and productivity of 10.1 million tonnes and 2163 kg ha^{-1}, respectively. In Andhra Pradesh, groundnut is grown in an area of 3.11 lakh hectares with a production and productivity of 3.23 lakh tonnes and 1011 kg ha^{-1}, respectively (www.indiastat.com, 2023-24). Any morphological trait that significantly contributes to yielding ability or is linked to better pod yield would be helpful in increasing yield. To overcome the yield constraints within the genotypes, morpho-physiological trait-based investigations are required (Dharanguttikar and Borkar, 2014). In many groundnut genotypes, there is insufficient knowledge regarding morpho-physiological characteristics. For achieving genotype with desirable traits, it is essential to look at the inter-relationships between different characters.

MATERIAL AND METHODS

The experiment was carried out using twenty groundnut genotypes at dryland farm of S.V. Agricultural College, Tirupati, Andhra Pradesh during rabi, 2024-25. The field trial was laid out in Randomized Block Design (RBD) with twenty genotypes and replicated thrice, with a spacing of 22.5 cm between the rows and 10 cm between the plants within a row, with row length of 5 m and four rows. The morpho-physiological traits studied in the field were days to 50 % flowering, number of branches per plant, initial and final plant population per plot, plant height, total dry matter production per plant, days to maturity, leaf area index and SCMR. The various plant components were picked and dried in a hot air oven at 80 °C until they reached a consistent weight in order to determine the Total dry matter production (TDMP). The leaf area index was calculated by dividing the total leaf area by the corresponding ground area. SPAD chlorophyll meter reading (SCMR) was measured on five randomly selected plants from each genotype in each replication at 60 DAS using Minolta SPAD-502 chlorophyll meter and the measurements were taken on the third leaf from the terminal bud of main axis. The data recorded were analysed statistically using OPSTAT software by adopting Randomized Block Design (RBD) with three replications for field experiment as described by Panse and Sukhatme (1985). The standard error of difference was calculated at 5 and 1 per cent probability levels to compare the mean difference among the treatments.

RESULTS AND DISCUSSION

The morpho-physiological data obtained from

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Table 1. Analysis of variance for morpho-physiological in twenty groundnut genotypes

S. No.	Characters	Mean sum of squares		
		Replications (df:2)	Genotypes (df:19)	Error (df:38)
1.	Days to 50%flowering	4.72	3.67**	1.51
2.	Number of branches per plant	2.00	14.13**	0.65
3.	Initial plant population	5.72	2023.33**	103.84
4.	Final plant population	3.65	1994.21**	101.58
5.	Plant height (cm)	1.53	29.16**	4.72
6.	Total dry matter production(g/plant)	51.54	157.20**	17.60
7.	Days to maturity	24.35	178.82**	5.61
8.	Leaf area index	0.17	0.48**	0.08
9.	SCMR	64.90	31.33**	9.81
10.	Pod yield per plant(g)	0.64	35.02**	3.79

the ANOVA is presented in Table 1. The result showed significant differences among all the morpho-physiological traits of twenty groundnut genotypes. However, Singh *et al*. (2003) found a significant variation in leaf area index and SPAD chlorophyll meter reading of eight different Virginia type peanuts.

Number of days to 50 per cent flowering of different genotypes ranged from 23.67 to 28.67 days. Significant differences were found among the genotypes and highest was recorded by Kadiri-1812 (28.67). Second highest days to 50 per cent flowering was recorded by Kadiri-9 (28.00) which was on par with TCGS-2370 (28.00). Lowest days to 50 per cent flowering was recorded by TAG-24 (23.67) followed by TCGS-2361 and Dharani (25.67). The results are in line with Maurya *et al*. (2014) in which analysis of variance revealed the prevalence of significant difference among the genotypes for days to 50 per cent flowering.

Number of branches per plant for different genotypes ranged from 5.52 to 12.81. Significant differences were found among the genotypes and highest number of branches per plant was recorded by Kadiri-8 (12.81). Second highest number of branches per plant was recorded by Kadiri-7 (12.47). Lowest number of branches per plant was recorded in TAG-24 (5.52) which was on par with TCGS-2490 (5.52) followed by Kadiri-6 (5.65). The results in the present study are also in agreement with Bharathi (2010) that the number of

Table 2. Mean values for morpho-physiological traits of twenty groundnut genotypes

Genotypes	Days to 50% flowering	Number of branches per plant	Initial plant population	Final plant population	Plant height (cm)	Total dry matter production (g/plant)	Days to maturity	Leaf area index	SCMR	Pod yield per plant(g)
TCGS-1694	26.00	6.82	120.00	117.67	26.29	46.20	105.67	2.84	48.30	18.99
Dheeraj	27.00	6.00	137.00	134.67	35.43	33.48	110.67	2.26	46.57	15.76
Nithya Haritha	27.33	9.67	140.33	138.67	27.64	36.59	116.33	1.60	46.53	18.04
Dharani	25.67	5.78	114.00	111.67	30.62	31.95	111.33	2.73	43.67	12.86
Central Pragathi	27.00	6.58	139.33	137.33	27.40	34.87	105.33	2.48	45.13	14.94
ICAR Konark	26.67	8.49	136.33	133.33	27.50	36.53	111.67	2.05	44.40	17.34
TAG-24	23.67	5.52	141.00	139.00	28.05	36.92	96.33	1.61	43.63	17.80
Kadiri-6	27.00	5.65	133.00	131.00	31.27	27.69	112.00	2.56	45.13	15.74
Kadiri-7	26.00	12.47	110.00	108.00	33.97	48.64	125.00	2.51	49.67	28.13
Kadiri-8	27.00	12.81	100.00	98.00	31.77	53.03	125.33	1.83	52.63	19.00
Kadiri-9	28.00	7.18	113.00	111.00	31.60	44.86	116.00	1.73	54.10	17.23
Kadiri-1812	28.67	10.86	126.00	124.00	27.57	38.99	130.67	2.48	47.67	18.57
TCGS-2055	27.00	7.90	152.00	150.00	28.65	38.77	107.33	2.20	49.00	17.81
TCGS-2301	27.67	7.03	56.33	54.67	31.77	53.97	105.67	1.67	50.53	20.37
TCGS-2359	27.67	6.87	100.00	98.67	22.48	33.03	110.67	1.83	48.10	20.27
TCGS-2361	25.67	7.95	112.33	110.33	28.86	35.32	111.67	1.68	51.20	16.99
TCGS-2368	27.33	6.56	85.67	84.00	31.50	37.30	112.67	2.18	43.53	17.48
TCGS-2369	27.33	8.09	84.67	82.67	33.21	46.19	111.00	2.46	42.97	25.87
TCGS-2370	28.00	8.77	65.67	64.33	29.80	39.66	115.67	1.74	44.23	17.90
TCGS-2490	26.00	5.52	115.00	113.00	33.78	31.81	112.00	2.33	47.43	18.78
Mean	**26.83**	**7.83**	**114.08**	**112.10**	**29.96**	**39.29**	**112.65**	**2.14**	**47.22**	**18.49**
S.Em. ±	**0.71**	**0.46**	**5.88**	**5.82**	**1.25**	**2.42**	**1.37**	**0.16**	**1.81**	**1.12**
C.D. (0.05)	**2.03**	**1.33**	**16.84**	**16.66**	**3.59**	**6.93**	**3.92**	**0.47**	**5.18**	**3.22**
C.V. (%)	**4.57**	**10.26**	**8.93**	**8.99**	**7.25**	**10.68**	**2.10**	**13.31**	**6.63**	**10.52**

branches differed significantly among the seed sizes and varieties.

Initial plant population for different genotypes ranged from 56.33 to 152.00. Significant differences were found among the genotypes and highest initial plant population was recorded by TCGS-2055 (152) followed by TAG-24 (141) and lowest initial plant population was observed in TCGS-2301 (56.33) followed by TCGS-2370 (65.67). Final plant population of twenty genotypes was ranged from 54.67 to 150.00 Significant differences were found among the genotypes and highest final plant population was recorded by TCGS-2055 (150). Second highest final plant population was found in TAG-24 (139). Lowest final plant population was recorded in TCGS-2301 (54.67) followed by TCGS-2370 (64.33).

Plant height for different genotypes ranged from 22.48 to 35.43 cm. Significant differences were found among the genotypes and highest plant height was recorded by Dheeraj (35.43 cm) and second highest plant height was recorded by Kadiri-7 (33.97 cm). Lowest plant height was recorded by TCGS-2359 (22.48 cm) followed by TCGS-1694 (26.29 cm). Maurya *et al*. (2006) showed the similar findings that analysis of variance revealed the prevalence of significant difference among the genotypes for plant height. Bharathi (2010) reported that the plant height increased with increase in age of the crop and attained maximum plant height at harvest in all the seed sizes.

Total dry matter production for different genotypes ranged from 27.69 to 53.97 g. Significant differences were found among the genotypes and highest total dry matter production was recorded by TCGS-2301 (53.97 g) followed by Kadiri-8 (53.03 g). Lowest total dry matter production was recorded by Kadiri-6 (27.69 g) followed by TCGS-2490 (31.81 g).

Days to maturity found significant differences among the genotypes and highest was recorded by Kadiri-1812 (130.67) followed by Kadiri-8(125.33) and lowest was TAG-24 (96.33) followed by Central Pragathi (105.33). Similar findings of Maurya *et al*. (2014) reported that analysis of variance revealed the prevalence of significant differences among the genotypes for days to maturity.

Leaf area index for different genotypes ranged from 1.60 to 2.84. Significant differences were found among the genotypes and highest was recorded by TCGS-1694 (2.84) followed by Dharani (2.73). Lowest leaf area index was found in Nithya Haritha (1.60) followed by TAG-24 (1.61).

SCMR for different genotypes ranged from 42.97 to 54.10. Significant differences were found among the genotypes and highest was recorded by Kadiri-9 (54.10). Second highest SCMR was recorded by Kadiri-8 (52.63) and lowest by TCGS-2369 (42.97) followed by TCGS-2368 (43.53).

The data of different genotypes for pod yield per plant with mean of 18.49 (g). Pod yield per plant for different genotypes ranged from 12.86 g to 28.13 g. Significant differences were found among the genotypes and highest pod yield per plant was recorded by Kadiri-7 (28.13 g). Second highest pod yield per plant was recorded by TCGS-2369 (25.87 g). Lowest pod yield per plant was observed in Dharani (12.86 g) followed by Central Pragathi (14.94 g).

The pod yield of genotypes was mainly due to favourable yield contributing characters like number of pods per plant, number of kernels and harvest index. These findings were on the similar lines to those reported by Borate *et al*. (1993)

Among all the genotypes, TAG-24 was the earliest genotype with respect to 50% flowering and maturity. Dheeraj is tall and TCGS-2359 is short in stature. Number of branches per plant were highest in Kadiri-8 and least in TCGS-2490. Leaf area index was highest in TCGS-1694 and least was observed in Nithya Haritha. SCMR was highest in Kadiri-9 and least was observed in TCGS-2369. Total dry matter production was highest in TCGS-2301and least was observed in Kadiri-6. Highest pod yield per plant was recorded by Kadiri-7.

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ASSESSMENT OF GENETIC VARIABILITY FOR LODGING RESISTANCE AND YIELD TRAITS IN DIVERSE RICE (*Oryza sativa* L.) GENOTYPES

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ABSTRACT

The field experiment was conducted during the *Rabi* 2024–2025 season at the Agricultural Research Station, Nellore, India to study the genetic variability, heritability, and genetic advance for lodging resistance and yield-related traits in a panel of 100 rice genotypes. Eleven key traits were evaluated viz., plant height, number of tillers per plant, culm thickness, culm diameter, panicle length, panicle weight, number of grains per panicle, grain yield per plant, section modulus, bending stress, and bending moment. Statistical analysis revealed significant genetic variation among the genotypes for all the studied traits. Traits such as panicle weight, number of grains per panicle, grain yield, section modulus, bending stress, and bending moment exhibited high genotypic and phenotypic coefficients of variation, indicating a broad range of variability. High heritability coupled with high genetic advance were observed for all the traits under study, suggesting the predominance of additive gene effects and the potential for effective improvement through pedigree method. These results highlight the importance of prioritizing high-heritability traits to accelerate genetic gains in breeding programs focused on enhancing lodging resistance and yield performance in rice.

KEYWORDS: Lodging resistance, variability, genetic advance, Rice, Bending moment.

INTRODUCTION

Rice (*Oryza sativa* L.) is the second most significant staple grain crop in the world after wheat. Rice serves as a primary source of calories for nearly half of the global population and holds a dominant position in terms of cultivation area and production, particularly in South and South-East Asian regions. However, yield losses due to various stresses, shrinking arable land, and rising population pose serious challenges. Climate change, with unseasonal rains and strong winds, further aggravates the problem by causing lodging, affecting both yield and quality. Proactive measures are needed to address these climate-induced stresses. Lodging is not only influenced by natural environmental factors but also by agronomic practices *viz.,* Excessive nitrogen application, inappropriate sowing dates and plant density, as well as factors like soil compaction and diseases such as sheath rot, significantly contribute to the risk of lodging (Zhang *et al*. 2014, 2016; Pan *et al*. 2019). Lodging can be categorized into three major types i.e., root lodging, bending type lodging, and breaking type lodging (Grafius and Brown 1954; Hirano *et al*. 2017). Upland-cultivated rice develops a weak root system leading to root lodging (Laosut m strength and for further improvement, knowledge of the genetic control of mechanisms that regulate culm strength is a prerequisite" (Badri *et al*. 2024).

The presence of adequate genetic variability is the fundamental pre-requisite to conduct any crop improvement programme. Therefore, it is essential to analyze the extent of variability within the species, understand the relationships among traits, and determine the contribution of each trait to enhancing rice productivity through breeding efforts (Khan *et al*. 2020). The genotypic coefficient of variation (GCV) indicates the extent of genetic variability and represents the inheritable component of trait variation. Genetic variability along with heritability estimates would provide the amount of genetic gain expected out of selection". Therefore, assessing variability is vital for establishing effective selection criteria aimed at enhancing culm strength and improving yield potential.

MATERIAL AND METHODS

A set of 100 rice genotypes were evaluated during 2024-25 rabi season at Agricultural Research Station (ARS), ANGRAU, Nellore, Andhra Pradesh, India. The genotypes were sown in the raised bed and transplanted into the main field 27 days after

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sowing with the spacing of 20 x 15 cm in Aplha Lattice Design. All the package of practices were followed for the good establishment of the crop. The genotypes were evaluated and observations were recorded on five randomly selected plants in each replication for morphological traits *viz.,* plant height (PH) (cm), tiller number (TN), culm thickness (CT) (mm), culm diameter (CD) (mm), section modulus (mm3), bending stress (BS) (Kg mm^{-2}), bending moment (BM) (g $stem^{-1}$), panicle length (PL) (cm), panicle weight (PW), number of grains per panicle (NGP), grain yield (GY). The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were computed following the procedure outlined by Burton *et al*. 1952. The magnitude of variability was classified based on the criteria suggested by Sivasubramanian and Madhavamenon (1973). Broad-sense heritability (h^2) and genetic advance as a percentage of the mean (GAM) were estimated using the methods described by Lush 1940 and Johnson et al. 1955 respectively.

The following traits were determined as per Ookawa *et al*. 2010 and Badri *et al*. 2024

Culm diameter (CD) = $(a_1+b_1)/2$

Culm thickness (CT) = $[(a_1+b_1)/2] – [(a_2+b_2)/2]$

Section modulus (SM) = $\pi/32 \times (a_1\ 3b_1\text{-}a_2\ 3b_2)/a_1$

Where, $a_1$is the outer diameter of the minor axis in an oval cross-section,

$b_1$is the outer diameter of the major axis in an oval cross-section.

a_2 is the inner diameter of the minor axis in an oval cross-section,

b_2 is the inner diameter of the major axis in an oval cross-section.

Bending stress (BS) = (TR÷40) × (1000÷TN)

Bending moment at breaking (M) = Section modulus (SM) × Bending stress (BS)

Where; TR is the prostrate tester reading value (measure of pushing resistance) and TN is the tiller number. The prostrate tester (DIK-7400, Daiki Rika Kogyo Co. Ltd., Tokyo, Japan) was used to measure the pushing resistance of the culm.

RESULTS AND DISCUSSION

The identification of the key traits that can be used in crop improvement through various breeding techniques is extremely important. The observed variability, heritability estimates, and the strength and direction of trait associations, provide a clear understanding of the underlying genetic architecture. These findings form a robust basis for selecting desirable traits to enhance culm strength in rice breeding programs.

Analysis of variance for 11 lodging resistance and yield related traits revealed significant differences among the genotypes for all the traits under study, indicating the existence of greater variability among the genotypes. Such variability forms the foundation for effective selection in breeding programs.

The variability analysis indicated that PCV was consistently higher than GCV for all traits (Table 1), suggesting that phenotypic variation was influenced by both genetic and environmental factors. Plant height exhibited moderate variability (GCV: 19.37%, PCV: 19.52%), with very high heritability (98.50%) and high genetic advance as percent of mean (GAM: 39.61%), implying strong additive gene action and effective selection potential, in agreement with Srilakshmi et al. (2018), and Sahu *et al*. (2024). Similarly, number of tillers per plant showed moderate GCV (17.92%) and PCV (18.57%), high heritability (93.13%), and GAM (35.63%), supporting its improvement through selection, as observed by Akshay *et al*. (2022) and Arun *et al*. (2023). Culm thickness and culm diameter both recorded high genetic variability (GCV: 16.98% and 17.35%) and heritability (92.79% and 98.61%), with GAM values of 33.68% and 35.49%, respectively suggesting reasonable scope for improvement, as supported by Nomura *et al*. (2021), Silva *et al*. (2022) and Arun *et al*. (2023). The section modulus also showed high GCV (30.57%), heritability (99.16%), and GAM (62.70%), indicating the effectiveness of selection, which is in line with the observations of Akshay *et al*. (2024). Bending stress and bending moment exhibited high variability and heritability (95.34% and 98.14%), with respective GAM values of 51.23% and 104.16%, indicating potential for significant genetic gains, as reported by Akshay *et al*. (2024). Panicle length showed moderate GCV (12.59%),

Table 1. Estimates of Genetic variability parameters for lodging resistance and yield related traits in rice

S. No.	Character	Mean	Range		Coefficient of Variation (%)		Heritability in broad sense (h^2) (%)	GA	GA as percent of mean
			Min	Max	Genotypic	Phenotypic			
1.	Plant height (cm)	88.62	60.60	154.40	19.37	19.52	98.50	35.06	39.61
2.	No of tillers per plant^{-1}	14.76	9.42	28.80	17.92	18.57	93.13	5.26	35.63
3.	Culm thickness (mm)	1.01	0.56	1.64	16.98	17.62	92.79	0.34	33.68
4.	Culm diameter (mm)	5.25	2.87	7.64	17.35	17.47	98.61	1.86	35.49
5.	Panicle length (cm)	21.49	13.74	29.38	12.59	13.21	90.84	5.31	24.71
6.	Panicle weight (g)	2.86	1.12	6.36	37.66	38.04	98.01	2.20	76.81
7.	No of grains per panicle	137.49	37.00	283.80	38.18	38.46	98.54	107.34	78.07
8.	Grain yield per plant^{-1} **(g)**	17.58	5.21	36.96	40.06	40.54	97.64	14.34	81.55
9.	Section modulus (mm^3)	8.92	4.42	19.30	30.57	30.70	99.16	5.60	62.70
10.	Bending stress (kg mm^{-2})	15.89	8.65	29.30	25.47	26.09	95.34	8.14	51.23
11.	Bending moment (g $stem^{-1}$)	148.32	51.38	437.37	51.04	51.52	98.14	154.49	104.16

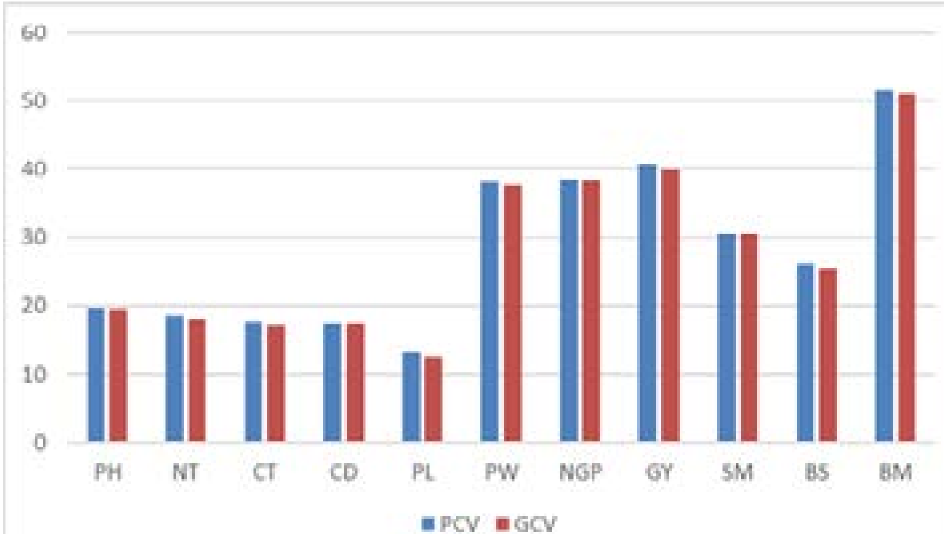

Fig 1. Phenotypiccoefficient of variation (PCV) and genotypic coefficient of variation (GCV) for 11 traits in Rice

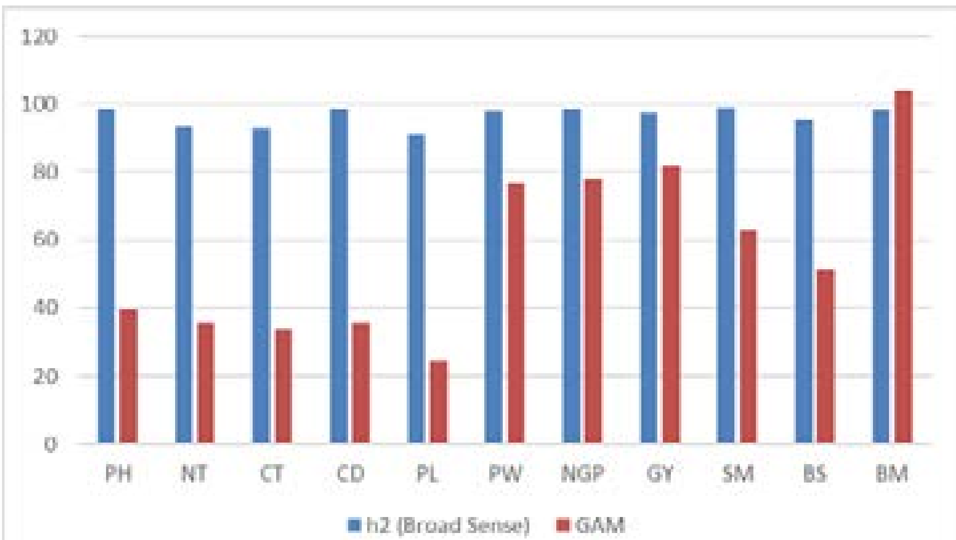

Fig. 2. Heritability (H_2bs) and genetic advance as percent of mean (GAM) for 11 traits in Rice

high heritability (90.84%), and GAM (24.71%), while Panicle weight and number of grains per panicle displayed high variability, with heritability estimates of 98.01% and 98.54%, and genetic advance as percent of mean values of 76.81% and 78.07%, respectively, suggesting considerable potential for selection gains. These results corroborate the findings of Hasan *et al*. (2022), Arun *et al*. (2023), and Harsharaj *et al*. (2024)Notably, grain yield per plant had the highest GCV (40.06%), PCV (40.54%), heritability (97.64%), and GAM (81.55%), indicating that it is largely controlled by additive gene action and can be improved efficiently through direct selection, accordance with Demeke *et al*. (2023) and Harsharaj *et al*. (2024). Overall, the combination of high heritability and high genetic advance observed for all the studied traits, indicates predominance of additive gene action, suggesting that direct selection would be highly effective in achieving genetic improvement, enhance genetic gain and accelerate progress in rice breeding programs.

The present study revealed substantial genetic variability, along with high heritability and notable genetic advance for several important lodging resistance and yield-related traits in rice. Traits such as culm thickness, culm diameter, section modulus, bending stress, bending moment, panicle weight, number of grains per panicle, and grain yield per plant were found to be under strong genetic control, indicating the effectiveness of direct selection for these traits in breeding programs. These findings offer valuable guidance for rice breeders in developing lodging-resistant and high-yielding varieties, thereby supporting sustainable rice cultivation and addressing the growing challenges of global food demand and resource limitations.

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YIELD AND NUTRIENT UPTAKE AS INFLUENCED BY IRRIGATION REGIMES AND NITROGEN LEVELS IN SUMMER SESAME (*Sesamum indicum* L.)

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ABSTRACT

A field experiment was conducted during summer, 2025 at S.V. Agricultural College Farm, Tirupati. The experiment was laid out in split-plot design and replicated thrice. The treatments consisted of three irrigation regimes viz., IW/CPE-0.6 (I1), IW/CPE-0.8 (I_2) and IW/CPE-1.0 (I_3) assigned to main plots and four nitrogen levels *viz.,* control (N_1), 40 kg N ha^{-1} (N_2), 60 kg N ha^{-1} (N_3) and 120 kg N ha^{-1} (N_4) allotted to sub plots. The results of the study revealed that significantly higher dry matter production, seed yield and uptake of N, P and K by sesame was recorded with scheduling of irrigation at IW/CPE-1.0. Application of 120 kg N ha^{-1} resulted in significantly higher dry matter production, seed yield and uptake of N, P and K by sesame crop and the lower nutrient uptake of N, P and K by sesame crop was registered with control. Scheduling of irrigation at IW/CPE-1.0 along with application of 120 kg N ha^{-1} resulted in higher dry matter production, seed yield and uptake of N, P and K by sesame crop.

KEYWORDS: Irrigation regimes, IW/CPE, Nitrogen levels, Sesame.

INTRODUCTION

Sesame (*Sesamum indicum* L.) is an important oilseed crop cultivated in India. The crop is more commonly referred as 'Queen of Oilseeds' which contains 50-60% oil, 8% protein, 5.8% water, 3.2% crude fiber, 18% carbohydrates, 5.7% ash and it is very rich in minerals such as calcium, phosphorus and vitamin E. Globally, India is the largest sesame producer and it is cultivated in an area of 15.23 lakh hectares with a production of 8.47 lakh tonnes and productivity of 553 kg ha^{-1} during 2023-24. In Andhra Pradesh, sesame is grown over an area of 0.31 lakh hectares with an annual production of 0.11 lakh tonnes and productivity of 376 kg ha^{-1} (www.indiastat.com, 2023-24). Irrigation is of great importance to sesame production due to it's positive effect on flowering and capsules formation. Water stress limits sesame growth and development. Besides meeting water requirement of crop plants, supply of irrigation water may cause considerable changes in availability of plant nutrients in soil through stimulation of microbial activities and dissolution of salts. Hence, assured water supply through efficient irrigation practice is an essential basic input for obtaining higher yield. Nitrogen plays a key role as it is a constituent of protein, nucleic acid and chlorophyll. It also plays an important role in synthesis of chlorophyll and amino acids that contributes to the building unit of protein and thus growth of plants. An adequate supply of nitrogen is essential for vegetative growth and desirable yield. On the other hand, excessive application of nitrogen is not only uneconomical, but it can also prolong the growing period and delay the crop maturity. Among agronomic interventions, the two most crucial inputs boosting the seed yield and quality of summer sesame are irrigation and nitrogen. However, the limited work done on this aspect for white sesame does not provide a comprehensive information on its irrigation and nitrogen requirement for summer season.

MATERIAL AND METHODS

The field experiment was conducted at S.V. Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University, Andhra Pradesh during summer, 2025. The soil of experimental field was sandy loam in texture, neutral in reaction, low in organic carbon (0.26%) and available nitrogen (187 kg ha^{-1}), medium in available phosphorus (27.3 kg ha^{-1}) and available potassium (197.5 kg ha^{-1}). The experiment was laid out in split-plot design and replicated thrice. The treatments consisted of three irrigation regimes *viz.,* IW/CPE-0.6 (I1), IW/CPE-0.8 (I_2) and IW/CPE-1.0 (I_3) assigned to

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Table 1. Dry matter production (kg ha^{-1}) and seed yield (kg ha^{-1}) of sesame as influenced by irrigation regimes and nitrogen levels

Treatments	Dry matter production	Seed yield
Main plots: Irrigation regimes		
I_1: IW/CPE- 0.6	2177	665
I_2: IW/CPE- 0.8	2571	763
I_3: IW/CPE- 1.0	3096	885
SEm±	76.1	18.0
CD (P=0.05)	307	72
Sub plots: Nitrogen levels		
N_1: 0 kg N ha^{-1}	1386	389
N_2: 40 kg N ha^{-1}	2420	635
N_3: 80 kg N ha^{-1}	3132	938
N_4 : 120 kg N ha^{-1}	3521	1105
SEm±	105.7	22.9
CD (P=0.05)	316	69
Interaction		
N at I		
SEm±	152.1	35.9
CD (P=0.05)	NS	128
I at N		
SEm±	175.8	38.8
CD (P=0.05)	NS	125

main plots and four nitrogen levels viz., control (N_1), 40 kg N ha^{-1} (N_2), 60 kg N ha^{-1} (N_3) and 120 kg N ha^{-1} (N_4) allotted to sub plots. The crop period (January to April) was characterized by the weekly mean maximum temperature during the crop growth period ranged from 29.8 to 39.2°C and weekly mean minimum temperature during the crop period ranged from 12.8 to 23.6°C. Total amount of 2 mm of rainfall was received during the crop growth period. "Swetha Til" was used as a test variety and sown at a spacing of 30 cm x 15 cm with a seed rate of 5 kg ha^{-1}. The crop was sown on 23-01-2025 and harvested on 26-04-2025 during the study period. Two common irrigations of 50 mm each were given, one at post sowing for emergence and second at 8th day after sowing for crop establishment. Thinning and gap filling were done at 15 days after sowing. Scheduling of irrigation was started whenever the cumulative pan evaporation (CPE) reached the value of 83.3, 62.5 and 50 mm in I_1, I_2 and I_3 treatments. A common dose of 20 kg P_2O_5 and 20 kg K_2O ha^{-1} was applied basally. Nitrogen was applied in two equal split doses *i.e*, as basal and at 25 DAS as per the treatments. The other recommended cultural and pest management practices were adopted.

RESULTS AND DISCUSSION

Higher dry matter production was recorded with irrigation scheduled at IW/CPE ratio of 1.0 followed by that with IW/CPE ratio of 0.8 and IW/CPE ratio of 0.6 in the order of descent with significant disparity between each other. This might be due to optimum soil moisture availability favouring the nutrient uptake attributing to increased plant height and leaf area maintained throughout the crop period resulting in enhanced synthesis, which ultimately led to higher dry matter production. Similar findings were reported by Reddy *et al*. (2010) and Tripathy and Bastia, (2012). Dry matter production of sesame was found to be significantly higher with application of 120 kg N ha^{-1} than with 80

Table 2. Seed yield (kg ha^{-1}) of sesame as influenced by irrigation regimes and nitrogen levels

Treatments	**Irrigation regimes**			
Nitrogen levels	I_1: IW/CPE- 0.6	I_2: IW/CPE- 0.8	I_3: IW/CPE- 1.0	**Mean**
N_1: 0 kg N ha^{-1}	320	409	439	389
N_2: 40 kg N ha^{-1}	617	649	692	653
N_3: 80 kg N ha^{-1}	811	877	1124	938
N_4: 120 kg N ha^{-1}	913	1118	1284	1105
Mean	665	763	885	

	SEm±	**CD (P=0.05)**
I	18.0	72
N	22.9	69
N at I	35.9	128
I at N	38.8	125

kg N ha^{-1}. The next best nitrogen level was 40 kg ha^{-1}. It could be attributed to the fact that due to higher leaf area with greater photosynthetic activity together result in increased dry matter accumulation at higher level of nitrogen. These findings were in close conformity with those of Reddy *et al*. (2010). Significantly lower dry matter production was observed with control.

Higher seed yield of sesame was recorded with the scheduling of irrigation at IW/CPE ratio of 1.0, which was significantly superior than the other irrigation regimes tried. This was followed by IW/CPE ratio of 0.8, which was significantly superior to that of IW/CPE ratio of 0.6, which recorded the lower seed yield. Higher seed yield due to irrigation might be accounted to their favourable influence on the crop growth and yield attributes. These findings were in line of the findings of Reddy *et al*. (2010).

With regard to the varied nitrogen levels, application of 120 kg N ha^{-1} resulted in significantly higher seed yield. The next best nitrogen level was 80 kg N ha^{-1}, which was significantly superior to that of 40 kg N ha^{-1}. The lowest seed yield was observed with control. Better availability of nitrogen with application of 120 kg N ha^{-1} might have enhanced the total biomass accumulation and its efficient translocation from source to sink which resulted in elevated growth parameters (Plant height, dry matter production and leaf area index) and yield attributes (number of branches plant-1, number of capsules plant-1, weight of seeds capsule-1 and test weight) and hence the seed yield. Similar results were also reported by Jamdhade *et al*. (2017). The interaction effect due to irrigation regimes and nitrogen levels practices was found to be significant. Scheduling of irrigation at IW/CPE ratio of 1.0 along with 120 kg N ha^{-1} resulted in the highest seed yield. These might be due to the better availability of nutrients under higher soil moisture and at high nitrogen conditions which might have increased the crop growth and translocation of photosynthates from source to sink. Interaction effect between irrigation regimes and nitrogen levels with respect to seed yield were in conformity with the findings of Reddy *et al*. (2010). The lowest seed yield was recorded with scheduling of irrigation at IW/CPE ratio of 0.6 along with control (I1N1).

Nutrient uptake by plant at harvest was found to be significantly influenced by irrigation regimes and nitrogen levels. The interaction effect of irrigation regimes and nitrogen levels on nitrogen uptake was found significant, while phosphorus and potassium uptake were not statistically significant. The higher nutrient

Table 3. Nutrient uptake (kg ha) of sesame at harvest as influenced by irrigation regimes and nitrogen levels

Treatments	Nitrogen	Phosphorus	Potassium
Main plots: Irrigation regimes			
I_1: IW/CPE- 0.6	49.6	15.8	29.7
I_2: IW/CPE- 0.8	65.4	18.2	32.0
I_3: IW/CPE- 1.0	77.1	20.4	33.9
SEm±	1.83	0.38	0.42
CD (P=0.05)	7.4	1.5	1.7
Sub plots: Nitrogen levels			
N_1: 0 kg N ha^{-1}	37.2	16.6	30.2
N_2: 40 kg N ha^{-1}	57.3	17.6	31.4
N_3: 80 kg N ha^{-1}	74.2	18.5	32.4
N_4: 120 kg N ha^{-1}	87.4	19.8	33.4
SEm±	2.28	0.20	0.54
CD (P=0.05)	6.8	0.6	1.6
Interaction			
N at I			
SEm±	3.66	0.76	0.85
CD (P=0.05)	12.7	NS	NS
I at N			
SEm±	3.88	0.49	0.92
CD (P=0.05)	12.5	NS	NS

(nitrogen, phosphorus and potassium) uptake at harvest was observed with the scheduling of irrigation at IW/CPE ratio of 1.0, which was significantly higher than the other irrigation regimes tried. This might be due to optimal air and water balance in the soil, which consequently increased the mobilization of the nutrients along with the absorbed water through well-developed root system. This was followed by IW/CPE ratio of 0.8, which was significantly superior to that of IW/CPE ratio of 0.6, which recorded significantly lower nutrient uptake. The results demonstrate that the uptake of N, P and K was recorded higher, when the crop was irrigated at IW/CPE ratio of 1.0. At lower irrigation frequency, insufficient soil water might not have facilitated mass flow, root interception and diffusion processes to mobilize the nutrients for uptake. The uptake pattern mostly followed the biomass yield trend. The results were in conformity with the findings of Tripathy and Bastia, (2012) and Dutta *et al*. (2015). With regard to nitrogen levels tried, application of 120 kg N ha^{-1} resulted in higher nutrient (nitrogen, phosphorus and potassium) uptake, which was significantly superior than with 80 kg N ha^{-1}. The later was in turn significantly superior to that of 40 kg N ha^{-1}. Significantly lower nutrient uptake was noticed with control. Application of 120 kg N ha^{-1} might have improved the microbial activity through enhanced root exudates and increased translocation of nutrients which might have contributed to higher nitrogen, phosphorus and potassium contents respectively in the plant tissue which were further being complemented with their higher dry matter production. These results were in accordance with the findings of Sarkar *et al*. (2010), Patel *et al*. (2014) and Chauhan *et al*. (2016). The interaction effect of irrigation regimes and nitrogen levels on nitrogen uptake was found to be significant. The highest nitrogen uptake was recorded with scheduling of irrigation at

Table 4. Nitrogen uptake (kg ha^{-1}) of sesame as influenced by irrigation regimes and nitrogen levels

Treatments	Irrigation regimes			
Nitrogen levels	I_1: IW/CPE- 0.6	I_2: IW/CPE- 0.8	I_3: IW/CPE- 1.0	**Mean**
N_1: 0 kg N ha^{-1}	27.9	34.9	48.7	37.2
N_2: 40 kg N ha^{-1}	51.7	53.8	66.4	57.3
N_3: 80 kg N ha^{-1}	56.4	80.9	85.3	74.2
N_4: 120 kg N ha^{-1}	62.3	91.9	108.0	87.4
Mean	49.6	65.4	77.1	

	SEm±	**CD (P=0.05)**
I	1.83	7.4
N	2.28	6.8
N at I	3.66	12.7
I at N	3.88	12.5

IW/CPE ratio of 1.0 along with 120 kg N ha^{-1} and the lowest nitrogen uptake was recorded with scheduling of irrigation at IW/CPE ratio of 0.6 along with control.

Scheduling of irrigation at IW/CPE-1.0 along with 120 kg N ha^{-1} resulted in higher dry matter production, seed yield and NPK uptake by sesame at harvest during summer on sandy loam soils of Southern Agro-Climatic Zone of Andhra Pradesh.

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CONSUMERS' BUYING BEHAVIOUR TOWARDS ORGANIC FOODS IN RETAIL OUTLETS OF ANANTHAPURAMU CITY, ANDHRA PRADESH

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ABSTRACT

This study explores consumer buying behaviour towards organic foods in Ananthapuramu city, Andhra Pradesh, based on a survey of 150 respondents across five retail outlets. The study aimed to assess awareness, preferences, willingness to pay, price acceptance and the influence of demographic variables. The majority of consumers were aged 21-35 years, held undergraduate degrees and earned ₹25,001-₹50,000 monthly. Grains followed by millets, vegetables, fruits and pulses were the most preferred organic categories, while meat, eggs and baby foods were least preferred. Nearly half the respondents were willing to pay a premium, mainly up to 20 per cent, with most allocating 11-30 per cent of their monthly food budget to organic products. Factor analysis revealed ten key behavioural influences such as health and safety, environmental and ethics, reference group, awareness, affordability and availability, convenience, credibility, brand and promotional, palatability and visual appeal explaining 73.81 per cent of total variance. Age and income significantly influenced several behavioural factors. The study highlights the need for affordable pricing, trust-building and awareness campaigns to strengthen organic food adoption in Tier-II cities.

KEYWORDS: Organic food, Consumer behaviour, Factor analysis, Price acceptance, Willingness to pay.

INTRODUCTION

India's agricultural sector is witnessing a shift as health concerns, environmental degradation, and food safety issues drive consumer interest toward organic products. Organic farming, which avoids synthetic inputs and promotes sustainable practices like composting and crop rotation, offers a viable solution. Globally, the organic food market crossed USD 350 billion by 2025, with India emerging as a leader in certified organic production (FiBL and IFOAM, 2025).

Urban centers like Ananthapuramu are seeing growing demand for organic foods, driven by rising awareness and income. Yet, challenges such as limited awareness, price sensitivity, and certification trust continue to impact consumer adoption. This study examines consumer awareness, preferences, willingness to pay for organic foods, factors influencing the buying behaviour and chi-square test was adopted to explore the association of identified factors with demographic variables.

MATERIAL AND METHODS

The study was conducted in Ananthapuramu city, Andhra Pradesh, using an ex-post facto research design. A total of 150 organic food consumers were selected through judgmental sampling from five purposively chosen retail outlets. Statistical tools used include descriptive statistics, Garrett's Ranking, Chi-square test, Cross-tabulation and Factor analysis. Data were collected using structured interviews and google forms covering demographics, willingness to pay and price acceptance. Consumer price acceptance was measured using Likert scale statements and categorized into 3 based on mean and standard deviation. Factor analysis with PCA and varimax rotation was applied to identify key behavioural dimensions. The suitability of data was confirmed using KMO and Bartlett's tests. Chi-square tests were used to examine the association between demographic variables and the identified factors.

RESULTS AND DISCUSSIONS

I.Socio-Economic Profile of The Consumers

Table 1 shows that out of 150 respondents, more than half (54.0%) were male and 46.0 per cent were female. A majority (52.0%) were aged 21-35 years; these results are in line with findings of Kataria *et al.* (2019) and Magesh and Rajeswari (2024). With regard

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to education most of the respondents (56.0%) studied undergraduate or higher. In terms of income 39.3 per cent of them earned ₹25,001-₹50,000 and 28.0 per cent earned ₹50,001-₹1,00,000. Regarding marital status, 52.7 per cent of them were married. The largest occupational group was private employees with 27.3 per cent followed by business/self-employed (18.0%), students (16.7%) & homemakers (16.0%). Over 54.0 per cent of them belonged to households with 4-6 members. These findings suggest that organic food consumption is driven by a younger, educated and economically stable population whose awareness, digital access and health consciousness contribute to their willingness to pay a premium & accept existing price levels for organic food.

II.Consumer Awareness and Buying Behaviour Towards Organic Foods

Table 2 indicates that the total number of the sample respondents was 150. Among them 68.7 per cent had been aware of organic foods for over three years, while only 4.0 per cent had recent awareness, indicating limited new consumer reach. Social media was the leading source of awareness (30.7%), followed by in-store promotions (22.0%) and friends/family (16.0%). Awareness of organic certifications remained low, with 46.0 per cent showing limited understanding. With regard to frequency of purchase, nearly half (49.3%) of the respondents had quarterly purchase and 22.0 per cent had monthly followed by fortnightly (18.0%), occasionally (6.0%) and weekly (4.7%).

Organic outlets (44.0%) and supermarkets (29.3%) were the main places of purchase, while in-person buying (57.3%) remained the preferred mode. Long-term users (over 3 years) accounted for 38.7 per cent, showing stable loyalty, with only 16.0 per cent being recent adopters. Regarding brand consideration, less than half (41.3%) considered brand as important, 37.3 per cent did not felt. However, 21.3 per cent were neutral, which reflects mixed preferences between brand trust and other attributes like price or origin.

Table 3 indicates that grains (mean score: 74.05), millets/instant foods (73.48) and vegetables (69.74) were the most preferred organic categories, while baby foods (23.87%), meat (36.81%) and eggs (36.77%) were least preferred, this preference pattern in the current study is also supported by Tanishka and Thangavel (2021).

III.Consumers' Willingness to Pay and Price Acceptance of Current Retail Prices

3.1.Consumers' willingness to pay, extent of premium and expenditure share on organic foods

Table 4 outlines respondents' willingness to pay a premium, the extent of that premium and their monthly expenditure on organic foods. About 48 per cent of the respondents were willing to pay more and 30 per cent were uncertain followed by 22 per cent were unwilling, these results indicating a cautiously receptive attitude towards premium pricing. Among these, 27.3 per cent preferred an 11-20 per cent premium and 23.3 per cent accepted up to 10 per cent, suggesting greater tolerance for modest price hikes. Only a smaller segment (14.7% and 12.7%) was open to premiums above 20 per cent.

Regarding expenditure 42 per cent allocated 21-30 per cent of their monthly food budget to organic foods next by 28.7 per cent respondents allocating 11-20 per cent. Less than one tenth of the respondents reported spending more than 30 per cent, reflecting that while organic foods are increasingly mainstream, affordability still shapes spending patterns. These findings align with Tanishka and Thangavel (2021).

3.2 Consumers' Acceptance of Current Prices for Organic Food Products

Table 5 presents the level of consumer acceptance toward the current pricing of organic food products, categorized across four key statements. Responses were grouped into low, moderate and high acceptance levels to assess varying degrees of consumer sentiment regarding pricing flexibility, continued purchasing and price-related preferences.

The analysis revealed that over half of the respondents (52.7%) moderately accepted current market prices, while 30.0 per cent expressed high acceptance, reflecting a generally balanced outlook. When asked about continued purchasing despite slight price increases, majority (66.7%) showed moderate acceptance and (20.7%) high acceptance, indicating resilience towards minor price fluctuations. However, 32.0 per cent of consumers strongly agreed that high prices discourage regular buying, with nearly half (47.3%) showing a moderate response highlighting price as a potential barrier. Notably, 52.0 per cent moderately agreed and 31.3 per cent strongly agreed that they

Table 1. Socio-economic profile of the consumers

S. No.	PARTICULARS	Frequency	Percentage (%)
	SEX		
1.	Male	81	**54.0**
2.	Female	69	46.0
	AGE GROUP		
1.	Below 20 years	16	10.7
2.	21- 35 years	78	**52.0**
3.	36 – 50 years	41	27.3
4.	More than 50 years	15	10.0
	EDUCATIONAL STATUS		
1.	No formal education	9	6.0
2.	Up to 10th standard	23	15.3
3.	Intermediate	34	22.7
4.	Undergraduate and above	84	**56.0**
	MONTHLY INCOME LEVEL		
1.	< Rs.25,000	30	20.0
2.	Rs.25,001 - Rs.50,000	59	**39.3**
3.	Rs.50,001 - Rs.1,00,000	42	28.0
4.	> ₹1,00,000	19	12.7
	MARITAL PROFILE		
1.	Unmarried	71	47.3
2.	Married	79	**52.7**
	OCCUPATION		
1.	Student	25	16.7
2.	Private Employee	41	**27.3**
3.	Government Employee	23	15.3
4.	Business	27	18.0
5.	Homemaker	24	16.0
6.	Others	10	6.7
	HOUSEHOLD SIZE		
1.	1 - 3 Members	35	23.3
2.	4 - 6 Members	81	**54.0**
3.	More than 6 Members	34	22.7

Table 2. Consumer awareness and buying behaviour towards organic foods (n=150)

S. No.	Parameter	Category	Frequency	Percentage (%)
1.	Duration of Awareness	Less than 1 year	6	4.0
		1 – 2 years	14	9.3
		3 years	27	18.0
		More than 3 years	94	68.7
2.	Source of Awareness	Friends / Family	24	16.0
		Television	19	12.7
		Social media / Online platforms	46	30.7
		In-store promotions / Retail displays	33	22.0
		Newspapers and Magazines	17	11.3
		Others	11	7.3
3.	Awareness on Organic Certifications	Low	69	46.0
		Moderate	50	34.7
		High	31	19.3
4.	Purchase Frequency	Weekly	7	4.7
		Fortnightly	27	18.0
		Monthly	33	22.0
		Quarterly	74	49.3
		Occasionally	9	6.0
5.	Preferred Place of Purchase	Organic Outlets	66	44.0
		Supermarkets	44	29.3
		Online Stores	19	12.7
		Direct from Farmers	21	14.0
6.	Mode of Purchase	Buying In-Person	86	57.3
		Online Purchase	25	16.7
		Phone / WhatsApp Orders	21	14.0
		Home Delivery Subscription	7	4.7
		Directly from Farms	11	7.3
7.	Duration of Consumption	Less than 1 year	24	16.0
		1 – 2 years	29	19.3
		3 years	36	26.0
		More than 3 years	61	38.7
8.	Brand Consideration	Yes	62	41.4
		No	56	37.3
		May or May Not	32	21.3

Table 3. Most preferred categories of organic foods among the sample respondents (n = 150)

S. No.	Organic Food Categories	Total	Mean score	Rank
1	Millet-Based & Instant Foods (Dosa mixes, upma mixes, khichdi, etc.)	11022	73.48	II
2.	Fruits	10357	69.05	IV
3.	Pulses	9884	65.89	V
4.	Grains (Cereals, Millets – Rice, Ragi, Jowar, Bajra, etc.)	11108	**74.05**	**I**
5.	Vegetables	10461	69.74	III
6.	Dairy (Milk, Curd, Paneer, Ghee, etc.)	9480	63.20	VI
7.	Organic Sweeteners and desserts	6795	45.30	XI
8.	Packaged Organic Snacks / Beverages (Cookies, Health Drinks, Energy Bars, etc.)	7152	47.68	IX
9.	Spices & Condiments (Turmeric, Chili Powder, Coriander, etc.)	6584	43.89	XIII
10.	Cooking oils	8702	58.01	VII
11.	Organic Pickles / Chutneys	6699	44.66	XII
12.	Mushroom	6061	40.41	XIV
13.	Dry Fruits & Nuts (Cashews, Almonds, Raisins, etc.)	7595	50.63	VIII
14.	Honey	6924	46.16	X
15.	Meat	5521	36.81	XV
16.	Eggs	5515	36.77	XVI
17.	Organic Baby foods	3581	23.87	XVII
18.	Others	2759	18.39	XVIII

Table 4. Consumers' willingness to pay, extent of premium and expenditure share on organic foods (n=150)

S. No.	Category	Frequency	Percentage (%)
	A. Willingness to Pay Premium		
1.	Willing to pay	72	**48.0**
2.	Not willing to pay	33	22.0
3.	Uncertain	45	30.0
	B. Extent of Price Premium Willing to Pay		
1.	Up to 10%	35	23.3
2.	11-20%	41	**27.3**
3.	21-30%	22	14.7
4.	More than 30%	19	12.7
5.	Unwilling to pay extra	33	22.0
	C. Monthly Expenditure Share on Organic Foods		
1.	Less than 10%	30	20.0
2.	11-20%	43	28.7
3.	21-30%	63	**42.0**
4.	31-40%	9	6.0
5.	More than 40%	5	3.3

Table 5. Consumers acceptance of current prices for organic foods (n = 150)

S. No.	Statement	Low Acceptance Level	Moderate Acceptance Level	High Acceptance Level
1.	I accept current market prices	26 (17.3%)	79 (52.7%)	45 (30.0%)
2.	I will continue buying even if prices increase slightly	19 (12.6%)	100 (66.7%)	31 (20.7%)
3.	High prices discourage regular buying	31 (20.7%)	71 (47.3%)	48 (32.0%)
4.	I prefer them if priced closer to regular ones	25 (16.7%)	78 (52.0%)	47 (31.3%)

Table 6. KMO and Bartlett's Test of Sphericity

Test	Value
Kaiser-Meyer-Olkin (KMO)	0.746
Bartlett's test of sphericity – χ^2	3382.5
Degrees of freedom (df)	561
Significance level (p-value)	0.000

Table 7. Total Variance Explained by Extracted Factors

Component	Eigenvalue	% of Variance	Cumulative %
1.	7.289	21.44%	21.44%
2.	5.233	15.39%	36.83%
3.	2.629	7.73%	44.56%
4.	2.154	6.33%	50.90%
5.	1.747	5.14%	56.04%
6.	1.376	4.05%	60.08%
7.	1.301	3.83%	63.91%
8.	1.231	3.62%	67.53%
9.	1.118	3.29%	70.82%
10.	1.018	2.99%	73.81%

would prefer organic products if priced closer to regular items, emphasizing the role of comparative pricing in influencing consumer decisions.

The results align with Aryal *et al*. (2009) and Nandi *et al*. (2016) who found consumers were willing to pay extra for organic products, mainly driven by health and quality concerns.

IV.FACTORS INFLUENCING CONSUMERS' BUYING BEHAVIOUR TOWARDS ORGANIC FOODS

4.1.KMO and Bartlett's Test of Sphericity

The adequacy of data for factor analysis was verified using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's Test of Sphericity. The KMO value was 0.746, indicating sampling adequacy. Bartlett's Test of Sphericity was significant (χ^2 = 3382.5, df = 561, p < 0.000), supporting the suitability of the data for factor analysis.

4.2 Factor Extraction and Variance Explained

Principal Component Analysis (PCA) was used to extract the key dimensions influencing consumer behaviour. Ten factors were retained based on eigen values greater than one, collectively explaining 73.81% of the total variance. The first three components alone accounted for 21.44%, 15.39% and 7.73% respectively, suggesting a strong data structure.

4.3 SCREE PLOT

The scree plot illustrates the eigenvalue distribution for the 34 components, with a distinct elbow at the 10th component. This supports the retention of ten factors, aligning with Kaiser's criterion (eigenvalues >1) and the cumulative variance of 73.81 per cent. Beyond this point, additional components contribute minimally.

4.4 .Factor Interpretation and Naming:

Based on the rotated component matrix using Varimax rotation, 10 significant factors were identified. Each factor consists of items with high loadings (≥ ±0.4), grouped & named in the following Table 8.

Factor analysis revealed that consumer buying behaviour towards organic food products is influenced by a diverse set of factors. Health and safety, environmental and ethics, affordability and availability, reference group, awareness, convenience factor and credibility factor attributes emerged as dominant influencers. This multi-dimensional insight can help retailers and marketers tailor their strategies to address specific consumer motivators more effectively. The findings align with Basha *et al*. (2015) and Sivathanu (2015), who reported that health, environment, awareness and convenience strongly influenced organic food choices supporting the top-ranked factors in the present study.

V.Association Between Demographic Variables and Behavioural Factors

Chi-square tests were conducted to examine the association between demographic characteristics (age and income) and the extracted behavioural factors. Significance levels were tested at 1%, 5% and 10%.

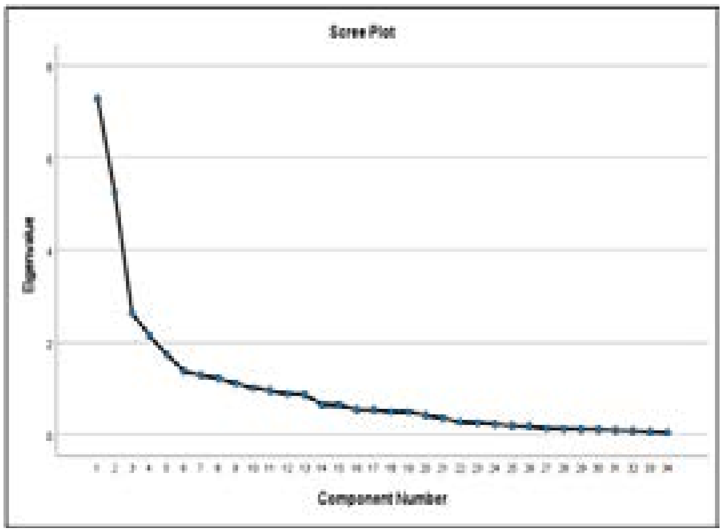

Figure 1: Scree Plot of Principal Component Analysis

Table 8. Summary of Factors Extracted from Factor Analysis

Factor No.	Factor Name	Significantly Loading Variables	Interpretation
1.	Health and Safety	Organic food is healthier (0.837) Free from harmful chemicals (0.762) Food safety concerns (0.580) For children health (0.557) High fibre/carb (0.571) Chemical risks awareness (0.719) Natural ingredients (0.702)	Indicates strong preference for health benefits as a primary motivation for organic food purchase.
2.	Environmental & Ethics	Environmental reasons (0.799) Supporting local farmers (0.779) Biodegradable packaging (0.533) Personal values (0.503)	Driven by eco-consciousness and social responsibility.
3.	Affordability & Availability	Reasonable price (0.683), Discounts (0.634) Affordability (0.657) Availability (0.574)	Price and cost-related factors impact organic purchase decisions.
4.	Credibility	Certification on pack (0.598) FSSAI check (0.810) Trust in certified products (0.689) Nutrition info (0.411)	Consumers value official labeling and safety assurances.
5.	Reference Group	Family encouragement (0.853) Doctor recommendation (0.473) Peer recommendation (0.621)	Decisions influenced by personal networks and healthcare advice.
6.	Convenience	Easy and fast cooking (0.912) Pre-packed format (0.538) Shelf-life (0.801)	Convenience and usability motivate purchases.
7.	Awareness	Attended awareness program (0.565) Influencer/Ad following (0.449) COVID-19 awareness (0.714)	Marketing and information exposure affect buying behaviour.
8.	Visual appeal	Smell, taste, texture (0.719) Packaging (0.692)	Aesthetic and sensory attributes influence consumer choices.
9.	Brand Influence	Brand matters (0.741) Celebrity endorsements (0.471)	Brand image and celebrity ties shape preferences.
10.	Palatability	Taste (0.467)	Taste remains a subtle yet stand-alone influence.

Table 9. Association with Age

Factor	Chi-square	p-value
Affordability and Availability	21.12	0.001***
Brand and Promotional	17.434	0.008**
Reference Group	15.167	0.019**
Health and Safety	14.16	0.028**
Convenience	13.038	0.043**
Awareness	11.424	0.076*
Credibility	11.88	0.064*
Environmental and Ethics	11.69	0.069*
Visual Appeal	5.668	0.461
Palatability	7.828	0.251

Table 10. Association with Income

Factor	Chi-square	p-value
Affordability and Availability	22.315	0.001***
Health and Safety	13.249	0.039**
Convenience	13.074	0.041**
Credibility	10.723	0.097*
Visual Appeal	11.64	0.071*
Awareness	6.264	0.282
Reference Group	9.212	0.162
Brand and Promotional	2.943	0.816
Environmental and Ethics	1.383	0.967
Palatability	1.969	0.923

INTERPRETATION

Chi-square analysis showed that, from Table 9 it indicates that age significantly influenced five factors, notably affordability, brand and promotion, reference group, health and safety and convenience. Marginal influence was observed for awareness, credibility and environmental ethics, while visual appeal and palatability showed no significant variation with age.

From Table 10 it indicates that income significantly affected affordability, health & safety and convenience, with moderate influence on credibility and visual appeal. other factors such as awareness, brand and promotional, reference group, palatability and ethical concerns were found to be non-significant with income.

The study highlights that organic food consumption in Ananthapuramu city is primarily driven by a younger, educated and economically active population with growing awareness of health and sustainability. Grains, millets, vegetables and fruits were the most preferred categories and nearly half of the respondents expressed a willingness to pay a premium, though mostly within a modest range of 10-20 per cent. Despite moderate to high acceptance of current prices, affordability remains a barrier, especially for frequent consumption. Factor analysis revealed ten significant behavioural dimensions, including health and safety, environmental & ethics, affordability & availability, credibility, brand and promotion, palatability, visual appeal, reference group, awareness and convenience explaining 73.81 per cent of the total variance. The chi-square analysis further established that demographic factors such as age and income significantly influence several of these behavioural aspects.

To expand the organic food market in Tier-II cities like Ananthapuramu, it is crucial to implement targeted pricing strategies, improve consumer trust through transparent certification and enhance awareness campaigns. These insights can guide policymakers, retailers and marketers in developing more inclusive and effective strategies for promoting organic food consumption at the grassroots urban level.

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EFFECT OF SOWING WINDOW ON NODULATION, YIELD AND POST - HARVEST SOIL NUTRIENT STATUS UNDER VARIED CROP GEOMETRIES IN SHORT DURATION PIGEONPEA (*Cajanus cajan* L.)

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ABSTRACT

A field experiment was conducted during kharif, 2024 at wetland farm, S.V. Agricultural College, Tirupati, Andhra Pradesh. The experiment was laid out in a split-plot design and replicated thrice. The treatments consisted of four sowing windows *viz.,* I FN of July (M_1), II FN of July (M_2), I FN of August (M_3) and II FN of August (M_4) assigned to main plots, three crop geometries *viz.,* 30 cm x 10 cm (S_1), 45 cm x 10 cm (S_2) and 60 cm x 10 cm (S_3) allotted to sub plots. Among the sowing windows tried, higher seed yield (957 kg ha^{-1}) and stalk yield (2894 kg ha^{-1}) was recorded with I FN of July (M_1) and pigeonpea sown during II FN of August (M4) registered higher post-harvest soil available nutrient status. Crop geometry of 45 cm x 10 cm resulted in higher seed yield (833 kg ha^{-1}) whereas 30 cm x 10 cm recorded higher stalk yield (2794 kg ha^{-1}) and 60 cm x 10 cm resulted in higher post-harvest soil available nutrient status (N, P_2O_5, K_2O:146, 24.6, 197 kg ha^{-1}), number of nodules plant^{-1} (5.3, 9.7) and dry weight of nodules plant^{-1} (5.3, 79.4 mg) at 25 and 50 DAS.

KEYWORDS: Pigeonpea, crop geometry, sowing windows, nodules.

INTRODUCTION

Pigeonpea (*Cajanus cajan* L.) also known as red gram or tur or arhar, is an important pulse crop that is ranked second in India in terms of acreage and production and is the fifth most popular legume crop worldwide. It is originated in the regions of Angola and the Nile River in South Africa. Pigeonpea provides 20 – 22 % protein, 1.2 % fat, 65 % carbohydrates and 3.8 % ash. In India pigeonpea has high demand because it can supply high-quality protein in the diet, particularly to the vegetarian population. In India, the area under cultivation of redgram is 40.68 lakh ha with an annual production of 33.12 lakh tonnes. In Andhra Pradesh, it is cultivated in an area of 2.24 lakh ha with an annual production of 0.78 lakh tonnes (www.indiastat.com, 2022-23). The time of sowing acts as a biological clock, dictating the crop's exposure to weather patterns, pests and nutrient dynamics. Meanwhile, plant spacing sets the stage for intra-specific interactions, influencing canopy architecture, root distribution and ultimately the yield. A strategic balance between these two factors can significantly enhance growth efficiency, water use and photosynthetic performance of short-duration pigeonpea. Exploring the synergy between sowing window and spatial arrangement is not just an agronomic necessity but, it is a key to unlock resilient and high-yielding pigeonpea production systems.

MATERIAL AND METHODS

The field experiment was conducted at wetland farm, S.V. Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University, Andhra Pradesh. The soil of experimental field was sandy loam in texture, neutral in soil reaction, low in organic carbon (0.35%) and available nitrogen (240 kg ha^{-1}), medium in available phosphorus (38.5 kg ha^{-1}) and available potassium (235 kg ha^{-1}). The experiment was laid out in a split-plot design and replicated thrice. The treatments consisted of four sowing windows viz., I FN of July (M_1), II FN of July (M_2), I FN of August (M_3) and II FN of August (M_4) assigned to main plots, three crop geometries *viz.,* 30 cm x 10 cm (S_1), 45 cm x 10 cm (S_2) and 60 cm x 10 cm (S_3) allotted to sub plots. A total rainfall of 1040.8 mm was received in 50 rainy days during the crop growing period. The nutrients were applied as per the recommended dose for the crop *i.e.,* 20 - 50 - 0 kg N, P_2O_5 and K_2O ha^{-1}.

RESULTS AND DISCUSSION

Number of nodules plant^{-1} and dry weight of nodules plant^{-1} at 25 and 50 DAS were not significantly influenced by the sowing window but were significantly influenced by crop geometries. The Interaction effect of

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sowing window and crop geometry was found to be non-significant.

Number of nodules plant^{-1} (5.3, 9.7) and dry weight of nodules plant^{-1} (5.3, 79.4 mg) at 25 and 50 DAS were significantly higher with the crop geometry of 60 cm x 10 cm (S_3) compared to that of 45 cm x 10 cm (S_2) except for the dry weight of nodules plant^{-1} at 25 DAS. Higher number of nodules plant^{-1} and dry weight of nodules plant-1 in pigeonpea at 25 and 50 DAS with crop geometry of 60 cm x 10 cm (S_3) was due to more access of the plant to resources at wider spacing and also due to the reduction in inter row competition between plants. These findings are in support of Kaur and Saini (2018). The lower number of nodules plant^{-1} and dry weight of nodules plant^{-1} were recorded with crop geometry of 30 cm x 10 cm (S_1) which were however comparable with that of 45 cm x 10 cm (S_2).

Significantly higher seed yield (957 kg ha^{-1}) and stalk yield (2894 kg ha^{-1}) was recorded when pigeonpea was sown during I FN of July (M_1) followed by sowing on II FN of July (M_2), I FN of August (M_3) and II FN of August (M_4) in the order of descent with significant disparity between each other. Higher seed yield realized with the pigeonpea sown during I FN of July (S_1) was due to the fact that the crop have experienced favourable weather conditions (light, temperature, rainfall) which might have facilitated the crop to maintain better source sink relationship. In addition to this there was enhanced yield attributing characters resulting in higher seed yield. These findings are in support of Dahariya *et al*. (2018), Patel *et al*. (2019), Kumar *et al*. (2018), Sandeep (2021) and Aruna and Kumar (2023). Higher stalk yield was recorded with early sown crop *i.e.,* I FN of July (M_1) compared to delayed sowings, which was likely due to higher plant height, leaf area, number of branches plant^{-1} and greatly accumulation of dry matter. Similar findings on higher stalk yield were also reported by Dahariya *et al*. (2018) and Sandeep (2021). Sowing window and crop geometry exerted significant influence on seed and stalk yield of pigeonpea, while their interaction could not exert significant variation.

Among the crop geometries tested, 45 cm x 10 cm (S_2) resulted in significantly higher seed yield (833 kg ha^{-1}). The next best crop geometry was 30 cm x 10 cm (S_1) which was significantly superior to that of 60 cm x 10 cm (S_3). Higher seed yield with the crop geometry of 45 cm x 10 cm (S_2) might be due to optimum plant stand that have enabled the plant for better resource utilisation throughout the growing period. Significantly lower seed yield recorded with the crop geometry of 60 cm x 10 cm (S_3) was due to lower plant population unit area^{-1}, though the individual plants at this crop geometry had higher yield attributing characters. Similar findings were observed with Ammaiyappan *et al*. (2021) Sujathamma *et al*. (2022) and Abhishek *et al*. (2023).

Significantly higher stalk yield (2794 kg ha^{-1}) was recorded with 30 cm × 10 cm (S_1) followed by that with 45 cm × 10 cm (S_2). Significantly lower stalk yield (2377 kg ha^{-1}) was recorded with 60 cm × 10 cm (S3). Higher stalk yield with the crop geometry of 30 cm × 10 cm (S_1) was due to higher number of plants per unit area^{-1}, coupled with superiority of growth characters like plant height, leaf area index and dry matter accumulation. The above findings were in accordance with that of Kavin *et al*. (2018), Tungoe *et al*. (2018), Shinde *et al*. (2021), Tuppad *et al*. (2012), Bansal *et al*. (2023) and Saikumar (2024).

Post harvest soil nutrient status was significantly influenced by sowing windows and crop geometries, but the interaction between them was noticed to be non-significant. With reference to the varied sowing windows tried, pigeonpea sown during II FN of August (M_4) recorded significantly higher post-harvest soil available nitrogen (146 kg ha^{-1}), phosphorus (24.6 kg ha^{-1}) and potassium (197 kg ha^{-1}) compared to that of I FN of August (M_3). The later was significantly superior than that of II FN of July (M_2). Significantly lower post-harvest soil available nutrient status was noticed with the crop sown during I FN of July (M_1). This might be due to higher nutrient uptake by the crop sown during I FN of July (M_1) to accumulate maximum dry matter resulting in greater reduction in soil available nitrogen, phosphorus and potassium at harvest. These results corroborate with the findings of Dash *et al*. (2024).

Pigeonpea sown at a crop geometry of 60 cm x 10 cm (S_3) resulted in significantly higher post-harvest soil available nitrogen (139 kg ha^{-1}), phosphorus (24.4 kg ha^{-1}) and potassium (188 kg ha^{-1}). This might be due to lower plant population unit area^{-1} which reduced the uptake of nutrients and increased the post-harvest soil available nitrogen, phosphorus and potassium. The next crop geometry recorded higher post-harvest soil available nutrients was 45 cm x 10 cm (S_2) which was significantly superior to that of 30 cm x 10 cm (S_1). These results are

Table 1. Number of nodules plant^{-1} and dry weight of nodules (mg plant^{-1}) of pigeonpea as influenced by sowing window and crop geometry

Treatments	Number of nodules plant^{-1}		Dry weight of nodules (mg plant^{-1})	
	25 DAS	50 DAS	25 DAS	50 DAS
Main plots: Sowing window (M)				
M_1: I FN of July	5.3	9.7	5.3	79.3
M_2: II FN of July	5.2	9.6	5.1	77.2
M_3: I FN of August	5.2	9.4	5.1	76.3
M_4: II FN of August	5.1	9.3	5.0	75.7
SEm±	0.06	0.10	0.14	1.53
CD (P=0.05)	NS	NS	NS	NS
Sub plots: Crop geometry (S)				
S_1: 30 cm × 10 cm	5.0	9.2	5.0	73.1
S_2: 45 cm × 10 cm	5.2	9.3	5.0	76.5
S_3: 60 cm × 10 cm	5.5	9.8	5.4	81.7
SEm±	0.07	0.13	0.13	1.20
CD (P=0.05)	0.2	0.4	0.4	3.6
Sowing window × Crop geometry				
M at S				
SEm ±	0.12	0.23	0.25	2.48
CD (P = 0.05)	NS	NS	NS	NS
S at M				
SEm ±	0.11	0.17	0.23	2.64
CD (P = 0.05)	NS	NS	NS	NS

Table 2. Seed, stalk yield (kg ha^{-1}) and post-harvest soil available N, P_2O_5 and K_2O (kg ha^{-1}) of pigeonpea as influenced by sowing window and crop geometry

Treatments	Seed yield	Stalk yield	Available N	Available P_2O_5	Available K_2O
Main plots: Sowing window (M)					
M_1: I FN of July	957	2894	108	18.1	157
M_2: II FN of July	804	2691	120	20.1	169
M_3: I FN of August	646	2454	132	22.1	182
M_4: II FN of August	505	2232	146	24.6	197
SEm±	28.0	52.8	2.9	0.51	2.8
CD (P=0.05)	97	183	10	1.8	10
Sub plots: Crop geometry (S)					
S_1: 30 cm × 10 cm	722	2794	113	18.4	164
S_2: 45 cm × 10 cm	833	2532	128	20.9	177
S_3: 60 cm × 10 cm	629	2377	139	24.4	188
SEm±	26.7	49.7	2.5	0.47	2.6
CD (P=0.05)	80	149	7	1.4	8
Sowing window × Crop geometry					
M at S					
SEm ±	51.8	96.7	4.95	0.92	7.17
CD (P = 0.05)	NS	NS	NS	NS	NS
S at M					
SEm ±	48.4	91.3	5.06	0.89	5.24
CD (P = 0.05)	NS	NS	NS	NS	NS

in confirmity with that of Prathibha (2017), Dathamma (2023) and Saikumar (2024).

With regard to the sowing windows tried, pigeonpea sown during I FN of July (M_1) recorded higher seed and stalk yields, indicating that early sowing is the most favourable sowing window for maximizing productivity. Among the plant geometries tested, 45 cm x 10 cm resulted in higher seed yield whereas stalk yield was recorded higher with crop geometry of 30 cm x 10 cm. Crop sown during II FN of August (M_4) with crop geometry of 60 cm x 10 cm registered higher post-harvest soil available nutrient status due to lower plant population unit area^{-1} which reduced the uptake of nutrients and increased the post-harvest soil available nutrient status. Number of nodules plant^{-1} and dry weight of nodules plant^{-1} at 25 and 50 DAS was not significantly influenced by the sowing windows. Crop geometry of 60 cm x 10 cm resulted in highest number of nodules plant^{-1} and dry weight of nodules plant^{-1} at 25 and 50 DAS. Overall, sowing of short duration pigeonpea during kharif, with proper sowing window and optimum crop geometry results in maximum productivity.

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INFLUENCE OF NANO CHITOSAN ENCAPSULATED GROWTH HORMONES ON MORPHO-PHYSIOLOGICAL AND YIELD ATTRIBUTES OF GROUNDNUT

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ABSTRACT

Groundnut (*Arachis hypogaea* L.) is a vital leguminous oilseed crop rich in oil and protein, extensively cultivated in tropical and subtropical regions. In India, it occupies 48.80 lakh hectares with a productivity of 1,847.4 kg/ha. Plant growth regulators (PGRs) such as GA3, auxins and cytokinins enhances growth, nodulation, and yield. The treatment with GA3 at 50 ppm significantly improved pod and seed development. Nanoparticles, particularly nano-chitosan, facilitate targeted and sustained delivery of PGRs, though research in groundnut remains limited. An experiment titled "Influence of nano chitosan encapsulated growth hormones on morpho-physiological attributes of groundnut" was conducted during kharif 2024 at wetland farm, S.V. Agricultural College, Tirupati. Treatments included nano-encapsulated GA3, auxins, and cytokinins, with observations on growth and yield parameters. Significant variability was observed among eight treatments in groundnut under the influence of nano chitosan encapsulated growth promoters. At 60 DAS, maximum plant height was recorded in T_2 (GA3 @ 50 ppm) 31.11 cm. The highest number of branches (5.67) and stem diameter (1.78 mm) were noted in T_5 (Nano chitosan encapsulated GA3 @ 50 ppm). While differences in SPAD chlorophyll meter readings and Leaf area index were not statistically significant, T_5 consistently exhibited superior values. These results highlighted the potential of nano chitosan-based GA3 for enhancing groundnut vegetative growth. Nano chitosan encapsulated GA3 recorded the highest seed yield (2533.2 kg ha^{-1}), harvest index (41.36 %) and haulm yield (45.89 g). Results showed that the improved plant responses under nano-chitosan encapsulated PGR treatments, indicating their potential for enhancing groundnut productivity.

KEYWORDS: Nano chitosan, NAA, GA3, BAP.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is derived from two Greek words, Arachis meaning a legume and hypogaea meaning below ground, referring to the formation of pods in the soil. Groundnut is an upright annual plant. It is an important leguminous oilseed crop. Generally distributed in the tropical, sub-tropical and warm temperate zones. It contains high oil content and edible seeds. It is the fourth most important source of oil and third most important source of vegetable protein in the world.

Groundnut is an economically important oilseed crop cultivated in an area of approximately 373 lakh hectares globally, with production of 559 lakh tonnes and productivity of 1,656 kilograms per hectare (FAOSTAT, 2024). In India groundnut covers an area about 48.80 lakh hectares and production was estimated about 102.89 lakh tonnes with a productivity of 1847.4 kg/ha. In Andhra Pradesh groundnut covers area about 3.66 lakh ha and production is estimated about 3.56 lakh tonnes with an average productivity of 1141 kg ha^{-1} (Crop Outlook Reports of Andhra Pradesh, 2023-24).

Auxins play an important role in gravitropic response and Amyloplast accumulation and Spatial distribution during the peg development in groundnut. Cytokinin at the tissue and organ levels include the differentiation of phloem and meta xylem in roots regulation of cell division, photomorphogenic cell differentiation in expanding leaves and shoots inhibition of leaf senescence.

Nanoparticles act as a bridge in between atomic/ molecular structures and their bulk counterparts, and thus are known to have great scientific interest. The use of nano-carriers for the application of plant growth regulators (PGRs) can ensure the slow delivery and sustained release of bioactive components, thereby avoiding their supra-optimal levels. The use of nanoparticles in the modern system of agriculture is highly advantageous due to the effective delivery of agrochemicals at the targeted location, mainly because of larger surface area, high mass transfer rate and easy

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attachment of applied chemicals.

Chitosan is derived from arthropods exoskeleton and fungi cell walls and the second renewable carbon source after lignocellulosic biomass and effective nutrient delivery material. Further, the study on effect of nano chitosan encapsulated plant growth promoters on morphological, physiological and biochemical aspects of crops is meagre.

MATERIAL AND METHODS

The experiment entitled "Influence of nano chitosan encapsulated growth hormones on morpho-physiological attributes of groundnut (*Arachis hypogea* L.)" was conducted during kharif, 2024 in wetland farm, S.V. Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University which is geographically at 79°E longitude and 13°N latitude was used for each treatment.

Treatments:

T_1 – Auxin (NAA) @ 50 ppm

T_2 – GA3 @ 50 ppm

T_3 - Cytokinin (BAP) @ 50 ppm

T_4 – Nano chitosan encapsulated NAA @ 50 ppm

T_5 – Nano chitosan encapsulated GA3 @ 50 ppm

T_6 - Nano chitosan encapsulated BAP @ 50 ppm

T_7 - Nano chitosan @1 %

T_8 – Normal chitosan

Note

NAA- Naphthalene acetic acid

GA- Gibberellic acid

BAP- Benzyl amino purine

Stages of Spray: 30 DAS and 60 DAS

Stages of observation: 30, 60 and 90 DAS

1. Morpho-physiological attributes

1.1 Plant Height (cm)

Three plants were collected randomly and measured the p lant height from base of the plant to shoot tip and expressed in centimeters (cm).

1.2 Number of Branches (no.)

Three plants were collected randomly from each plot and number of branches per plant were counted.

1.3 Stem Diameter (mm)

Three plants were collected randomly and measured the stem diameter by using digital vernier calliper and average value were recorded.

1.4 SCMR (SPAD chlorophyll meter reading)

SCMR was measured by using of SPAD (SPAD-502, Minolta corp., Ramsey, NJ). Three plants were selected randomly and taken the reading of every third leaf from the top of each plant in each plot, averaged.

1.5 Leaf Area Index (LAI)

The total leaf area was measured using a Leaf Area Meter (LICOR, Model LI 3000) and the results were expressed as cm^2 $plant^{-1}$. The leaf area index was calculated as follows by employing the formula of Williams (1946).

$$LAI = \frac{\text{Leaf area per plant}}{\text{Ground area occupied by the plant (spacing)}}$$

2. Yield attributes

2.1 Haulm Yield Plant^{-1}

The total dry matter was estimated from the three randomly selected plants sampled from each treatment in three replications. The plants were kept in hot air oven for drying at 80oC for two days and the dry weights were recorded and expressed in gm plant^{-1}.

2.2 Seed Yield kg ha^{-1}

After harvesting the plants were shade dried for 5 days. After complete drying of the plants, weight of kernels of an individual plants were collected and recorded in gm plant^{-1}.

2.3 Harvest Index

Harvest index (HI) is defined as the ratio of economic yield to total biological yield (Donald and Humblin, 1976) and expressed in percentage. Harvest index was calculated by using the formula,

$$\text{Harvest index} = \frac{\text{Economiv yield}}{\text{Biological yield}} \times 100$$

3. RESULTS AND DISCUSSION

Influence of nano chitosan encapsulated growth promoters on groundnut revealed significant variability on morpho-physiological and yield parameters. The data provided in the Table 1. represents the comparative performance of eight different treatments in groundnut.

3.1 Plant Height (cm)

Plant height is an important character of the vegetative phase and indirectly influences the yield components. In this study, maximum plant height was recorded in T_5 (Nano chitosan encapsulated GA3 @ 50 ppm) 27.41 cm and minimum plant height was observed in T_8 (control) 22.28 cm at 30 DAS. No significant difference was observed in plant height at 60 DAS. In T_5 (Nano chitosan encapsulated GA3 @ 50 ppm) highest plant height (38.00 cm) was recorded at 90 DAS. When gibberellic acid is applied as a foliar spray, it leads to an elongation of the hypocotyl and the two nodes directly above it, which in turn contributes to an overall increase in plant height. Patil (2019) also reported comparable results, indicating that the application of GA3 lead to a significant increase in plant height in groundnut. This outcome is consistent with the findings reported by Emongor (2007).

3.2 Number of Branches (no.)

Branches are the site of the leaves, flower and peg formation. So, number of branches is desirable attribute for higher biomass production and yield. Number of branches per plant was observed maximum in T_2 (GA3 @ 50 ppm) 4.44 which is on par with T_6 (Nano chitosan encapsulated BAP @ 50 ppm) 4.00 at 30 DAS. No significant difference was observed at 60 and 90 DAS. Highest number of branches observed in T_6 (Nano chitosan encapsulated BAP @ 50 ppm) 6.67 and lowest branches recorded in T_4 (Nano chitosan encapsulated NAA @ 50 ppm) at 90 DAS. Hong Yan and Shu Yu (2001) stated that number of branches might be due to increased number of internodes or length of internodes because of increased cell number in soybean.

3.3 Stem Diameter (mm)

Groundnut stem supports leaves, flowers, and pegs for pod development. A continuous increase in stem diameter was observed from 30 DAS to 45 DAS irrespective of treatments. Significance difference was recorded among the treatments at 60 DAS. Maximum stem diameter was observed in T_5 (Nano chitosan encapsulated GA3 @ 50 ppm) 1.41 mm and minimum diameter was found in T_1 (NAA @ 50 ppm) and T_8 (control) 1.00 mm at 30 DAS. At 60 DAS, T^3 (BAP @ 50 ppm) recorded the highest stem diameter (2.36 mm) and T_2 (GA3 @ 50 ppm) recorded minimum stem diameter (1.51 mm) which is on par with T_1 (NAA @ 50 ppm)1.53mm. No significance difference was observed at 90 DAS where T_3 (BAP @ 50 ppm) showed maximum stem diameter (3.27 mm) and minimum in T_2 (GA3 @ 50 ppm) 2.10 mm. Leite *et al*. (2003) also reported the increase stem diameter in soybean with foliar application of cytokinin. BAP (6-benzylaminopurine) increases stem diameter in groundnut mainly because it promotes cell division and expansion, especially in the vascular and cambial tissues of the stem. Ozkurt and Bektas (2022) reported that chitosan application improved various growth parameters, including an increase in shoot diameter in tomato plants.

3.4 SPAD Chlorophyll Meter Reading (SCMR)

Chlorophyll is a photosynthetic pigment, plays a pivotal role in capturing sunlight and then converting it to luminous energy. Irrespective of treatments imposed SCMR values increased from 30 DAS to 75 DAS. No significant difference was observed among treatments. Maximum SCMR value recorded in T_5 (Nano chitosan encapsulated GA3 @ 50 ppm) 38.1 and lowest was observed in T_2 (GA3 @ 50 ppm) 35.7 followed by T_7 (Nano chitosan @ 1 %) 35.8 at 30 DAS. At 60 DAS, T_2 (GA3 @ 50 ppm) recorded the highest SCMR readings (42.9) followed by T_6 (Nano chitosan encapsulated BAP @ 50 ppm) 42.5 and T_5 (Nano chitosan encapsulated GA3 @ 50 ppm) 42.1. At 90 DAS, SCMR values decreased and lowest was recorded in T_7 (Nano chitosan @ 1 %) 38.8.

Saini *et al*. (2016) stated that maximum total chlorophyll content was observed in NAA and GA3 treatments. NAA and other plant growth regulators improve chlorophyll content by boosting nitrogen efficiency, encouraging chloroplast development, and

Table 1. Influence of nano chitosan encapsulated growth hormones on morpho-physiological attributes of groundnut

Treatment	Plant height (cm)			No. of branches			Stem diameter (mm)			SPAD readi	
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS
T_1 (NAA @ 50 ppm)	26.6	32.82	35.37	3.89	4.78	5.67	1.00	1.53	2.50	38.1	41.6
T_2 (GA3 @ 50 ppm)	24.8	33.20	35.70	4.44	5.78	5.78	1.08	1.51	2.10	35.7	42.9
T_3 (BAP @ 50 ppm)	23.7	31.59	34.50	3.78	6.00	6.56	1.36	2.36	3.27	36.9	40.7
T_4 (Nano chitosan encapsulated NAA @ 50 ppm)	23.0	33.87	35.93	2.78	5.44	5.56	1.34	1.94	2.43	37.6	41.3
T_5 (Nano chitosan encapsulated GA3 @ 50 ppm)	27.4	34.67	38.00	3.11	6.00	6.44	1.41	1.87	2.33	37.8	42.1
T_6 (Nano chitosan encapsulated BAP @ 50 ppm)	23.1	31.82	34.33	4.00	5.67	6.67	1.22	1.81	2.37	36.5	42.5
T_7 (Nano chitosan @ 1 %)	23.9	33.12	35.80	2.89	5.78	6.00	1.17	1.96	2.33	35.8	39.2
T_8 (Normal control)	22.2	32.67	35.40	3.78	5.44	6.00	1.03	1.70	2.37	37.2	41.3
MEAN	24.3	32.96	35.60	3.58	5.61	6.08	1.20	1.83	2.46	36.9	41.4
SEm	0.44	0.68	0.56	0.30	0.30	0.36	0.11	0.15	0.22	1.2	0.9
CD(P=0.05)	1.34	NS	1.70	0.93	NS	NS	NS	0.46	NS	NS	NS
CV	3.16	3.59	2.73	14.84	9.49	10.50	17.16	14.36	15.84	5.6	3.8

Table 2. Influence of nano chitosan encapsulated growth hormones on morpho-physiological and yield attributes of groundnut

Treatment	Leaf area index			Seed yield (kg ha^{-1})	Haulm yield (kg plant^{-1})	Harvest index (%)
	30 DAS	60 DAS	90 DAS			
T_1 (NAA @ 50 ppm)	1.40	2.06	2.27	1999.9	36.52	39.13
T_2 (GA3 @ 50 ppm)	1.44	2.44	2.13	2077.6	41.20	39.46
T_3 (BAP @ 50 ppm)	1.59	2.05	2.25	1955.4	37.63	39.10
T_4 (Nano chitosan encapsulated NAA @ 50 ppm)	1.62	1.89	2.17	2377.6	41.72	39.34
T_5 (Nano chitosan encapsulated GA3 @ 50 ppm)	1.72	2.14	2.32	2533.2	45.89	41.36
T_6 (Nano chitosan encapsulated BAP @ 50 ppm)	1.46	1.68	2.26	2122.1	29.94	39.26
T_7 (Nano chitosan @ 1 %)	1.34	1.66	2.03	1988.8	31.99	39.00
T_8 (Normal control)	1.43	2.02	2.07	1922.1	38.33	34.61
MEAN	1.50	1.99	2.18	2122.1	37.90	38.90
SEm	0.10	0.14	0.15	0.30	2.34	1.56
CD(P=0.05)	NS	0.44	NS	0.93	7.11	NS
CV	12.39	12.72	12.37	14.84	10.72	6.96

delaying leaf aging. These effects help plants produce, retain, and increase chlorophyll levels more effectively.

3.5 Leaf Area Index (LAI)

Leaf area index is determined by the ratio between leaf area and space occupied by the crop and it is one of the main factors influence the photosynthetic rate of canopy. The results indicated that the LAI was continuously increased from 30 DAS to 90 DAS. No significant difference was observed among the treatments. However, at 30 DAS, T_5 (Nano chitosan encapsulated GA3 @ 50 ppm) 1.72 recorded the highest LAI and lowest was seen in T_7 (Nano chitosan @ 1 %) 1.34. At 60 DAS, minimum LAI was recorded in T_7 (Nano chitosan @ 1 %) 1.66 followed by T_6 (Nano chitosan encapsulated BAP @ 50 ppm) 1.68 and maximum observed in T2 (GA3 @ 50 ppm) 2.44. At 90 DAS, lowest LAI recorded in T_7 (Nano chitosan @ 1 %) 2.07 and highest in T5 (Nano chitosan encapsulated GA3 @ 50 ppm) 2.32. Surendar *et al*. (2013) reported that foliar application of plant growth regulators in blackgram significantly increased the Leaf area index, Crop growth rate, Net assimilation rate and Specific leaf weight by showing higher accumulation of total dry matter production with increased yield.

3.6 Seed Yield kg ha^{-1}

Source-sink relation contributes the seed yield. It includes phloem loading at source (leaf) and unloading at sink (seed and pod) by which the economic part will be getting assimilates synthesized by photosynthesis, resulted by Gardner *et al*., (1988). No significant difference was observed in seed yield in groundnut among all treatments. Highest seed yield was observed in T5 (Nano chitosan encapsulated GA3 @ 50 ppm) 2533.2 kg ha^{-1} and lowest seed yield was recorded in T8 (control) 1922.1 kg ha^{-1}. The increase in yield due to growth regulators in groundnut might be due to an increase in distribution of peg and pod dry weight, higher partitioning of dry matter towards reproductive organs, increase in leaf thickness, number of pods per plant, higher no. of peg and total dry matter production (Faldu *et al*., 2018).

3.7 Haulm Yield

Among the treatments, significantly maximum haulm yield per plant was observed in T_5 (Nano chitosan encapsulated GA3 @ 50 ppm) 45.89 g followed by T_4 (Nano chitosan encapsulated NAA @ 50 ppm) 41.72 g. Minimum haulm yield per plant was observed in T_6 (Nano chitosan encapsulated BAP @ 50 ppm) 29.94 g followed by T_7 (Nano chitosan @ 1 %) 31.99 g. Dry matter is the end product of assimilates from source organs via a transport path to the sink organs. The potential growth rate and potential capacity to accumulate assimilates has been shown to be an important parameter that quantitatively reflects the sink strength of an organ (Faldu *et al*., 2018).

3.8 Harvest Index (HI)

Harvest index denotes the partitioning efficiency of any genotype. Groundnut being semi determinate growth habit, Harvest index is generally low due to overlapping of vegetative and reproductive growth stages.

No significant difference was observed among all treatments in HI. Maximum harvest index was recorded in T_5 (Nano chitosan encapsulated GA3 @ 50 ppm) 41.36 % and minimum was observed in T_8 (control) 34.61 %. A rise in harvest index could be attributed to the synchronized interaction between growth and developmental characteristics (Chande *et al*., 2021).

An experiment was conducted to study the influence of nano chitosan encapsulated growth promoters on morpho-physiological and yield attributes of groundnut (*Arachis hypogaea* L.). Significant variability was observed among eight treatments. At 60 DAS, the tallest plants were recorded in T_2 (GA3 @ 50 ppm) with 34.67 cm height, while the highest number of branches (4.44) and stem diameter (1.87 mm) were found in T_5 (Nano chitosan encapsulated GA3 @ 50 ppm). Although no significant differences were observed in SPAD chlorophyll meter readings and leaf area index (LAI), T_5 consistently showed superior values. These findings suggest that nano chitosan encapsulated GA3 enhances vegetative growth in groundnut and has potential for yield improvement. Highest seed yield was observed in T_5 (Nano chitosan encapsulated GA3 @ 50 ppm) 2533.2 kg ha^{-1} and lowest seed yield was recorded in T8 (control) 1922.1 kg ha^{-1}. Significantly maximum haulm yield per plant was observed in T_5 (Nano chitosan encapsulated GA_3 @ 50 ppm) 45.89g followed by T_4 (Nano chitosan encapsulated NAA @ 50 ppm) 41.72 g. Minimum haulm yield per plant was observed in T_6 (Nano chitosan encapsulated BAP @ 50 ppm) 29.94 g. Maximum harvest index was recorded in T_5 (Nano chitosan encapsulated GA3 @ 50 ppm) 41.36 % and minimum was observed in T_8 (control) 34.61 %.

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FIELD SCREENING OF SESAME (*Sesamum indicum* L.) GENOTYPES FOR RESISTANCE TO *ALTERNARIA* LEAF SPOT

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ABSTRACT

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Sesame (*Sesamum indicum* L.) is an important oilseed crop valued for its high oil and protein content, widely cultivated in semi-arid tropical regions. Among the various diseases affecting sesame, Alternaria leaf spot caused by Alternaria spp. is a significant constraint, leading to considerable yield losses. This study evaluated the response of 30 sesame genotypes, including germplasm lines, released varieties, and checks, against Alternaria leaf spot under natural field conditions during the kharif 2024 season at S.V. Agricultural College, Tirupati. Disease severity was assessed using the standardized 0-9 rating scale (Mayee and Datar, 1986) at 15-day intervals, and Percent Disease Index (PDI) along with the apparent rate of infection (r) were calculated. Results revealed variation in disease reaction, with no genotypes showing immune or resistant response. Twenty genotypes exhibited tolerance with PDI values ranging from 12.74% to 25.50%, while 10 genotypes were susceptible, with PDI ranging from 27.45% to 44.10%. The highest apparent rate of infection (r = 0.49) was observed in the susceptible check *viz.,* SI-2174-1, indicating a potential for epidemic development in susceptible genotypes. Disease symptoms initiated around 45 days after sowing and progressed from leaf spots to stem and pod lesions, significantly impacting seed quality and yield. The study highlights considerable genetic variability for Alternaria leaf spot tolerance in sesame germplasm, underscoring the need for incorporating tolerant genotypes in breeding programs. The findings also emphasize the influence of environmental factors and crop management on disease development.

KEYWORDS: Sesame, *Alternaria* leaf spot, *Alternaria* spp, Percent disease index, Apparent rate of infection.

INTRODUCTION

Sesame (*Sesamum indicum* L.), a self-pollinating crop from the Pedaliaceae family, is one of the oldest oilseeds known to humanity. Originally from Africa, it is now widely cultivated across Asia, with India as a major producer. Known as gingelly, til, or benne seed, sesame thrives in semi-arid tropical climates and exhibits excellent drought tolerance due to its deep root system. The seeds are rich in oil (48–55%) and protein (20–28%), along with essential nutrients and antioxidants like sesamin and sesamol, making them valuable for nutrition and medicine. The stable sesame oil is widely used in food, health, and cosmetic industries.India leads global sesame production, cultivating it on 1039 lakh hectares with an annual yield of 429 lakh tonnes and an average productivity of 413 kg/ha (India Stat, 2023–2024). Major sesame-growing states include Rajasthan, Uttar Pradesh, Madhya Pradesh, Gujarat, and Andhra Pradesh. In Andhra Pradesh, sesame is grown on 0.23 lakh hectares with a production of 0.07 lakh tonnes and productivity of 287 kg/ha, grown in both kharif (rainfed) and rabi (irrigated) seasons. Sesame is vulnerable to several diseases such as charcoal rot, Fusarium wilt, Phytophthora blight, and phyllody, which cause significant yield losses worldwide (Vashisht *et al*., 2023). Among these, Alternaria leaf spot, caused by *Alternaria* spp., is a major fungal disease affecting various crops including apples, brassicas, and citrus (Zhang *et al*., 2021; Dharmendra *et al*., 2014). In sesame, Alternaria leaf spot begins as small, dark brown to black circular lesions on lower leaves, often surrounded by a yellow halo. As the disease advances, lesions enlarge and form concentric rings, creating a target-like appearance. Severe infections lead to coalesced lesions causing leaf blight, defoliation, and may spread to stems and capsules, reducing plant vigor and seed quality. Alternaria is a diverse fungal genus in the Dematiaceae family, with over 250 species. Species like A. alternata, A. solani, and A. sesami cause leaf spots, blights, and rots on many crops. These fungi produce dark, multicelled conidia, often seed-borne, which aids in disease spread. Given the significant impact of Alternaria on sesame, the following experiment was conducted to evaluate disease reaction among sesame genotypes.

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MATERIAL AND METHODS

This study was conducted in dry land farm, S.V. Agricultural college Tirupati during kharif 2024. In this study 30 genotypes including, germplasm lines, released varieties and checks were sceened against Alternaria leaf spot disease based on the disease rating scale 0-9 (Mayee and datar 1986). Genotypes SI-25, SI-2174-1 (Check), SI-7650, SI-3264-2, VS-15-007 , AT-324, AT-480 , IS-1162-13, MT-2019, VS-19-064, IIOS-1101, SI-253-1-C, SI-770, IS-1162-13, SI-1169, AT-336, JCS-RF-2, PT-10, SWETHA TIL, GKVKS-112, IS-208, TBS-6, RT-392, NIC-10621-13, LT-210, IS-475 , TKG 22-4, JCS-DT-26, VS-19-045, IS-4 were screened in field using RBD randomized block design in two replications keeping SI-2174-1 as susceptible check, with plant spacing of 30 cm x 10 cm. Each plot has a row length of 3 meters and consists of two rows. The fertilizer dose applied to the crops is 40 kg/ha of nitrogen (N),20 kg/ha of phosphorus (P_2O_5), and 20 kg/ha of potassium (K_2O).

Based on the disease rating scale given, following are the grades for screening the germplasm reaction against Alternaria leaf spot of sesamum.

Calculation of Per cent Disease Index

Disease index (wheeler 1969) of infected germplasm was calculated on sesame plant by observing leaves of 5 random plants per genotype, applying 0-9 grade disease rating scale (Mayee and Datar 1986). Per cent Disease Index (PDI) is calculated by using the below formula. The data was recorded at 15 days interval after commencement of disease.

$$Per\ cent\ Disease\ Index\ (PDI) = \frac{Sum\ of\ observed\ numerical\ disease\ ratings}{No.of\ leaves\ observed\ \times Max.Disease\ score} \times 100$$

Apparent rate of infection (r)

Apparent rate of infection is a measure of how quickly a disease spreads within a population over time, calculated from successive assessments of disease extent. For the assessment of rate of Alternaria infection in each genotype, the data was recorded at 15 days interval after the commencement of disease to calculate the apparent rate of disease development using the formula suggested by Vander plank (1968). The formula was given below.

Where r is apparent rate of infection in non-logarithmic phase, X1 and X2 symbolizes the percent disease index at time t_1 and subsequent week time t_2.

$$r = \frac{2.3}{t_2 - t_1}\left[log\left\{X_2 \times \frac{(1-X_1)}{X_1} \times (1 - X_2)\right\}\right]$$

RESULTS AND DISCUSSION

For the assessment of disease reaction to seed borne Alternaria spp. in sesame, 30 genotypes (Table 2) were evaluated under natural field infection in randomized block design (RBD). The readings were recorded after commencement of disease for every 15 days interval for each genotype. Five plants were taken randomly and disease reaction was scored based on the disease rating scale 0-9 (Mayee and Datar,1986).

The disease was started appearing from 45th day onwards. Two observations were taken at 60 DAS and 75 DAS and the crop was harvested at 90 days. When the plant is infected with Alternaria spp.in early stage of infection, disease manifests mainly on the leaf blade, as brown, round to irregular spots varying from 1 mm to 2mm in diameter, which later become darker in color with concentric zonation demarcated with brown lines inside the spots on the upper surface. On the lower surface, the spots exhibited greyish brown in color. In severe infections, affected leaves dried and dropped off. Infection on stem exhibited and produces browning and blighting of stem, covering more area while on pods deep seated spots developed and damaged the seed quality causing heavy loss in seed yield. In tolerant genotype the symptoms appeared as leaves showed round to irregular brown lesions that enlarged and developed concentric rings, giving a target-like appearance. Lesions expanded to cover 11-25% of the leaf area, often coalescing and causing necrotic blighted patches with chlorotic halos. In susceptible the symptoms appeared as lesions that enlarged and coalesced to form irregular brown patches with distinct concentric rings, covering approximately 26-50% of the leaf area. In addition to foliar symptoms, similar lesions were observed on petioles and pods.

From the field evaluation of 30 genotypes percent disease index (PDI) values at 60 DAS ranged from 6.06 to 18.41% and at 75 DAS, percent disease index (PDI) values ranged from 12.74 to 44.10% (Table.4.1). SI-2174-1(susceptible check) which showed highest percent disease index (PDI) values of 16.69% and 44.10% at 60 and 75 DAS respectively. At 60 DAS, highest disease reaction was showed by SI-25 (18.41%) and least disease reaction was observed in genotype VS-19-064 (6.06%). At 75 DAS, highest disease reaction was showed by

Table 1. Disease rating scale for grading sesame germplasm for Alternaria leaf spot (Mayee and Datar,1986)

Disease rating scale of *Alternaria* leaf spot	Affected leaf area (%)	Description	Disease reactions
0	No disease	No symptoms on the leaf.	Immune (I)
1	< 1	Small, irregular brown spots covering 1 per cent or less of the leaf area.	Resistant (R)
3	01 to 10	Small, round to irregular brown spots with concentric rings covering 1-10 per cent of the leaf area.	Moderately resistant (MR)
5	11 to 25	Round to irregular brown lesions enlarging, with concentric rings covering 11-25 per cent of the leaf area	Tolerant (T)
7	26 to 50	Lesions enlarging and coalescing to form irregular brown patches with concentric rings and covering 26-50 per cent of the leaf area. Lesions also appeared on stem petioles and pods	Susceptible (S)
9	51 and above	Lesions enlarged coalesced to form irregular, dark brown patches with concentric rings covering 51 per cent or more of the leaf area. Lesions observed on stem petioles and pods.	Highly susceptible (HS)

SI-2174-1 (44.10%) and least disease reaction was observed in genotype SI-7650 (12.74%).The results of field screening showed a total of 20 genotypes (SI-25, SI-3264-2, VS-15-007, AT-324, AT-480, IS-1162-13, MT-2019, VS-19-064 ,IIOS-1101, SI-770, IS-1162-13, SI-1169, AT-336, JCS-RF-2, Swetha til,TBS-6, LT-210, TKG 22-4, SI-7650, VS-19-045) have shown tolerant reaction to Alternaria with PDI ranged from 12.74-25.50 (Table 3), while 10 genotypes (SI-253-1-C, PT-10, SI-2174-1, GKVKS-112, IS-208, RT-392, NIC-10621-13, IS-475, JCS-DT-26, IS-4) have shown susceptible reaction to Alternaria with PDI values ranged from 27.45-44.1(Table 3). None of the genotype was immune nor resistant to Alternaria disease reaction under natural conditions.

4.1.2 Apparent rate of infection (r)

For assessment of rate of Alternaria infection in each genotype, the apparent rate of infection (r) was determined as per the procedure described in materials and methods. The disease data was recorded at 15 days interval (60 and 75 DAS) to calculate the apparent rate of disease development using the formula suggested by vander plank (1968). The apparent rate of infection is as showed in (Table 4).

As increase in the rate of Alternaria infection growth, apparent rate of infection was also increased in all genotypes. Hence the chances of epidemics is more in susceptible genotypes of sesame. The apparent rate of infection values ranged from 0.32-0.49. Highest apparent rate of infection was observed in SI-2174-1 (0.49) and least apparent rate of infection was observed in SI-7650 (0.32). The apparent rate of infection noticed in susceptible genotypes such as SI-2174-1(0.49), NIC-10621-13(0.463), IS-208(0.462), SI-253-1-C (0.45), indicates disease has epidemic rate of infection (Fig. 1).

The experiment demonstrated variability in the

Table 2. Screening of sesame genotypes for Alternaria disease reaction under natural disease epiphytic conditions

S. No.	Genotypes	Percent Disease Indices		Disease reaction category*
		60 DAS	75 DAS	
1.	SI-25	18.41 (25.41)	22.19 (28.10)	T
2.	SI-7650	12.55 (20.74)	12.74 (20.91)	T
3.	SI-3264-2	17.10 (24.42)	20.45 (9.97)	T
4.	VS-15-007	13.92 (21.91)	24.65 (11.53)	T
5.	AT-324	10.56 (18.96)	24.00 (14.17)	T
6.	AT-480	15.98 (23.56)	24.70 (15.34)	T
7.	IS-1162-13	11.88 (20.16)	25.50 (16.42)	T
8.	MT-2019	11.52 (19.84)	21.29 (17.45)	T
9.	VS-19-064	6.06 (14.26)	18.65 (18.43)	T
10.	IIOS-1101	6.87 (15.20)	15.75 (19.36)	T
11.	SI-253-1-C	9.73 (18.18)	33.80 (20.26)	S
12.	SI-770	9.01 (17.47)	21.80 (21.13)	T
13.	IS-1162-13	12.41(20.62)	19.45 (21.97)	T
14.	SI-1169	18.35 (22.78)	19.30 (26.06)	T
15.	AT-336	11.12 (19.47)	13.07 (23.57)	T
16.	JCS-RF-2	9.25 (17.70)	16.96 (24.35)	T
17.	PT-10	11.19 (19.54)	29.75 (25.10)	S
18.	SWETHA TIL	10.99 (19.36)	22.30 (25.84)	T
19.	SI-2174-1	16.69 (24.11)	44.10 (26.56)	S
20.	GKVKS-112	17.79 (24.94)	28.80 (27.27)	S
21.	IS-208	16.51 (23.97)	33.85 (27.97)	S
22.	TBS-6	14.75 (22.58)	19.65 (28.65)	T
23.	RT-392	11.91 (20.18)	27.45 (29.33)	S
24.	NIC-10621-13	9.5 0(17.95)	34.85 (30.00)	S
25.	LT-210	14.01 (21.98)	22.44 (30.65)	T
26.	IS-475	10.49 (18.89)	31.00 (31.30)	S
27.	TKG 22-4	7.95 (16.38)	15.90(31.94)	T
28.	JCS-DT-26	8.99 (17.44)	27.60 (32.58)	S
29.	VS-19-045	16.90 (24.27)	23.87 (33.21)	T
30.	IS-4	6.83 (15.15)	31.20 (33.83)	S
	SEm (±)	1.40	1.18	
	CV (%)	9.76	5.72	
	CD at 5%	4.05	3.42	

T-Tolerant (11-25) , S - Susceptible (26-50)
Data in parenthesis = arc sin transformed values

Table 3. Grouping of sesame genotypes based on disease reaction to *Alternaria* spp.

Disease Reaction	Disease rating Scale	Genotypes
Immune (I)	0	-
Resistant (R)	1.1-3.0	-
Moderately resistant (MR)	3 .1-5.0	-
Tolerant (T)	5.1-7.0	SI-25, SI-3264-2, VS-15-007, AT-324, AT- 480, IS-1162-13, MT-2019, VS-19-064, IIOS-1101, SI-770, IS-1162-13, SI-1169, AT-336, JCS-RF-2, Swetha til,TBS-6, LT-210, TKG 22-4, SI-7650, VS-19-045
Susceptible (S)	7.1-9.0	SI-253-1-C, PT-10, SI-2174-1, GKVKS-112, IS-208, RT-392, NIC-10621-13, IS-475, JCS-DT-26, IS-4
Highly susceptible (HS)	9	-

resistance levels of sesame genotypes against Alternaria leaf blight, by 66.66% exhibiting tolerance and 33.33 % susceptiblity and none of the genotype showed immune or resistant. This result underscores the genetic diversity in sesame for disease resistance, a critical aspect for breeding programs aimed at enhancing crop resilience.

Environmental factors and crop management practices also play a role in disease development and resistance expression. Warmer temperatures due to climate change might increase the abundance of Alternaria species, potentially affecting resistance levels (Jindo *et al*., 2021). Additionally, crop development stages, cultivation methods, and field management practices influence the development of early blight disease (Jindo *et al*., 2021).

Resistance to Alternaria leaf blight in different crops is influenced by various factors: Genetic factors play a crucial role in determining resistance levels. Studies have identified wild relatives of cultivated crops with higher natural resistance to Alternaria species. For instance, wild potato species like Solanum berthaultii and S. commersonii subsp. malmeanum showed promising resistance against early blight caused by A. solani (Wolters *et al*., 2021). The resistance in these wild species was inherited in offspring when crossed with cultivated potato, suggesting a genetic basis for resistance.

Plant age and maturity can also influence susceptibility to Alternaria leaf blight. In tomatoes, susceptibility increased as plants matured, with plants being susceptible at all growth stages but becoming more vulnerable as they aged (Vioutoglou & Kalogerakis, 2000). Similar observations were also observed in this study as plants were not effected in the early stages, symptoms were seen fom 45 days in the field.

Ram *et al*. (2007) reported in linseed that similar trends where a small percentage of genotypes exhibited moderate resistance, while the majority ranged from susceptible to highly susceptible. These alignments reinforce the need for continued exploration of genetic resources to identify and utilize resistant germplasm effectively.

The presence of tolerant genotypes in this study is encouraging for future breeding efforts. However, the susceptibility observed in tested genotypes highlights the urgency to integrate molecular tools such as marker-assisted selection (MAS) and genome-wide association studies (GWAS) to identify resistance genes.

In sesame, Natrajan and Shanmuga (1983) reported that none of the cultivar was resistant to Alternaria sesami. Rani *et al*. (1985) while working on sesamum against Alternaria alternata reported that no cultivar was

Fig 1. Disease progression curve for selected genotypes

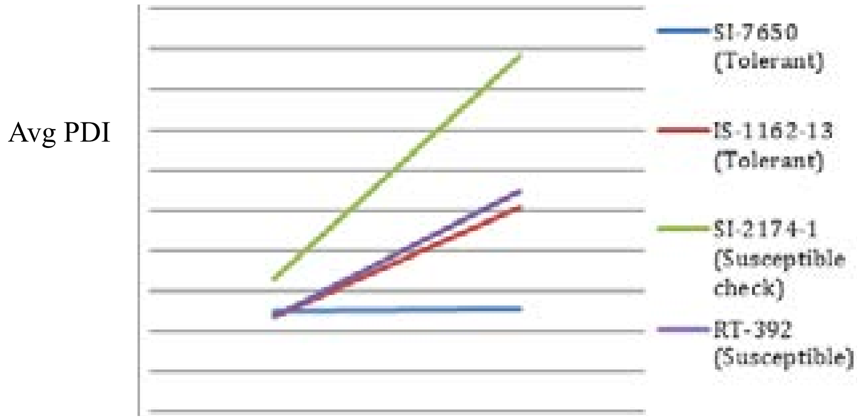

Table 4. Apparent rate of infection of sesame genotypes

S. No.	Genotypes	Apparent rate of infection (r)
1	SI-25	0.40
2	SI-7650	0.32
3	SI-3264-2	0.39
4	VS-15-007	0.41
5	AT-324	0.41
6	AT-480	0.42
7	IS-1162-13	0.42
8	MT-2019	0.39
9	VS-19-064	0.37
10	IIOS-1101	0.35
11	SI-253-1-C	0.45
12	SI-770	0.39
13	IS-1162-13	0.38
14	SI-1169	0.38
15	AT-336	0.33
16	JCS-RF-2	0.36
17	PT-10	0.44
18	SWETHA TIL	0.40
19	SI-2174-1	0.49
20	GKVKS-112	0.44
21	IS-208	0.46
22	TBS-6	0.38
23	RT-392	0.43
24	NIC-10621-13	0.46
25	LT-210	0.40
26	IS-475	0.44
27	TKG 22-4	0.35
28	JCS-DT-26	0.43
29	VS-19-045	0.41
30	IS-4	0.44
	Mean	0.41

shown resistant reaction. Shekharappa and Patil, (2001) reported that some cultivars showed resistant reaction to Alternaria but none was shown immune to Alternaria. Basavraj *et al*. (2007) while working on sesame against Alternaria sesame, none of the cultivar showed immune to Alternaria. Similar kind of studies were also reported by Marri *et al*. (2012) and Pawar *et al*. (2019).

None of the genotypes demonstrated complete immunity or resistance, highlighting the absence of resistant lines in the tested material. The apparent rate of infection (r) further confirmed a rapid disease progression in susceptible genotypes, indicating potential risk of epidemics. The findings emphasize the need for continuous screening and utilization of tolerant lines in breeding programs. Integrating molecular tools and resistant sources from wild relatives may accelerate the development of resistant sesame cultivars.

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TRAIT INTERACTIONS INFLUENCING YIELD IN SESAME (*Sesamum indicum* L.): A CORRELATION AND PATH ANALYTICAL APPROACH

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ABSTRACT

The present investigation was carried out at dry land farm of S.V Agricultural College, Tirupati, Andhra Pradesh during Rabi 2023-24. Sixty-four genotypes including checks were evaluated in Augmented block design for 20 DUS traits and 10 yield and yield attributing traits *viz.,* days to 50% flowering, plant height, number of primary branches per plant, number of capsules per plant, capsule length, number of seeds per capsule, 1000-seed weight and seed yield per plant to study character association and the magnitude of direct and indirect effects of yield component traits on seed yield per plant. The association analysis revealed that plant height, number of capsules per plant and showed strong significant and positive correlation with seed yield per plant indicating that yield improvement could be possible through the indirect selection of these traits. The path coefficient analysis has disclosed that an ideal sesame plant should have more plant height followed by more number of capsules per plant to boost seed yield per plant as plant height and number of capsules per plant exhibited high and moderate direct effect on seed yield per plant respectively.

KEYWORDS: Sesamum, Seed yield, Character association, Path analysis, direct and indirect effects.

INTRODUCTION

Sesame (*Sesamum indicum* L.) generally known as benni seeds, gingelly seeds and til etc. belongs to the family Pedaliaceae. Globally, it is highly valuable oilseed crop which is commonly known as "queen of oilseeds". Sesame oil contains oleic acid (35 to 54%), linoleic acid (39 to 59%), about 10% of palmitic acid and around 5% of stearic acid (Wacal *et al*., 2019). Some of the quality traits like oil content, protein content and fatty acid composition in sesame are the most important characters for both oil and confectionary purposes. Oleic acid and linoleic acid are two essential fatty acids that play a crucial role in maintaining human health. Foods that are deep-fried using sesame oil exhibit prolonged durability as the oil contains protective antioxidants known as lignans, sesamol, and sesaminol.

In India, Sesame is cultivated in an area of 15.23 lakh hectares with an annual production of 8.02 lakh tonnes and productivity of 527kg/ha (Ministry of Agriculture, 2023-24). Gujarat, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, Karnataka, West Bengal, Bihar and Assam are the major sesame-growing states of India. In Andhra Pradesh, this crop occupies an area of 0.23 lakh hectares with a production of 0.07 lakh tonnes and productivity of 287 kg/ha (Ministry of Agriculture, 2023-24). The average productivity in Andhra Pradesh (287 kg/ha) is very less as compared to the Indian average (527 kg/ha), necessitates the development of high yielding varieties.

Sesame production is lower in India as compared to the world. To address the current issue, developing of improved and high yielding varieties is necessary. Correlation helps in assessing relationship among yield and yield attributing traits. Information about the association of several yield components can be obtained through correlation analysis. Hence, correlation provides a more robust understanding of the nature of the relationship among the characters, which is crucial for yield enhancement. Path coefficient analysis provides a thorough understanding of contribution of various characters by partitioning the correlation coefficient into components of direct and indirect effects (Wright, 1921), which helps the breeder in determining the yield components. Hence, association analysis and path coefficient analysis are to be carried out to determine the direction of selection and the characters to be considered in improving the yield in sesame.

MATERIAL AND METHODS

Plant Material and Experimental Site

The experiment was laid out in an Augmented

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Block Design. The design consisted of 6 blocks and each block had 10 genotypes and 4 checks. Each genotype was sown in single row of four meters length with a spacing of 30 cm between rows and 15 cm between the plants. The crop was provided with fertilizers to supply 40:20:20 N:P: K kg ha^{-1}. Half of N and entire P and K were applied as basal dose and second half of N was applied as top dressing after 30 days of sowing. The crop was raised under completely irrigated conditions. All the recommended cultural and agronomic measures were followed during the crop period.

Statistical Analysis

Observations were recorded on randomly five selected plants for yield attributing characters viz., plant height (cm), number of primary branches per plant, number of capsules per plant, capsule length (cm), number of seeds per capsule, thousand seed weight (g), and seed yield per plant (g), Whereas the trait days to 50% flowering which is recorded on per plot basis. The correlation coefficients were calculated to determine the degree of association of the yield components with seed yield and also among themselves. Phenotypic correlation coefficients were compared against 'r' values given in Fisher and Yates (1963) tables for (n – 2) degrees of freedom at probability levels of 0.05 and 0.01 to test their significance. Significance of correlation coefficients was tested by comparing phenotypic correlation coefficients with the table values (Fisher and Yates, 1963) at (n-2) degrees of freedom at 5% and 1% level where 'n' denotes the number of paired observations used in the calculation. Path coefficients analysis was carried out by using the phenotypic and genotypic correlation coefficients, to know the direct and direct effects of the yield components on yield suggested by Wright (1921) and as illustrated by Dewey and Lu (1959). Path coefficient values were rated as described by Lenka and Mishra (1973).

RESULTS AND DISCUSSION

The nature and magnitude of association among yield and yield attributing traits by providing the symmetrical measurement of degree of association between two variables or characters. Therefore, identification of important yield attributes and information about their association with yield and also with each other is very useful for developing the efficient breeding strategy and for developing high yielding varieties. The association of yield and yield attributing traits is given in Table 1.

Correlation between seed yield per plant and yield attributing traits

Seed yield per plant had positive and significant association with plant height (0.481**) followed by number of capsules per plant (0.370**) and number of primary branches per plant (0.107*). It implied that selection of genotypes with high plant height, number of capsules per plant and number of primary branches per plant would result in simultaneous yield improvement. Similar kind of positive association was reported by Kaliayarasi *et al*. (2019a), Navaneetha *et al*. (2019), Takele and Abera (2023), Kante *et al*. (2022) and Gadifew *et al*. (2024) for plant height; Patil and Lokesha (2018), Sasipriya *et al*. (2018), Navaneetha *et al*. (2019), Umamaheswari *et al*. (2019), Takele and Abera (2023), Kante *et al*. (2022) and Gadifew *et al*. (2024) for number of capsules per plant; Patil and Lokesha (2018), Navaneetha *et al*. (2019) and Gadifew *et al*. (2024) for number of primary branches per plant.

Inter-se correlation among yield and yield attributing traits

The desirable and undesirable associations among yield attributing traits as well as with yield were revealed by inter-se association. Association of different traits gives an insight about simultaneous selection of characters and yield can be improved by improving the favourable components based on the desirable associations. Results of inter-se associations between the traits were explained hereunder.

Days to 50% flowering showed positive significant association with number of primary branches per plant (0.529**) followed by number of capsules per plant (0.515**) and plant height (0.389**) and negative significant association with test weight (-0.423**).

Days to maturity registered negative significant association with capsule length (-0.183*). Plant height had significant positive association with number of capsules per plant (0.515**) and number of seeds per capsule (0.345**) and negative significant association with test weight (-0.245*). Therefore, selection of taller genotypes would be helpful in increasing seed yield per plant by having more number of capsules per plant and more number of seeds per capsule.

Number of primary branches per plant showed positive significant association with number of capsules

Table 1. Phenotypic Correlation coefficients among yield and yield attributing traits in sesame

	DF	DM	PH	NPB	NCP	NSC	CL	TW	OC	SYP
DF	1	0.072	0.389**	0.529**	0.515**	0.067	0.023	-0.423**	-0.018	0.169
DM		1	0.177	-0.051	0.418	0.142	-0.183*	0.138	0.004	-0.035
PH			1	0.259	0.515**	0.345**	-0.230	-0.245*	0.075	0.481**
NPB				1	0.418**	0.049	-0.251*	-0.224	-0.134	0.107*
NCP					1	0.039	-0.132	-0.361**	0.007	0.370**
NSC						1	0.057	-0.038	0.121	0.093
CL							1	0.152	0.029	0.059
TW								1	0.064	-0.059
OC									1	0.025
SYP										1

* Significant at 5 % level, **significant at 1% level

DF= Days to 50% flowering, DM= Days to maturity, PH= Plant height (cm), NPB= Number of primary branches plant-1, NCP= Number of capsules plant-1, NSC= Number of seeds capsule-1, CL= Capsule length (cm), TW= 1000 seed weight (g), OC= Oil content (%), SYP= Seed yield plant-1 (g).

Table 2. Path coefficients among yield and yield attributing traits in sesame

	DF	DM	PH	NPB	NCP	NSC	CL	TW	OC	Correlation with SYP
DF	-0.0921	-0.0083	0.1781	0.0181	0.1278	-0.0030	-0.0055	-0.0458	0.0001	0.169
DM	-0.0064	-0.1191	0.0822	-0.0030	0.0088	-0.0060	-0.0703	0.0152	0.0000	-0.035
PH	-0.0359	-0.0214	0.4567	0.0077	0.1146	-0.0145	0.0006	-0.0262	0.0005	0.481
NPB	-0.0497	0.0107	0.1050	0.0336	0.1035	0.0021	-0.0082	-0.0229	0.0012	0.107
NCP	-0.0534	-0.0047	0.2375	0.0158	0.2204	-0.0017	-0.0039	-0.3933	-0.0000	0.370
NSC	-0.0064	-0.0166	0.1552	-0.0016	0.0088	-0.0429	-0.0018	-0.0043	-0.0009	0.093
CL	0.0165	0.0274	0.0091	-0.0090	-0.028	-0.0025	0.03058	0.0163	-0.0002	0.059
TW	0.038	-0.0166	-0.0110	-0.0070	-0.0793	0.0017	0.0045	0.1092	0.0004	-0.059
OC	0.0018	0.0000	0.0319	-0.0053	0.0022	--0.0051	0.0009	0.0065	-0.0078	0.025

Residual Effect = 0.7129444

DF= Days to 50% flowering, DM= Days to maturity, PH= Plant height (cm), NPB= Number of primary branches plant^{-1}, NCP= Number of capsules plant^{-1}, NSC= Number of seeds capsule^{-1}, CL= Capsule length (cm), TW= 1000 seed weight (g), OC= Oil content (%), SYP = Seed yield plant^{-1} (g).

per plant (0.418**) and negative significant association with capsule length (-0.251*). Number of capsules per plant had negative significant association with test weight (-0.361**).

Among the ten traits studied in sesame, plant height, number of capsules per plant and number of primary branches per plant showed strong significant and positive correlation with seed yield per plant, indicating that yield improvement could be possible through the indirect selection of these traits.

PATH COEFFICIENT ANALYSIS

Path coefficient analysis provides information about the cause and effect of different yield components which gives better index for selection other than mere correlation coefficient. Correlation gives only the relation between two variables while, path analysis allows partitioning of the correlation coefficients as direct and indirect effects through other attributes. The path coefficients among yield and yield attributing traits are provided in Table 2.

Plant height exhibited significant positive correlation (0.481**) and high direct effect (0.4567) on seed yield per plant. Similar result of direct effect of plant height was reported by Umamaheswari *et al*. (2019). Whereas, Abate and Mekbeb (2015) and Sorathiya *et al*. (2021) reported moderate direct effect. Number of capsules per plant displayed significant positive correlation (0.370**) and moderate direct effect (0.2204) on seed yield per plant.

In contrast, high direct effect of number of capsules per plant was given by Kumar and Vivekanandan (2009), Ibrahim and Khidir (2012), Vanishree *et al*. (2011), Abate (2018), Haibru *et al*. (2018), Vinoth (2018), Sasipriya *et al*. (2018), Patil and Lokesha (2018), Saravanan *et al*. (2020), Patidar *et al*. (2020), Sarathiya *et al*. (2021), Ahmed and Hassan (2021), Kumar *et al*. (2022), Disowja *et al*. (2020) and Bharati *et al*. (2021).

Regarding indirect effects, days to 50% flowering had low positive indirect effect on seed yield per plant via plant height (0.1781), plant height recorded low positive indirect effect via number of capsules per plant (0.1146). Number of primary branches per plant exhibited low positive indirect effect via plant height (0.1050) and number of capsules per plant (0.1035). Ibrahim and Khidir (2012) reported high indirect effect of number of primary branches per plant via number of capsules per plant.

Number of capsules per plant showed moderate positive indirect effect via plant height (0.2375) and high negative indirect effect via test weight (-0.3933). Number of seeds per capsule recorded low positive indirect effect via plant height (0.1552). Fazal et al. (2015) reported indirect effect of number of seeds per capsule via number of capsules per plant.

The aforesaid points therefore have clearly disclosed that an ideal sesame plant should have more plant height followed by more number of capsules per plant to boost seed yield per plant.

The study shows that seed yield per plant in sesame is significantly and positively correlated with plant height, number of capsules per plant, and number of primary branches per plant. This indicates that selection for genotypes exhibiting these traits can lead to improved seed yield.

Path coefficient analysis revealed that plant height has a high direct positive effect on seed yield per plant, while the number of capsules per plant shows a moderate direct positive effect. While other traits exhibited significant correlations, their effects on seed yield were often mediated indirectly through other yield components. Specifically, days to 50% flowering, number of primary branches per plant, and number of seeds per capsule had indirect positive effects on yield, mainly through plant height and number of capsules per plant.

To boost sesame seed yield, directly selecting for increased plant height and number of capsules per plant is the most effective method. This strategy can be enhanced by indirectly selecting for traits that positively affect these two primary yield components.

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CONSTRAINTS OF CHCS AS PERCEIVED BY FARMERS IN KURNOOL DISTRICT OF ANDHRA PRADESH

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ABSTRACT

Custom Hiring Centres (CHCs) serve as a crucial support system for advancing farm mechanisation, particularly helping marginal and small-scale farmers. CHCs help reduce cultivation costs and guarantee timely farming activities by renting out farm equipment. Despite these advantages, farmers continue to face several operational challenges in accessing CHC services effectively. The current research was conducted in Kurnool district, Andhra Pradesh, to identify the major constraints experienced by CHC users. Data from 100 farmers were analysed using the Garrett ranking method to rank the constraints based on their severity. Findings revealed that the most pressing concerns were the unavailability of machinery during peak seasons, delays in service delivery, and high hiring costs. Other difficulties included a shortage of trained operators, insufficient machinery options, poor equipment maintenance, and limited awareness of available services. Issues like favouritism and lack of transparency also hindered fair access. These insights highlight the need for systemic improvements in CHC functioning. The study suggests steps such as expanding machine inventory, skill development for local operators, implementation of real-time service systems, and improved accountability mechanisms. These actions can greatly improve the efficiency, accessibility, and inclusivity of CHCs, driving sustainable mechanization in agriculture.

KEYWORDS: Custom Hiring Centres (CHCs), Farm mechanization, Farmer constraints in CHCs, Rural mechanization.

INTRODUCTION

Agriculture remains the primary livelihood for a majority of the rural population in India, with about 59.8 per cent of the rural workforce engaged in agricultural activities, as per the Periodic Labour Force Survey (PLFS) 2023-24. However, with increased land fragmentation and rising cultivation expenses, particularly for marginal and small-scale farmers, the demand for accessible and inexpensive automation has grown. Mechanization not only improves efficiency and productivity but also reduces labour dependency, which is particularly important given the growing shortage of work force in agriculture due to urban migration and alternate employment opportunities. Custom Hiring Centres (CHCs) began to arise as a realistic answer to this problem, providing farm machinery and tools for lease. These centres enable farmers especially those with limited capital to use modern equipment without the burden of owning and maintaining costly machines. By doing so, CHCs support timely agricultural operations, minimize drudgery, and support to boost the yield. (Bethi *et al*. 2023)

CHCs have been supported by the Indian government and multiple state legislatures under a number of programs to guarantee that farm equipment is available even in isolated locations. Despite these initiatives, several ground-level challenges continue to restrict the optimal functioning of CHCs. Farmers often report difficulties such as unavailability of machinery during critical cropping seasons, delayed service delivery, high rental charges, and lack of trained machine operators. Moreover, the variety of equipment available is often limited and not aligned with the specific crop needs of the region. Political favouritism in equipment allocation and poor awareness about the CHC services also reduce their reach and impact. These issues result in unequal access, dissatisfaction among users, and underutilization of resources.

As a result, it is critical to consider these issues from the viewpoint of farmers who rely on CHCs for vital agricultural processes. Gaining an understanding of these limitations can help improve policy design, service delivery, and the overall effect of CHCs on rural lives. The present study aims to explore in greater depth the key challenges faced by farmers in the Kurnool region of Andhra Pradesh in accessing CHCs.

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MATERIAL AND METHODS

The study was carried out in Kurnool district of Andhra Pradesh in the year 2025. The study area chosen intentionally because of its active implementation of CHCs and a wide range of crop cultivation. A sample of 100 farmers who had used CHC services during the recent crop season was selected through purposive sampling.

Data collection was carried out through face-to-face interviews using a structured and pre-tested schedule in the local language, Telugu. The schedule captured key details, including the types of equipment accessed, difficulties experienced, and suggestions for service improvement. To prioritise the constraints reported by farmers, the Garrett ranking technique was applied.

Participants assigned ranks to each identified problem, and these were subsequently transformed into scores. The mean score for every problem was calculated to determine its relative importance. In addition to primary data, basic statistical tools such as averages and percentages were employed to summarise the findings. Relevant literature and official documents were also consulted to strengthen the interpretation. This thorough technique made it possible to precisely identify and rank the main constraints of CHC.

Garrett Ranking Technique

Garrett's Ranking Technique was employed to examine the challenges faced by farmers in availing services from Custom Hiring Centres (CHCs). The method involves calculating the percentage position for each rank using the formula:

$$\textit{Percentage position} = \frac{100(R_{ij} - 0.5)}{N_j}$$

where Rij is the rank assigned to the i-th constraint by the j-th respondent, and Nj represents the total number of factors ranked by each respondent.

Once percentage positions were determined, the corresponding Garrett scores were obtained from the standard Garrett table. For every identified constraint, the total score was computed by multiplying the number of respondents assigning a particular rank with its respective Garrett value. The mean score was then derived by dividing the total score by the total number of respondents. Finally, all constraints were ranked according to their mean scores, with the highest mean indicating the most critical issue as perceived by farmers.

RESULTS AND DISCUSSION

Key challenges in CHC services were identified by analysing ten major constraints using the Garrett ranking technique, based on responses collected from 100 farmers in Table 1.

Insufficient equipment during the most productive time of season was the most listed problem (Garrett Score: 64.18), leading to unmet demand and delayed operations. This was followed by delay in service delivery due to high demand (Score: 58.42) and high equipment rental costs during hectic periods (Score: 57.22), which deter smallholders from utilizing CHC services. Other significant constraints included the lack of trained operators (Score: 54.85), and Poor maintenance and frequent breakdown of machines (Score: 50.61), affecting service reliability. (Meena *et al*. 2018 and Sharma *et al*. 2022)

Farmers also reported limited machinery types, inadequate and delayed information on availability, and favouritism in machine allocation, which impacted fair access. Finally, low awareness of CHC services and ineffective feedback systems were cited as concerns. Resolving these problems with enhanced planning, operator training, digital scheduling, and transparent service protocols can greatly enhance the reach and efficiency of CHCs in supporting farm mechanization.

The study concludes that poor resource planning, high rental costs, lack of trained operators, and limited machinery options hinder effective CHC utilization in Kurnool. Addressing these through better scheduling, operator training, and transparent operations can significantly enhance service efficiency and farmer trust.

The recommendations given by beneficiary farmers for improving the efficiency of Custom Hiring Centres (CHCs) are presented in Table 2. The majority of farmers (93.00%) highlighted the need to boost the accessibility of equipment during peak crop times of year, noting present shortages and delays.

Additionally, 78 per cent of respondents suggested lowering rental charges, reflecting financial constraints faced by smallholders. About 65per cent recommended establishing CHCs closer to villages to reduce travel time and improve accessibility. Another 52 per cent called for

Table 1. Dry matter production (kg ha^{-1}) and seed yield (kg ha^{-1}) of sesame as influenced by irrigation regimes and nitrogen levels

S No.	Problems	Garrett Score	Rank
1.	Insufficient equipment during the most productive time of season	64.18	I
2.	Delay in service delivery due to high demand	58.42	II
3.	High equipment rental costs during hectic periods	57.22	III
4.	Lack of trained operators	54.85	IV
5.	Poor maintenance and frequent breakdown of machines	50.61	V
6.	Limited machinery options	50.54	VI
7.	Information gap on equipment availability (lack of coordinatio between CHC staff and farmers)	44.42	VII
8.	Favouritism or political influence in allocation of machinery	43.16	VIII
9.	Poor knowledge of CHC services	41.25	IX
10.	Inadequate feedback systems leave farmer concerns unaddressed	40.35	X

Table 2. Farmer recommendations for enhancing CHCs utilization (n = 100)

S.NO.	Suggestions	Frequency	Percentage	Rank
1.	More machines should be made available during peak agricultural seasons	93	93.00	I
2.	Hiring rates must be altered in order to render them more reasonable to farmers	78	78.00	II
3.	CHCs should be established within or near village limits to reduce travel burden	65	65.00	III
4.	Crop-specific machinery should be provided based on local cultivation patterns	52	52.00	IV
5.	Marginal and small-scale farmers should receive concessional rates or subsidies	47	47.00	V
6.	Awareness programs are needed to inform farmers about available equipment and procedures	38	38.00	VI
7.	Machinery for horticultural and non-traditional crops should also be made accessible	22	22.00	VII

crop-specific machinery aligned with local cultivation patterns, while 47 per cent advocated for concessional rates for marginal and small-scale farmers. A smaller proportion of farmers (38.00%) highlighted the need for awareness campaigns to improve understanding of CHC services and booking procedures. Meanwhile, 29 per cent recommended extending CHC services to horticultural crops, signalling the need for service diversification. (Verma *et al*. 2022)

Overall, the responses underline the importance of improving access, affordability, and availability of machinery, alongside targeted support and outreach, to ensure CHCs better serve the needs of diverse farming communities.

Suitable strategies to overcome barriers in obtaining CHC services

Based on the suggestions and feedback gathered from 100 beneficiary farmers in Kurnool district, several strategies can be proposed to enhance the accessibility and effectiveness of CHCs. Farmers emphasized issues such as limited availability of machinery, high rental charges, long distances to CHCs, there is a dearth of awareness about operations. These findings highlight the importance for a multi-dimensional approach to improve the functioning and reach of CHCs.

a) Provide certified training for local youth as operators

b) Schedule regular maintenance and establish service centres

c) Diversify the types of machinery available at CHCs

d) Develop real-time information system for equipment availability

e) Establish transparent allocation protocols and grievance system

f) Conduct awareness campaigns through village-level meetings

The analysis revealed that the predominant constraint in accessing Custom Hiring Centre (CHC) services was the insufficient availability of equipment during peak agricultural seasons (Garrett Score = 64.18, Rank I), followed by delays in service delivery due to excessive demand (58.42, Rank II) and high rental charges during busy periods (57.22, Rank III). Other notable issues included the lack of trained operators (54.85) and frequent machinery breakdowns due to inadequate maintenance (50.61).

Addressing these challenges requires enhancing the availability of machinery during peak agricultural seasons (93.00%) and rationalizing rental rates to ensure affordability for small and marginal farmers (78.00%). Further recommendations included establishing CHCs within or near village limits (65%) and provision of crop-specific machinery based on local cultivation patterns (52.00%). Overall, the results emphasize the necessity of improving equipment availability, enhancing operational efficiency, and strengthening farmer awareness to ensure the effective functioning of CHCs.

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