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IN VITRO CALLUS INDUCTION AND PLANT REGENERATION IN *BRYONIA LACINIOSA* FROM LEAF

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ABSTRACT

This study investigates effective sterilization methods for the *in vitro* culture of *Bryonia laciniosa* (Linn.) in 2022-23, revealing optimal disinfection with 0.2 per cent sodium hypochlorite followed by fungicide (Sofia) treatment. Although 0.3 per cent mercuric chloride yielded high explant survival, it elevated culture mortality, favoring sodium hypochlorite for successful disinfection. An efficient protocol for callusing and regeneration via direct and indirect means was established using leaf segments. The different forms of callus such as compact, nodular and green callus were produced only multiple shoots. Better quality of pure callus was obtained in the medium fortified with MS nutrients, 3.0 mg/L 2,4-D. The induced callus produced multiple shoots on the same mother medium after 3-4 weeks of culture. The induced shoots were also elongated in the same mother medium without the addition of any other plant growth regulator. 7 shoots were regenerated in leaf explants in MS medium with KIN (4 mg/L) and IAA (1 mg/L).Elongated shoots took roots supplemented with 4.0 mg/L KIN and 1.0 mg/L IBA. The regenerated plants were successfully hardened into pots after proper acclimatization. These findings underscore the potential of explants for callus induction, morphological analysis, and indirect plantlet regeneration, emphasizing the importance of *in vitro* techniques in preserving endangered medicinal plants.

Keywords: *Bryonialaciniosa*, leaf, rooting, Regeneration, Callus and MS medium.

INTRODUCTION

Bryonialaciniosa (Linn.), also known by its synonym *Diplocyclospalmatus*, is a medicinal plant from the family Cucurbitaceae, widely recognized in India for its diverse therapeutic applications. Locally called “Shivlingi” due to the resemblance of its seeds to a Shivling, it is also referred to as the Lollipop Climber or Striped Cucumber Plant. The plant is known by multiple botanical synonyms, including *Bryonopsislaciniosa* and *Diplocyclo-spalmatus*, and has numerous Sanskrit names such as Linguini, Bahupatra, Ishwari, Shaivamallika, Swayambhu, Lingi, Chitraphala, Amruta, Pandoli, Lingaja, and Devi. Various parts of the plant’s leaves, fruits, seeds, and roots are traditionally used for medicinal purposes (Chavhan *et al.,* 2019).

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alkaloids, phenols, flavonoids, tannins, sterols, anthraquinones, cardiac glycosides, saponins, and volatile oils, with aqueous extracts showing the highest concentration of these secondary metabolites (Patel and Kazi, 2023). Literature reports suggest that species from this family are used in the treatment of malaria, epilepsy, diarrhea, leprosy, diabetes, boils, asthma, and as antioxidants (Rolnik and Olas, 2020). The seeds, in particular, are known for improving sexual health and are used in the treatment of male and female infertility, impaired spermato-genesis, asthenozoospermia, teratospermia, constipation, obesity, weight loss, hypergly-cemia, and diabetes (Sud and Sud, 2017).

Additionally, *in vitro* adventitious root culture systems have been established as effective platforms for producing plant secondary metabolites and for investigating metabolic pathways (Moradi *et al.,* 2019). Such root cultures offer advantages for clonal propagation and germplasm conservation in medicinal plant species (Srivastava *et al.,* 2019).

MATERIAL AND METHODS

Leaf materials

The leaf of *BryoniaLaciniosa* was obtained from the Botanical Garden, St. Thomas College. Bhilai. Good and healthy explants were selected from the raised plants which weregrown on a 1:1 mixture of sand and soil in earthen pots. Leaves (0.5-0.9 cm) were selected from the first node of 10-15-day-old plantlets. All the explants were used for direct and indirect organogenesis. Explants were washed with tap waterthen sterilized with distilled water and taken in a sterilized glass plate.

Phytochemical studies have identified bioactive constituents including terpenoids,

Surface Sterilization of explants

After washing the explants were then transferred to laminar air flow. After washing, the explants were dipped in 100ml sterilized distilled water for 15 minutes followed by washing in Tween-20 (1-2 drops in 100ml sterile distilled water) for 1 minute and then were rinsed 3 times with sterile distilled water (SDW) in the laminar flow cabinet. For the pre-sterilization step, the fungicide Sofia (Bhilai Market sector-10) was tested at concentrations of 0.2%. The plant materials were then surface sterilized using mercuric chloride ($HgCl_2$), Sodium hypochlorite, Calcium Hypochlorite, and Hydrogen peroxide (H_2O_2) (HiMedia) with a concentration of 0.1%, 0.2%, 0.3%, and 0.4% for 2 -20 minutes as shown in Table 1.

Organogenic callus induction

Surface sterilized explants were inoculated on MS medium supplemented with different concentrations of growth hormones. In addition to nutrients, it is generally necessary to add growth hormones, so as to get good growth of tissues and organs of the major phytohormones cytokinin in combination with auxins were here used for callus induction and regeneration studies Murashige and Skoog (1962). Leaf explants were cultured on MS basal medium containing 3% (w/v) sucrose, 0.7% (w/v) agar with various concentrations of 2,4-D,NAA and IAA (1.0 – 4.0 mg/l) for callus induction. The effect of hormones on callus induction response was studied and effort was made to determine the appropriate hormone combination for optimal callus growth. Callus induction was observed from 7-15 days. All the cultures were incubated at 25 ± 2^0C under 16h light (2,500 lux) condition.

Plantlet regeneration

Well-developed calli were transferred to regeneration medium containing MS basal salts, 3%(w/v) sucrose, 0.7% (w/v) agar, Different concentrations of IAA (0.5- 1.5 mg/L) in combination with cytokinin (KIN 1.0 – 5.0 mg/L) for shoot bud regeneration were used. Shoot bud differentiation was observed from 10-15 days. These calli were maintained on the same medium and regenerated shoot buds were developed in plantlets. The influence of the auxins (IAA) and cytokinin (KIN) on plantlet development was studied.

Root induction and acclimatization

The plantlets were excised 3cm in length and were transferred to MS basal medium containing 3% (w/v) sucrose, 0.7% (w/v) agar, different concentrations of KIN (1.0- 5.0 mg/L)and IBA (0.5- 1.5 mg/L) for root initiation. Rooting was observed from 7-15 days plantlets with well-developed roots in running tap water, they were grown in red soil, sand, and farm yard (manure) mixture (1:1:1) in the plastic cubs for 15 days and subsequently transferred to pots. All the tissue culture-raised plantlets need gradual acclimatization for their survival in the field condition after growing in the controlled environment Instead of transferring directly to the pots, plantlets were left for a week in the plastic cups at a controlled temperature 24 ± 2^0 C) with 60% relative humidity.

RESULTS AND DISCUSSION

Effect of different sterilizing agents and their different concentrations on the level of microbial and fungal contamination

Sodium hypochlorite at a different concentration ranging from 0.1%-0.4% for 20 minutes with 0.2% Saaf (fungicide) for 15 minutes, the highest average survival rate (90.5%) was achieved. At this optimal concentration, the average contamination rate was a low 6% and the average mortality rate remained minimal at 3%. Leaf explants treated with 0.2% sodium hypochlorite exhibited an even higher survival rate of 95% with just 2% contamination, while internode explants showed a slightly lower, yet still respectable, survival rate of 86% with 10% contamination. Notably, increasing the sodium hypochlorite concentration beyond 0.2% led to a decrease in both survival and contamination, suggesting between effectiveness and plant health. Mercuric chloride (0.3%) for 2 minutes and Sofia (fungicide) (0.2%) for 15 minutes yielded a survival mean value of 87.5%, contamination of 6.5%, and a mortality rate of 6%. Leaf explants exhibited a survival rate of 90%, contamination of 10%, and a mortality rate of 5%. Increasing the mercuric chloride concentration reduced the survival rate and increased mortality. Similarly treating explants with a calcium hypochlorite (0.4%) for 2 minutes, followed by Sofia (fungicide) (0.2%) for 15 minutes, resulted in an average resulted in the average survival rate of 55% an average contamination rate of 38.5% and an average mortality rate of 6.5%.

When treated with hydrogen peroxide (0.4%) for 2 minutes and Sofia (fungicide) (0.2%) for 15 minutes, explants exhibited an average survival rate of 37.5%, a contamination rate of 50% and a mortality rate of 12.5%. leaf explants fared better, with a 50% survival rate, 40% contamination and 10% mortality. All the results were shown in Table 1.

Effect of growth regulator on callus induction

The investigation was carried out on the various concentration of 2,4-D (0.5-3mg/l) Kinetin (1.5-0.5mg/l) and NAA (0.5-3mg/l), Kinetin (0.5-1.5mg/l) for Establishment of culture and callus induction in Table 2-3. The data were recorded on the number of leaves and callus formation. Three replicates were taken for each treatment, and each experiment

Table 1. Standardization of surface sterilization for various explants in *Bryonialaciniosa* (Linn.) by $HgCl_2$, NaOCl, $CaOCl_2$ and H_2O_2.

SterilizingAgent	Leaf explants			Mean		
	% CON	% SUR	% MOR	% CON	% SUR	% MOR
$HgCl_2$ (0.1%) (2min)	79	15	6	87	8.5	4.5
$HgCl_2$ (0.2%) (2min)	45	50	5	51.5	45	3.5
$HgCl_2$ (0.3%) (2min)	3	90	7	6.5	87.5	6
$HgCl_2$ (0.4%) (2min)	0	0	100	1.5	01	97.5
NaOCl (0.1%) (20min)	60	36	4	45	48	7
NaOCl (0.2%) (20min)	2	95	2	6	90.5	3
NaOCl (0.3%) (20min)	2	3	95	01	50.5	48.5
NaOCl (0.4%) (20min)	0	0	100	00	01	50
$CaOCl_2$ (0.1%) (20min)	93	5	7	96.5	2.5	3.5
$CaOCl_2$ (0.2%) (20min)	65	25	10	69.5	22.5	8
$CaOCl_2$ (0.3%) (20min)	46	50	4	50.5	45	4.5
$CaOCl_2$ (0.4%) (20min)	35	60	5	38.5	55	6.5
H_2O_2 (0.1%) (20min)	96	3	1	98	1.5	0.5
H_2O_2 (0.2%) (20min)	85	10	5	88.5	7.5	4
H_2O_2 (0.3%) (20min)	50	40	10	60	30	10
H_2O_2 (0.4%) (20min)	40	50	10	50	37.5	12.5

% CON- % Contamination, **% SUR**- % Survival,
% MOR- % Mortality (Browning or Blacking of explants).

was repeated three times. The observations were recorded at the end of each. The data were analyzed and put in the table form. However, the best results in the form of an amount of callus obtained were on MS medium augmented with different concentrations and combinations of 2,4-D and kinetin (Table 2). Among all combinations and concentrations tested, the highest callus induction (65%) was achieved for leaf explants cultured on a medium containing 3mg/l 2,4-D and 0.5mg/l kinetin. Increasing or decreasing either the 2,4-D or kinetin concentration resulted in a lower percentage of callus formation. So the concentration of 3mg/l of both 2,4-D and 0.5mg/l kinetin proved to be the threshold concentration. While using the combination of NAA and kinetin maximum amount of callus obtained was 57% on a combination of 1.5 mg/l of NAA and 1.5mg/l of kinetin (Table 3). In Figure 1(A-C) results were shown. In this study organogenic callus induction was achieved from explants by using the above said concentration. But in other cases, the concentration of phytochormones varies for the induction of organogenic callus depending on the explants. These results conform with Ibrahim and Al-Nema (2023).

Table 2 Callus induction in *Bryonialaciniosa* (Linn.) in MS medium with different combinations of 2, 4 D and Kinetin (mg/l)

2,4-D + Kinetin(mg/l)	Callus from leaves	Remarks on callus	No. of Day	Callus induction %
0.5+0.5	+	Friable callus	19	51
1.0 + 0.5	+	Friable callus	19	52
1.5+0.5	+	White yellow friable	19	52
2.0+0.5	++	White yellow friable	20	56
2.5+0.5	++	Brownish callus	20	56
3.0 +0.5	+++	Friable callus	19	65
0.5+1.0	+	Friable callus	20	51
1.0 + 1.0	+	Friable callus	20	50
1.5+1.0	++	White Friable	19	50
2.0+1.0	++	Compact green	18	58
2.5+1.0	+++	Compact green	18	63
3.0 +1.0	+++	White green	18	62
0.5+1.5	+	White green	20	60
1.0 + 1.5	+	White green	20	60
1.5+1.5	++	Compact green	20	60
2.0+1.5	++	Compact green	20	58
2.5+1.5	+++	Compact green	18	60
3.0 +1.5	+++	Compact green	17	60

Effect of growth regulator on Plant Regeneration

Greenish compact nodular calli obtained from leaf explants were selected for regeneration studies. These calli were transferred to regeneration medium, before that these calli were cut into 2 or 3 pieces and subcultured. After subculture on the parental medium shoot buds were initiated between 10-15 days. The shoots were maintained on the same medium for 20 to 25 days to get sufficient growth. The regeneration frequency ranged between 20.0 to 68.8%. Higher frequency of shoot regeneration was observed on medium containing 1.0 mg/l IAA (66.6%)(Fig.1). Greenish compact nodular calli were suitable for plant regeneration. These calli were maintained on parental medium for long time (or) subcultured on parental medium where they induced shoot buds between 15 to 25 days (Table 4). After that the shoots were elongated and established into plantlets. There are differences in shoot regeneration frequency among different concentrations and combinations of auxin and cytokinin. The IAA was highly significant than the other treatments. During callus induction there is no significant change in callus morphology and all the obtained calli at KIN (1-5 mg/L and IAA (0.5-1.5 mg/L) showed green, friable and nodular in nature. But in the case of multiple shoot induction significant variation was observed. In leaf explant organogenic callus was derived

Table 3 Callus induction in *Bryonialaciniosa* (Linn.) in MS medium with different combinations of NAA and Kinetin (mg/l)

NAA + Kinetin (mg/l)	Callus from leaves	Remarks on callus	No. of Day	Callus induction %
0.5+0.5	+	Friable callus	19	50
1.0 + 0.5	++	Friable callus	19	52
1.5+0.5	++	Greenish white	18	50
2.0+0.5	++	Greenish white	18	40
2.5+0.5	++	Greenish white	18	51
3.0 +0.5	++	Greenish white	18	54
0.5+1.0	+	Friable callus	20	51
1.0 + 1.0	+	Friable callus	20	53
1.5+1.0	++	White Friable	19	51
2.0+1.0	++	Greenish white	20	50
2.5+1.0	+	Whitish yellow Friable	19	49
3.0 +1.0	+	Whitish yellow Friable	19	49
0.5+1.5	++	Whitish yellow Friable	19	47
1.0 + 1.5	++	Greenish white	20	46
1.5+1.5	+++	Compact green	21	57
2.0+1.5	+++	Compact green	22	55
2.5+1.5	+++	Compact green	23	56
3.0 +1.5	++	Greenish white	21	46

only 7.1 ± 0.5 shoots which were regenerated (Fig. 1 D-H). This variation in the number of shoots may be due to the explant dependent response. The maximum regeneration frequencies are leaf explants respectively. Regeneration frequency was very low at the lower concentration treatments. Higher concentrations of auxin reduced the shoot regeneration frequency. The increase and decrease in regeneration frequency is attributed to the cytokinin concentrations. Teshome and Feyissa (2015) demonstrated that the highest regeneration frequency was achieved on a medium supplemented with 0.5 mg/L BAP, while the maximum number of shoots and the greatest shoot length per explant were obtained with a combination of 0.25mg/L BAP and 0.5mg/L kinetin.

Rooting of regenerants and acclimatization

The well-developed shoots were transferred to rooting media containing different concentrations of KIN and IBA (Table 5). The well-developed shoots from leaf derived callus were isolated and transferred to root induction medium.

Table 4. Response of leaf bit explant to various combination of Kinetin and IAA in MS medium on induction of shoots after 30 and 60 days of culturer text here

Concentration of Kinetin + MS (mg/l)	Concent-ration of IAA + MS (mg/l)	Mean no.of shoots per explant after 15 days± S.E.	Frequency of regene- .ration	Amount of callus*	Physical Nature of callus *
0	0.0	0.0	0.0	-	-
1	0.5	2.3 ± 0.2	25	+	B, F, S
2	0.5	3.4 ± 0.6	27	+	B, F, S
3	0.5	3.8 ± 0.2	37	+	B, F, S
4	0.5	4.7 ±0.1	40	+	B, F, S, N
5	0.5	3.9 ± 0.2	42	++	B, F, S, N
1	1.0	2.9 ± 0.8	47	+	B, F, S
2	1.0	3.6 ± 0.4	51	+	B, F, S
3	1.0	5.7 ± 0.9	59	+	B, F.S
4	1.0	7.0 ± 0.4	66	+	B, F, S, N
5	1.0	6.4 ± 0.6	62	++	B, F, S, N
1	1.5	4.9 ± 0.6	62	+	B, F, S
2	1.5	4.2 ± 0.8	54	+	B, F, S
3	1.5	5.0 ± 0.7	35	+	B, F, S
4	1.5	5.8 ± 0.5	26	+	B, F, S, N
5	1.5	4.4 ± 0.2	15	++	B, F, N, S

As the concentration of KIN was gradually increased the response of explant to the medium also increased to a certain extent i.e. up to 5 mg/L, it was also observed that KIN 4 mg/L and IBA 1 m/L showed maximum 4.0 shoots after 30 days and 7 shoots after 60 days of inoculation. A further increased in the level of IBA up to 1.5 mg/l lowered the number of shoots developed per explant. Callus was formed at base of shoots when concentrations of Kinetin were low as well as high. Callus formed is brownish, friable, and soft but also in some combination it was nodular.

Rhizogenesis was observed to a maximum level in these leaf explants i.e., 78% maximum of rhizogenesis was obtained at 4 mg/L KIN and 1.0 mg/l IBA (Table 3). Root induction took place between 15 to 20 days after transfer to rooting media. The rooting frequency was high in all these three explants' regenerants. In general, higher levels of IBA showed a low frequency of root induction.

The well-developed rooted plantlets were first transferred to plastic pots having vermiculture and garden soil (3:1). The pots were kept in covered glass trays for a week in an incubator at 25 ± 2°C under a 16th photoperiod. After 8 to 10 days these plantlets were transferred to the earthen pots and then to the field. The hardened plants showed 78.5 ± 2.0 % survival rates in the field condition (Figure 1I). Based on this protocol we planned to induce the somaclonal variation among the regenerants and this may be lead to the

Table 5. Effect of Kinetin and IBA on root induction in regenerated plantlets.

Concentrationof Kinetin + MS (mg/l)	Concentration of IBA + MS (mg/l)	Mean no. of shoots per explant after 15days ± S.E.	Frequency of rooting
0	0.0	0.0	00
1	0.5	1.1 ± 0.1	17
2	0.5	1.9 ± 0.3	20
3	0.5	2.0 ± 0.4	26
4	0.5	2.8 ± 0.7	37
5	0.5	2.3 ± 0.6	42
1	1.0	1.6 ± 0.2	53
2	1.0	2.2 ± 0.2	64
3	1.0	3.0 ± 0.1	70
4	1.0	4.0 ± 0.2	78
5	1.0	2.6 ± 0.9	66
1	1.5	1.5 ± 0.4	43
2	1.5	2.4 ± 0.7	47
3	1.5	2.7 ± 0.6	35
4	1.5	3.9 ± 0.1	22
5	1.5	2.6 ± 0.3	14

regeneration of a new variety in bryonia. It will also be useful for the improvement of Bryonia germplasm improvement. Dasari and Shasthree (2015) reported that the highest rooting ability was achieved from stem explants cultured on MS medium supplemented with 2.0mg/L IAA and 1.5 mg/L IBA; multiple fibrous roots developed from cotyledon explants on MS medium fortified with 2.0 mg/L 2,4-D, while leaf explants produced clustered roots onMS medium containing 1.5mg/L IBA and 2.0mg/L IAA.

CONCLUSIONS

In this study, a simple and effective regeneration system was developed for *Bryonialaciniosa* using leaves as an explant source for callus induction and regeneration. Findings revealed that 0.2% NaOCl (20 min) achieved the highest survival rate (95%) and low contamination (2%) for leaf explants.High potential for callus induction in leaf explants was found when grown in MS medium with 3.0 mg/L 2,4-D. The highest plant regeneration capacity was observed for callus when it was developed in MS culture medium with KIN (4 mg/L) and IAA (1 mg/L). Overall the results suggest that for optimal tissue culture in *Bryonialaciniosa*, a combination of 0.2% NaOCl, 3 mg/l 2,4-D, 4 mg/l kinetin, and1.0 mg/l IAA would yield the best outcomes in terms of explant survival, callus induction, plant regeneration, and rooting.The presented plant regeneration system is an important tool for genetic manipulation and improvement of this valuable medicinal plant.

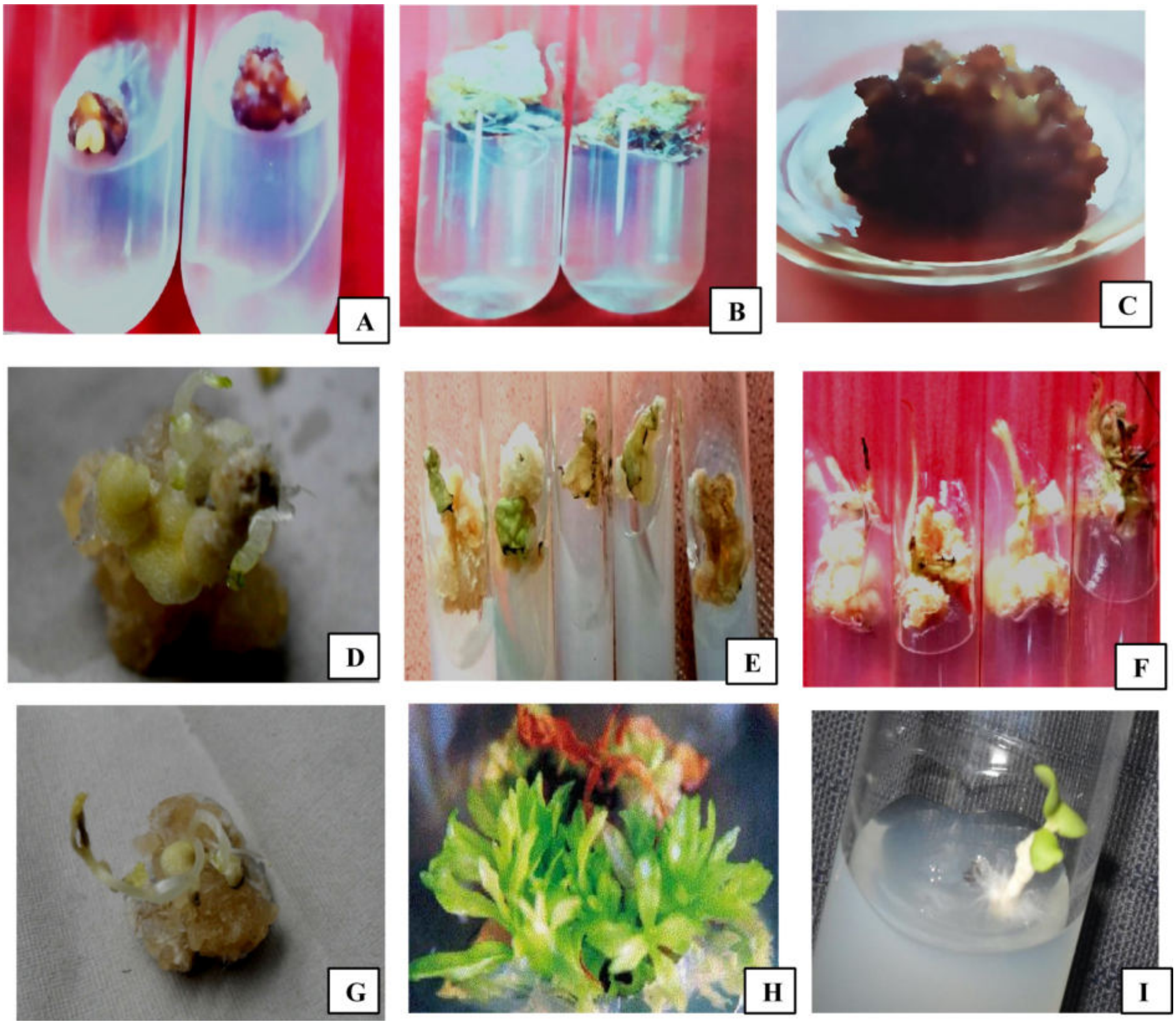

Figure 1.Organogenic callus induction and plant regeneration in *BryoniaLaciniosa*

A) 2 weeks old callus from leaf explant in MS medium with 3 mg/l 2,4-D

B) 2 weeks old callus in MS medium supplemented with Kinetin and IAA

C) Subcultured callus after 2 weeks containing 4 mg/l IBA and Kinetin

D-G) Induction of adventitious bud in callus **A**

H) Multiple shoot proliferation from callus

I) Single Regenerated shoot of *BryoniaLaciniosa* with roots**A**

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PERFORMANCE OF TOMATO UNDER PROTECTED CULTIVATION WITH DIFFERENT TRANSPLANTING TIME, PLANT SPACING AND TRAINING SYSTEM

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ABSTRACT

Cultivation shift towards the cash crops becomes a major thrust area for generating higher incomes but the approach requires scientific attention. Therefore, a study was conducted during 2021-22 and 2022-23 to access the effect of different transplantation time, spacing and training system on soil nutrients status and growth of tomato. The results showed that early transplanting on 15th March, with a spacing of 75 cm × 30 cm and training the plants to two shoots, led to the highest fruit length and breadth, indicating a significant improvement in fruit development under these conditions. Similar treatment combinations resulted in the highest values across various yield parameters. These included fruits per cluster at 5.0, 4.6, and 4.5; fruits per plant at 26.8, 25.1, and 25.7; average fruit weight of 75.6 g, 71.5 g, and 79.9 g; and fruit yield per plant of 2.04 kg, 1.81 kg, and 1.75 kg. In another observation, similar treatments achieved fruits per cluster of 5.3, 5.0, and 5.0; fruits per plant of 32.0, 28.9, and 28.5; fruit weights of 76.8 g, 72.9 g, and 71.8 g; and fruit yields per plant of 2.22 kg, 1.91 kg, and 1.89 kg. Additionally, the maximum fruit yield per 100 m² was registered with 1007.5 kg and 1100 kg, and thus, highlighting the effectiveness of these treatment combinations in enhancing fruit productivity. However, plants spaced at 60 cm ×30 cm attained maximum yield which was 10.6-14.4% higher over 75 cm ×30 cm. No significant difference was found on soil available nutrient content. Study identified the treatment combination of early transplanting along with wider planting with 75 cm ×30 cm and two shoots training as an eminent approach for growing tomato hybrids under poly house.

Keywords: Tomato, growth, nutrients, training system, polyhouse

INTRODUCTION

The world's population is expected to outreach 9.6 billion by 2050, posing a major challenge for global food production. To meet this growing demand, food production must increase by 70% compared to current levels. This is not just about producing abundant food but also ensuring it is nutritious, affordable, and sustainable. Achieving this goal will require advancements in farming techniques, efficient resource management, and better food distribution. At the same time, challenges like climate change, shortages of water and soil degradation must be addressed to secure long-term food supplies (Shubham *et al.,* 2022).

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One of the most effective ways to boost agricultural growth is by developing improved crop varieties and increasing cropping intensity. In India, vegetables are cultivated on 10.86 million hectares, producing around 200.45 million tonnes annually. Among these, tomatoes (*Solanum lycopersicum* L.) are among one of the most widely consumed vegetables. They are highly nutritious, rich in vitamins A and C and valued for their taste and colour making them an important cash crop globally (Ughade *et al.,* 2016).

Despite their widespread use, tomato plants are difficult to grow in open field conditions due to their sensitivity to prevailing harsh environmental factors such excessive humidity, wind and temperature swings. High-yield hybrid tomato varieties have greatly increased productivity while strengthening resilience to unfavourable weather and disease.

With shrinking farmland and rising global temperatures, protected cultivation has emerged as an efficient solution. Growing crops like tomatoes, cherry tomatoes, coloured capsicum, cucumbers, muskmelons, and summer squash in greenhouses or polyhouse leads to higher yields and better quality produce. It is hybrid tomato varieties that have truly revolutionized tomato production. In addition to its superior yield, disease resistance, adaptability to harsh environments, uniformity of production, and increased plant vigour, hybrids also hold considerable promise for addressing the problem of the rising demand for both fresh and processed goods. Its development, output, and produce quality are, nevertheless, constrained by production constraints. An alternative to raising tomato yield while preserving a greater level of fruit quality is shielded culture. From an economic and environmental perspective, high-value crops cultivated under protection are now irreplaceable. There are several advantages to producing higher-quality, high-value crops even in marginal and unfavourable circumstances. The ideal time to transplant is crucial because it promotes healthy plant growth and development, which maximizes agricultural yield and makes economical use of available land (Islam *et al.,* 2010). In addition to making training easier, training plants to produce two or three branches will allow for closer planting, earlier fruit ripening, and increased yields of larger fruits.

Tomato cultivars have varied development tendencies and varying plant densities requires different training approaches. In certain foreign nations, such as Europe and Japan, it is common practice to train indeterminate and semi-determinate cultivars to produce two or three shoots under glass house or open field circumstances. Other than cutting off lower leaves and branches, there is no training procedure in India. Tomato greenhouse production system places a strong emphasis on the necessity of appropriate density to maximize production per unit area by making use of the available space and applied fertilizers. Information about greenhouse horticulture and how it reacts to changing plant populations is scarce. In light of this, a study was carried out to evaluate the performance of tomato with varying plant spacing, training and transplanting time.

MATERIAL AND METHODS

Poly house trials were conducted in 2021-22 & 2022-23 at research farm of University Institute of Agricultural Sciences (UIAS), at Chandigarh University, Gharuan, Punjab situated at longitude (76^{o}34’28" E) and latitude (30^{o}46’ 05" N). The Trans Gangetic plains region of India’s Agro-climatic Zone-I, which has a semi-arid to sub-humid environment with an average annual temperature of 23.1°C and rainfall of 792 mm during the crop season, is where the experimental site is located. The crop trial site was situated 296.86 meters above mean sea level in the Punjab plains, which are undulating. To preserve the variability of the outcomes, a completely randomized block design (CRBD) was chosen for the experiment. The sandy loam soils were discovered with sand (54.70%), silt (31.05%), and clay (14.25%). Furthermore, the soils were found to be nearly neutral in reaction (7.8) and to have a medium electrical conductivity (EC; 0.47 dS/m).

Summer trials were conducted during March to August months inside poly house conditions. Tomato hybrid namely Rakshita was selected as crop cultivar and further tested for its growth and yield attributes to different transplanting time, plant spacing and training systems. For treatments, three dates of transplanting were selected with 15 days gap i.e. 15th March, 30th March & 15th April for both study years, two plant spacing i.e. 60 cm×30 cm & 75 cm×30 cm and two training systems i.e. two shoots and three shoots were selected. Overall, the treatment combinations were replicated thrice to maintain heterogeneity in results. Nursery seeds were sown during 1st fortnight of February in plug trays where it took around 30 days to get ready for transplantation. Raised beds of size (1.8×1.2 m^2) were prepared and treatment selection done on factorial randomized block design basis. Soil of beds were sterilized thoroughly with 40 % formalin solution (1:7 formalin: water), for removal of formalin fumes the beds were covered for 7 days using polyethylene sheets and then followed by rakings operations.

After 30 to 35 days after transplanting, the plants were trained and then staked with threads. As irrigation source, drip system was aligned and crop was watered on daily basis. Nutrient requirement of NPK @100 kg ha^{-1} were applied through straight fertilizers *i.e.* Urea (21.5 g m^{-2}), Single Super Phosphate (62.5 g m^{-2}) and Murate of Potash (16.5 g m^{-2}). Water soluble fertilizer polyfeed (19:19:19) was applied to serve the purpose. Fertigation with polyfeed@ 5 kg/1000 lts water was given from the 3rd week after transplanting and up to 15 days prior to final harvest with frequency of twice a week. Data on plant attributes have been taken as number of fruits/cluster (count method), number of fruits/plant (count method), fruit weight (g) (using high-precision digital scale), fruit length (cm), fruit breadth (cm) (using a vernier caliper), fruit yield/ plant (kg/ plant) and fruit yield (kg/100m^2) were recorded using standard procedures. After estimating the soil texture using the Hydrometer method, the textural class was determined using the USDA-developed soil textural triangle. The pH and EC of the soil were measured using a digital pH meter and an EC meter, and the results showed that the soil reaction was 1:2 (Soil: Water suspension). The amount of organic carbon in the soil was measured using the wet digestion method (Walkley and Black, 1934). The amount of soil accessible N (kg/ha) was calculated using the alkaline potassium permanganate method (Subbiah and Asija, 1956). A Spectronic-20D at 660 nm was used to estimate the quantity of phosphorus accessible in the soil (kg/ha) using the Stannous chloride (SnCl2) reduced ammonium molybdate method. The amount of potassium accessible in the soil (kg/ha) was determined using the neutral normal ammonium acetate method, and its quantity was measured using a flame photometer**.**

RESULTS AND DISCUSSION

Fruit length, breadth and shape index

Data pertaining to effect of transplanting dates, training systems and spacing on fruit growth presented in Table. 2 showed that the crop transplanted on 15thMarch increased the fruit length and breadth by 11.11 and 5.26 per cent over the later transplanting dates. However, crop transplanted at 30th March and 15th April were found non-significant variations among themselves on fruit growth, moreover, tomato fruit length was found significantly higher with 6.77 percent in crop transplanted on 30th March (6.3 cm) over 15th April (5.9 cm). Fruit shape index during both the years remained non-significant. Results on spacing showed that the crop responded very well with 75 cm×30 cm with highest of fruit length (6.1 and 6.6 cm), fruit breadth (5.4 and 5.9 cm) which was 12.96 and 11.86 per cent higher than plant spaced with 60 cm×30 cm. However, highest fruit shape index of 1.13 and 1.12 was recorded with plant spacing of 60 cm×30 cm. Furthermore, plant trained with two shoots recorded higher fruit length breadth as compared to three shoots and therefore, showed the supremacy of tomato hybrids for growth with two shoots.

The data also showed that early plantation provided better tomato growth attributes *i.e.* length and breadth during the study period. Major reasons behind such growth hikecould be attributed to translocation of more photosynthates from source to sink and furthermore, availability of favorable microclimate throughout the crop growth. Fruits grown under wide spacing *i.e.* 75 cm×30 cm attained more length and breadth as compared to closer spaced plants. Availability of moisture, light, essential nutrients and lesser plant intra competition with wider spacing might have facilitated plants with better growth conditions. In double shoot plants, there were enough assimilates available for the early fruits; but, in triple shoot and unpruned plants, the sink to source ratio was high. As a result, availability of lesser assimilation directly affected fruit length. Furthermore, the fruit form index was not significantly affected by the transplanting date or the plant spacing. In both years, training techniques also had no discernible impact on the fruit shape index.

Growth attributes

As the data illustrated in table 3 it is evident that early transplanting brought a significant increase in fruits/cluster with a maximum of 5 as compared to late sowing dates. Least fruit count was recorded with 15th April transplantation date during both the years (3.8 and 4). Similar trend was observed on fruit count per plant, where early transplanting recorded significantly higher fruit count of 26.8 which was 12.13 and 18.08 per cent over 30th March and 21.81 and 34.45 per cent higher than the 15th April transplanting, during both the study years respectively. Furthermore, highest tomato fruit weight (75.6 g and 76.8 g), highest fruit yield/plant (2.04 kg and 2.22 kg) and fruit yield/100m^2 (1000.7 kg and 1100.3 kg) were recorded with the early transplantation treatment (15th March) during 2021-22 and 2022-23, respectively. Plants performed very well when spaced at 75 cm×30 cm, growth attributes *i.e.* fruits/cluster (4.6), fruit/plant (25.1 and 28.9), fruit weight (71.5 and 72.9 g), fruit yield/plant (1.81 and 1.91 kg), but here interestingly higher plant yield/100m^2 of 887.2 and 968.6 kg was recorded with closer spacing of 60 cm×30 cm and registered a per cent increase of 10.58 and 14.37 per cent over 75×30 cm during study years, respectively. Training the plants to two shoots recorded significantly higher fruit yield/100 m^2 (866.5 and 939.0kg) than plants trained to three shoots with a per cent increase of 5.28 and 7.13 during 2021-22 and 2022-23, respectively. The higher yield from the plants trained to two shoots may be attributed to its better performance in yield per plant which ultimately resulted in increase in yield/100 m^2 (Ara *et al.* 2007).

Highest fruits count was recorded in plants which were transplanted on 15th March, trained to two shoots with spacing 75 cm ×30

Table 1. Initial physical and chemical properties of the experimental soil

S.No	Physico-chemical properties	Initial values
1	Soil texture	Sandy loam
	Sand (%)	54.70
	Silt (%)	31.05
	Clay (%)	14.25
	Textural class	Sandy loam
2	Bulk density (g cm^{-3})	1.51
3	Particle density (g cm^{-3})	2.46
4	Soil pH	7.76
5	EC (dSm^{-1})	0.46
6	Organic carbon (g kg^{-1})	8.54
7	Available N (kg ha^{-1})	522.18
8	Available P (kg ha^{-1})	20.8
9	Available K (kg ha^{-1})	212.48

Table.2 Effect of different transplanting dates, spacing and training systems on fruit length, breadth and shape index of tomato during both the years

Treatments	Fruit length (cm)		Fruit breadth (cm)		Fruit shape index	
Date of transplanting	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
15th March	6.0	6.7	5.5	6.0	1.11	1.10
30th March	5.7	6.3	5.0	5.5	1.13	1.12
15th April	5.4	5.9	4.8	5.3	1.14	1.12
SE m+	0.1	0.1	0.1	0.1	0.02	0.03
CD (P=0.05)	0.3	0.3	0.3	0.3	NS	NS
Spacing						
60 cm×30 cm	5.4	5.9	4.7	5.2	1.13	1.12
75 cm× 30 cm	6.1	6.6	5.4	5.9	1.12	1.11
SE m+	0.1	0.1	0.1	0.1	0.01	0.01
CD (P=0.05)	0.2	0.2	0.2	0.2	NS	NS
Training systems						
Two shoots	5.9	6.5	5.3	5.8	1.12	1.11
Three shoots	5.5	6.1	4.9	5.4	1.13	1.12
SE m+	0.1	0.1	0.1	0.1	0.01	0.01
CD (P=0.05)	0.2	0.2	0.2	0.2	NS	NS

Table. 3 Effect of different transplanting dates, spacing and training systems on growth parameters and yield of tomato during both the years

Treatments	Fruits/cluster		Fruits/plant		Fruit weight (g)		Fruit yield/plant (kg)		Fruit yield (kg/100 m^2)	
Date of transplanting	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**
15th March	5.0	5.3	26.8	32.0	75.6	76.8	2.04	2.22	1007.5	1100.3
30th March	4.0	4.5	23.9	27.1	68.9	70.2	1.65	1.75	821.8	869.8
15th April	3.8	4.0	22.0	23.8	64.3	66.1	1.42	1.52	705.1	753.1
SE m±	0.1	0.1	0.4	0.6	0.6	0.5	0.03	0.03	17.3	21.7
CD (P=0.05)	0.2	0.3	1.2	1.8	1.7	1.5	0.09	0.10	50.8	63.7
Spacing										
60 cm×30 cm	3.9	4.2	23.3	26.4	67.7	69.3	1.60	1.75	887.2	968.6
75 cm× 30 cm	4.6	5.0	25.1	28.9	71.5	72.9	1.81	1.91	802.3	846.9
SE m±	0.1	0.1	0.3	0.5	0.5	0.4	0.02	0.03	14.2	17.7
CD (P=0.05)	0.2	0.2	1.0	1.5	1.4	1.2	0.07	0.08	41.5	52.0
Training systems										
Two shoots	4.5	5.0	25.7	28.5	70.9	71.8	1.75	1.89	866.5	939.0
Three shoots	4.0	4.2	22.7	26.8	68.3	70.3	1.66	1.76	823.0	876.5
SE m±	0.1	0.1	0.3	0.5	0.5	0.4	0.02	0.03	14.2	17.7
CD (P=0.05)	0.2	0.2	1.0	1.5	1.4	1.2	0.07	0.08	41.5	52.0

Table. 4 Effect of different transplanting dates, spacing and training systems on soil physico-chemical properties after the harvest of tomato during both the years

Treatments	pH		SOC*		ASN*		ASP*		ASK*	
Date of transplanting	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**
15th March	7.79	7.81	0.93	0.94	578.7	588.8	21.1	23.4	235.4	249.7
30th March	7.81	7.82	0.91	0.91	579.7	591.2	21.7	24.8	236.7	251.2
15th April	7.84	7.85	0.90	0.90	581.2	593.6	23.4	26.8	238.2	253.1
SE m±	0.12	0.12	0.04	0.04	1.5	1.6	1.2	1.3	2.0	2.1
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Spacing										
60 cm×30 cm	7.81	7.82	0.91	0.92	579.1	589.8	21.7	24.1	239.7	250.6
75 cm× 30 cm	7.85	7.86	0.93	0.94	580.6	592.6	23.2	25.9	242.3	252.1
SE m±	0.10	0.10	0.02	0.02	1.3	1.4	0.9	1.0	1.8	1.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Training systems										
Two shoots	7.82	7.83	0.93	0.94	580.0	592.7	23.0	26.1	233.1	252.2
Three shoots	7.84	7.85	0.91	0.92	579.7	589.7	21.9	23.9	231.4	250.5
SE m±	0.10	0.10	0.02	0.02	1.3	1.4	0.9	1.0	1.8	1.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

**SOC= Soil organic carbon (%), ASN= Available soil nitrogen (kg ha^{-1}), ASP= Available Soil phosphorus (kg ha^{-1}), ASK= Available soil potassium (kg ha^{-1})*

cm. The major reason could be due to increased availability of growth promoting components *viz,* less intra-plant competition among plants for nutrients, air and moisture. Higher fruit weight under the similar conditions could be explained on the basis of higher fruit length and breadth of fruits, where plants were transplanted on 15th March. Plants wide spacing provides better exposure to sunlight lead to better carbohydrates and protein assimilation and therefore, buildup of sufficient photosynthates which might have improved the nutrient uptake and the fruit size (Hossain *et al.* 2013; Ara *et al.* 2007; Shubham *et al.,* 2023). Significant improvement on tomato yield was observed, when the crop was early transplanted and spaced 60 cm ×30 cm and two shoots, such significant rise of yield could be attributed to favorable climatic conditions prevailed throughout the crop growth period. Moreover, more fruits cluster^{-1}, more diameter, fruit volume ultimately leads to highest yield per area.

One of the most crucial elements influencing the yield per unit area is the yield per plant. The practicality of implementing various training systems in conjunction with changing plant populations per unit area as spacing in tomatoes will eventually be determined by improvements in quality and production. In our study, plants taught to two shoots outperformed those trained to three shoots on all growth criteria. An additional explanation might be that the two productive branches are making greater use of the photosynthates. It's possible that training to three shoots caused excessive branch retention, which would have reduced the total photosynthetic capacity (Abriham and Kefale, 2020).

Soil physico-chemical properties

A perusal of data presented in table 4 highlighted that the soils of the experimental field were silty clay loam in textural analysis. Results showed that there were no significant effects encountered between different transplanting dates, spacing and training systems on soil pH, OC, soil available N, P and K during both years**.** Since the crop was grown in a protected environment, the inefficiency of treatments to change the available soil nutrient content may be the cause of the lack of significance in the available nutrients.

CONCLUSIONS

In the present study, early transplantation (15th March) of tomato hybrid Rakshita plants trained to 2 shoots planted with 60 cm × 30 cm instead of 75cm × 30 cm spacing registered the maximum yield as compared to rest of the treatments. However, growth attributes were found to be improved with 75cm × 30 cm spacing under 2 shoots trained early plants. Lower yield in widely spaced treatment could be attributed to less plant count per area which might have lowered the overall yield. Therefore, two year field study identified the treatment combination of early planting along with wider plant spacing of 75 cm×30 cm and two shoots training as a superior approach for growing tomato hybrids under poly house conditions for achieving higher crop growth and productivity.

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IMPACT OF INDUCED EMS MUTAGENESIS ON SEED YIELD OF GROUNDNUT (*ARACHIS HYPOGEAE* L.) GENOTYPES

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ABSTRACT

The aim of the study is to investigate the effect of induced Ethyl methanesulfonat (EMS) on seed yield of three groundnut genotypes under various EMS concentrations. The field work was carried out with three groundnut genotypes viz; (ICG2106, ICG5236, ICG76) collected from plant molecular lab, ICRISAT, Hyderabad. The results showed that all three genotypes recorded lower seed yield under 0.3 percent EMS, 0.4 percent EMS, and 0.5 percent EMS over their control where as in M_2 generation the results showed that all three genotypes recorded higher seed yield under 0.3% EMS, 0.4% EMS, and 0.5% EMS over their control. ICG2106 was recorded higher seed yield at 0.3% EMS (37.90 gm per plant), 0.4% EMS (33.90 gm per plant) and 0.5% EMS (32.30 gm per plant) over its control plant (24.70) and compare to their other genotypes. It was observed the higher seed yield was at 0.3% EMS followed by 0.4% EMS and 0.5% EMS. It is revealed that when the concentration of EMS increased the seed yield of the groundnut is increased in M_2 generation.It is revealed that when the concentration of EMS increased the seed yield of the groundnut is decreased in M_1 generation and increased in M_2 generation. Hence highest increase of seed yield was observed by the variety ICG2106- 0.3% (37.90 gm) followed by ICG5236- 0.3% (30.30 gm) and ICG76- 0.3% (29.97gm) under three various EMS concentrations in M_2 generation.

Keywords: EMS, Groundnut mutants, M_1 generation, M_2 generation, Seed yield.

INTRODUCTION

In India, groundnut is a significant oil seed that ranks first in terms of acreage and second in terms of production, after soybean. With 18.36 million tonnes, china leads the second in terms of production. India comes in second with 10.24 million tonnes, Nigeria fourth with 4.61 lakh tonnes, the USA with 2.90 million tonnes, and Sudan with 2.36 million tonnes. These five countries accounted for 34, 19, 9, 5 and 4 percent of the world's total production of 53.97 million tonnes in 2020-2021 first advance projections from the Government of India indicate that 2023-2024. Estimates for the groundnut crop in *Kharif* are 78.29 lakh tonnes, down from 85.62 lakh tonnes 2022-2023. With 36.76 lakh tonnes, Gujarat leads the states in groundnut output, followed by Rajasthan (18.95 lakh tonnes), Madhya Pradesh (9.61 lakh tonnes)

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(www.agri.telangana.gov.in). As per the Government of India's all-India *Rabi* crop coverage report, as of January 5, 2024, 4.88 lakh hectares of groundnut had been sown, compared to 5.68 lakh hectares the previous year. With 1.11 lakh hectares, Karnataka led the states in area coverage, followed by Odisha (1.00 lakh hectares) and Tamilnadu (0.72 lakh tonnes). www.agri.telangana.gov.in is the source. Groundnuts were planted on around 2, 00,235 acres in Telangana as of January 31, 2024. With 1,03,698 acres planted to groundnuts, Nagarkurnool was the district with the largest amount, followed by Wanaparthy (20,286 acres), Nalgonda (17,386 acres), Vikarabad (13,144 acres), and Mahaboobnagar (10,482 acres) among the other districts. The marketing season 2023–2024 would see a rise in groundnut MSP of Rs. 527 to 6377 per quintal; up from Rs. 5850 per quintal in 2022-2023(www.agri.telangana.gov.in) groundnut oil is widely used in Vietnam, China, India, and Myanmar for culinary purposes. The production of improved cultivars through the advantageous application of grain legume mutation breeding has also been documented (Bell, 2008).

Induced mutagenesis occurs when agricultural plants are exposed to a mutagenic agent, such as radiation (neutrons, gamma rays, UV rays) or a chemical (EMS, SA, MMS), which then causes mutations in the DNA. Mutation breedingis an alternative to conventional plant breeding as a source of increasing variability and could confer specific improvement without significantly altering its acceptable phenotype (Menshah and Obadoni, 2007). The various studies with chemical mutagens have been extensively reviewed by several authors from 1960 only following the introduction of EMS (Ehrenberg, 1965). They reported that EMS has a higher mutagenic efficiency than radiations. Anbuselvam *et al.,* 2010, reported that chemical mutagenesis in groundnut breeding helped to produce mutant lines. EMS has been successfully applied to a large number of plants to produce morphological diversity and promote the improvement of ideal traits (Lethin *et al*., 2020). The efficiency of a mutagen in producing desired changes is just as important as the mutagen's mutagenic efficacy (number of mutations produced) when it comes to producing unwanted changes (sterility, fatality, damage, etc), (Girija and Dhanavel, 2009).

The mutation approach to crop enhancement was defended by (Gustafsson, 1947) as being superior to other strategies.In general, for plants propagated by seeds, their seeds are usually preferentially selected mutagenic material (Gottwald *et al*., 2009). In recent years, there has been a lot of interest in the use of chemical and physical mutagens to induce mutagenesis. The amount present determines the rate of mutation. The range of mutations could be greatly influenced by the concentration. The length of time and the conditions under which the mutations occur determine how successful it is in raising the frequency of favorable mutations in a crop (Wang *et al*., 2015).

MATERIAL AND METHODS

The field work was carried out with three groundnut genotypes viz., (ICG2106, ICG5236 and ICG76) collected from plant molecular lab, ICRISAT, Hyderabad. In M_1 generation ten seeds were used per treatment of three groundnut genotypes treated with 0.3 percent EMS, 0.4 percent EMS, and 0.5 percent EMS respectively. In M_2 generation thirty seeds were used per treatment of three groundnut genotypes treated with 0.3 percent EMS, 0.4 percent EMS, and 0.5 percent EMS respectively.The treated and untreated (control) seeds were sown in ten and thirty replications in CRBD method at experimental farm department of Genetics, Osmania University during *Kharif season and Rabi* season 2021-

2022. The recommended agronomic practices and plant protection measures were followed uniformly for all the treatments at appropriate stages during the entire crop growth period. Observations were recorded at harvest stage of the plants on quantitative traits viz; plant height (cm), number of branches, number of leaves, days to flower initiation, days to 50% of flowering, seeds per pod, number of pods per plant, pod weight (g/pl), number of seeds per plant, seed weight (g/pl) and the average performance was worked out M_1 and M_2 generation.

RESULTS AND DISCUSSION

The ANOVA results showed that all the quantitative traits under study observed highly significant values due to treatments except number of branches per plant and seeds per podin M_1 generation (Table 1). It is revealed that for majority of traits, the mutants showed significant variation in the genotype ICG 2106. The ANOVA results showed that all the quantitative traits under study observed highly significant values due to treatments except Number of branches per plant, Seeds per pod, 50 percent flowering and Pod weight (gm)in M_1 generation (Table 2). It revealed thatmajority of traits showed significant variation in the genotypeICG 5236.The ANOVA results showed that all the quantitative traits under study observed highly significant due to treatments except seeds per pod and 50 per cent floweringin M_1 generation (Table 3). It wasrevealed that majority of traits showed significant variation in the genotype ICG 76. The similar variability was found in earlier studies of Yugandhar *et al*., (2023) in groundnut.

The ANOVA results showed that all the quantitative traits under study observed highly significant due to treatments except seeds per pod in M_2 generation (Table 4). It was revealed that majority of traits, the mutants showed significant variation in the genotype ICG 2106. The ANOVA results showed that all the quantitative traits under study observed highly significant due to treatments except seeds per pod in M_2 generation (Table 4). It was revealed that majority of traits, the mutants showed significant variation in the genotype ICG 5236. The ANOVA results showed that all the quantitative traits under study observed highly significant due to treatments except seeds per pod in M_2 generation (Table 4). It was revealed that majority of traits, the mutants showed significant variation in the genotype ICG 76.

The mean performance of plant height in our population shown in Table- 5, the highest plant height was recorded in ICG76 in control by 32.90 cm and lowest plant height was recorded in ICG 2016 at 0.5% EMS by 22.97 cm. The genotype ICG2106 recorded highest plant height with 32.83 cm by control. The lower plant height was recorded in induced EMS mutants in M_1 generation as compared with control and our results meet with Gunasekaran and Pavadai (2015) in groundnut. The trait number of branches per plant was recorded highest in ICG 76 at control by 9.10 and lowest number of branches was recorded in ICG5236 at 0.5% EMS by 5.00. The genotype ICG2106 recorded highest number of branches by 8.53 with control; this finding result is consistent with Raina *et al.*, (2022).

The character number of leaves per plant showed highest in ICG 2106 in control by 53.80 and lowest number of leaves was recorded in both genotypes ICG 2106 at 0.5% EMS by 31.87 and ICG 5236 at 0.5% EMS 31.87. The genotype ICG 2106 recorded highest number of leaves by 53.80 as compared to control. The results of present study indicated that in EMS is that when increase the dose concentration then decreases the number of leaves referred by Patel, (2020) in groundnut plant. The days to flower initiation was observed early in

Table 1. Analysis of variation for the quantitative traits in groundnut genotype-ICG2106 in M_1 generation

S.No	Source of Variations	DF	MSSQ									
			Characters									
			Pl. Ht (cm)	Bran/Pl	Lea/Pl	Flow. Ini	50% Flow.Ini	Seeds/Pod	pods/pl	Pod. Wt(g/pl)	Seeds/pl	Seed.Wt (g/pl)
1	Replications	9	91.067	18.641	506.219	72.364	39.711	0.275	198.085	107.204	620.543	70.653
2	Treatments	3	11.625 **	0.140NS	33.991 **	9.368 **	2.815 **	0.003NS	17.997 **	7.331 **	181.814 **	4.098 **
3	Error		17.407	1.804	81.926	12.087	4.641	0.025	41.564	14.428	114.100	6.887
4	St E		1.319	0.425	2.862	1.099	0.681	0.050	2.039	1.201	3.378	0.830
5	SD		1.866	0.601	4.048	1.555	0.963	0.071	2.883	1.699	4.777	1.174
6	CV (%)		15.246	19.467	21.767	12.340	5.932	8.338	20..231	19.826	23.167	20.940

**Significant at 0.05% and ** at 0.01 % level, respectively*

Pl. Ht- Plant height (cm), No.of Br/Pl- Number of branches per plant, No.of Lea/Pl- Number of leaves per plant, Flow.ini-Days to flower initiation, 50% Flow.ini- days to 50% of flower initiation, No.of Seeds/Pod- Number of seeds per pod, No.of Pods/Pl-Number of pods per plant, Pod.Wt (g/pl)- pod weight per plant (g), No.of seeds/Pl- Number of seeds per plant, Seed.Wt (g/Pl)-seed weight per plant (g).

Table 2. Analysis of variation for the quantitative traits in groundnut genotype-ICG5236 in M_1 generation

S.No.	Source of Variations	DF	MSSQ Characters									
			Pl. Ht (cm)	Br/Pl	Lea/Pl	Flow.ini	50% Flow.Ini	Seeds/Pod	pods/pl	Pod. Wt(g/p)	Seeds/pl	Seed.Wt(g/pl)
1	Replications	9	81.856	33.214	493.401	14.637	12.333	0.166	186.284	133.274	1,371.030	40.724
2	Treatments	3	6.883**	0.373NS	42.295**	9.056 **	0.455 NS	0.025 NS	2.401 **	0.675 NS	68.805 **	4.628 **
3	Error		16.179	2.379	82.972	7.808	2.949	0.027	26.976	8.351	83.099	6.744
4	St E		1.272	0.488	2.880	0.884	0.543	0.051	1.642	0.914	2.883	0.821
5	SD		1.799	0.690	4.074	1.250	0.768	0.073	2.323	1.292	4.077	1.161
6	CV (%)		14.482	22.412	22.208	10.146	4.973	8.603	17.034	15.937	21.344	21.293

*Significant at 0.05% and ** at 0.01 % level, respectively.*

Pl. Ht- Plant height (cm), No.of Br/Pl- Number of branches per plant, No.of Lea/Pl- Number of leaves per plant, Flow.ini-Days to flower initiation, 50% Flow.ini- days to 50% of flower initiation, No.of Seeds/Pod- Number of seeds per pod, No.of Pods/Pl- Number of pods per plant, Pod.Wt (g/Pl)- pod weight per plant (g), No.of seeds/Pl- Number of seeds per plant, Seed.Wt (g/Pl)- seed weight per plant (g).

Table 3. Analysis of variation for the quantitative traits in groundnut genotype-ICG76 in M_1 generatio

S.No	Source of Variations	DF	MSSQ									
			Characters									
			Pl. Ht(cm)	Bran/Pl	Lea/Pl	Flow.ini	50% Flow.Ini	Seeds/Pod	pods/pl	Pod. Wt (g/p)	Seeds/pl	Seed.Wt (g/pl)
1	Replications	9	102.476	27.726	373.324	42.155	25.638	0.112	67.085	64.606	588.995	63.464
2	Treatments	3	7.402 **	1.970 **	16.475 **	3.056**	0.162 NS	0.017 NS	16.360 **	30.283 **	341.546 **	14.888 **
3	Error		15.745	2.486	84.617	10.185	2.787	0.029	10.536	12.686	70.070	10.768
4	St E		1.255	0.499	2.909	1.009	0.528	0.054	1.026	1.126	2.647	1.038
5	SD		1.775	0.705	4.114	1.427	0.747	0.077	1.452	1.593	3.744	1.468
6	CV (%)		14.244	22.877	22.436	11.301	4.723	9.050	10.904	21.265	17.046	23.993

**Significant at 0.05% and ** at 0.01 % level, respectively.*

Pl. Ht- Plant height (cm), No.of Br/Pl- Number of branches per plant, No.of Lea/Pl- Number of leaves per plant, Flow ini- Days to flower initiation, 50% Flow.ini- days to 50% of flower initiation, No.of Seeds/Pod- Number of seeds per pod, No.of Pods/Pl- Number of pods per plant, Pod.Wt (g/Pl)- pod weight per plant (g), No.of seeds/Pl- Number of seeds per plant, Seed.Wt (g/Pl)- seed weight per plant (g).

Table 4. Analysis of variation for the quantitative traits in groundnut genotypes ICG2106, ICG5236 and ICG76 in M_2 generation

Source of variations	DF	MSSQ									
		Characters									
		Pl. Ht (cm)	Bran/pl	Lea/pl	Flow-Ini	50% of flow.Ini	Seeds/Pod	Pods/pl	Pod. Wt(g/pl)	Seeds/pl	Seed.Wt(g/pl)
Replications	29	26.500	17.483	83.796	88.935	28.125	0.764	26.558	21.622	27.933	15.081
Treatments	11	179.255 **	146.849 **	1,711.458 **	107.991 **	207.080 **	0.014 NS	585.443 **	1,097.681 **	1,767.300 **	696.330 **
Error		0.607	0.538	1.275	0.550	0.481	0.008	0.845	0.741	0.724	0.797
St E		0.142	0.134	0.206	0.135	0.127	0.017	0.168	0.157	0.155	0.163
SD		0.201	0.189	0.292	0.191	0.179	0.024	0.237	0.222	0.220	0.231
CV (%)		2.270	5.522	1.823	3.458	2.408	4.665	2.723	1.857	1.516	3.127

**Significant at 0.05% and ** at 0.01 % level, respectively.*

Pl. Ht- Plant height (cm), Bran/pl- Number of branches per plant, Lea/pl- Number of leaves per plant, Flow-ini- Days to flower initiation, 50% of flow.ini- days to 50% of flower initiation, Seeds/Pod- Number of seeds per pod, Pods/Pl- Number of pods per plant, Pod.Wt (g/Pl)- Pod weight per plant (g), Seeds/Pl- Number of seeds per plant, Seed.Wt (g/Pl)- seed weight per plant (g).

Table 5. Mean performance of quantitative characters of groundnut mutants of three groundnuts (ICG2106, ICG5236 and ICG 76) in M_1 generation.

Genotypes	Characters	Pl.ht(cm)	Bran/pl	Lea/pl	Flo.ini	50%.flow	Seeds/Pod	Pods/pl	Pod.Wt(g/pl)	Seeds/Pl	Seed.Wt(g/pl)
ICG2106	**Control**	32.83	8.53	53.80	23.87	33.43	1.93	39.40	22.18	55.10	15.45
	0.3% EMS	28.20	8.41	44.23	25.90	35.70	1.90	30.00	21.70	52.33	12.16
	0.4% EMS	26.20	7.80	41.60	27.10	37.23	1.87	28.70	20.50	51.50	11.53
	0.5% EMS	22.97	6.80	31.87	32.37	38.90	1.87	27.30	16.84	46.70	10.99
ICG5236	**Control**	28.90	8.70	48.90	24.20	32.63	1.93	31.10	21.50	52.60	14.06
	0.3% EMS	27.30	8.30	44.53	25.50	33.73	1.90	30.10	20.70	50.40	12.77
	0.4% EMS	25.77	7.30	40.90	27.30	35.37	1.87	29.40	19.90	47.20	11.32
	0.5% EMS	23.17	5.00	31.87	29.83	36.40	1.87	27.03	17.60	46.80	10.64
ICG76	**Control**	32.90	9.10	48.85	24.47	33.10	1.93	33.21	21.40	56.13	15.97
	0.3% EMS	28.13	8.40	45.70	25.70	35.03	1.90	31.86	20.70	54.80	14.25
	0.4% EMS	25.93	7.40	43.20	26.70	36.13	1.87	28.90	19.20	51.50	13.53
	0.5% EMS	23.20	6.40	40.50	31.67	37.10	1.87	27.57	15.03	50.20	10.95

Pl. Ht- Plant height (cm), No.of Bran/Pl- Branches per plant (number), No.of Lea/Pl- Leaves per plant (number), Flow.ini- flower initiation (days), 50% Flow.ini- 50% of flower initiation (days), No.of Seeds/Pod- Seeds per pod (number), No.of Pods/Pl- Pods per plant (number), Pod.Wt (g/Pl)- Pod weight (g/pl), No.of seeds/Pl- Seeds per plant (number), Seed.Wt (g/Pl)- Seed weight (g/pl).

Table 6. Mean performance of yield and yield contributing characters of mutants of three groundnuts (ICG2106, ICG5236 and ICG 76) in M_2 generation.

Genotypes	Characters	Pl.ht(cm)	Bran/pl	Lea/pl	Flo.ini	50% offlow	Seeds/Pod	Pods/pl	Pod.Wt(g/pl)	Seeds/Pl	Seed.Wt(g/pl)
ICG2106	Control	31.00	10.00	50.95	24.71	33.10	1.94	29.13	38.70	47.40	24.70
	0.3% EMS	37.10	15.60	71.40	19.50	26.10	2.00	42.10	56.70	70.37	37.90
	0.4% EMS	35.40	14.30	64.20	20.50	27.50	1.97	38.10	51.90	64.00	33.90
	0.5% EMS	34.30	13.20	61.70	21.50	28.50	1.95	35.20	48.40	58.90	32.30
ICG5236	Control	30.10	10.20	50.50	24.09	32.20	1.94	28.73	37.00	45.70	21.87
	0.3% EMS	36.90	15.84	68.20	19.10	26.30	2.00	36.90	48.97	59.83	30.30
	0.4% EMS	35.60	14.50	64.90	20.10	27.30	1.97	35.57	46.90	57.77	28.70
	0.5% EMS	34.30	13.30	62.10	21.10	28.30	1.95	33.80	44.97	54.93	26.93
ICG76	Control	30.80	9.80	50.68	24.10	33.30	1.94	26.17	37.47	43.90	21.20
	0.3% EMS	36.80	15.76	71.90	19.90	26.40	2.00	34.77	50.87	60.00	29.97
	0.4% EMS	35.40	14.10	64.60	20.90	27.40	1.97	33.20	48.77	57.17	28.30
	0.5% EMS	34.30	12.80	62.30	21.80	29.10	1.95	31.43	45.90	53.43	26.57

Pl. Ht- Plant height (cm), No.of Bran/Pl- Branches per plant (number), No.of Lea/Pl- Leaves per plant (number), Flow.ini- Flower initiation (days), 50% Flow.ini- 50% of flower initiation (days, No.of Seeds/Pod- Seeds per pod (number), No.of Pods/Pl- Pods per plant (number), Pod.Wt (g/Pl)- Pod weight (g/pl), No.of seeds/Pl- Seeds per plant (number), Seed.Wt (g/Pl)- Seed weight (g/pl).

ICG2106 genotype in control with 23.87 days and for the days to late flowering in ICG2106 genotype in 0.5% EMS with 32.37 days. The genotype ICG5236 recorded early flower initiation in control with 24.20 days and late flowering was observed in the mutants of 0.5% EMS with 29.83 days. The genotype ICG76 recorded early flower initiation in control with 24.47 days and late flowering was observed in the mutants of 0.5% EMS with 31.67 days.Kumar (2020) reported by the decrease in the number of days until flower initiation under EMS induced conditions. The days to 50% of flowering was observed early in ICG5236 genotype in control with 32.63 days and for the days to late 50% of flowering in ICG2106 genotype in 0.5% EMS with 38.90 days. The genotype ICG2106 recorded early 50% of flowering in control with 33.43 days and late 50% flowering was observed in the mutants of 0.5% EMS with 38.90 days. The genotype ICG5236 recorded early 50% of flowering in control with 32.63 days and late 50% flowering was observed in the mutants of 0.5% EMS with 36.40 days. The genotype ICG76 recorded early 50% of flowering in control with 33.10 days and late 50% flowering was observed in the mutants of 0.5% EMS with 37.10 days (Fig.1). Gupta, (2019) and Kalyanababu (2019) reported by conversely, EMS mutagenesis can also cause mutations that lead to delayed flowering, resulting in longer days to 50% of flowering.

The mean performance of number of seeds per pod was recorded highest in ICG2106, ICG5236 and ICG76 at control by 1.93 and lowest number of seeds per pod was recorded in ICG2016, ICG5236 and ICG76 at 0.5 percent EMS with 1.87.The highest number of pods per plant was recorded in ICG2106 at control by 39.40 and lowest number of pods per plant was recorded in ICG5236 at 0.5 percent EMS with 27.03. For the genotype ICG76, the character number of pods per plant was recorded highest in control by 33.21 and lowest pods per plant were observed at 0.5 percent EMS with 27.57 (Fig.2). Increased EMS doses and decreased yield characters was observed earlier in groundnut by Chen *et al*., (2020) and Sudhakar, (2019), Gunasekaran and Pavadai (2015).The results also showed that the highest pod weight per plant was recorded in ICG2106 at control by 22.18gm and lowest pod weight per plant was recorded in ICG76 at 0.5 percent EMS with 15.03 gm.

The genotype ICG2106 recorded highest pod weight per plant by 22.18 gm with control and lowest in 0.5 percent EMS with 16.84 gm. Mahtab *et al.* (2015) studies have also reported similar findings, including decreased pod weight per plant and decreased yield attributes in groundnut plants treated with EMS.The highest number of seeds per plant was recorded in ICG76 at control by 56.13 and lowest number of seeds per plant was recorded in ICG5236 at 0.5 percent EMS with 39.80. The genotype ICG 2106 recorded highest number of seeds per plant by 55.10 with control.The highest seed weight per plant was recorded in ICG76 at control by 15.97 gm and lowest seed weight per plant was recorded in ICG5236 at 0.5 percent EMS with 10.64 gm. The genotype ICG2106 recorded highest seed weight per plant by 15.45 gm with control followed by 0.3 percent EMS with 12.16 gm, 0.4% EMS with 11.53 gm, and 0.5 percent EMS with 10.99 gm respectively.

For the genotype ICG5236 was recorded highest seed weight per plant by 14.06 gm in control followed by 0.3 percent EMS with 12.77 gm, 0.4 per cent EMS with 11.32 gm and 0.5 percent EMS with 10.64 gm (Fig.3) respectively. For the genotype ICG76 the character seed weight per plant was recorded highest in control with 15.97 gm followed by 0.3 percent EMS with 14.25 gm, 0.4 percent EMS with 13.53 gm and 0.5 percent EMS with

10.95 gm respectively (Fig.3). Wang *et al*., 2015 were also reported that the similar decreased trend for various traits in groundnut under EMS induced mutagenesis.

In M_2 generation (Table- 6) displays the average number of pods per plant in our population. ICG2106 at 0.3% EMS had the highest pods per plant (42.10), while ICG76 at control had the lowest (26.17). In the genotype ICG2106, 0.3% EMS produced the most pods per plant (42.10), followed by 0.4% EMS (38.10), 0.5% EMS (35.20), and control (29.13). Among the genotype ICG5236, 0.3% EMS produced the most pods per plant (36.90), followed by 0.4% EMS (35.57), 0.5% EMS (33.80), and control (28.73). The highest character number of pods per plant for the genotype ICG76 was found in 0.3% EMS (34.77) followed by, 0.4% EMS (33.20), 0.5% EMS (31.43) and control with (26.17) respectively.Kumar 2020 was also reported that the similar results for pods per plant increase trend for various traits in groundnut under EMS induced mutagenesis (Fig.4).The table-6 displays the average pod weight (g) per plant for our population. ICG2106 at 0.3% EMS had the highest pod weight (g) per plant, measuring 56.70 (g), while ICG5236 at control had the lowest pod weight (g), measuring 37.00 (g).

The genotype ICG2106 had the highest pod weight per plant, measuring 56.70 (g) for 0.3% EMS, 51.90 (g) for 0.4% EMS, 48.90 (g) for 0.5% EMS, and 38.70 (g) for the control. With 48.97 (g) for 0.3% EMS had the highest pod weight per plant for the genotype ICG5236. This was followed by 4.90 (g) for 0.4% EMS, 44.97 (g) for 0.5% EMS, and 37.00 (g) for control. The character pod weight per plant for the genotype ICG76 was recorded highest in 50.87 (g) for 0.3% EMS followed by 48.77 (g) for 0.4% EMS, 45.90 (g) for 0.5% EMS and 37.47 (g) for control respectively. Patel 2020 was also reported that the similar results for pod weight (g) per plant increase trend for various traits in groundnut under EMS induced mutagenesis. According to the table-6, which displays the average number of seeds per plant in our population, ICG2106 at 0.3% EMS had the most seeds per plant (70.37), while ICG76 at control had the fewest (13.90%). The genotype ICG2106 produced the most seeds per plant with 0.3% EMS (70.37), followed by 0.4% EMS (64.00), 0.5% EMS (58.90), and control (47.40). The highest number of seeds per plant for genotype ICG5236 was recorded by 0.3% EMS (59.83), followed by 0.4% EMS (57.77), 0.5% EMS (54.93), and control (45.70). The highest character number of seeds per plant for the genotype ICG76 was found in 0.3% EMS (60.00) followed by 0.4% EMS (57.17), 0.5% EMS (53.43) and control (43.90) respectively.

Reddy 2019 was also reported that the similar results for seeds per plant increase trend for various traits in groundnut under EMS induced mutagenesis.The average seed weight (g) per plant for our population is displayed in the table-6. ICG2106 at 0.3% EMS had the highest seed weight (g) per plant, measuring 37.90 (g), while ICG76 at control had the lowest, measuring 21.20 (g). The highest seed weight per plant was recorded by the genotype ICG2106 by 0.3% EMS (37.90 g), 0.4% EMS (33.90 g), 0.5% EMS (32.20 g), and control (24.70 g), in that order. The highest seed weight per plant for genotype ICG5236 was recorded by 0.3% EMS at 30.30 (g), followed by 0.4% EMS at 28.70 (g), 0.5% EMS at 26.93 (g), and control at 21.87 (g). The characteristic seed weight per plant for the genotype ICG76 was recorded highest in 0.3% EMS at 29.97 (g) followed by 0.4% EMS at 28.30 (g), 0.5% EMS at 26.57 (g) and control at 21.20 (g) respectively.

The results showed that highest percentage decrease of seed weight (g/pl)

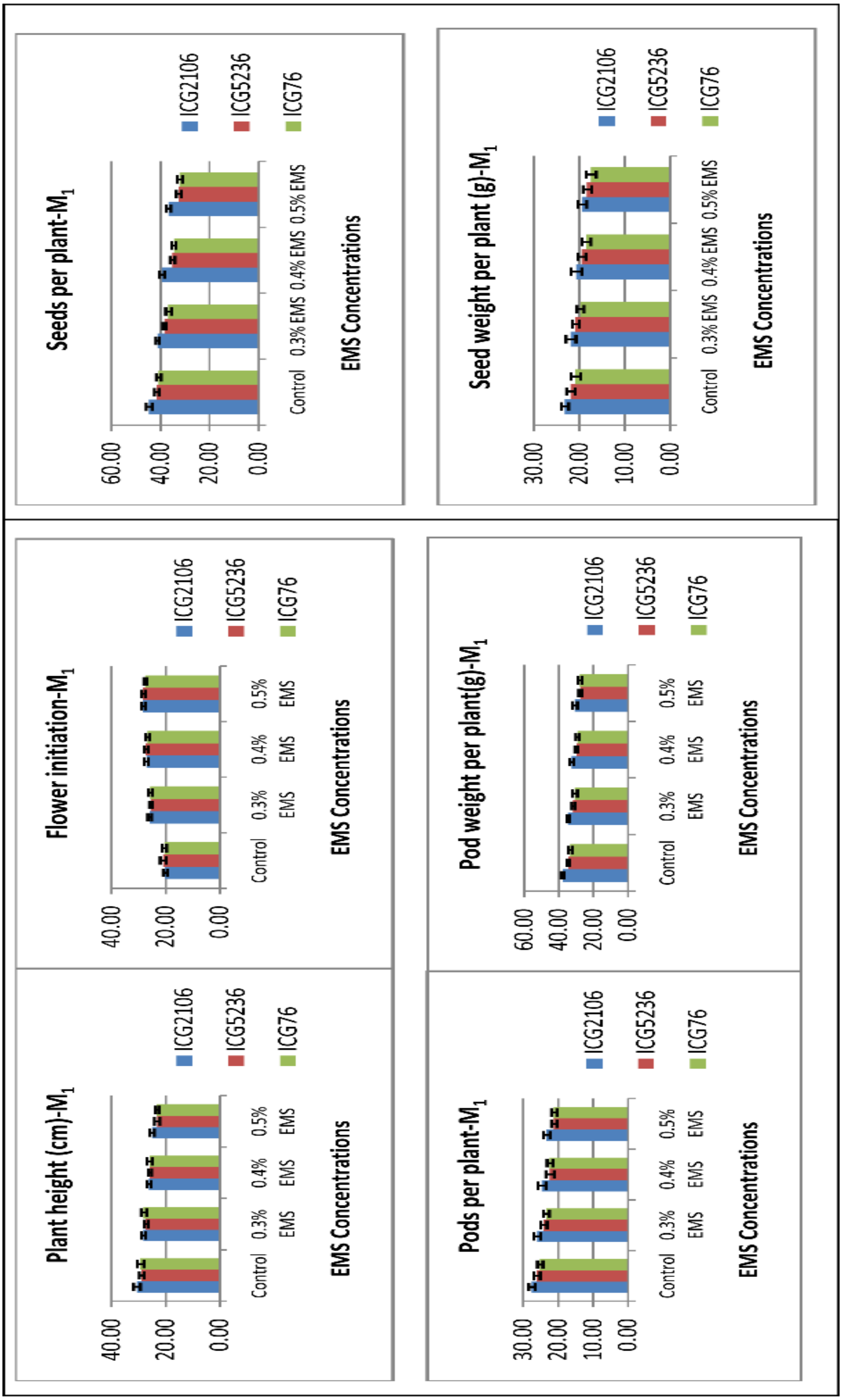

Fig 1. Graphical representation ofquantitative traits in groundnut mutant in M_1 generation

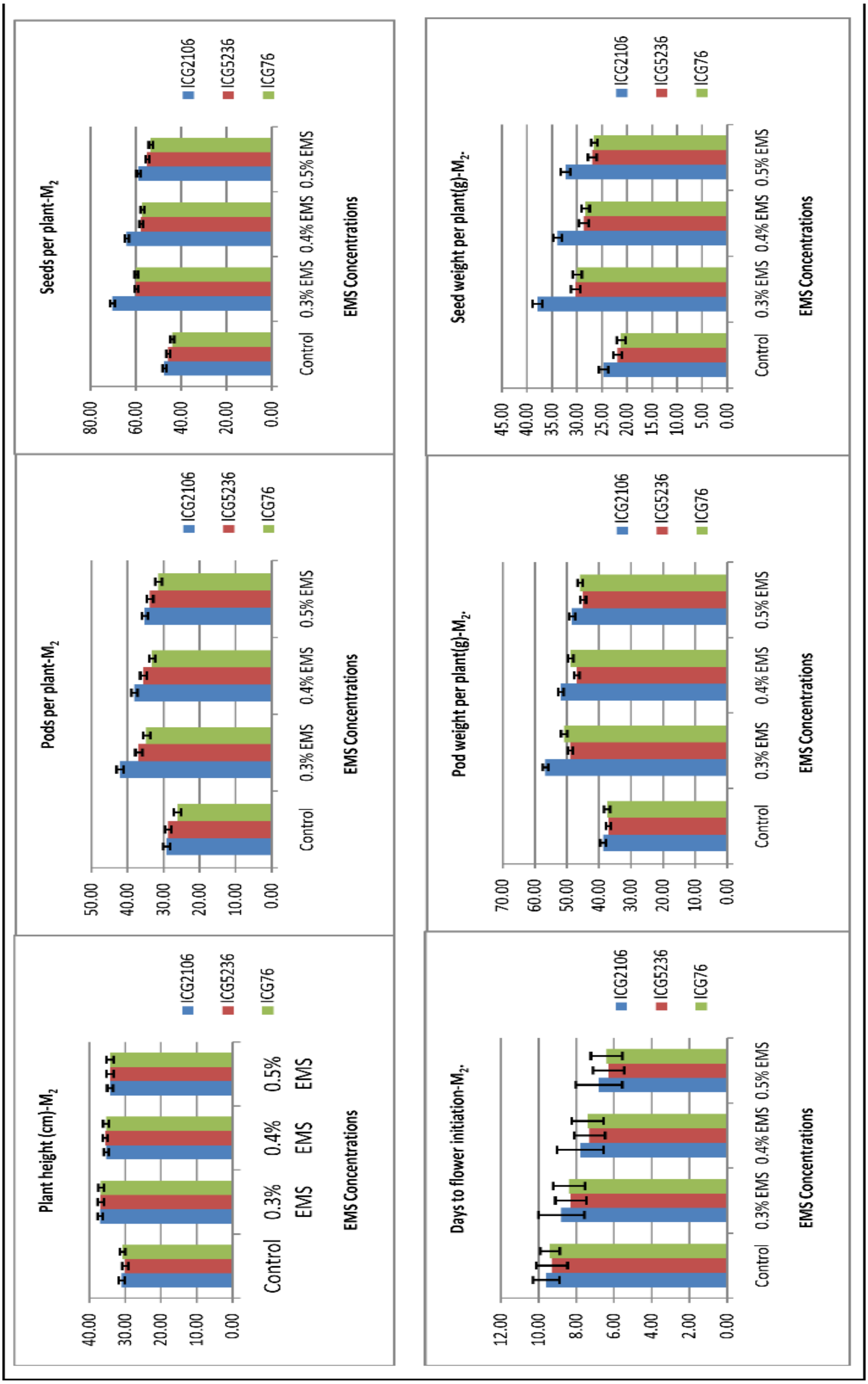

Figure 2. Graphical representation of quantitative traits in groundnut mutant in M_2 generation

Figure 3. Photographical representation of quantitative characters in groundnut under induced EMS mutagenesis in M_1 generation.

Fig 4. Photographical representation of quantitative characters in groundnut under induced EMS mutagenesis in M_2 generation.

Table 7. Percentage of increase or decrease of Seed weight (g/pl) of three groundnut mutants over its control in M_1 generation

S.No	Trait	ICG2106				ICG5236				ICG76			
		Control	0.3% EMS	0.4% EMS	0.5% EMS	Control	0.3% EMS	0.4% EMS	0.5% EMS	Control	0.3% EMS	0.4% EMS	0.5% EMS
1	Seed.Wt (g/Pl)	15.45	12.16	11.53	10.99	14.06	12.77	11.32	10.64	15.97	14.25	13.53	10.95
2	Percentage of increase or decrease over Control	0.00	-21.29	-34.00	- 40.58	0.00	-10.10	-24.20	-32.14	0.00	-12.07	-18.03	-45.84

Table 8. Percentage of increase or decrease of Seed weight (g/pl) of three groundnut mutants over its control in M_2 generation

S.No	**Trait**	**ICG2106**				**ICG5236**				**ICG76**			
		Control	**0.3% EMS**	**0.4% EMS**	**0.5% EMS**	**Control**	**0.3% EMS**	**0.4% EMS**	**0.5% EMS**	**Control**	**0.3% EMS**	**0.4% EMS**	**0.5% EMS**
1	Seed.Wt (g/Pl)	24.70	37.90	33.90	32.30	21.87	30.30	28.70	26.93	21.20	29.97	28.30	26.57
2	Percentage of increase or decrease over Control	0.00	34.83	27.14	23.53	0.00	27.83	23.81	18.81	0.00	29.25	25.09	2020

over control was observed in the mutant ICG 76 at 0.5 percent EMS with -45.84 percent and lowest percent decrease was found in the mutant of ICG 5236 at 0.3 percent with -10.10 percent in M_1 generation. The similar results are meet with Chen *et al*., (2020) and Sudhakar, (2019), Gunasekaran and Pavadai (2015) in groundnut. The results of M_2 generation showed that highest percentage increase of seed weight (g/pl) over control was observed in the mutant ICG2106 at 0.3% EMS with 34.83 percent and lowest percent increase was found in ICG5236 at 0.5% percent with 27.83 percent in M_2 generation. The similar results are reported with singh (2020) in groundnut.

CONCLUSIONS

The results of the study revealed that when the concentration EMS increased the seed yield of groundnut is decreasing in mutants of three groundnut genotypes (ICG2106, ICG5236 and ICG76) in M1 generation. In M1 generation it was clearly observed that the control of ICG2106 (15.45 g) genotype recorded highest yield over its different concentrations viz., 0.3% EMS, 0.4% EMS and 0.5% EMS. These concentrations recorded that the 0.3% EMS (12.16 g), 0.4% EMS (11.53 g) and 0.5% EMS (10.99 g). In M2 generation the results revealed that when the concentration EMS increased the seed yield of groundnut is decreasing in mutants of three groundnut genotypes (ICG2106, ICG5236 and ICG76). Where as in M2 generation it was observed that the mutant of 0.3% EMS of ICG2106 (37.90 g) that the genotype recorded yield increased over its control (24.70 g).

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GENETIC VARIABILITY AND DIVERGENCE STUDIES FOR YIELD AND ITS RELATED TRAITS IN SUNFLOWER

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ABSTRACT

The development and cultivation of hybrids is the key to improving the productivity of sunflower crop. The present study evaluated 52 hybrids during *Rabi* 2023-24 for genetic parameters and genetic variability in relation to yield and its attributing traits. Among the experimental hybrids, the analysis of variance revealed significant differences in yield and its attributes. The traits seed yield (kg ha^{-1}) and oil yield (kg ha^{-1}) recorded the high GCV (26.5 and 27.8) and PCV (28.2 and 29.9) values, respectively. The traits seed yield (kg ha^{-1}), hundred seed weight and oil yield (kg ha^{-1}) recorded the high heritability (>60%) along with high genetic advance expressed as a percentage of mean (>20%). Accordingly, additive genetic effects play a major role in theinheritance of these traits with little influence from the environment.The assessment of genetic diversity grouped the 52 hybrids into six distinct clusters, with the majority (34 hybrids) falling into Cluster I. Among the clusters, the maximum intra-cluster distance was observed in Cluster II (12.14). The greatest inter-cluster distance (75.18) was observed between Cluster VI and Cluster II, suggesting that interbreeding among members in these two clusters could facilitate the production of highly desirable transgressive segregants. Based on a genetic divergence study, the hybrids SH 2876, SH 2883, SH 2896, SH 2904, SH 2895, SH 2878, SH 2886, SH 2899, SH 2884, SH 2922 and KBSH 78 were utilized in the sunflower inbred line development programme.

Keywords: Sunflower, Variability, Diversity, Cluster analysis

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is the fourth leading oilseed crop after soybean, mustard and groundnut in India. In India, sunflower is cultivated over an area of2.69 lakh ha with a production of 2.79 lakh tonnes and a productivity of 1037 kg ha^{-1}(IIOR, 2023). Karnataka, Odisha, Haryana, Maharashtra, Bihar, and West Bengal are the leading sunflower-producing states in India. Andhra Pradesh ranks eighth,covering 0.1 lakh ha area with a production of .085 lakh tonnes and productivity of 695 kg ha^{-1}.The advantageous features of sunflower crop include photo-insensitivity, thermo-insensitivity and short growth cycle that enables the well adaptation to various environments (Chen *et al.,* 2023). In addition to its major contribution in edible oil production, it is also employed as a raw material for the manufacturing of various

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industrial products, including pharmaceuticals, paints and biodiesel.

The performance of early introduced sunflower varieties in India was satisfactory in the beginning. On the other hand, a gradual reduction in yield and oil content due to inherent self-incompatibility problem (Debaeke *et al*., 2021). This led to a shift towards the production of hybrids. Exploitation of heterosis on the commercial scale is made possible owing to high cross-pollinating nature of sunflower (Mohan *et al.,* 2022). A survey of genetic variability determinants *viz.,*genotypic and phenotypic coefficient of variations (GCV and PCV) indicates the degree of variation exists among sunflower genotypes with respect to particular character and also detail about role of the environment in expression of the character. Broad senseheritability (h^2) and genetic advance as percent of mean (GAM) defines selection effectiveness and also nature of gene action in inheritance of particular character. Hence the study of these variability parameters is absolutely necessary to start an efficient breeding programme (Vamsi *et al.,* 2022).

Genetic diversity plays a crucial role in ensuring the success of breeding programs, particularly when aiming to produce hybrids through crosses involving genetically different lines with contrasting and complementary features (Reddy *et al*., 2024b). Breeders typically select genetically diverse parents with contrasting traits to maximize heterosis (hybrid vigour). Biometrical techniques like Mahalanobis D^2statistic offer a quantitative approach to assess genetic divergence among breeding lines. This method considers the interplay between various traits and their combined effect, enabling the classification of crop genotypes at both inter-varietal and sub-species levels. Mahalanobis D^2 statistic provides a valuable index of genetic diversity, allowing the researchers to group the genotypes based on D^2 values (Meena *et al*., 2022). The genetic diversity analysis in the studied hybrids helps in identifying most diverse and distantly related hybrids to be employed in getting desirable segregants for inbred line development programme in sunflower. The key to future improvement lies in exploiting a wider range of inbred lines to create even better hybrids. Hence, this study was conducted to assess the variability and genetic diversity in newly developed sunflower hybrids.

MATERIAL AND METHODS

Fifty-two sunflower hybrids including four checks namely NDSH 1012, KBSH 44, KBSH 78 and Tilhan Tech SUNH1 were evaluated at the Regional Agricultural Research Station, Nandyal during *Rabi* 2023-24. The details of hybrids employed in the investigation are detailed in Table 1. Analpha lattice design was employed to carry out the field experiment in two replications. Each replication consists of four blocks with 13 plots each. The genotypes were sown at a spacing of 60 cm between the rows and 30 cm between the plants within a row. All recommended agronomic practices and measures for plant protection were undertaken to ensure healthy, uniform, and stable crop growth.The data were collected from random sample of five plants of each hybrid in each replication for number of days to 50% flowering, hundred seed weight (g), plant height (cm), head diameter (cm), seed yield (kg ha^{-1}), oil content (%) and oil yield (kg ha^{-1}).

The data were subjected to analysis of variance (ANOVA) based on Alpha lattice design to test the significance as suggested by Patterson and Williams (1976). In this study, the genetic parameters including GCV, PCV, heritability in broad sense (h^2) and genetic advance as percent mean (GAM) were computed. The estimates of GCV and PCV were classified as low, moderate and high as <10%, 10-20% and >20%, respectively according to Sivasubramanian and Menon (1973). The estimates of heritability were classified into low, moderate and high as 0-30%, 30-60% and >60% according to Johnson *et al.,* (1955). The estimates of GAM were classified into low, moderate and high as <10%, 10-20% and >20%, respectively according to Johnson *et al.,* (1955). The analysis of genetic divergence was executed according to Mahalanobis D^2 statistic. The grouping of hybrids into different clusters was done by using Tochers method. The genetic divergence analysis using mean data of all traits over two replications was carried out by employingthe INDOSTAT 9.2 software.

RESULTS AND DISCUSSION

Genetic Parameters

The variance analysis showed significant disparities among the studied hybrids for all the traits,suggesting the adequate variability present in the studied material (Table 2). Further, no significant variation was observed among the blocks for any of the traits except number of days to 50% flowering. The summary statistics such as mean, range,GCV, PCV, GAM and heritability values of the studied traits were shown in Table 3. Seed yield (kg ha^{-1}) trait ranges from 316.1 kg $ha^{-1}$to 1447.1 kg ha^{-1} with mean value of 1091.1 kg ha^{-1}. Whereas, the trait oil yield (kg ha^{-1}) ranges from 104.9 kg ha^{-1} to 501.7 kg $ha^{-1}$with mean value of 357.5 kg ha^{-1}. The findings showed that the PCV estimates exceeded the GCV estimates for all traits, suggesting a significant environmental influence on their expression. Notably, seed yield (kg ha^{-1}) and oil yield (kg ha^{-1}) traits recorded the higher estimates of PCV and GCV values. The high GCV values enable the rewarding of direct selection for these traits. The research performed by Lakshman *et al*. (2021) showed a narrow gap between the estimates of PCV and GCV for head diameter, hundred kernel weight,hundred seed weight and yield traits indicating the low effect of environment and genetic factors majorly influence the expression of trait. Moderate PCV and GCV values observed for plant height (cm), head diameter (cm) and oil content (%) traits. The lower estimates of PCV and GCV was observed for the trait number of days to 50% flowering. Roja *et al*. (2021) reported low GCV values for number of days to 50% flowering,number of days to maturity, oil content and volume weight indicating the major environmental role in the trait expression. Further, the low GCV value implies that the direct selection is not rewarding for such traits.

The broad sense heritability ranged from 29.3% (oil content (%)) to 87.8% (seed yield (kg ha^{-1})). The heritability estimates were observed to be high for the traits number of days to 50% flowering, seed yield (kg ha^{-1}), hundred seed weight (g) and oil yield (kg ha^{-1}). The traits plant height (cm) and head diameter (cm) showed moderate heritability. Whereas, the heritability estimate was observed to be low for the trait oil content (%).Yasir and Abed (2024) reported high heritability for the traits seed yield, seed weight and disc diameter indicating the genetic progress through heritable gene action.The direct selection derived from the phenotypic values is effective for the traits with high heritability. The GAM values were varied from 6.2 (number of days to 50% flowering) to 53.1 (oil yield (kg ha^{-1})). The recorded GAM values showed higher estimates for seed yield (kg ha^{-1}), hundred seed weight (g) and oil yield

(kg ha^{-1}) traits, moderate for head diameter (cm) and plant height (cm) and low for oil content (%) and number of days to 50% flowering traits. Interestingly, the traits seed yield (kg ha^{-1}), hundred seed weight (g) and oil yield (kg ha^{-1}) showed higher estimates of

Table 1. Details of sunflower hybrids utilized in the study

S.No	Hybrid	Parentage	S. No	Hybrid	Parentage
1	SH 2876	ARM 248 A × HOCL 20R	27	SH 2916	CMS 30A × NDI 39
2	SH 2878	NDLA 2 × CSFI 99	28	SH 2917	NDLA 2 × NDI 39
3	SH 2883	NDCMS 30A × GMU 736	29	SH 2918	NDLA 3 × NDI 39
4	SH 2884	NDLA 2 × GMU 736	30	SH 2919	CMS 30A × NDI 43
5	SH 2886	NDLA 5 × GMU 736	31	SH 2920	NDLA 2 × NDI 43
6	SH 2888	ARM 248A × GMU 736	32	SH 2922	NDLA 2 × NDI 44
7	SH 2894	NDCMS 30A × TSG 27	33	SH 2924	NDLA 2 × NDI 49
8	SH 2895	NDLA 2 × TSG 27	34	SH 2926	NDLA 2 × NDI 50
9	SH 2896	NDLA 3 × TSG 27	35	SH 2927	NDLA 3 × NDI 50
10	SH 2897	NDLA 5 × TSG 27	36	SH 2928	NDLA 2 × NDI 51
11	SH 2899	ARM 248A × TSG 27	37	SH 2929	NDLA 3 × NDI 51
12	SH 2900	NDCMS 30A × OPH 137	38	SH 2930	CMS 30A × NDI 52
13	SH 2901	NDLA 2 × OPH 137	39	SH 2931	NDLA 2 × NDI 52
14	SH 2902	NDLA 3 × OPH 137	40	SH 2932	NDLA 3 × NDI 52
15	SH 2903	NDLA 5 × OPH 137	41	SH 2933	CMS 30A × NDI 55
16	SH 2904	NDLA 7 × OPH 137	42	SH 2934	NDLA 2 × NDI 55
17	SH 2905	ARM 248A × OPH 137	43	SH 2935	NDLA 3 × NDI 55
18	SH 2906	CMS 30A × NDI 24	44	SH 2936	CMS 30A × NDI 56
19	SH 2907	NDLA 2 × NDI 24	45	SH 2937	NDLA 3 × NDI 56
20	SH 2908	CMS 30A × NDI 32	46	SH 2938	CMS 30A × NDI 61
21	SH 2909	NDLA 2 × NDI 32	47	SH 2939	NDLA 2 × NDI 61
22	SH 2910	CMS 30A × NDI 34	48	SH 2940	NDLA 3 × NDI 61
23	SH 2911	NDLA 2 × NDI 34	49	NDSH 1012	Check
24	SH 2912	NDLA 2 × NDI 35	50	KBSH 44	Check
25	SH 2913	NDLA 3 × NDI 35	51	KBSH 78	Check
26	SH 2915	NDLA 3 × NDI 36	52	TTSUNH 1	Check

heritability and GAM. Mariyam *et al.* (2024) reported the high estimates of heritability and genetic advance forvolume weight, head diameter, seed filling percentage and seed yield suggesting the manifestation of traits is attributed to additive gene action and the influence of environment is least. Further, Baraiya *et al*. (2018) showed that the response to direct selection is effective with high heritability and high GAM.The trait number of days to 50% flowering exhibited high heritability coupled with low GAM value. Roja *et al*. (2021) reported the high heritability accompanied by low genetic advance for volume weight, number of days to 50% flowering and days to maturity indicating that the nonadditive gene action prevails, making selection potentially ineffective.

Table 2. Analysis of variance for yield and its attributing traits in 52 sunflower hybrids

Variables	Mean sum of squares				
	Replica-tion	Treatment (unadjusted)	Treatment (adjusted)	Block (adjusted)	Error
df	1	51	51	12.42	38.58
Number of days to 50% flowering	1.38	8.32***	-3855.58	3.08**	0.81
Plantheight(cm)	44.43	680.40	1703905.99***	111.08	218.45
Head diameter (cm)	0.24	11.19**	137.33***	3.47	3.88
Hundredseed weight (g)	0.21	2.69***	-232.05	0.36	0.16
Seed yield (kg ha^{-1})	24192.22	178296.02***	4857173.92***	8219.02	12604.38
Oil content (%)	7.09	20.34*	1149.03	17.57	9.03
Oil yield(kg ha^{-1})	440.11	21585.26***	1470112.36	761.89	1853.41

Table 3. Estimates of mean, variability, genetic advance as per cent ofmean and heritability (broad sense) for yield and its attributes in 52 sunflower hybrids

Traits	Mean	Range		Coefficient of Variation		Heritability (%)	GAM
		Minimum	Maximum	PCV (%)	GCV (%)		
Number of days to 50% flowering	52.75	45.0	56.5	4.2	3.5	71.8	6.2
Plantheight(cm)	133.5	80.7	167.9	15.6	11.7	55.9	18.0
Head diameter (cm)	16.8	8.1	21.0	16.3	11.5	49.5	16.6
Hundredseed weight (g)	5.7	3.6	8.0	21.2	19.6	85.3	37.3
Seed yield (kg ha^{-1})	1091.1	316.1	1447.1	28.2	26.5	87.8	51.1
Oil content (%)	32.8	27.1	36.7	12.0	6.5	29.3	7.3
Oil yield (kg ha^{-1})	357.5	104.9	501.7	29.9	27.8	86.3	53.1

Genetic diversity

The 52 sunflower hybrids were classified into six clusters using Tocher's method with criterion that average intra cluster distance estimates were lower than inter cluster distance estimates (Table 4 and Fig.1.). Further, the spread of hybrids to these six clusters is at random only. The highest number of hybrids was grouped into cluster I (34 hybrids). The cluster II and cluster III had ten and five hybrids each, respectively. Clusters IV, V and VI are having single hybrid each. The all check

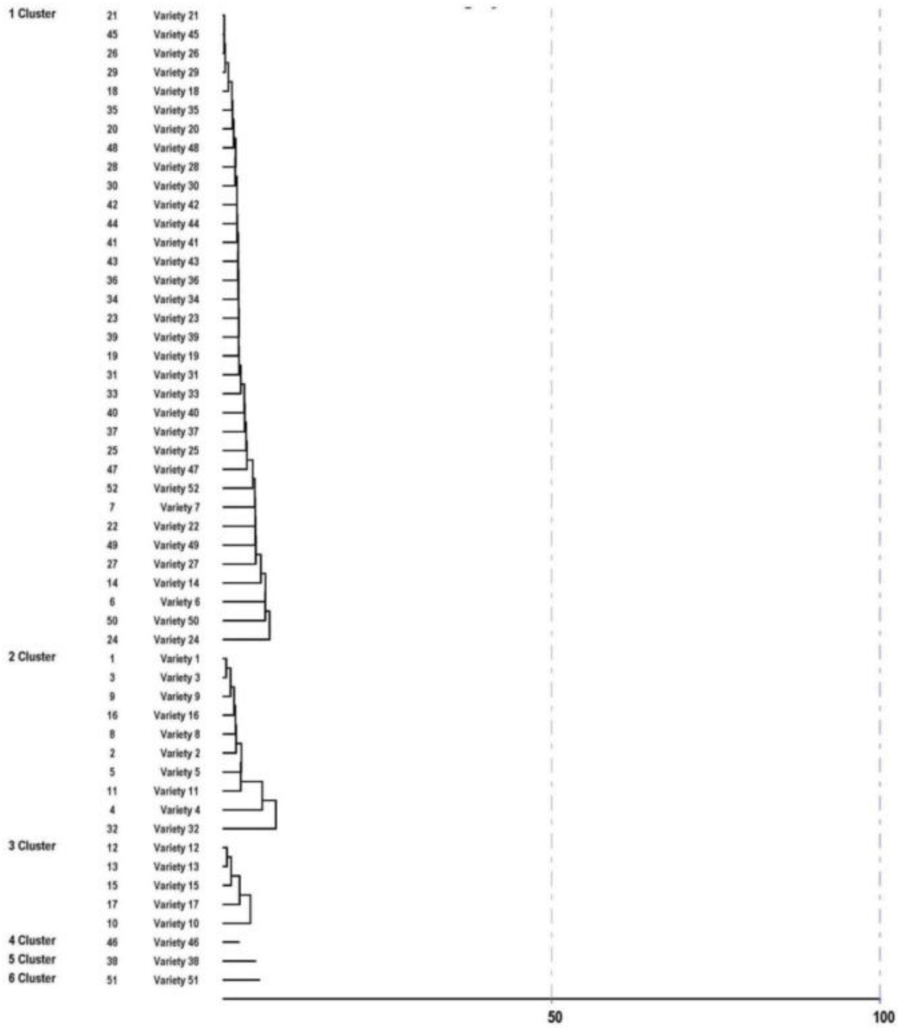

Fig. 1. Dendrogram showing relationship among 52 sunflower genotypes in six clusters based on D^2 values

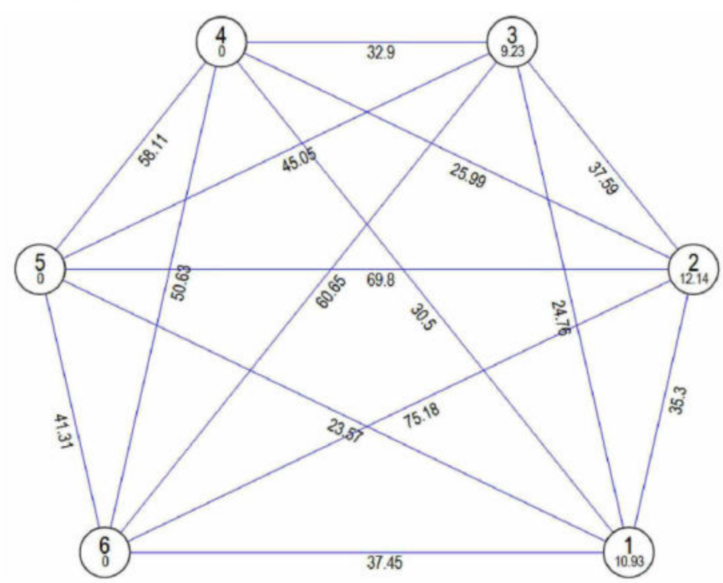

Fig. 2. Cluster diagram showing average intra and inter cluster distance

Table 4. Clustercompositionof52sunflower hybrids basedon Tocher's method

Cluster Group	No. of Genotypes	List of Genotypes
1 Cluster	34	SH 2909, SH 2937, SH 2915, SH 2918, SH 2906, SH 2927, SH 2908, SH 2940, SH 2917, SH 2919, SH 2934, SH 2936, SH 2933, SH 2935, SH 2928, SH 2926, SH 2911, SH 2931, SH 2907, SH 2920, SH 2924, SH 2932, SH 2929, SH 2913, SH 2939, Tillhan Tech SUNH 1, SH 2894, SH 2910, NDSH 1012, SH 2916, SH 2902, SH 2888, KBSH 44, SH 2912
2 Cluster	10	SH 2876, SH 2883, SH 2896, SH 2904, SH 2895, SH 2878, SH 2886, SH 2899, SH 2884, SH 2922
3 Cluster	5	SH 2900, SH 2901, SH 2903, SH 2905, SH 2897
4 Cluster	1	SH 2938
5 Cluster	1	SH 2930
6 Cluster	1	KBSH 78

Table 5.Averageintraandinterclusterdistancesforthe 52 sunflowerhybrids

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Cluster 1	10.93					
Cluster 2	35.30	12.14				
Cluster 3	24.76	37.59	9.23			
Cluster 4	30.50	25.99	32.90	0.00		
Cluster 5	23.57	69.80	45.05	58.11	0.00	
Cluster 6	37.45	75.18	60.65	50.63	41.31	0.00

hybrids were placed in cluster I except KBSH 78, which is grouped into cluster VI. Lakshman *et al*. (2021) reported the presence of single genotype in five clusters and highlighted the role of solitary clusters in harnessing heterosis in hybrid development in sunflower.

The mean intra cluster and intercluster distances are provided in Table 5 and Figure. 2.The intra cluster D^2 values varied from 0 (cluster IV, V and VI) to 12.14 (cluster II). The Cluster II with large intracluster distance suggests a substantial variation in genetic makeup among the genotypes within that cluster.The genotypes which were stocked under the same cluster may show minimum variation from one another as the aggregate of the measured trait. The inter cluster distance was ranged from 23.57 to 75.18. The greatest inter-cluster distance was noted between Cluster II and Cluster VI (75.18), followed by Cluster II and V (69.80), Cluster III and VI (60.65), and Cluster IV and V (58.11), highlighting substantial genetic diversity within these clusters. Further, cluster I was nearest to cluster V (23.57) and farthest to cluster VI (37.54). The cluster II was nearest and farthest to cluster IV (25.99) and cluster VI (75.18), respectively. The cluster III was nearest to cluster I (24.76) and farthest to cluster VI (60.65). The cluster IV was nearest and farthest to cluster II (25.99) and cluster V (58.11), respectively. The cluster V was nearest to

Table6. Cluster means with respect to yield and its at tributes among 52 sunflower hybrids

S. No	Character	Cluster number						Contribution %	Times ranked 1st
		I	II	III	IV	V	VI		
1.	Number of days to 50% flowering	52.88	52.30	54.50	52.00	52.50	45.00	15.16	201
2.	Plantheight (cm)	130.66	146.33	143.13	92.90	148.20	80.70	4.75	63
3.	Head diameter (cm)	17.33	17.32	15.02	8.10	16.80	14.10	6.26	83
4.	hundred seed weight (g)	6.26	4.58	3.97	4.80	7.10	5.85	31.83	422
5.	Seed yield (kg ha^{-1})	1192.31	581.22	1336.75	856.60	1441.45	1400.75	35.14	466
6.	Oil content (%)	32.99	32.23	31.88	30.74	49.63	34.72	2.41	32
7.	Oil yield (kg ha^{-1})	397.07	186.07	423.26	263.95	34.72	486.55	4.45	59

cluster I (23.57) and farthest to cluster II (69.8). The cluster VI was nearest and farthest to cluster I (37.45) and cluster II (75.18), respectively. Based on these studies, crosses made between cluster II (SH 2876, SH 2883, SH 2896, SH 2904, SH 2895, SH 2878, SH 2886, SH 2899, SH 2884, SH 2922) and cluster VI (KBSH 78) followed by cluster II and cluster V (SH 2930) provide the greatest opportunity to break the undesirable linkages and releases the hidden variability to give desirable transgressive segregants.Lagiso *et al*., (2021) suggested that hybridizing clusters with large inter-cluster distances would be a logical approach for recombining desirable traits in sunflower hybrid development programs.

The average values for seven quantitative traits across clusters were recorded and showed in Table 6. The cluster mean values for number of days to 50% flowering range from 45.0 (cluster VI) to 54.5 (cluster III). For the traits, plant height (cm) and head diameter (cm), the cluster mean values range from 80.7 (cluster VI) to 148.2 (cluster V) and 8.1 (cluster IV) to 17.33 (cluster I), respectively. The cluster mean values of hundred seed weight (g) and seed yield (kg ha^{-1}) range from 3.97 (cluster III) to 7.1 (cluster V) and 581.22 (cluster II) to 1441.45 (cluster V), respectively. Whereas, the oil content (%) and oil yield (kg ha^{-1}) showed cluster mean values ranging from 30.74 (cluster IV) to 49.63 (cluster V) and 34.72 (cluster V) to 486.55 (cluster VI). The wide range of cluster mean values indicates a significant variation between the genotypes and can be exploited in future breeding programmes in sunflower (Reddy *et al*., 2024a). Among the studied traits, the trait seed yield (kg ha^{-1}) showed the highest contribution (35.14%) towards total divergence followed by hundred seed weight (g) (31.83%), number of days to 50% flowering (15.16%), head diameter (cm) (6.26%), plant height (cm) (4.75%), oil yield (kg ha^{-1}) (4.45%) and oil content (%) (2.41%). The traits hundred seed weight (g), seed yield (kg ha^{-1}) and number of days to 50% flowering are the main contributors which accounted for 82.13% of total genetic divergence. Neelima *et al*. (2016) observed that hundred seed weight played a most significant role in total genetic diversity after that plant height and days to maturity and highlighted the role of classifying the genotypes based on diversified traits in sunflower hybrid development programmes.

CONCLUSIONS

The present investigation showed the interrelationship between the yield and its attributing traits with the occurrence of significant variability and diversity among the hybrids. The traits seed yield (kg ha^{-1}) and oil yield (kg ha^{-1}) recorded the high GCV, PCV, heritability coupled with high genetic advance as percent of mean. Further, the trait seed yield (kg ha^{-1}) showed the maximum contribution to the overall genetic divergence. The highest inter cluster distance was noted between cluster II and VI followed by cluster II and V, cluster III and VI and cluster IV and V. Based on the genetic distance and *perse* performance for yield and its contributing traits, the hybrids SH 2876, SH 2883, SH 2896, SH 2904, SH 2895, SH 2878, SH 2886, SH 2899, SH 2884, SH 2922 and KBSH 78 were exploited in future breeding programmes to get the desirable segregants for inbred line development in sunflower.

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MANAGEMENT OF BROAD MITE, *POLYPHAGOTARSONEMUS LATUS* (BANKS) USING BIOLOGICAL CONTROL AGENTS AND THEIR IMPACT ON THE QUANTITATIVE AND QUALITATIVE PARAMETERS OF MULBERRY

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ABSTRACT

The study was conducted during April 2022 to February 2024. The broad mite, *Polyphagotarsonemus latus* occurrence alters the plant growth,leaf yield and quality parameters of mulberry. The study revealed that the damages of broad mite influences greatly on quality and nutritional content of mulberry leaf. Significant differences were observed on plant growth, leaf yield and nutritional content of mulberry leaves. All the growth parameters were highest when the broad mite occurrence was managed by using treatment Pongamia oil @ 3 ml/l *i.e.*, Number of shoots per plant (15.89), number of leaves per shoot (16.61), plant height (183.27cm), number of leaves per plant(168.27), leaf yield per plant (882.07 g). On the other hand the biochemical constituents of the mulberry leaves were also increased in the treatment imposed plots compared untreated control. The treatment Pongamia oil @ 3 ml/l recorded highest amount crude protein (21.46 mg/g), chlorophyll-A (1.535 mg/ml) and total chlorophyll content (1.850 mg/ml) of mulberry leaves. Overall the study revealed that the biological agents including entomopathogenic fungi (*H. thompsonii*(26.46%) & *L. lecanii*(26.12%)) botanicals (Pongamia (32.83)& Neem oil (32.28%)) and predator (*S. punctillum*(21.09%) & *N. indicus* (24.09%)) could be used successfully to manage the broad mite occurrence in mulberry to enhance the leaf yield and quality.

Keywords: Management, Neem, Occurrence, *Polyphagotarsonemus latus*, Pongamia.

INTRODUCTION

Mulberry (Morus spp.) leaf is the sole food plant for the silkworm, Bombyx mori L. it is a deep rooted, perennial and fast growing plant. Yield and quality of mulberry leaf has direct impact on silkworm rearing influencing the cocoon quality and productivity. Throughout the year, mulberry cultivation and silkworm rearing which are the two important farm based activities face challenges from various pests and pathogens. These issues adversely impact cocoon quality and productivity, leading to economic losses for both farmers and the sericulture industry. Among the major insect orders that attack the mulberry crop, the most numerous species are orders Lepidoptera, Hemiptera, Coleoptera, Thysanoptera, Orthoptera and Isoptera.

Additionally, acaridssuch as *Aceria mori* Keifer, *Panonychusulmi* McGr., *Tetramychu-*

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sludeni Zacher, *Tetranychusurticae* Koch and mollusks popularly known as Giant African snail, *Achatinafulica* have also been observed to cause damage (Sengupta *et al*., 1990). The phytophagous mites are devastating many economically important crops worldwide. *Tetranychusurticae* Koch, broad mite, *Polyphagotarsonemus latus* Banks and *Panonychusulmi* Koch(European red mites) are widely known for their extensive damage to many crops. To manage these mites, farmers generally use the pesticides into their crop cultivation. However, chemical control comes with many problems such as insect resistance, detrimental environmental effects and various human health implications. As such biological control is an environmentally friendly alternative that uses bio-control agents such as predators, pathogens and parasitoids to control pests (Daniels Alicia *et al.,* 2023).The broad mite damage has reached alarming levels and is causing significant loss to the mulberry leaf production. As a result, crop losses ranging from 20–70% have been recorded (Prakya Sree ramakumar and Richa Varshney, 2020). Several factors contribute to the severity of the mite menace. These include the availability of mulberry as a preferred host for the mites, changes in climate conditions and elimination of natural enemies due to increase in usage of modern pesticides (Prakya Sree ramakumar and Richa Varshney, 2020). The bioassay results revealed varying resistance ratios of *P. latus* to five acaricides, 26.03 to 81.16-fold for diafenthiuron, 27.35 to 83.47-fold for dicofol, 9.72 to 45.42-fold for fenazaquin, 8.77 to 16.84-fold for propargite, and 48.37 to 163.39-fold for spiromesifen. However, a decline in resistance ranging from 14.11 to 102.53-fold was observed across generations. These findings indicate that applying acaricides at economic threshold levels or adopting a rotational application strategy over one or more seasons can enhance the management of *P. latus* by delaying resistance development. (Neenu *et al*., 2023)

At present, the primary approach for managing mites in mulberry cultivation relies heavily on the use of acaricides namely, Propargite 57% EC, Dicofol 18.5% EC, Fenazaquin 10% EC and Wettable sulphur 80% WP. Broad mite infestation occur during sprouting and leaf harvesting phases of the mulberry cultivation and the use of pesticides especially during harvesting leads to residue problems in the mulberry leaves required for the silkworm rearing. Therefore there is an urgent requirement to develop management strategies using biological control agents, specifically tailored to broad mite management in mulberry ecosystem. The current study aims to promote practical application of biological control agents in managing the broad mite occurring on mulberry. This approach holds great promise for effectively managing broad mite, while considering the socio-economic and environmental well-being of sericulture farmers. Management practices of broad mite, *P. latus* using biological control agents in mulberry cultivation have great impact on plant growth, leaf yield as well as the improvement in biochemical constituents which are the most important factors contributing to quality mulberry leaf, cocoon and silk production.

MATERIAL AND METHODS

Materials used in the study

Mulberry variety: Victory-1(V-1) variety mulberry was used for the field study.This variety was developed and released by Central Silk Board, in the late 1990s. it features erect branches with a greyish stem colour. The leaves are thick, succulent, large entire and ovate with a truncate base, displaying smooth and glossy surface. V-1 mulberry variety is noted for its high rooting ability, rapid growth and substantial yield producing around 60MT/

ha/year under irrigated conditions with recommended practices (Chaitanya and Kishore, 2024).

Predators:

Predator, *Stethoruspunctillum* Weise was collected from mite infested agriculture and horticulture crops at University of Agricultural Sciences, GKVK, Bangalore, Indian Institute of Horticulture Research [IIHR], Bangalore and National Institute of Plant Health Management [NIPHM], Hyderabad and *S. punctillum* was identified through field observation and laboratory studies. The predatory mite, *Neoseiulus indicus* [Narayanan & Kaur] was obtained from the Indian Council of Agricultural Research-National Bureau of Agricultural Insect Resources [ICAR-NBAIR], Bengaluru were used for the study.

Pathogens [Entomopathogenic fungi]:

Entomopathogenic fungi are microorganisms that infect and often kill susceptible insect population through conidia and fungal entomo-pathogens serves as an alternative to insecticides. In the current study, the entomopathogenic fungi, *Leconicilliu-mlecani* and *Hirsutellathomsonii* were used to know the pathogenesis against broad mite, *P. latus* damaging mulberry. Stock culture of *L. lecanii* obtained from Mulberry Pathology and Microbiology Section of KSSR&DI, Bengaluru and *H. thompsonii*was obtained from NBAIR, Bengaluru and also procured from IPL [International Panaacea Limited] Biologicals Limited, Bengaluru.

Botanicals: Botanicals were found as an effective alternative to conventional pesticides and are environmentally safer with rich source of biologically active compounds. Commercially available Neem oil [Azaneem-10000 ppm] and Pongamia oil [Pure Karanja seed carrier oil] were procured from insecticide retailer shops and used for the study.

Acaricides: Commercially available acaricides or miticides,procured from insecticide retailer shops were used for the field study which includes Propargite[Omite] 57% EC and Fenazaquin [Magister] 10% EC.

Experimental garden and design

The field experimental study was conducted in 15 years old established V-1 mulberry garden maintained with recommended package of practices during 2019-20 to 2021-22. Completely randomised design was followed for experimentation and three replications were maintained for each treatment.

Field evaluation: The field evaluation was conducted for efficacy of predators, *Stethoruspunctillum* and *Neoseiulus indicus*, entomopathogenic fungi, *Lecanicilliumlecanii* and *Hirsutellathompsonii*, botanicals [Neem oil, Pongamia oil] and acaricides [Propargite and Fenazaquin] against broad mite occurrence on mulberry.

Treatment details

T-0: Control ; T-1:*Stethoruspunctillum*@ 200/Plant ; T-2:*Neoseiulus indicus* @ 200/Plant ; T-3:*Lecanicilliumlecanii*(CFU-2x10^8/ml) 3ml/l) ; T-4:*Hirsutellathompsonii*(CFU-2x10^8/ml) 3ml/l) ; T-5: Neem oil @ 3ml/l; T-6: Pongamia oil @ 3ml/l ; T-7: Propargite@ 2ml/l; T-8: Fenazaquin @ 2ml/l

Treatment and observation recorded

Entomopathogenic fungi, botanicals and acaricides were sprayed by using hand sprayers and release of predators was carried out under controlled condition on mulberry after 15 days of pruning and observations were recorded on 60^{th} day after pruning. In each replication five plants were randomly selected and labelled for recording the observations.

Statistical Analysis of the Data

The data from the study has been analyzed using statistical methods to determine the efficacy of biological control agents on managing the broad mite. ONE-WAY Analysis of Variance(ANOVA) was employed using SPSS statistical package (Ver. 21.0) following the methods outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The use of biological agents to manage broad mite, *P. latus* on mulberry significantly enhanced the plant growth, leaf yield and qualitative parameters of the mulberry. The data pertaining to the quantitative and qualitative aspects of mulberry has been presented in Table 1 to 3.

Plant height (cm)

The approaches adopted for the management of broad mite on mulberry, significantly impacted in plant height (F-value=28.747**). The height of the plant was longestin T_6: Pongamiaoil @ 3ml/l(165.83 ±0.255 cm), followed by T_2: *Neoseiulus indicus* @200/ plant (164.94 ± 0.555cm), T_5: Neem oil @ 3ml/l (164.83 ± 0.674 cm),T_8: Fenazaquin @ 2ml/l (164.22 ± 0.642 cm), T_3: *L. lecanii* @ 3ml/l(164.05 ± 0.274 cm), T_1:*Stethoruspunctillum*@200/plant,(162.94 ± 1.583), T_7: Propergite 57%EC @ 2 ml/l (162.78 ± 0.863) andT_4: *Hirsutellathompsonii*(CFU = 2x10^8/ml) @3ml/l (162.67 ± 1.069 cm)whereas, T_0: Control could register shortest plant height (151.22 ± 0.476cm) (Table 1).

Number of shoots/plant

The number of shoots per plant varied significantly (F-value=16.597**)in adopted practices for the management of broad mite on mulberry. Notably, more number of shoots per plant was observed in T_6: Pongamia oil @ 3ml/l (12.33 ± 0.003shoots/plant) and the other treatments namely T_5: Neem oil @ 3ml/l (12.28± 0.110shoots/plant),T_4: *Hirsutellathompsonii* (CFU- 2x10^8/ml) @ 3ml/l(12.28± 0.053shoots/plant),T_3: *L. lecanii* @ 3ml/l(12.22 ± 0.147),T_8: Fenazaquin@ 2ml/l(12.22 ± 0.053shoots/plant), T_7: Propergite 57%EC @ 2 ml/l (11.89 ± 0.241shoots/plant), T_1-*Stethorus punctillum* @ 200/plant,(11.44 ± 0.391shoots/plant) in T_2: *Neoseiulus indicus* @ 200/plant,(11.39 ± 0.220shoots/plant) found next best with respect to number of shoots per plant. However, less number of shoots per plant was observed in T_0: Control (10.00 ± 0.098shoots/plant).

Number of leaves/plant

Number of leaves per plant is a cumulative effect of number of shoots per plant and number of leaves/shoot. Number of leaves per plant varied significantly (F-value=27.763**) with management practices followed against broad mite occurrence on mulberry. Considerably, more number of leaves per plant (343.75± 0.500leaves/plant) was observed in T_6: Pongamia oil @ 3ml/l. The treatments T_5: Neemoil @ 3ml/l (340.14± 0.220leaves/plant), T_8: Fenazaquin 10% EC @2ml/l(337.15± 2.698leaves/plant), T_3: *Lecanicilliumlecanii*(CFU = 2x10^8/ml)@3ml/l(336.74± 4.315leaves/plant), T_4: *Hirsutellathompsonii*(CFU = 2x10^8/ml) @3ml/l (335.69± 1.361leaves/plant), T_7: Propargite 57% EC @2ml/l(324.80± 5.446leaves/plant), T_2:*Neoseiulus indicus* @ 200/plant(315.93± 5.044leaves/plant) and T_1: *Stethoruspunctillum* @ 200/plant(313.14± 12.27 leaves/plant) stood next in the order with respect to number of leaves per plant. On contrast, T_0: Control could register less number of leaves per plant (253.81 ± 3.175leaves/plant).

Leaf yield (g/plant)

Statistically significant (F-value=26.193**) variations registered due to imposition of biological agents against broad mite on mulberry. Leaf yield per plant was highest with T_6: Pongamia oil @ 3ml/l (973.50± 2.024 g/plant), followed by T_5: Neem oil @ 3ml/l (963.74± 4.394 g/plant), T_8: Fenazaquin 10% EC @2ml/l(954.44 ± 7.748 g/plant), T_3: *Lecanicilliumlecanii*(CFU = 2x10^8/ml)@3ml/l(952.85± 13.22 g/plant), T_4: *Hirsutellathompsonii*(CFU = 2x10^8/ml) @3ml/l (950.91± 4.459 g/plant), T_7: Propargite 57% EC @2ml/l(918.59± 16.00 g/plant), T_2:*Neoseiulus indicus* @ 200/plant(896.48± 15.49 g/plant) and T_1:*Stethorus punctillum* @ 200/plant(889.12± 34.89 g/plant). However, leaf yield per plant was considerably less in T_0: Control (719.74± 9.150 g/plant) (Table 1).

There is relatively no information available on managing the broad mite on mulberry through biological control agents. However, for comparison insights from studies on the management of mite infestations on other crops which are severely affected by broad mite, *P. latus* are utilized for discussion. Islam *et al.* (2019) reveal that the neem seed kernel extracts efficacy in managing the jute yellow mite, suggesting its potential for mulberry cultivation. Sarkar *et al*. (2018) demonstrated the feasibility of integrating cost-effective and safer inputs, such as *L.lecanii* and spiromesifen, for yellow mite management in jute. Adopting this approach in mulberry cultivation could minimize mite infestation with minimal environmental impact. Chemical management in mulberry poses significant challenges due to the sensitivity of silkworms to most pesticides. Broad mite occurrence in mulberry affects the plant growth, leaf yield, and nutritional parameters. This study aims to fill this gap by evaluating the impact of bio-intensive management approaches to manage broad mite occurrence and maintaining mulberry leaf production, considering various quantitative and qualitative parameters.

control Leaf moisture (%)

Leaf moisture content in mulberry differed significantly (F-value=4.725**) among the management approaches when adopted broad miteon mulberry. Highest leaf moisture content was recorded in treatment T_3: *Lecanicilliumlecanii*(CFU- 2x10^8/ml) @ 3ml/l(66.47 ± 0.478%) when compared to other treatments such as T_6: Pongamia oil @ 3ml/l (66.41 ± 0.488 %),T_5: Neem oil @ 3ml/l (66.35 ± 0.992%), T_4: *Hirsutellathompsonii*(CFU = 2x10^8/ml) @3ml/l (65.42 ± 2.115%), T_8: Fenazaquin 10% EC @2ml/l(65.40 ± 0.366%), T_2: *Neoseiulus indicus*@200/plant(65.09 ± 0.289%),T_1:*Stethorus punctillum* @200/plant(65.08 ± 1.574%)and T_7: Propargite 57% EC @2ml/l(64.89 ± 1.140%). Lowest leaf moisture content of mulberry was recorded in T_0: Control (63.41 ± 0.577%)(Table 2).

Mite occurrence in mulberry alters the moisture content of the leaf as mites suck the sap from leaf and becomes unpalatable to silkworms. In the present experiment the leaf moisture content in mulberry varies from 63.41% in untreated control and 66.47% in the treated leaves. The present results are conformity with the findings of Abou-Awad *et al*. (2014) studied the effect of broad mite feeding on apical leaves of sweet pepper (*Capsicum annuum* L.) and reported that increase in the population of mites (from 5.2 to 14.9 /leaf) was accompanied with 56.3% decrease in fresh weight and 49.2% decrease in dry weight of apical leaves.

Carbohydrates (mg/g)

Carbohydrate content in mulberry leaf did not vary statistically (F-value=0.727^{NS}) among the biological control agent management practices when followed for broad mite on mulberry. However, carbohydrate content was marginally more in T_5: Neem oil @ 3ml/l (18.56 ± 0.064mg/g) and the treatments followed next in the order were T_6:Pongamia

Table 1: Impact biological control agents on growth and yield of mulberry

Treatment	Plant height (cm)	Number of Shoots/plant	Number of leaves/plant	Leaf yield (g/plant)
T_0: Control	137.97 ± 3.407	10.11 ± 0.110	136.63 ± 0.441	657.73 ± 9.374
T_1: *Stethoruspunctillum* @200/plant	173.70 ± 5.008 (21.99)	12.33 ± 0.095 (12.39)	153.53 ± 1.105 (12.37)	751.67 ± 20.30 (14.28)
T_2: *Neoseiulus indicus*@200/plant	171.20 ± 2.001 (24.09)	12.11 ± 0.147 (19.78)	151.93 ± 0.470 (11.28)	743.17 ± 23.71 (12.99)
T_3: *Lecanicilliumlecanii*(CFU = 2x10^8/ml)@3ml/l	174.00 ± 2.065 (26.12)	13.95 ± 0.147 (37.95)	156.50 ± 0.929 (14.54)	810.27 ± 37.49 (23.19)
T_4: *Hirsutellathompsonii*(CFU = 2x10^8/ml) @3ml/l	174.47 ± 5.610 (26.46)	14.00 ± 0.254 (38.48)	154.17 ± 0.273 (12.83)	806.60 ± 49.78 (22.63)
T_5:Neem oil @3ml/l	182.50 ± 20.25 (32.28)	14.83± 0.839 (46.72)	161.43 ± 1.438 (18.15)	875.33 ± 11.03 (33.08)
T_6: Pongamia oil @3ml/l	183.27 ± 2.601 (32.83)	15.89± 0.910 (57.17)	168.27 ± 0.649 (23.15)	882.07 ±17.49 (34.11)
T_7: Propargite 57% EC @2ml/l	173.50 ± 4.519 (25.75)	12.78± 0.147 (26.38)	154.73 ± 0.578 (13.25)	774.50 ± 26.02 (17.75)
T_8: Fenazaquin 10% EC @2ml/l	162.53 ± 4.519 (17.81)	12.44± 0.241 (23.18)	158.57 ± 0.593 (16.05)	795.13 ± 17.55 (20.90)
Mean	170.35± 2.772	13.16 ± 0.338	154.54 ± 1.663	788.56 ± 14.70
F-value	10.315**	15.070**	124.399**	6.697**

oil @ 3ml/l (18.36 ± 0.675 mg/g),T_5: Neem oil @ 3ml/l (66.35 ± 0.992%), T_4: *Hirsutellathompsonii*(CFU = 2x10^8/ml) @3ml/l (18.34 ± 0.376 mg/g), T_3: *Lecanicilliumlecanii*(CFU- 2x10^8/ml) @ 3ml/l(18.22 ± 0.252mg/g), T_7: Propargite 57% EC @2ml/l(17.94 ± 0.311mg/g),T_2: *Neoseiulusindicus*@200/plant(17.92 ± 0.215mg/g),T_1:*Stethorus punctillum* @200/plant(17.86 ± 0.127mg/g)andT_8: Fenazaquin 10% EC @2ml/l(17.85± 0.162mg/g). On the other hand, relatively less carbohydrate content in mulberry leaf was recorded in treatment T_0: Control (17.75± 0.390mg/g)(Table 2). The present results are agreement with the findings of earlier reports of Mohd Yaqoob Dar *et al*. (2011) who reported the carbohydrate content in the mite damaged leaves was 73.1 mg/g dry wt. ranging between 65.8 to 87.5 mg/g dwt. While the mean value of carbohydrate content in healthy leaves were 98.72 and varied between 92.1 to 110.0 mg/g dry weight. The carbohydrate content in mite damaged leaves was reduced compared to healthy mulberry leaves.

Crude protein (mg/g)

Crude protein varied significantly (F-value=4.790**) among the management practices when imposed against broad mite management on mulberry. The mulberry leaves which are harvested from T_6: Pongamia oil @ 3ml/l recorded highest protein content (21.46 ± 0.131mg/g), followed by T_5: Neem oil @ 3ml/l (21.23 ± 0.115mg/g), T_3: *Lecanicilliumlecanii* (CFU- 2x10^8/ml) @ 3ml/l(20.68 ± 0.100mg/g),T_4: *Hirsutellathompsonii*(CFU = 2x10^8/ml) @3ml/l (20.64 ± 0.313 mg/g),T_2: *Neoseiulus indicus* @200/plant (20.39 ± 0.343mg/g), T_1: *Stethoruspunctillum* Weise @200/plant (20.38 ± 0.123mg/g),T_8: Fenazaquin 10% EC @2ml/l (20.15 ± 0.101mg/g)and T_7: Propargite 57% EC @2ml/l (17.94 ± 0.311mg/g). Notably, lowest crude protein content (19.88 ± 0.363mg/g) was found in T_0: Control (Table 2). The present results are agreement with the findings of earlier reports. Mohd Yaqoob Dar *et al*. (2011) recorded the protein content of the mite damaged leaves was 23.72 mg/gram dry weight compared to 36.50 in the healthy leaves. It ranged from 20.1 to 27.5 and 32.4 to 40.0 in the damaged and healthy leaves respectively.

Chlorophyll 'a' (mg/g)

Chlorophyll'a' content in mulberry leaf differed significantly (F-value=5.474**) among the management practices adopted against broad mite on mulberry. Higher chlorophyll 'a' content in mulberry leaf(1.535± 0.039mg/g) was recorded in T_6: Pongamia oil @ 3ml/l, followed by T_5:Neem oil @ 3ml/l (1.532 ± 0.022mg/g), T_4: *Hirsutellathompsonii*(CFU- 2x10^8/ml) *3ml/l* (1.520± 0.079mg/g), T_7: Propargite 57% EC @2ml/l (1.512 ± 0.021mg/g), T_3: *Lecanicilliumlecanii* (CFU- 2x10^8/ml) @ 3ml/l(1.500± 0.024mg/g),T_8: Fenazaquin 10% EC @2ml/l (1.495 ± 0.030mg/g), T_1:*Stethorus punctillum*@200/plant (1.488 ± 0.028mg/g)and T_2: *Neoseiulus indicus* @200/plant (1.480 ± 0.026mg/g). Whereas, lowest chlorophyll'a' content (1.397mg/g± 0.047mg/g) was recorded in T_0: Control (Table 3).

Chlorophyll 'b' (mg/g)

Chlorophyll 'b' content in mulberry leaf did not vary significantly(F-value=1.284^{NS}) when biological control agents management practices imposed on broad mite in mulberry.However, relatively highest chlorophyll 'b' content in mulberry leaf (0.250 ± 0..35 mg/g) was recorded in treatment T_8: Fenazaquin 10 % EC @ **2ml/l,over** other treatments namely T_6:Pongamia oil @ 3ml/l (0.247 ± 0.033 mg/g), T_5:Neem oil @ 3ml/l (0.247 ± 0.027 mg/g), T_3: *Lecanicilliumlecanii* (CFU- 2x10^8/ml) @ 3ml/l (0.243± 0.034 mg/ml),T_4: *Hirsutellathompsonii* (CFU- 2x10^8/ml) *3ml/l* (0.241 ± 0.032mg/g),T_2: *Neoseiulus indicus* @200/plant (1.480 ± 0.026mg/g), T_7:

Table 2: Impact of biological control agents on biochemical composition of mulberry

Treatment	Leaf moisture (%)	Carbohyd-rates (mg/g)	Crude protein (mg/g)
T_0: Control	63.41 ± 0.577	17.75 ± 0.390	19.88 ± 0.363
T_1: *Stethoruspunctillum* Weise @200/plant	65.08 ± 1.574 (2.644)	17.86 ±0.127 (0.620)	20.38 ±0.123 (2.532)
T_2: *Neoseiulus indicus* @ 200/plant	65.09 ± 0.289 (2.649)	17.92 ± 0.215 (0.977)	20.39 ± 0.343 (2.582)
T_3: *Lecanicilliumlecanii*(CFU = 2x10^8/ml)@ 3ml/l	66.47 ± 0.478 (4.826)	18.22 ± 0.252 (2.648)	20.68 ± 0.100 (4.007)
T_4: *Hirsutellathompsonii*(CFU = 2x10^8/ml) @3ml/l	65.42 ± 2.115 (3.180)	18.34 ± 0.376 (3.324)	20.64 ± 0.313 (3.823)
T_5:Neem oil @3ml/l	66.35 ± 0.992 (4.642)	18.56 ± 0.064 (4.563)	21.23 ± 0.115 (6.791)
T_6: Pongamia oil @3ml/l	66.41 ± 0.488 (4.736)	18.36 ± 0.675 (3.437)	21.46 ± 0.131 (7.964)
T_7: Propargite 57% EC @2ml/l	64.89 ± 1.140 (2.339)	17.94 ± 0.311 (1.070)	20.14 ± 0.302 (1.325)
T_8: Fenazaquin 10% EC @2ml/l	65.40 ± 0.366 (3.149)	17.85 ± 0.162 (0.582)	20.15 ± 0.101 (1.375)
Mean	66.05±0.521	18.09±0.106	20.55±0.116
F-value	4.725**	0.727**	4.790**

CFU: Colony forming unit   ***pd"0.01*   (   ): Per cent change over control

Propargite 57% EC @2ml/l (0.240 ± 0.073mg/g) and T_1:*Stethorus punctillum* @200/plant (0.232 ± 0.039mg/g). On the other hand, T_0: Control recorded lowest chlorophyll 'b'content of 0.206 ± 0.035mg/g (Table 3).

Total Chlorophyll (mg/g)

The total chlorophyll content in mulberry leaf differed significantly (F-value=9.444**) among the management practices when adopted against broad mite on mulberry. Considerably, highest total chlorophyll content (1.850 ± 0.031 mg/g) was recorded in T_6:Pongamia oil @ 3ml/l and the treatmentsT_5:Neem oil @ 3ml/l (1.848± 0.011 mg/g), T_4:*Hirsutella thompsonii*(CFU- 2x10^8/ml) *3ml/l* (1.837 ± 0.051mg/g),T_1:*Stethorus punctillum* @200/plant(1.794 ± 0.012mg/g), T_2:*Neoseiulus indicus*@200/plant(1.786 ± 0.013mg/g),T_3:*Lecanicillium lecanii*(CFU-2x10^8/ml/l) @ 3ml/l (1.821 ± 0.015 mg/g),T_8: Fenazaquin 10 % EC @ 2ml/l(1.780 ± 0.013 mg/g) andT_7: Propargite 57% EC @2ml/l(1.750± 0.052mg/g) stood next in the rank with respect to total chlorophyll content. However, lowest total chlorophyll content (1.603± 0.028mg/g) was recorded in T_0: Control (Table 3). In the present experiment total chlorophyll content is the addition of Chlorophyll A and Chlorophyll B. This chlorophyll content in mite

Table 3: Impact of biological control agents on chlorophyll content of mulberry

Treatment	Leaf moisture (%)	Carbohyd-rates (mg/g)	Crude protein (mg/g)
T_0: Control	1.397 ± 0.047	0.206 ± 0.035	1.603 ± 0.028
T_1: *Stethoruspunctillum* Weise @200/plant	1.488 ± 0.028 (6.500)	0.232 ± 0.039 (12.39)	1.794 ±0.012 (11.96)
T_2: *Neoseiulus indicus*@ 200/plant	1.480 ± 0.026 (5.905)	0.241 ± 0.026 (16.92)	1.786 ± 0.013 (13.09)
T_3:*Lecanicilliumlecanii* (CFU=2x10^8/ml)@ 3ml/l	1.500 ± 0.024 (7.333)	0.243 ± 0.034 (17.83)	1.821 ± 0.015 (15.59)
T_4:*Hirsutellathompsonii*(CFU= 2x10^8/ml) @3ml/l	1.520 ± 0.079 (8.762)	0.241 ± 0.032 (16.87)	1.837 ± 0.051 (16.74)
T_5:Neem oil @3ml/l	1.532 ± 0.022 (9.648)	0.247 ± 0.027 (19.68)	1.848 ± 0.011 (17.51)
T_6: Pongamia oil @3ml/l	1.535 ± 0.039 (9.798)	0.247 ± 0.033 (19.78)	1.850 ± 0.031 (17.62)
T_7: Propargite 57% EC2ml/l	1.512 ± 0.021 (8.190)	0.240 ± 0.073 (16.39)	1.750 ± 0.052 (10.50)
T_8: Fenazaquin 10% EC@2ml/l	1.495 ± 0.0.030 (6.998)	0.250 ± 0.035 (21.11)	1.780 ± 0.013 (12.64)
Mean	1.514±0.020	0.239±0.106	1.796±0.019
F-value	5.474*	1.284	9.444**

CFU: Colony forming unit ****pd”0.01**(): Per cent change over control

infested plants altered significantly (pd”0.01; F-value=9.444**) among the different management practices followed to manage the broad mite incidence in mulberry. In contrast, Malakah and Elsadany, (2018) also studied the influence of host plants and some leaf contents on biological aspects of *Tetranychusurticae* Koch and reported that the total chlorophyll content in mulberry is reduced on the other hand the chlorophyll content in castor leaves has been increased when the mites were infested to these host plants.

CONCLUSIONS

The present study revealed that the use of biological control agents and plant-derived oils significantly enhanced the growth and leaf yield of mulberry while effectively managing the broad mite, *Polyphagotarsonemus latus*. The application of *Pongamia oil* at 3 ml/l (T6) yielded the best results, with the highest plant height (165.83 cm), number of shoots (12.33), leaves per plant (343.75), and leaf yield (973.50 g/ plant), followed closely by *Neem oil* and other treatments like *Lecanicilliumlecanii* and *Hirsutellathompsonii*. Notably, the leaf moisture content, crude protein, and total chlorophyll levels were significantly higher in treatments with biological agents, particularly *Lecanicilliumlecanii* and *Pongamia oil*. The control treatment (T0) showed the lowest values across all parameters, indicating the negative impact of broad mite infestation. These approaches not only mitigate the impact of the pest but also improve the overall quality and yield of mulberry leaves, contributing to more sustainable agricultural practices in sericulture.

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INCIDENCE OF MATURITY ONSET DIABETES OF THE YOUNG (MODY) AMONG THE SELECTED YOUNG ADULTS

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ABSTRACT

This study investigated the incidence of maturity onset diabetes of the young (MODY) among young adults aged 18-35 years in Thoothukudi City, Tamil Nadu in the year 2021. Data was collected with the help of a well-structured interview schedule among 506 young adult participants. Four of the 506 participants, who met the MODY parameters (BMI below 30, two to three generations with diabetes, age below 35) were proceeded with additional genetic testing. Among the four, two were reported to have genetic mutations. One of the participants had a type 2 diabetes gene variation (AKT2 gene) and another had a MODY gene variation (KLF11 gene). Both Participants had a strong paternal side family history with diabetes and parents with diabetes. It indicates that having a strong family history of diabetes increases the likelihood that MODY and other kinds of diabetes will develop through heredity by some percent chance. The overall significance of this study is that it highlights the importance of early and accurate diagnosis for better treatment and management of this type of diabetes and also contributes to the spreading of knowledge on MODY.

Keywords – Diabetes,Gene Variation, Identification, Maturity Onset Diabetes of the Young (MODY).

INTRODUCTION

Genetical mutations can induce a monogenic type of diabetes called Maturity Onset Diabetes of the Young, affecting people below the age of 35 years with the 14 different subtypes of MODY such as: "MODY 1 (Hepatocyte Nuclear Factor 4 Alpha or HNF4A), MODY 2 (Glucokinase or GCK), MODY 3 (Hepatocyte Nuclear Factor 1 Alpha or HNF1A), MODY 4 (Pancreatic and Duodenal homeobox 1 or PDX1) , MODY 5 (Hepatocyte Nuclear Factor 1 Beta or HNF1B), MODY 6 (Neuronal Differentiation 1 or NEUROD1), MODY 7 (Kruppel-like factor KLF11), MODY 8 (Carboxyl Ester Lipase or CEL), MODY 9 (Paired box gene 4 or PAX4), MODY 10 (Insulin gene or INS), MODY 11 (B Lymphocyte Kinase or BLK), MODY 12 (ATP Binding Cassette subfamily C member 8 or ABCC8), MODY 13 (KCNJ11), MODY 14 (APPL1) (Naylor *et al.,* 2018)". Among the 14 subtypes, three genetic variations (Hepatic Nuclear Factor 1 Alpha, Hepatic Nuclear Factor 4 Alpha and Glucokinase) cause MODY in 95 % of all cases

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(Delvecchio *et al.,* 2020). Delvecchio *et al.,* (2020) also points out, "misdiagnosis of MODY with type 1 and type 2 diabetes can result in suboptimal glycemic control and unnecessary use of insulin or oral hypoglycemic agents." This misdiagnosis from the lack of awareness of clinical and genetic features of MODY from other diabetes types leads to inappropriate treatment. Because of this many misdiagnosis of MODY among young adults and the delaying the use of specific medications. Therefore, timely detection and raising awareness of MODY to avoid misdiagnosis is important for appropriate treatment and understanding of the disease. According to Urakami, (2019), "MODY runs in the strong family history of diabetes, insulin independence, absence of autoantibodies, lack of ketoacidosis, normal BMI and persistent mild fasting hyperglycemia. After a clinical diagnosis, next-generation sequencing is required to confirm the cases of MODY ". However, the effective diagnostic method for detecting MODY has yet to be researched and there is a need for more accurate and effective diagnostic strategies.

The study aimed to discover the incidence of MODY cases among young adults in Thoothukudi City, India. The overlapping symptoms of MODY often lead to misdiagnosis with both type 1 and type 2 diabetes. This study helps in knowing the role of heredity in the onset of diabetes and contributes to the improvisation of accurate management and treatment of the rare form of diabetes in the later years. Understanding the incidence of MODY in this young adult population can inform healthcare professionals about the importance of considering MODY in the differential diagnosis of young-onset diabetes.

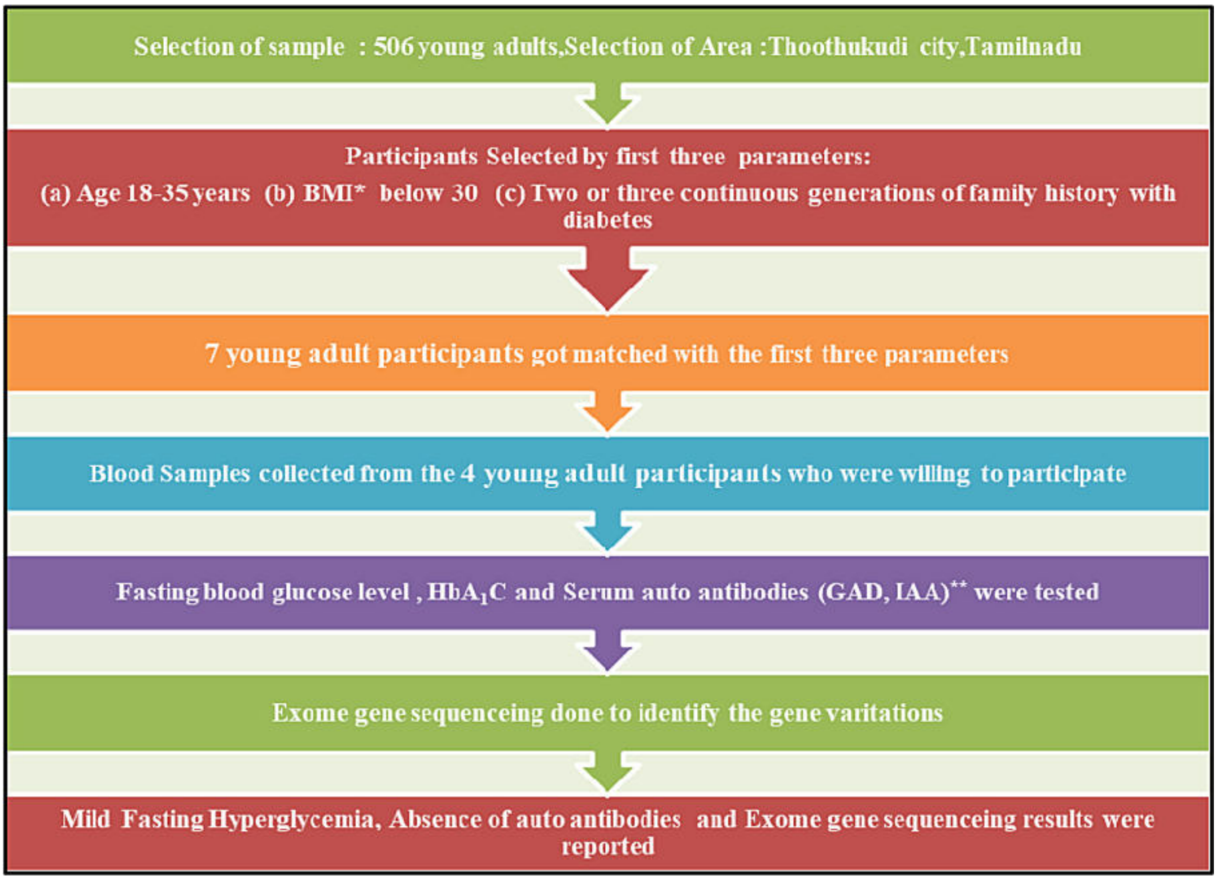
MATERIAL AND METHODS

Research Area and Sample Selection

The cross-sectional study aimed to find the incidence of Maturity Onset Diabetes of the Young (MODY) among young adults in Thoothukudi City, Tamil Nadu, India in April to July 2021. The individuals at risk for Maturity Onset Diabetes of the Young (MODY) were selected using a convenience non-random sampling method. The sample size was calculated using Yamane's sample size calculation method. According to census of Thoothukudi City conducted in 2011, the city's population was 2,37,830. Taking this population size into consideration and applying the formula of Yamane [Sample Size (n)=N/(1+N*(e^2))], the sample size of the study was 384. The sample size was expanded to include total of 500 participants to increase statistical power and to ensure the enough cases of MODY were captured for meaningful analysis. This would increase the generalizability and credibility of the findings of the study. The study focuses on to find the maturity onset diabetes of the young participants. Kant *et al.,* (2022) says, "children, adolescents and young adults who were not obese commonly developed maturity-onset diabetes of the young. And among them, young adults were the group affected more". Therefore, young adults between the ages of 18 and 35 years made up the target group.

Analysing the Data

Data were gathered with a help of well structure interview schedule which elicits information such as background information, anthropometry and clinical information. Socio-demographic information includes gender, marital status, educational status, income, etc. The four factors that comprise anthropometry were height, weight, waist to hip ratio (WHR) and body mass index (BMI). Clinical information includes biochemical parameters and family history with diabetes. Anthropometry and clinical data were performed to determine the patients who were at risk for maturity onset diabetes of the young.



**BMI (Body Mass Index),*

***Auto antibodies (IAA-Insulin Antibodies, GAD-Glutamic Acid Decarboxylase)*

Figure 1. Procedure adopted for the selection of participants for High-Risk Maturity Onset Diabetes of the Young

Young adults between 18 and 35 years, Body Mass Index less than 30, two or three continuous generations with diabetes, mild fasting persistent hyper glycemia and absence of autoantibodies (Kant *et al.,* 2022) were the parameters taken into account while identifying maturity onset diabetes of the young. As this study was carried out in the general population, the study consists of a mixed population (participants may or may not have clinical data). The first three parameters, young adults in the age group of 18-35 years, Body Mass Index - less than 30 (Kant *et al.,* 2022), two or three continuous generations with diabetes were considered to filter the data (Figure 1).

Collection of Blood Sample

Blood samples were drawn from the selectedparticipants with the help of a professional lab technician early in the morning on an empty stomach. Fasting blood glucose level, HbA_1C and Serum autoantibodies (GAD, IAA) were the tests to be run. A total of 15 ml of blood was drawn for the test. The collected blood specimen was stored in blood vials and taken to run the test by the lab technician. To meet the maturity onset diabetes of the young, parameters such as fasting blood glucose level, HbA_1C and serum autoantibodies (GAD, IAA) were measured. The participants' genes were also examined using the next-generation

Table 1- Testing Procedures and Normal Values of Blood Parameters

S.No	Blood Parameters	Testing Procedure	Normal Values
1	Fasting Blood glucose level	Glucose Oxidase and Peroxidase test (GOD-POD)	70 to 100 mg/dl
2	Serum HbA_1C (Glycosylated Hemoglobin)	High-Performance Liquid Chromatography test (HPLC)	4 to 5.7.0%
3	Serum GAD-65 (Glutamic Acid Decarboxylase-65)	Enzyme Immuno Assay (EIA)	<10 IU/ml
4	Serum Insulin AutoAntibodies	Enzyme Immuno Assay (EIA)	<12 U/ml
5	Next Generation Maturity Onset Diabetes of the Young (MODY) sequencing	Exome gene sequencing	Positive or Negative

Reference for normal values-Fasting Blood glucose level and Serum HbA1C (American Diabetes Association, 2022), Serum GAD-65 and Serum Insulin AutoAntibodies(Belhiba *et al.,* 2020)

exome gene sequencing method to look for variations in the MODY or other diabetes genes.

RESULTS AND DISCUSSION

Background Information of the Young Adult Participants

Background information such as gender, family type, marital status, educational status and family income was given in Table 2.

Among the 506 selected participants, 55.7% were female participants and 44.3% were male participants. The majority of participants (99.6%) belonged to nuclear families, with a small percentage (0.4 %) from joint families. This aligns with the study by Jamila *et al.,* (2017), where the participants from urban areas were influenced by nuclear families. Most participants were married (78.9%), while 21.1 % were unmarried. A study by Singh *et al.,* (2023) also found out that there was a high proportion of marriage was increasing between the age of 18-35 years. Regarding educational status, 49.1 % had attended only school, followed by 29.4% undergraduates, 12.4 % uneducated, 7.5 % postgraduates and 1.4 % with higher education. The educational status of the participants in this study aligns with Negi and Nambiar (2021) regarding the educational distribution among breast cancer patients. In terms of income, 75.3 % of participants were from families earning more than Rs.10,000 per month, while 24.5 % were from families earning between Rs.5,000 and Rs.10,000. This income level distribution correlates with the study of Sarkar and Samanta (2023).

Mean of Anthropometric Measurements of the Young Adult Participants

Body Mass Index was calculated using anthropometric data (height in centimetres and weight in kilograms). The Waist to Hip Ratio of the young adult participants was calculated using both the waist circumference in inches and the hip circumference in inches. The mean of these anthropometric measurements was

Table 2. Background information of the Young Adult Participants

S.No	Background information		Frequency (n=506)	Percent
1	Gender	Male	224	44.3
		Female	282	55.7
2	Family Type	Nuclear	504	99.6
		Joint	2	0.4
3	Marital Status	Bachelor/Spinster	107	21.1
		Married	399	78.9
4	Educational Status	Uneducated	63	12.4
		School	249	49.1
		Undergraduate	149	29.4
		Postgraduate	38	7.5
		Higher Education	7	1.4
5	Income Status	Less than Rs.5,000	Nil	Nil
		Rs. 5,000-Rs.10,000	124	24.5
		More than Rs.10,000	382	75.3

Table 3- Mean of Anthropometric Measurements of the Young Adult Participants

Anthropometric Measurements	Mean of Anthropometric Measurements of the Young Adult Participants(n=506)			
	Male (n=224)	Ideal Anthropometric Measurements of Male	Female (n=282)	Ideal Anthropometric Measurements of Female
Height(cm)169±7	172.5 [a]	159±7	157 [a]	
Weight (Kg)67.92±11.9	65 [b]	60.82±12.1	55 [b]	
Body Mass Index (Kg/m^2)	24.88±3.8	22.9 [a]	24.19±4.5	22.6 [a]
Waist (inches)	33.63±4.0	34.5 [a]	34.05±4.8	33.2 [a]
Hip (inches)36.37±5.1	36.6 [a]	37.59±4.5	38.9 [a]	
Waist to Hip Ratio	0.93±0.7	0.94 [a]	0.91±0.7	0.85 [a]

Reference of Ideal Anthropometric Measurement values- a-(National Institute of Nutrition (NIN), 2020); b- (International Institute for Population Sciences (IIPS) and Macro International, 2017)

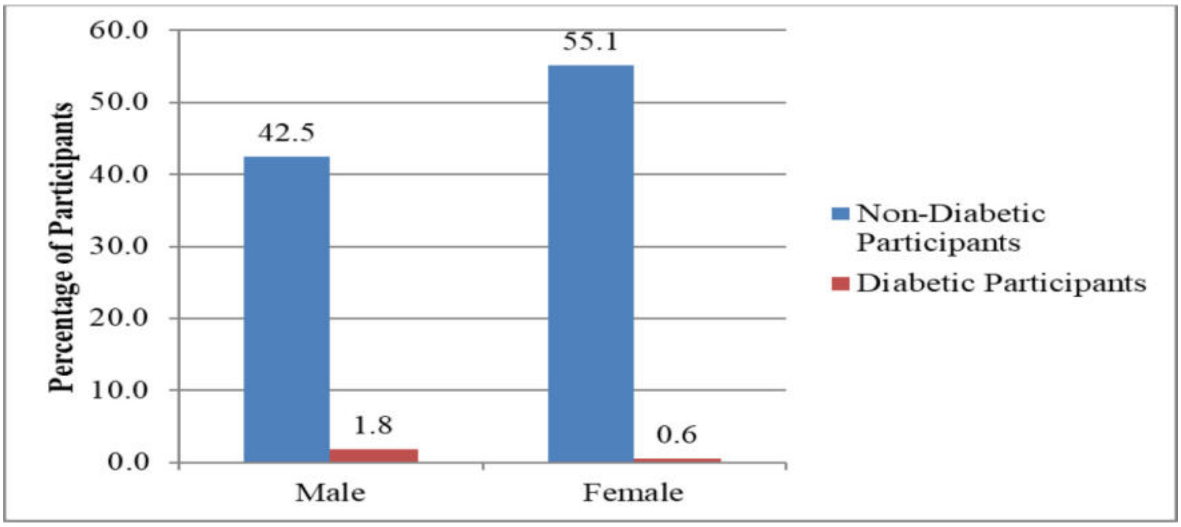


Figure 2- Incidence of Diabetes among the Selected Young Adult Participants

compared with the ideal anthropometric measurements of the male and female in India.

The analysis of anthropometric measurements revealed that young adult participants were close to their ideal values. Male participants were slightly shorter (169 cm) and heavier (67.82 kg) than the ideal, with a BMI of 24.88 kg/m^2. Female participants were slightly taller (159 cm) and lighter (60.82 kg) than the ideal, with a BMI of 24.19 kg/m^2. Both genders had healthy BMI (within 18.5-24.9 range) and healthy waist-to-hip ratio (males 0.93, females 0.91). BMI values between 18.5 and 24.9 were considered healthy and WHR values over 1.0 for male participants and over 0.8 for female participants were linked to higher

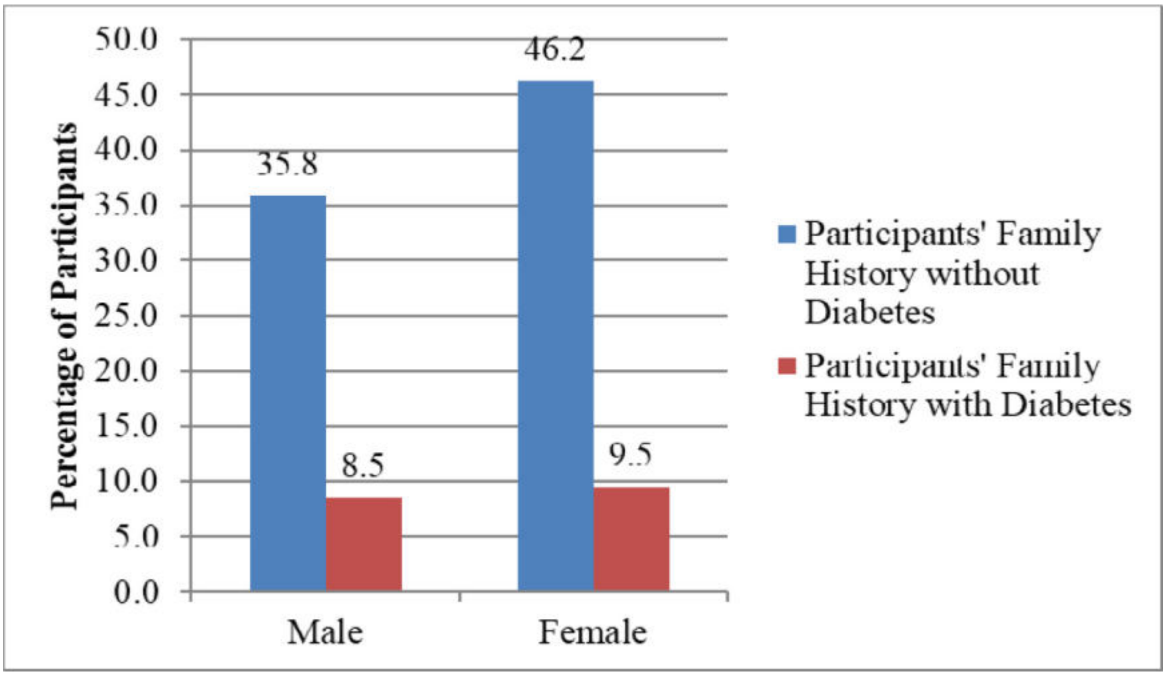


Figure 3 - Percentage of Participant's Family History with Diabetes

health risks so the participants were still within the healthy range but closer to the upper limit.

Incidence of Diabetes among the Selected Young Adult Participants

Diabetes has become alarming in all age groups; Figure 2 shows the diabetes incidence among 18-35 years participants.

The majority of the study participants were not affected by diabetes. There incidence of diabetes was slightly higher in male participants (1.8%) compared to female participants (0.6%). This aligns with the previous studies indicating a lower incidence of diabetes in younger populations (Maiti *et al.,* 2023).

Percentage of Participant's Family History with Diabetes

Family History was the leading cause of diabetes prevalence among people in the world(Abdulaziz Alrashed *et al.,* 2023). The figure illustrates the family history of diabetes among the selected young adult participants.

Almost 82% of the participants had no history of diabetes in the family line. Conversely, only 18% had a history of diabetes in the family line. Interestingly, a slightly higher percent of female participants (9.5%) had diabetes in their family line compared to the male participants (8.5%). The prevalence of family lines of diabetes among females aligns with the study of Moonesinghe *et al.,* (2018).

Body Mass Index and Family History of Diabetes among the selected Young Adults

Table 4 states the number of generations of diabetes prevalence among the young adult participants' families. It also gives information as to whether the generations of diabetes were continuous or not continuous in the family line. Table 4 shows the number of participants who satisfied the two parameters of Maturity Onset Diabetes of the Young (MODY).

The majority of 180 male and 236 female young adult participants had no diabetic family history. About 39 male and 37 female young adult participants had one generation with diabetes who majorly falls under the normal weight category. Two male and four young adult female participants in normal weight, obesity and obesity class II had two generations with diabetes but not in the continuous family line.

Another three male and three female young adult participants in underweight and obesity conditions had two continuous generations with diabetes. Only one female young adult participant under the normal weight category had three continuous generations with diabetes. These seven young adult participants had satisfied the two maturity onset diabetes of the young parameters (Body Mass Index below 30 and two or three continuous generations of diabetes). These cases resonate with the study of Asgarian*et al.,* (2024), which showed a continuous family line of diabetes linked to normal BMI, could indicate a number of specific genetic forms of diabetes such as MODY.

Health Status of the Selected Participants

Blood test results and the background information of the participants who were doubted as risk subjects were given in Table 5.

Blood Glucose Level and Genetic Report Interpretations of Subsample:

The fasting blood glucose levels, HbA_1C, and autoantibodies level testing of the participants shows that Participant 1 and 2 has a history of diabetes in a family that spans two to three generations. Participant 1 (a 34year old, male) with a normal weight (BMI 2.94 kg/

Table 4- Body Mass Index and Family History of Diabetes among the selected Young Adults

Body Mass Index (BMI)	Generations with Diabetes												Total
	No generations with diabetes		First generation		Second generation (Not Continuous)		Second generation (Continuous)		Third generation (Not Continuous)		Third generation (Continuous)		
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
Underweight (Below 18.5)	13	26	0	2	0	0	0	1	0	0	0	0	42
Normal weight (18.5-24.9)	106	114	21	16	2	0	0	0	0	0	0	1	260
Pre obesity (25.0-29.9)	49	70	14	17	0	2	2	3	0	0	0	0	157
Obesity Class I (30.0-34.9)	12	25	2	2	0	0	0	0	0	0	0	0	41
Obesity Class II (35.0-39.9)	1	1	2	0	0	2	0	0	0	0	0	0	6
Total	181	236	39	37	2	4	2	4	0	0	0	1	506

Table 5-Background information and Blood Test Report of the Selected Participants

S.No	Variables		Participant 1	Participant 2	Participant 3	Participant 4
1	Gender		Male	Female	Female	Female
2	Age (years)		34	32	29	21
3	Body Mass Index (BMI) (kg/m^2)		22.84 (Normal weight)	24.46 (Normal weight)	27.64 (Preobesity)	17.63 (Underweight)
4	Diabetic or Non diabetic		Diabetic	Nondiabetic	Nondiabetic	Nondiabetic
5	No.of Generations with Diabetes		Two continuous generations with diabetes (Paternal Grandfather, Paternal Grand Mother, Father, Mother)	Three continuous generations with diabetes (Paternal Grandfather, Paternal Grand Mother, Father, Mother, Brother)	Two continuous generations with diabetes (Paternal Grandfather, Father)	Two continuous generations with diabetes (Paternal Grand Mother, Father)
6	General Random Blood Glucose level (mg/dl)		223	135	100	120
7	Fasting Blood Glucose level (mg/dL)		180.56	107	83.60	96
8	Serum HbA_1C (%)		9.4	5.7	5.0	5.5
9	Estimated Average Glucose		223	117	97	111
10	Serum Glutamic Acid Decarboxylase-65 (IU/ml)		<5.00	<5.00	10.00	<5.00
11	Serum Insulin Auto Antibodies(U/ml)		1.73	1.50	0.53	2.66
12	Exome gene /sequencing	Gene	KLF11	AKT2	Negative	Negative
		Genomic Location	Chr2:10192597	Chr19:40747891		
		Variant	NM_003597.4:c.1502C>T;p.Pro501Leu	NM_001626.6:c.527G>T;p.Arg176Leu		
		Exon	4	6		
		Type of Mutation	Missense	Missense		
		Zygosity	Heterozygous	Heterozygous		

m^2) has mild fasting persistent hyperglycaemia (Fasting blood glucose level- 180.56 mg/dL, HbA_1C-9.4 %). Participant 2 (32year old female) with a normal weight (BMI 24.46 kg/m^2) has slight rise in the blood sugar levels (Fasting blood glucose level- 107 mg/dL, HbA_1C-5.7 %)which might be an alarm for a pre-diabetic condition. The blood glucose levels of pre-diabetic disease [Fasting blood glucose level- 100 to 125 mg/dL (American Diabetes Association, 2022), HbA_1C-5.7% to 6.5% (American Diabetes Association, 2022)] stated by the American Diabetes Association and Indian Council for Medical Research. Participant 3, a 29 years old female with a Body Mass Index of 27.64 kg/m^2 (pre-obesity) and participant 4, a 21 years old female with a Body Mass Index of 17.63 kg/m^2 (underweight) had normal blood sugar levels while comparing it with the normal blood glucose stated by the American Diabetes Association and Indian Council for Medical Research [Fasting blood glucose level- 70 to 100 mg/dL (American Diabetes Association, 2022), HbA_1C- 4% to 5.7% (American Diabetes Association, 2022)]. The auto antibodies (serum GAD and serum insulin autoantibodies) of four participants were reported to be absent.

Exome gene sequencing revealed a missense mutation in participant 1 in the KLF11 gene (Chr2:10192597; p.Pro501Leu), which is linked to type seven maturity onset diabetes of the young. A study by Sun *et al.,* (2021), also reported that KLF11 gene variation was responsible for type seven MODY (Sun *et al.,* 2021). This finding emphasizes the significance of considering MODY in the different diagnoses of early onset diabetes, especially when patients present with a strong family record of diabetes and negative autoantibody test. Participant 1's case emphasizes the potential role of genetic predisposition in MODY development, even in the absence of obesity, a prior misdiagnosis of type 2 diabetes. Participant 2 had a variation in the AKT2 gene (chr19:4074789; p.Arg176 Leu) linked to type 2 diabetes mellitus. This finding suggests the complexity of genetic contributions to diabetes development. While AKT2 gene variation might influence the participant's susceptibility to type 2 diabetes. A study by Liu *et al.,* (2023), also reported that AKT2 gene variation was linked to type 2 diabetes (Liu *et al.,* 2023). A noteworthy observation is the presence of diabetes in both parents of Participant 1 (Mother with IRS1 gene variation in chr2:226797016 linked to type 2 diabetes) and Participant 2. Participant 1 and his mother has variations in chromosome 2. This finding aligns with previous research suggesting an increased risk of diabetes in offspring if both parents are diabetic (Urakami, 2019). However, the exact mechanism of parental diabetes influences offspring risk remains unclear in Participant 2. Participants 3 and 4 didn't show any variations in the gene.

CONCLUSIONS

The findings revealed a low incidence of diabetes (2.4%) among the selected young adult participants, with a slightly higher prevalence in males (1.8%) compared to females (0.6%). Finally, this study clarifies the potential contribution of genetic predisposition in MODY development among young adults in Thoothukudi City situated in Tamil Nadu India. Identifying a MODY gene variation in one participant underscores the importance of considering MODY in the diagnostic method of young onset diabetes, particularly when individuals with a successive generation of family with diabetes and negative autoantibodies. Further research is needed to explore the link between genetic and environmental facts in MODY gene variations in the Indian population. Additional studies in this area will enhance the detection and management of MODY patients, ultimately resulting in lower mortality rates and more focused interventions.

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FORMULATION AND QUALITY EVALUATION OF CHOCOLATE FLAVOURED RICE BASED MEAL REPLACER FOR ADULTS

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ABSTRACT

This research (2021-2024) aimed to create nutritious meal replacers for adults that offer balanced nutrients. The meal replacer powder was developed using rice, ragi, and other functional ingredients at different levels (MR-T_1 to MR-T_{10}). Meal replacer powder was prepared using these treatments and subjected to organoleptic evaluation. The best treatment was selected through sensory evaluation using a scorecard with a nine-point hedonic scale. The maximum score for all the organoleptic attributes was obtained for meal replacement powder (MR-T_5), which were prepared by blending rice (50%), ragi (10%), jackfruit flour (15%), skimmed milk powder (15%), soy protein isolate (5%) and other ingredients like peanut and rice bran flour (5%). The nutritional composition of the selected meal replacement powder included 65.173g of carbohydrates, 22.88g of protein, 2.323g of fat, 4.137g of fibre, and 2.39g of total ash per 100g, offering 371.92 kcal of energy. Nutritious meal replacers made from locally sourced ingredients can be promoted as a healthy and convenient option for maintaining a balanced diet in busy lifestyles.

Keywords: Meal replacer, Nutritional qualities, Rice, Sensory qualities

INTRODUCTION

The adult population in developing countries faces significant health issues due to both underweight and rising rates of overweight and obesity. Factors such as dietary changes, urbanization, sedentary lifestyles, and improved economic conditions contribute to this trend. In India, urban areas exhibit three times the rates of overweight and obesity compared to rural areas, with women being more affected. The World Health Organization (2024) states that globally, 390 million adults are underweight, while 2.5 billion are overweight, including 890 million living with obesity.

Skipping breakfast was seen commonly in males and those between the age of 18- 34 years (Alkhulaifi and Darkoh, 2022). According to Singh (2024) every one in four urban Indian claim to skip breakfast and skipping of breakfast meal was seen across all age groups and bout 72 per cent skip by having a nutritionally inadequate breakfast meal.

The shift towards healthier lifestyles is growing among people of all ages, leading to

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a preference for nutritious, easy-to-prepare meals that are low in fat and high in nutrients. This trend has increased the demand for ready-to-use mixes, which can replace traditional meals and are becoming more popular due to rising rates of diabetes, obesity, and cardiovascular diseases. As awareness of the importance of weight management and health improves, the market for meal replacers is expanding. These products effectively curb hunger while providing essential nutrients such as fibre, vitamins, minerals, and proteins.

Meal replacers are available in various forms, including shakes, bars, and frozen entrees. They help individuals avoid the drawbacks of unhealthy, high-calorie meals, support immune function, aid in weight management, and ensure nutrient intake. However, the high cost and concerns about sugar and additives in existing meal replacement products are causing consumer hesitation. This underscores the need for innovation in convenient, healthier food options.

Meal replacers are a valuable choice for those who skip meals, working individuals, and anyone aiming for a healthier lifestyle. Therefore, this study focused on creating nutritious rice-based meal replacers for adults that deliver a well-balanced array of essential nutrients.

MATERIAL AND METHODS

Collection of materials

This study was carried out during 2021-2024 at Department of Community Science, College of Agriculture, Kerala Agricultural University, Thrissur, Kerala. Rice was the major ingredient for developing meal replacers. Other ingredients used were ragi, jackfruit flour, banana flour, skimmed milk powder and soya protein isolate. Peanut flour and rice bran flour were used as the functional ingredients at 5 per cent level. The rice was collected from farmers of Palakkad district. All the other ingredients were collected from local market.

Preparation of flours

The flours of different ingredients were prepared using standard procedures.

Preparation of rice flour

Rice flour was prepared by the method of Bangoura and Zhou (2007). After washing the rice, it is soaked in water for four hours. After draining the excess water the rice was placed in a cabinet dryer at 30°C for one hour and a half hours. Once dried, it was milled and sifted through 90 micron mesh to get the rice flour.

Preparation of ragi flour

Ragi flour was prepared by the method of Azeez *et al*. (2022). Cleaned finger millet grains were washed, drained, and dried in cabinet dryer at 40°C for 24 hours. The dried finger millet grains were milled and sieved through 90 ìm mesh to produce the flour.

Preparation of jackfruit flour

Raw jackfruit was collected from the households and the flour was prepared by modifying procedure suggested by Pandeay (2004). The raw jackfruit was washed and the bulbs and seeds were separated. After slicing the bulbs into 2.5 cm ß 1 cm, blanched in boiling water for 1 minute, cooled and immersed in 0.2 per cent KMS solution for 10 minutes. After draining the slices dried in a cabinet drier at 60Ú C for 12 hours. The dried chips were milled into flour and sieved through 90 mm mesh.

Preparation of banana flour

The banana was peeled and sliced into circular shape of 4 mm thickness using dicer. The slices were immersed in water (1: 3 ratio) containing 0.05% potassium meta bisulphite (K2S2O5) and 0.1 per cent citric acid for 10 minutes to arrest the enzymatic browning as suggested by Kumar *et al.* (2018). The banana slices were then dehydrated at a temperature of 55 ± 2 °C using laboratory scale hot air forced electrical convection drier, till the slices turned brittle. The dehydrated slices were ground in a commercial pulveriser for 2 minutes and then sieved using 90 micron mesh to get the flour.

Standardisation of meal replacers

Meal replacers were prepared using rice as main ingredient and ragi along with other ingredients in different combinations.

The amount of ingredients used in the treatments follows; rice 40 to 60 percent, ragi 0 to 20 per cent, and banana and jackfruit flour from 0 to 15 per cent. Skimmed milk powder 15 per cent, soya protein isolate andother ingredients (peanut flour and rice bran flour) at 5 per cent were used in all treatments at a fixed rate. The meal replacer was developed by combining the different flours in the above mentioned ratios, roasted for 5 minutes, pulverised, and sifted through a 90 micron mesh as detailed in figure 1. Later it was flavoured with chocolate at the rate of 4 per cent. The details of treatments used to standardise the meal replacers are given in Table 1.

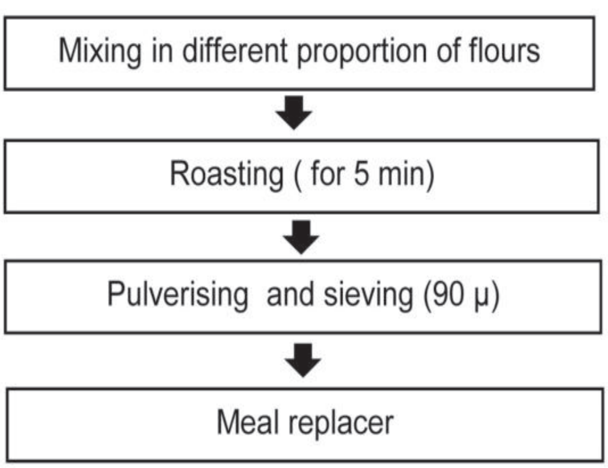

Figure 1: Preparation of meal replacers by roasting

Organoleptic evaluation

The developed meal replacer powder, 100g was diluted with 300ml of luke warm water for carrying out the organoleptic evaluation.

The sensory evaluation was carried out using score card of nine point hedonic scale by a panel of 20 judges for qualities like appearance, colour, flavour, consistency, taste and overall acceptability. The panel of twenty judges between age group of 18 to 35 years was selected by conducting a series of organoleptic trialsusing simple triangle test at laboratory level as suggested by Jellinek (1985).

Based on theorganoleptic scores the best combination of meal replacer was selected and nutritional evaluation were carried out.

Nutritional composition

The nutritional qualities like moisture (A.O.A.C. 1980), carbohydrate, protein, fat and fibre (Sadasivam and Manickam,1997) contents and energy value of the selected meal replacer were determined.

Statistical analysis

The statistical analysis was carried out for the mean score obtained from sensory evaluation.The data on organoleptic evaluation was statistically interpreted using Kendall Coefficient of concordance. Standard deviation was carried out for nutritional analysis.

Cost of production of meal replacement powder.

The costof production of the most acceptable meal replacement powder was computedbased on the market price of ingredients used for its preparation.

Labour charge, fuel charge, electricity charge and packaging cost incurred was also taken into consideration while computing the cost.The cost was calculated for100g ofthe

Table 1:Standardisation of meal replacers with chocolate flavour

Treatments	Combinations	Chocolate flavour
MR-T_1	40% R + 20% MR + 15% SMP + 5% SPI + 15% BF + 5% OI	
MR-T_2	40% R + 20% MR + 15 % SMP + 5% SPI + 15% JF + 5% OI	
MR-T_3	40% R + 20% MR + 15 % SMP + 5% SPI + 15% (BF+JF) + 5% OI	
MR-T_4	50% R + 10% MR + 15 % SMP + 5% SPI + 15% BF + 5% OI	**4 %**
MR-T_5	50% R + 10% MR + 15 % SMP + 5% SPI + 15% JF + 5% OI	**chocolate**
MR-T_6	50% R + 10% MR + 15 % SMP + 5% SPI + 15% (BF+JF) + 5% OI	**powder**
MR-T_7	60% R + 15 % SMP + 5% SPI + 15% BF + 5% OI	
MR-T_8	60% R + 15 % SMP + 5% SPI + 15% JF + 5% OI	
MR-T_9	60% R + 15 % SMP + 5% SPI + 15% (BF+JF) + 5% OI	
MR-T_{10}	60% R + 15% MR + 15 % SMP + 5% SPI + 5% OI	

(R- rice, MR- millet ragi, SMP- skimmed milk powder, SPI-soy protein isolate, OI-other ingredients)

Table 2: Mean score for organoleptic qualities of meal replacers (MR) with chocolate flavour

	Sensory parameters						
Treat-ments	Appea-rance	Colour	Flavour	Consis-tency	Taste	Overall Acceptability	Total mean score
MR-T_1	8.41(5.35)	8.41(5.35)	7.77(3.83)	7.83(2.86)	7.31(2.18)	7.76(3.30)	7.91
MR-T_2	8.43(5.68)	8.45(5.95)	7.9(4.18)	7.91(3.76)	7.78(3.85)	7.9(4.35)	8.06
MR-T_3	8.4(5.08)	8.43(5.80)	7.82(3.55)	7.86(3.26)	7.51(2.88)	7.83(3.38)	7.97
MR-T_4	8.42(5.65)	8.42(5.70)	8.42(7.08)	8.43(7.19)	8.38(6.53)	8.36(6.75)	8.40
MR-T_5	8.48(6.45)	8.46(6.05)	8.46(7.70)	8.49(7.48)	8.45(7.13)	8.46(7.58)	8.46
MR-T_6	8.46(6.28)	8.43(5.80)	8.44(7.38)	8.45(7.45)	8.41(6.63)	8.43(7.25)	8.43
MR-T_7	8.42(5.65)	8.4(5.30)	8.19(4.48)	8.01(5.52)	8.18(5.43)	8.06(5.35)	8.21
MR-T_8	8.44(5.93)	8.41(5.35)	8.30(5.83)	8.23(6.21)	8.23(8.30)	8.28(6.75)	8.31
MR-T_9	8.42(5.65)	8.4(5.30)	8.23(5.68)	8.21(5.83)	8.21(6.25)	8.16(5.68)	8.27
MR-T_{10}	8.44(5.93)	8.41(5.35)	8.14(5.33)	8.08(5.43)	8.06(5.85)	7.91(4.63)	8.17
Kendall"s W	0.061*	0.017*	0.278**	0.352*8	0.448**	0.306**	

Value in paranthesesare mean rank score based on Kendall's W

**Significant at 1 % level, *significance at 5 % level product and compared with similar products available in the market.

RESULT AND DISCUSSION

Organoleptic qualities of rice based meal replacers with chocolate flavour

The mean score and the mean rank scores obtained for different sensory attributes of meal replacers prepared with different combination of ingredients arepresentedin Table2.

The mean score for appearance of meal replacers prepared in different combinations (MR-T_1 to MR-T_{10}) ranged from 8.41 to 8.48. For colour and flavour, the mean score varied from 8.41 to 8.46 and 7.77 to 8.46 respectively. As the product was flavoured with 4 per cent of 100 per cent cocoa powder, all treatments had almost similar appearance and colour. Considerable difference in flavour was noticed with change in ingredients and treatments added with banana flour had lowest scores for flavour. Mean score for consistency of different treatments was between 7.83 to 8.49. The mean scores for taste varied from 7.31 to 8.45 and maximum mean score for taste was noticed for treatments added with jackfruit flour. For overall acceptability the scores ranged from 7.91to 8.46. Among the meal replacers, the highest mean score of 8.48, 8.46, 8.46, 8.49, 8.45 and 8.46 for appearance, colour, flavour, consistency, taste and overall acceptability respectively was noticed for treatment MR-T_5 (50 per cent rice, 10 per cent ragi, 15 per cent jackfruit flour, 15 per cent skimmed milk powder, 5 per cent soy protein isolate and 5 per cent other ingredients like peanut and rice bran flour) and it was selected for further studies. Based on Kendall's coefficient of concordance, significant agreement among judges was observed while determining the organoleptic qualities.

Meal replacers prepared with various combinations were generally acceptable in terms of organoleptic qualities. However, combinations including ragi flour and banana flour were less well-received, particularly in terms of flavor, texture, and taste. Adding more than 10% ragi flour negatively impacted the color and taste of the products, consistent with findings by Bansal and Kaur (2018), who reported reduced acceptance for milk beverages containing 15% ragi. Higher concentrations of ragi flour resulted in a slightly bitter taste (Taynath *et al.,* 2018), while banana flour contributed a slight astringency due to tannins and polyphenols (Sruthy *et al.,* 2020). In contrast, meal replacers containing jackfruit flour were the most accepted, as jackfruit flour added a subtle sweetness and slightly dense texture, enhancing overall taste, as noted by Soumya and Divakar (2021).

Nutritional qualities of rice basedmeal replacer

The prepared meal replacer powder was evaluated for nutritional qualities like moisture, energy, carbohydrate, protein, fat, and fibre(Table:3).

The rice-based meal replacer contained 3.03% moisture, 65.17g of carbohydrates, 22.88g of protein, 2.32g of fat, 4.13g of fibre, 2.39g of total ash, and 371.92 Kcal of energy per 100g. These values are similar to those found in germinated wheat and mung bean-based weaning food mixes, which have moisture levels of 3.30 to 3.70%, carbohydrates ranging from 52.80 to 61.20g, protein from 20.80 to 27.70g, fibre from 3.10 to 3.50g, ash from 2.08 to 2.36g, and energy from 411.40 to 419.30 Kcal per 100g, as reported by Jahan *et al.* (2021). Our results are consistent with findings from Mandal and Antarkar (2024) who reported that millet based wafer premixes developed using ingredients like finger millet flour (30%), rice flour (20%), milk powder (14%), sugar (30%), cocoa powder (5%). These premixes have a moisture content of 5.76%, 68.29 g of carbohydrates, 9.61 g of protein, and 0.74 g of fat. Similarly, Wandhekar *et al.* (2021) developed an instant appe mix

Table 3: Nutrient analysis of selected meal replacer

Nutrients (100 g^{-1})	T_5
Moisture (%)	3.303 ±0.005
Energy (Kcal)	371.92±0.100
Carbohydrate (g)	65.173±0.010
Protein (g)	22.883±0.010
Fat (g)	2.323±0.002
Crude fibre (%)	4.137±0.001
Total ash	2.397±0.002

(MR-T_5 =50 per cent rice, 10 per cent ragi, 15 per cent jackfruit flour, 15 per cent skimmed milk powder, 5 per cent soy protein isolate and 5 per cent other ingredients like peanut and rice bran flour)

by combining rice, black gram, finger millet, and foxtail millet in a proportion of 40:20:20:20. The resulting mix exhibited a moisture content of 5.51%, with 72.4% carbohydrates, 12.04% protein, 1.46% fat, 3.4% crude fiber, and 1.57% ash.

A meal replacement product should provide 200 to 400 kcal per serving as it used for replacing major meals (codex standards). The developed meal replacer could meet the specified requirements for such a product providing a balanced ratio of different nutrients.

Cost of production of meal replacement powder

The cost of production of meal replacement powder was Rs. 200/kg and was found to be much lower in price compared to such products available in the market. So the developed meal replacement powder offers affordability without sacrificing nutritional quality for consumers.

CONCLUSIONS

Rice based meal replacer powder is a nutrient-dense, cost effective alternative for dietary management and convenience. The formulation containing 50% rice, 10% ragi, 15% jackfruit flour, 15% skimmed milk powder, 5% soy protein isolate, and 5% peanut and rice bran flour (MR-T5) was found to have high acceptability, achieving excellent sensory scores in appearance, color, flavor, consistency, taste, and overall acceptability. Nutritional analysis revealed that MR-T5 provides 65.17g carbohydrates, 22.88g protein, 2.32g fat, 4.13g fiber and 371.92 Kcal per 100g, making it a balanced and effective meal replacement.

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EVALUATING THE EFFECTIVENESS OF A NUTRITIONAL INTERVENTION ON CHILD DIETARY DIVERSITY AND NUTRITIONAL STATUS IN RURAL ANGUL, ODISHA

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ABSTRACT

This study assessed the effectiveness of a three-month nutritional intervention on dietary diversity and nutritional status among 300 under-five children in rural Angul district, Odisha, covering the period between 2023-2024. The intervention led to a significant increase in dietary diversity scores, from 45.0% to 55.0% for achieving a dietary diversity score (DDS) of 4 ($p = 0.032$), and notable improvements in nutrient intake: energy (+4.84%, $p = 0.045$), protein (+12.15%, $p = 0.032$), and vitamin C (+22.22%, $p = 0.015$). Anthropometric measurements also showed significant changes, with weight increasing by 6.67% ($p = 0.038$) and mid-upper arm circumference (MUAC) improving by 7.88% ($p = 0.046$). Chi-square analysis revealed reductions in underweight (from 35.0% to 25.0%, $\chi^2 = 8.00$, $p = 0.005$), stunting (from 40.0% to 30.0%, $\chi^2 = 6.50$, $p = 0.010$), and wasting (from 30.0% to 20.0%, $\chi^2 = 7.00$, $p = 0.008$). Pearson correlations indicated a positive relationship between dietary diversity and weight ($r = 0.45$, $p = 0.001$), height ($r = 0.30$, $p = 0.015$), and MUAC ($r = 0.40$, $p = 0.005$). Multiple regression analysis identified significant predictors of improved nutritional status, particularly protein ($\beta = 0.25$, $p < 0.001$) and calcium intake ($\beta = 0.20$, $p = 0.001$). ANOVA confirmed significant differences in nutritional status improvement across groups ($F = 6.75$, $p = 0.003$). These findings highlight the intervention's effectiveness in improving child health outcomes and support the implementation of similar programs in comparable settings.

Keywords: Anthropometric measurements, dietary diversity, nutrientintake, nutritional intervention, rural Odisha.

INTRODUCTION

Malnutrition continues to be a critical concern in developing regions, especially among young children, where limited dietary diversity and insufficient nutrient intake hinder optimal growth and development (Jones and Lee, 2020). In Odisha, rural districts such as Angul still face a significant burden of child malnutrition, influenced by socioeconomic inequalities that affect dietary behaviors and nutritional outcomes (NFHS-5, 2022).

Government-led initiatives such as the Integrated Child Development Services (ICDS) and the Mid-Day Meal (MDM) Scheme have been pivotal in addressing child undernutrition across India. The ICDS, launched in 1975, aims

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to improve the health and nutritional status of children under six years of age, pregnant women, and lactating mothers through services like supplementary nutrition, immunization, health check-ups, and pre-school education. Similarly, the Mid-Day Meal Scheme, operational since 1995, provides cooked meals to school-going children to enhance school attendance, reduce classroom hunger, and improve nutritional intake. Both programs serve as foundational pillars in India's child nutrition strategy by ensuring regular access to basic nutrition.

However, despite these efforts, malnutrition persists, particularly in rural pockets where the implementation and effectiveness of these programs often vary. Challenges such as inadequate community participation, irregular supply of supplements, and limited parental awareness of child nutrition dilute the impact of these schemes. Therefore, the specific impact of structured household-level interventions—designed to complement and reinforce public nutrition schemes—remains underexplored.

This study assesses the effectiveness of a three-month nutrition intervention—comprising dietary education, food supplementation, and parental involvement—in enhancing dietary diversity, nutrient intake, and the nutritional status of young children in rural Odisha. Through a comparative analysis of outcomes before and after the intervention, the study seeks to highlight practical strategies for reducing malnutrition and shaping future policy directions.

MATERIAL AND METHODS

Study Design and Population

This study adopted a quasi-experimental pre- and post-intervention design to evaluate the impact of a structured nutrition program on dietary diversity and child growth outcomes. It was carried out in rural areas of Angul district, Odisha, involving 300 children under the age of five. Participants were selected through stratified random sampling to ensure diverse representation based on household structure and socioeconomic status. Ethical approval was secured from the Institutional Ethics Committee, and informed consent was obtained from caregivers prior to participation.

Nutritional Intervention

The intervention spanned three months and included a series of activities to improve child feeding practices and enhance nutritional intake. These included:

1 Nutrition education for mothers and caregivers focusing on balanced diets, cooking techniques, and the importance of varied food groups.

2 Distribution of supplementary nutrient-rich foods such as legumes, dairy, and seasonal vegetables.

3 Hands-on cooking demonstrations at the community level to promote healthy meal preparation.

4 Periodic home visits and counseling sessions to reinforce dietary guidance and ensure consistent participation.

The program was designed to align with community-based global nutrition strategies, taking into account local food availability and cultural preferences (Jones and Lee, 2020).

Dietary Diversity Assessment

Dietary diversity was measured using a standardized 7-food group model. A 24-hour dietary recall was administered to mothers to record children's food consumption, with a dietary diversity score (DDS) of four or more considered adequate. In addition, food frequency questionnaires were used to track regular food habits throughout the intervention period.

Anthropometric Measurements

Growth indicators were recorded both at the beginning and end of the study. Weight, height, and mid-upper arm circumference (MUAC) were measured using standardized tools and WHO-recommended techniques. Body Mass Index (BMI) and Z-scores for weight-for-age, height-for-age, and weight-for-height were also calculated using WHO growth standards to evaluate changes in nutritional status (NFHS-5, 2022).

Data Collection and Statistical Analysis

Data were collected at baseline and after the intervention period, covering socio-demographics, dietary patterns, and anthropometric details. Statistical analyses included descriptive statistics chi-square, pearson correlation, multiple regression, ANOVA and repeated-measures ANOVA were used

RESULTS AND DISCUSSION

Socio-Demographic Characteristics

The findings from this study demonstrate a strong relationship between family-related factors and the nutritional status of children under five in Angul district, Odisha. The results affirm that diverse diets and sufficient nutrient intake are vital for healthy growth and development in early childhood, reinforcing the importance of balanced nutrition in minimizing malnutrition risks.

Table 1 presents the socio-demographic characteristics of the participants. Notable statistical differences were observed in household income and family size, both of which are influential in shaping the effectiveness of nutritional interventions. A

Table 1: Socio-Demographic Characteristics of Study Participants

N=300

Parameter	Category	Number (%)	χ^2-value	p-value
Age Group (Months)	1-12	25 (8.33)	28.63	< 0.05
	13-24	65 (21.67)		
	25-36	72 (24.00)		
	37-48	78 (26.00)		
	49-60	60 (20.00)		
Gender	Male	168 (56.00)	3.56	0.059
	Female	132 (44.00)		
Maternal Education	No formal education	80 (26.67)	7.44	0.059
	Primary education	120 (40.00)		
	Secondary education	75 (25.00)		
	Higher education	25 (8.33)		
Family Income (per month)	< ₹ 15,000	85 (28.33)	10.21	0.017
	₹ 15,000 - ₹ 20,000	115 (38.33)		
	> ₹ 20,000	70 (23.33)		
Household Size	3-4 members	100 (33.33)	8.22	0.041
	5-6 members	130 (43.33)		
	7-8 members	50 (16.67)		
	> 8 members	20 (6.67)		

significant variation in age distribution was recorded ($\chi^2 = 28.63$, $p < 0.05$), with the highest number of children belonging to the 37–48 months (26%) and 25–36 months (24%) categories. The gender split was relatively balanced-56% male and 44% female-though this difference was not statistically significant ($\chi^2 = 3.56$, $p = 0.059$). Maternal education showed a marginally significant relationship ($\chi^2 = 7.44$, $p = 0.059$), with 40% of mothers reporting primary-level education. A statistically significant association was observed with family income ($\chi^2 = 10.21$, $p = 0.017$), where the majority (38.33%) of families earned between ₹ 15,000 – ₹ 20,000 per month. Family size was also significant ($\chi^2 = 8.22$, $p = 0.041$), with 43.33% of households having 5–6 members. These socio-demographic variables play a pivotal role in determining children's dietary practices and overall health outcomes.

Changes in Dietary Diversity Scores

Table 2 shows a meaningful shift in the dietary diversity scores (DDS) of children following the three-month intervention. A significant increase was observed in the proportion of children with a DDS score of 4, rising from 45.0% to 55.0% ($p = 0.032$), suggesting that the intervention successfully encouraged more varied food consumption. Additionally, the proportion of children with the lowest diversity score (DDS = 3) decreased from 8.0% to 4.0% ($p = 0.045$), indicating reduced nutritional vulnerability. However, the proportion of children scoring 5 remained constant at 35.0% ($p = 0.987$), suggesting moderate dietary diversity was maintained. Interestingly, although statistically significant reductions were seen in DDS scores of 7 ($p = 0.023$), and a near-significant trend in DDS 6 ($p = 0.065$), these changes might reflect challenges in sustaining very high dietary variety, possibly due to seasonal or economic constraints.

These results reflect the positive impact of targeted nutrition education and household engagement on improving meal diversity among children. Greater food variety contributes to better micronutrient adequacy, a key factor in child health.

Similar findings were observed by Jones and Brown (2018), who reported that community-based dietary interventions significantly improved children's intake diversity. Additionally, Ruel and Alderman (2019) emphasized that increased DDS is closely associated with better nutrient intake and reduced risk of under nutrition in low-resource settings.

Nutrient Intake Changes

Figure 1 presents a positive trend in nutrient intake following the three-month nutrition intervention, demonstrating its effectiveness in enhancing diet quality among young children. The significant increase in energy intake from 620 Kcal to 650 Kcal (+4.84%, $p = 0.045$) suggests improved meal frequency and quantity, likely due to better parental awareness and supplementary feeding. Protein intake increased from 10.7g

Table 2: Changes in Dietary Diversity Scores Pre- and Post-Intervention

DDS Score	Pre-Intervention (%)	Post-Intervention (%)	Change (%)	p-value
3	8.0	4.0	-4.0	0.045
4	45.0	55.0	+10.0	0.032
5	35.0	35.0	0.0	0.987
6	7.0	4.0	-3.0	0.065
7	5.0	2.0	-3.0	0.023

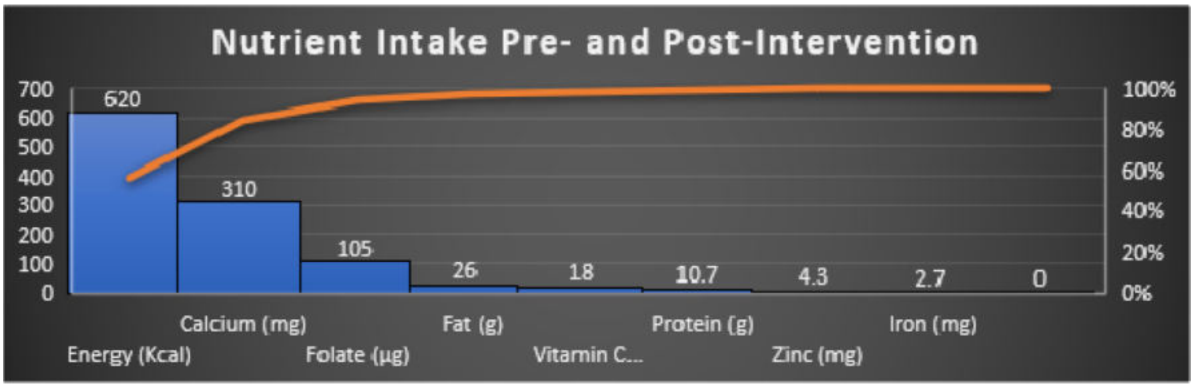

Figure 1: Nutrient Intake Pre- and Post-Intervention

to 12.0g (+12.15%, p = 0.032), indicating improved dietary diversity with inclusion of more protein-rich foods such as pulses and eggs. The rise in iron intake from 2.7mg to 3.2mg (+18.52%, p = 0.032) may reflect greater consumption of leafy vegetables and fortified foods introduced during the intervention.

Interestingly, fat intake reduced from 26g to 24g (–7.69%, p = 0.042), possibly reflecting a shift toward healthier cooking methods and reduced use of oils. Micronutrient improvements were evident in calcium (310mg to 340mg, +9.68%, p = 0.065), zinc (4.3mg to 4.7mg, +9.30%, p = 0.037), folate (105ìg to 120ìg, +14.29%, p = 0.025), and vitamin C (18mg to 22mg, +22.22%, p = 0.015), highlighting the success of targeted food-based education and inclusion of fruits and vegetables in daily meals.

These findings are consistent with who reported that tailored nutrition interventions significantly increased intake of energy, protein, and micronutrients among rural children in Bihar. Similarly and Lee Thompson (2020) observed that community-led food education improved children's vitamin and mineral intake in underserved populations. Together, these results reinforce the role of structured dietary education and caregiver engagement in improving nutritional outcomes in resource-limited settings.

Anthropometric Measurements

Figure 2 demonstrates significant improvements in key anthropometric indicators among children post-intervention, underscoring the positive impact of improved nutrition and caregiver engagement. The increase in mean body weight from 10.5 kg to 11.2 kg (+6.67%, p = 0.038) indicates a recovery from underweight conditions and better energy balance, likely influenced by increased intake of calorie-dense and protein-rich foods. Mid-upper arm circumference (MUAC) also improved from 16.5 cm to 17.8 cm (+7.88%, p = 0.046), reflecting enhanced muscle mass and overall nutritional status.

Although height increased slightly from 85.0 cm to 87.0 cm (+2.35%), the change was not statistically significant (p = 0.074), possibly due to the relatively short duration of the intervention, as linear growth generally takes longer to manifest. Notably, a significant reduction in skin fold thickness (SFT) from 24.0 mm to 21.0 mm (–12.50%, p = 0.031) was observed, suggesting a shift toward healthier body composition with reduced subcutaneous fat.

These anthropometric trends mirror findings from Patel and Kumar (2021), who reported similar gains in MUAC and weight among children receiving nutrition counselling and food supplementation in Madhya Pradesh.

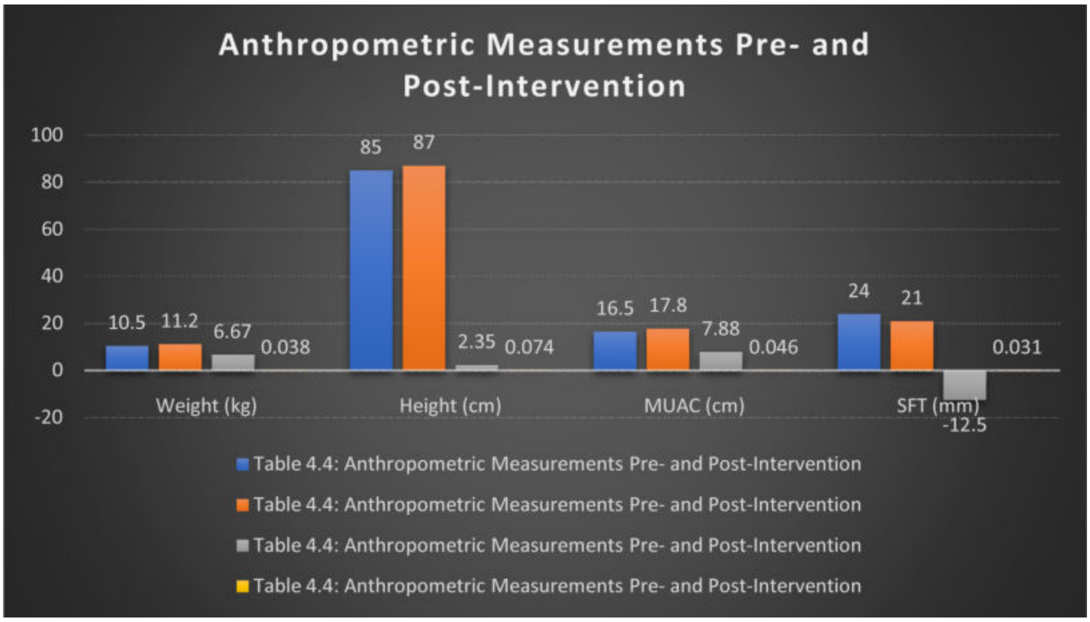

Figure 2: Anthropometric Measurements Pre- and Post-Intervention

Likewise, Sinha and Das (2020) found that focused dietary interventions improved body composition and reduced fat accumulation in children from low-income rural communities. This reinforces the evidence that timely and targeted nutrition programs can positively influence child growth metrics even within a short duration.

Chi-Square Analysis of Nutritional Status

Table 3 highlights a statistically significant reduction in the prevalence of undernutrition indicators—underweight, stunting, and wasting—among children under five following the nutrition intervention. The proportion of underweight children decreased from 35.0% to 25.0% (p = 8.00, p = 0.005), signifying notable improvement in weight-for-age, likely driven by increased energy and protein intake. Stunting, indicative of chronic undernutrition and long-term dietary inadequacy, dropped from 40.0% to 30.0% (p = 6.50, p = 0.010), reflecting enhanced food quality and caregiver awareness about child feeding practices. The prevalence of wasting, representing acute malnutrition, also declined significantly from 30.0% to 20.0% (p = 7.00, p = 0.008), suggesting that the intervention helped in meeting immediate caloric and nutritional needs more effectively.

These improvements underscore the success of a targeted, community-based approach in reversing malnutrition trends within a relatively short time frame. Comparable findings were reported by Patel and Kumar

Table 3: Nutritional Status Pre- and Post-Intervention

Status	Pre-Intervention (%)	Post-Intervention (%)	χ^2-value	p-value
Underweight	35.0	25.0	8.0	0.005
Stunting	40.0	30.0	6.5	0.010
Wasting	30.0	20.0	7.0	0.008

(2021), who noted significant reductions in underweight and wasting levels in response to household-level dietary counselling and supplementary feeding programs. Similarly, Sinha and Das (2020) observed that integrated nutrition education combined with local food-based solutions led to measurable declines in both acute and chronic malnutrition among rural children. These findings validate the role of intensive, localized nutrition strategies in combating undernutrition in resource-constrained settings.

Pearson Correlation of Dietary Diversity and Nutritional Status

Figure 3 illustrates significant positive correlations between dietary diversity and key anthropometric indicators, reinforcing the association between dietary variety and improved nutritional status in children. A moderate positive correlation was observed between dietary diversity score (DDS) and weight (r = 0.45, p = 0.001), indicating that children with more diverse diets tend to have higher body weight. DDS also showed a positive correlation with height (r = 0.30, p = 0.015) and mid-upper arm circumference (MUAC) (r = 0.40, p = 0.005), suggesting an overall improvement in growth outcomes with increased dietary variety. Conversely, a weak negative correlation was found between DDS and skinfold thickness (SFT) (r = –0.25, p = 0.050), implying that higher dietary diversity may contribute to healthier body composition and reduced adiposity.

These findings highlight the pivotal role of dietary diversity in promoting optimal growth and development among children under five. The results are in line with studies that advocate for improved food access, nutrition education, and maternal involvement as effective strategies to address childhood malnutrition. Policy-level integration of these approaches is essential for ensuring long-term nutritional improvements in vulnerable populations.

Multiple Regression Analysis of Nutrient Intake Impact

Table 4 presents regression analysis results indicating the significant positive influence of key nutrient intakes-namely protein, energy, calcium, and iron-on the nutritional status of children post-intervention. Protein intake emerged as a strong predictor (â = 0.25, p< 0.001), followed by calcium (β = 0.20, p = 0.001) and iron intake (β = 0.18, p = 0.011), each showing meaningful contributions to child growth and health. Energy intake also demonstrated a positive effect (β = 0.15, p = 0.033), reinforcing

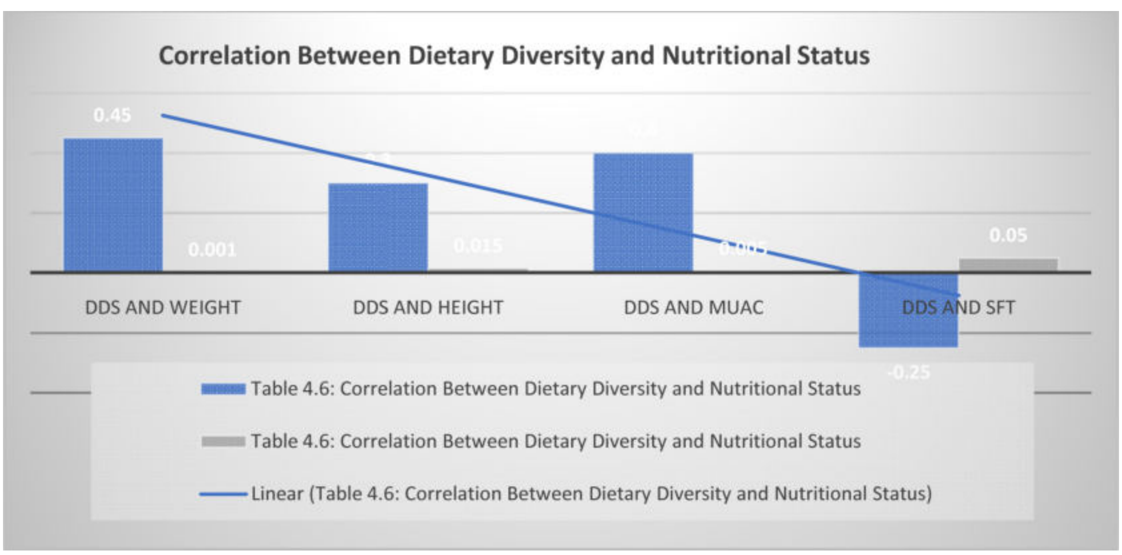

Figure 3: Correlation Between Dietary Diversity and Nutritional Status

Table 4: Multiple Regression Analysis of Nutrient Intake on Nutritional Status

Variable	β-coefficient	Standard Error	t-value	p-value
Protein Intake	0.25	0.05	5.00	<0.001
Energy Intake	0.15	0.07	2.14	0.033
Fat Intake	-0.10	0.08	-1.25	0.211
Calcium Intake	0.20	0.06	3.33	0.001
Iron Intake	0.18	0.07	2.57	0.011

its essential role in supporting physiological development. In contrast, fat intake did not significantly impact nutritional outcomes (β = –0.10, *p* = 0.211), suggesting that quality rather than quantity of dietary fat may be more relevant in this context.

ANOVA of Nutritional Status Improvement

Table 5 displays the results of the ANOVA test used to compare the impact of the nutritional intervention across different groups. A significant between-group variation was observed (*F* = 6.75, *p* = 0.003), indicating that the magnitude of nutritional status improvement varied based on specific characteristics of the intervention groups. The between-group sum of squares (450.00) and mean square (225.00) reflect the measurable differences in response to the intervention, while the within-group variance (sum of squares = 1800.00; mean square = 6.06) suggests that some individual differences still existed within each group.

This result implies that tailored intervention strategies—possibly influenced by baseline nutritional status, household environment, or parental involvement—produced more effective outcomes in some groups compared to others. It highlights the need to design flexible, group-specific nutrition programs rather than adopting a one-size-fits-all approach.

Similar conclusions were drawn by Roberts and Smith (2019), who found that nutrition interventions tailored to community demographics and socio-economic contexts produced more substantial improvements in child health. Additionally, Taylor and Green (2021) emphasized the role of caregiver education and local food availability in determining the success of nutrition programs, advocating for adaptive strategies to meet varied nutritional needs across different subpopulations.

CONCLUSIONS

The structured three-month nutritional intervention conducted in rural Odisha significantly improved dietary diversity, nutrient intake, and overall nutritional status among children under five. The intervention led to an increased intake of diverse food groups, resulting in more balanced dietary patterns and marked improvements in essential nutrients such as energy, protein, iron, and vitamin C. Notably, fat intake decreased post-intervention, indicating a shift toward healthier consumption patterns.

Table 5: ANOVA of Nutritional Status Improvement

Source	Sum of Squares	df	Mean Square	F-value	p-value
Between Groups	450.00	2	225.00	6.75	0.003
Within Groups	1800.00	297	6.06		
Total	2250.00	299			

Anthropometric measurements further validated these improvements, with significant gains in weight and mid-upper arm circumference, and a reduction in skinfold thickness, reflecting positive changes in body composition. The prevalence of underweight, stunting, and wasting also declined significantly, underlining the intervention's impact on reducing malnutrition. Regression analysis underscored the pivotal role of protein, calcium, and iron intake in influencing nutritional status, affirming the importance of micronutrient adequacy in child health.

Variance analysis confirmed differential improvements across groups, highlighting the context-specific effectiveness of the intervention. Overall, the study demonstrates that structured, community-based nutrition programs can play a critical role in improving child health outcomes. Future initiatives should explore long-term impacts and scalability to ensure broader application in similar vulnerable settings.

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PSYCHOLOGICAL IMPACT ON PRIMARY HYPOTHYROIDISM: GENDER DIFFERENCES IN ANXIETY, DEPRESSION AND STRESS

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ABSTRACT

The study was conducted in the year 2024 to emphasis on prevalence of anxiety, depression and stress in hypothyroidism patients. The study included a convenient sample of 100 hypothyroid patients aged between 20-60 years, encompassing both male and female participants. The results conferred that with respect to Body Mass Index (BMI), majority (46.87%) of the female respondents were fell under overweight category, whereas, 38.88 per cent of male respondents were found under pre-obese category. Whereas, in case of anxiety among hypothyroid subjects, both the gender reported similar feelings in-terms of numbness (62.00%) and heartbeat (46.00%). In case of depression, 71 per cent of females expressed that they had lost interest in everything, whereas 61 per cent of the male felt sad. With regard to stress, 75 per cent of females expressed that they couldnot tolerate the interruptions during working time. In case of males, majority of them (66.00%) expressed that stress full events cause problem in relationship with other people.

Keywords: Hypothyroidism, Anxiety, Depression, Stress

INRODUCTION

Hypothyroidism is a significant health issue, with prevalence rates around 4-5% in developed countries and 4-15% for subclinical hypothyroidism (Mark and Vanderpump, 2011). Hypothyroidism is more common in women and often has a genetic component. Symptoms include fatigue, depression, cold sensitivity, weight gain, dry skin, hair changes, constipation, and irregular menstrual cycles (Chaker *et al.*, 2017). These symptoms, particularly weight gain and hair loss, can increase depression risk, with obese individuals more probable to experience depressive symptoms

Other factors *viz.,* age, disease duration, and medication adherence also impact depression levels in hypothyroidism patients (Alghasham *et al.*, 2021). Subclinical hypothyroidism can lead to anxiety, irritability, poor concentration, and cognitive issues. Anxiety affects around 25% of the population (MalathyIyer, 2013) and depression significantly impacts quality of life and is a major global disease burden.

Anthropometric measurements such as height, weight, and BMI are recorded to assess obesity as a potential factor contributing to psychiatric issues. Obesity is linked to various mental health conditions, including anxiety,

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depression, and stress. By incorporating these measurements into the assessment, healthcare specialists can better comprehend the relationship among obesity and psychiatric issues in individuals with hypothyroidism. Hence, the present study aims to identify the prevalence of anxiety, depression, and stress in hypothyroidism patients.

MATERIAL AND METHODS

A cross-sectional study conducted in Visakhapatnam aimed to estimate the prevalence of anxiety, depression, and stress among hypothyroidism patients. The study included a convenient sample of 100 hypothyroid patients aged between 20-60 years, encompassing both male and female participants. Exclusions from the study criteria comprised pregnant women, ICU cases, cancer patients, individuals with chronic diseases, postpartum mothers, and subjects undergoing psychiatric treatment.

In the study, a structured questionnaire was administered to gather data, and personal interviews were conducted with subjects to assess symptoms related to anxiety, depression and stress. The data collected included socio-economic characteristics such as age, sex, marital status, educational background, and occupational status. Additionally, the biochemical history of thyroid-stimulating hormone (TSH), triiodothyronine (T3), and thyroxine (T4) levels was also recorded for each participant.

In this case, a checklist of questions related to anxiety (19), depression (15), and stress (14) was provided to the subjects. The subjects were asked these questions, and their reactions and responses were recorded for necessary analysis. This method can help in identifying potential mental health issues that may be associated with hypothyroidism. The symptoms and complications of hypothyroidism had been assessed through a questionnaire. The data was analyzed using percentage, mean, and standard deviation.

Stress exacerbates physical and mental health issues, including heart disease, cancer, and depression. The Anxiety Depression Stress Scale, developed by Singh and Bhatnagar (2016), provides an objective tool for assessing these conditions, using criteria from the ICD and DSM.

RESULTS AND DISCUSSION

The present study is an observational one that utilized convenient sampling of 100 hypothyroidism subjects. Numerous parameters were taken into consideration, including, Socioeconomic characteristics of hypothyroidism subjects, anthropometric measurements of hypothyroidism subjects, biochemical parameters of hypothyroidism subject, symptoms of hypothyroidism subjects, anxiety, depression, and stress rating scales

Age Distribution: The majority (44.00%) of the participants, are aged between 20-30 years, including 30 females and 14 males followed by the 30-40 age group, representing 26 per cent of the sample, comprising 16 females and 10 males. Those aged 40-50 years account for 20 per cent of the sample, with 12 females and 8 males, while only 10 per cent are aged 50-60 years, including 6 females and 4 males.

Residence: The majority, 77 per cent of the population, resides in rural areas, with 47 females and 30 males. The remaining 23 per cent live in urban areas, consisting of 13 females and 10 males.

Education Level: A small portion, 12 per cent of the participants, have no formal education, equally distributed between 6 females and 6 males. Those educated below the 10th standard represent 22 per cent of the sample, including 10 females and 12 males. The 10th standard has been completed by 10

Table 1: Demographic Characteristics of Hypothyroidism Population

Profile	Category	Percentage (%)	Patients n=100	Frequency Female (n=64)	Frequency Male (n=36)
Age in years	20-30	44	44	30	14
	30-40	26	26	16	10
	40-50	20	20	12	8
	50-60	10	10	6	4
Residence	Rural	77	77	47	30
	Urban	23	23	13	10
Educational	No formal education	12	12	6	6
status	<10th standard	22	22	10	12
	10th standard	10	10	6	4
	Intermediate	20	20	18	2
	Degree	28	28	20	8
	PG	8	8	4	4
Occupation	Government job	-	-	-	-
	Private job	26	26	6	20
	House wife	24	24	24	0
	Others	50	50	32	18
Income (Rs)	10000-20000	45	45	25	20
	20000-30000	43	43	26	17
	30000-40000	12	12	4	8
Marital Status	Married	86	86	32	54
	Unmarried	12	12	10	2
	Widow	2	2	2	0

The study involved a total of 100 individuals, comprising 64 females and 36 males.

per cent of participants, comprising 6 females and 4 males. Intermediate education is attained by 20 per cent, with 18 females and 2 males. Degree holders form 28 per cent of the sample, including 20 females and 8 males, while 8 per cent have a postgraduate degree, evenly split between 4 females and 4 males.

Occupation: Private jobs are held by 26 per cent of the population, with 6 females and 20 males. No participants were reported in government jobs. Housewives represent 24 per cent of the sample, all being female. Those engaged in other occupations account for 50 per cent, including 32 females and 18 males.

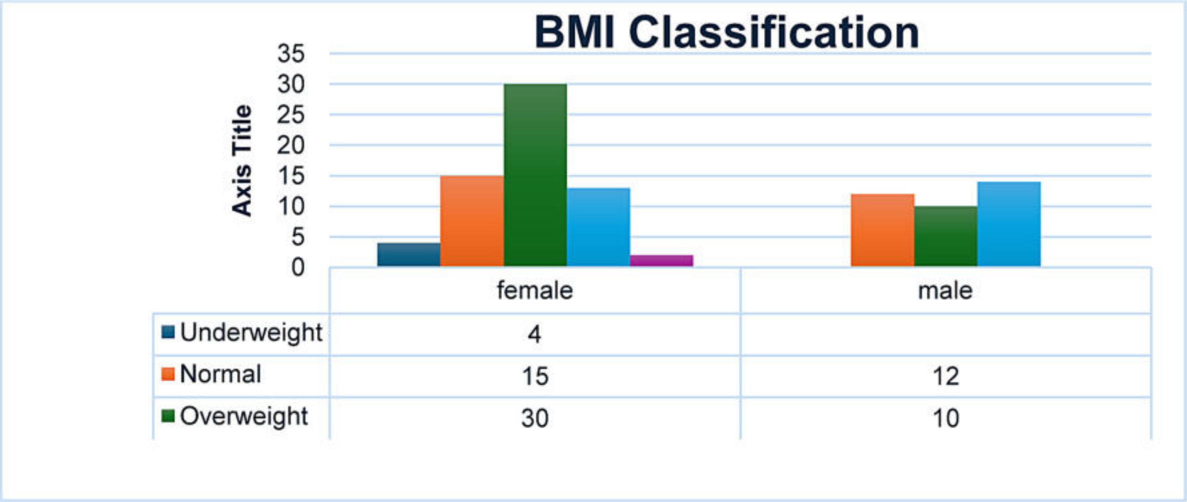


Fig 1: BMI classification of Hypothyroid subjects

Income: Regarding income, 45 per cent of participants earn between Rs 10,000-20,000, comprising 25 females and 20 males. Those earning Rs 20,000-30,000 represent 43 per cent of the sample, including 26 females and 17 males. Only 12 per cent earn between Rs 30,000-40,000, with 4 females and 8 males.

Marital Status: Most participants, 86 per cent, are married, including 32 females and 54 males. Unmarried individuals constitute 12 per cent, with 10 females and 2 males, while widows make up 2 per cent, all being female.

From the above fig 1 the BMI classification data shows a detailed distribution of individuals across different BMI categories for both females and males. Among females, 4 are classified as underweight (BMI < 18.5), 15 have a normal BMI (18.5-22.9), 30 are overweight (BMI 23-24.9), 13 fell into the pre-Obese category (BMI 25-29.9), and 2 are in the pre-Obese category (BMI > 30). For males, 2 are underweight, 12 have a normal BMI, 10 are overweight, 14 are classified as pre-Obese, and none are in the pre-Obese category. The largest group among females is the overweight category, while the largest group among males is the pre-Obese category, indicating a significant difference in the distribution of BMI classifications between genders. In studies, it has been observed that overweight and obesity are more prevalent among females than males, especially in the overweight category. This difference may be influenced by variations in lifestyle, dietary choices, or genetic factors.

A study conducted by Ogden *et al.* (2006) found higher rates of overweight and

Table 2. Biochemical Parameters with Mean and SD of Hypothyroid subjects

Biochemical tests	Normal Values	Female		Male	
		Mean	SD	Mean	SD
T3	**0.6-2.0ng/ml**	1.307	1.588	1.028	0.309
T4	**4-12mg/dl**	9.246	2.158	1.028	2.254
TSH	**0.5-5.5mIU/ml**	4.289	4.345	5.702	10.51
Haemoglobin	**12.0-16.0**	10.438	1.257	11.231	1.155

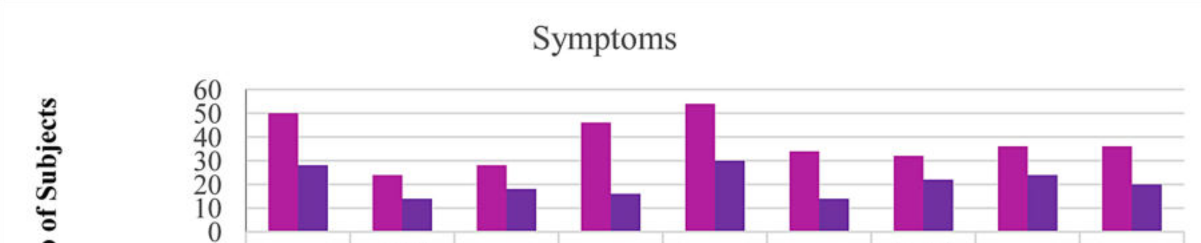
obesity among women in the United States, emphasizing the importance of gender-specific interventions.

The table 2 provides a comparison of mean and standard deviation (SD) values for T3, T4, TSH, and hemoglobin levels between female and male subjects, along with their corresponding normal ranges. For T3 levels, the mean for females was 1.307 ng/ml with an SD of 1.588, whereas for males, it was 1.028 ng/ml with an SD of 0.309. Similarly, for T4 levels, females had a mean of 9.246 mg/dl with an SD of 2.158, while males had a mean of 1.028 mg/dl with an SD of 2.254. TSH levels in females had a mean of 4.289 mIU/ml with an SD of 4.345, while in males, it was 5.702 mIU/ml with an SD of 10.51. Finally, hemoglobin levels in females had a mean of 10.438 with an SD of 1.257, whereas in males, it was 11.231 with an SD of 1.155.

Moron-Diaz *et al.,* 2021 conducted a study to investigate how TSH levels are related to health-related quality of life. It focused on individuals with hypothyroidism who were adequately treated for their condition. Using the ThyPRO-39 questionnaire, they assessed HRQL in 218 patients with primary hypothyroidism from a single endocrinology department. The research discovered that higher TSH levels were associated with a decline in HRQL. Additionally, TSH levels were found to be connected to assessments of tiredness and emotional sensitivity

The data from Figure 2 shows the prevalence of various symptoms among the total participants, broken down by gender. In terms of fatigue, 78 per cent of the total participants reported experiencing it, with 50 per cent being females and 28 per cent being males. Cold sensitivity was reported by 38 per cent of the participants, with 24 per cent being females and 14 per cent being males. Dry skin was reported by 46 per cent of the total participants, with 28 per cent being females and 18 per cent being males. Constipation was reported by 62 per cent of the total participants, with 46 per cent being females and 16 per cent being males.

Weight gain was reported by 84 per cent of the total participants, with 54 per cent being females and 30 per cent being males. Hair loss was reported by 48 per cent of the total participants, with 34 per cent being females and 14 per cent being males. Facial puffiness was reported by 54 per cent of the participants, with 32 per cent being females and 22 per cent being males. Muscle cramps were reported by 60 per cent of the total participants, with 36 per cent being females and 24 per cent being males. Anorexia was reported by 56 per cent



	fatigue	cold senstivity	dry skin	constipation	weight gain	hair loss	facial puffiness	muscle cramps	anorexia
FEMALE (64)	50	24	28	46	54	34	32	36	36
MALE (36)	28	14	18	16	30	14	22	24	20

Fig 2. Clinical Symptoms of Hypothyroid subjects

Table 3. Anxiety among Hypothyroid subjects

S.No	Anxiety Scale	Total (100)	Female N=64 (%)	Male N=36(%)
1	Are you feeling difficulty while breathing.	28	18(28)	10(27)
2	Are you feeling more nervous and anxious than usual.	40	26(40)	14(38)
3	Do you feel pressure in chest.	40	28(43)	12(33)
4	Do you feel weak and tired.	64	44(68)	20(55)
5	Do you feel your heartbeat faster.	48	30(46)	18(50)
6	Do you feel scare for small reasons.	56	34(53)	22(61)
7	Do you feel faintness.	30	18(28)	12(33)
8	Do you have a feeling like numbness.	62	40(62)	22(61)
9	Do you have headache, neck and back pain.	48	32(50)	16(44)
10	Do you have any blurred vision.	50	32(50)	18(50)
11	Do you have aware of the dryness of mouth.	86	54(84)	32(88)
12	Will perspire heavily even in absence of physical exertion and high temperature (Eg:- hands sweaty)	60	34(53)	26(72)
13	Do you feel panic and male of fool of you self.	64	44(68)	20(55)
14	Have you felt empty your bladder often.	62	42(65)	20(55)
15	Often do you have feeling of nausea.	64	46(71)	18(50)
16	Do you have nightmares.	36	24(37)	12(33)
17	Are you feeling bothered by stomach and indigestion.	44	30(46)	14(38)
18	Difficulty in swallowing.	36	20(31)	16(44)
19	Get scared without good reason	56	30(46)	26(72)

of the total participants, with 36 per cent being females and 20 per cent being males.

Lang *et al.,* 2020 conducted a cross-sectional study with 1,706 Chinese patients diagnosed with major depressive disorder and found that severe subclinical hypothyroidism was associated with an increased risk of suicide attempts and psychiatric symptoms. The study also identified links between elevated thyroid-stimulating hormone levels, severe anxiety, depressive and psychotic symptoms, increasing age, and higher body mass index.

In Table 3, females reported higher percentages in several symptoms: 43 per cent of them expressed feeling pressure in the chest followed by feeling weak and tired (68.00%), numbness and tingling in fingers and toes (53.00%), dryness of mouth (84.00%), heavy perspiration without physical exertion (53.00%), panic and feeling like a fool (68.00%), frequent bladder emptying (65.00%), feeling nauseous often (71.00%), and getting scared without a good reason (46.00%).

On the other hand, 27 per cent of males reported higher percentages in feeling difficulty while breathing followed by feeling more nervous and anxious than usual (38.00%), feeling faint (33.00%), having blurred vision (50.00%), having nightmares (33.00%), feeling

Table 4. Depression among Hypothyroid subjects

S.No	Depression Scale	Total (100)	Female N=64 (%)	Male N=36(%)
1	Do you want to be alone.	56	38(59)	18(50)
2	Do you feel sad and depressed.	58	36(56)	22(61)
3	Feel that your life is meaningless.	60	40(62)	20(55)
4	Can you handle or control your feelings.	50	30(46)	20(55)
5	Do you have any expectations or hope for your future.	38	26(40)	12(33)
6	Often feel have nothing to look forward	66	40(62)	26(72)
7	Are you losing interest in everything.	66	46(71)	20(55)
8	Difficulty in taking initiatives for new tasks	54	36(56)	18(50
9	Not able to feel good.	60	40(62)	20(55)
10	Not able to do anything.	28	18(28)	10(27)
11	Down hearted and sad.	52	36(56)	16(44)
12	Not able to be enthusiastic about anything.	50	30(46)	20(55)
13	Do you feel unwell.	62	40(62)	22(61)
14	Do you feel not worth as a person.	42	22(34)	20(55)
15	I often have crying bouts without good reasons	46	30(46)	16(44)

bothered by stomach and indigestion (38.00%), and experiencing difficulty in swallowing (44.00%). Both genders reported similar percentages in feeling their heartbeat (46.00%) and having a feeling of numbness in hands and legs (62.00%).

The study by Baxter *et al.* (2013) sheds light on the gender differences in anxiety reporting. While females tend to report higher anxiety levels, it's essential to recognize that males are not exempt from feeling anxiety. Interestingly, males may manifest anxiety through distinct symptoms compared to females. This underscores the importance of considering gender-specific approaches when addressing mental health concerns.

The depression scale results indicated that a significant percentage of both females and males reported various symptoms.

In Table 4, females reported higher percentages in several areas: 59 per cent of them wanting to be alone followed by feeling that life is meaningless (62.00%), having nothing to look forward to (62.00%), losing interest in everything (71.00%), not feeling good (62.00%), feeling unwell (62.00%), and having crying bouts without good reasons (46.00%).

On the other hand, majority of males (61.00%) reported higher percentages in feeling sad and depressed followed by having difficulty in handling or controlling feelings (55.00%), lacking expectations or hope for the future (33.00%), being unable to do anything (27.00%), feeling downhearted and sad (44.00%), not feeling worth as a person (55.00%), and not being enthusiastic about anything (55.00%). Both genders (56.00%) reported similar percentages in difficulty taking initiatives for new tasks.

In a study conducted in 2017 by Tayde *et al.*, 2017 involving 33 participants,

Table 5. Stress among Hypothyroid subjects

S.No	Stress Scale	Total (100)	Female N=64 (%)	Male N=36(%)
1	Do you have any difficulty in concentration.	52	34(53)	16(44)
2	Does your mind go blank.	38	28(43)	6(16)
3	Stressful events cause problem in my relationship with people	64	40(62)	24(66)
4	Feel that, you are more irritable.	44	32(50)	12(33)
5	Do you find, that it is difficult to relax.	56	34(53)	22(61)
6	Do you get upset easily.	36	26(40)	10(27)
7	Do you feel restless.	56	42(65)	14(38)
8	Are you slow to respond.	48	34(53)	14(38)
9	Unwanted memories of mind.	48	26(40)	22(61)
10	Do you feel stress to attend events.	52	40(62)	12(33)
11	Do you feel agitated in everything.	28	12(18)	16(44)
12	Are you tolerating any interruption in between your work.	60	48(75)	12(33)
13	Do you feel hard to calm down after getting upset.	48	36(56)	12(33)
14	Do you feel that, you are touchy.	50	32(50)	18(50)

researchers used the Montgomery-Åsberg Depression Rating Scale and found that half of the participants experienced mild to moderate depression. A study conducted in the clinics of King Fahd Hospital of the University revealed different levels of depression among hypothyroidism patients: no depression in a quarter of the study population, mild depression in 38 per cent, moderate depression in 10 per cent, moderately severe depression in 20 per cent, and severe depression in 3.6 per cent of patients.

The stress scale results showed that both females and males reported various symptoms related to stress.

It was inferred from Table 5, that 53 per cent females reported higher percentages in experiencing difficulty in concentration followed by finding it difficult to relax (53.00%), feeling restless (65.00%), being slow to respond (53.00%), having unwanted memories in mind (40.00%), feeling stressed to attend events (62.00%), tolerating interruptions in work (75.00%), finding it hard to calm down after getting upset (56.00%), and feeling touchy (53.00%).

On the other hand, 43 per cent of males reported higher percentages in their minds going blank followed by feeling more irritable (50.00%), getting upset easily (40.00%), feeling agitated in everything (44.00%), and having difficulty in calming down after getting upset (50.00%). Both genders (62.00%) reported similar percentages in stressful events causing problems in relationships with people.

Table 6 presents data in terms of anxiety levels, females exhibited a higher mean score of 9.78 with a standard deviation of 1.52, while males had a comparatively lower mean score of 5.56 with a standard deviation of 1.30. The mean depression score for females was 7.94 with a standard deviation of 0.86, while for

Table 6. Mean and Standard Deviation of Anxiety, Depression and Stress Scale

Anxiety		**Female**	**Male**
	Mean	9.781	5.555
	Standard Deviation	1.515	1.300
Depression	Mean	7.937	7.77
	Standard Deviation	0.863	2.069
Stress	Mean	7.25	7.38
	Standard Deviation	1.145	0.950

males, it was slightly lower at 7.78 with a higher standard deviation of 2.07. For stress levels, females had a mean score of 7.25 with a standard deviation of 1.15, whereas males had a slightly higher mean score of 7.39 with a lower standard deviation of 0.95.

Females exhibited a higher mean score of 9.78 with a standard deviation of 1.52 in terms of anxiety whereas the mean score of 7.94 with a standard deviation of 0.86 was observed in case of depression when compared with males. In case of stress, males had a slightly higher mean score of 7.39 with a lower standard deviation of 0.95.

Table 7 presents data on the anxiety, depression, and stress levels, measured by z-scores, for both females and males. The findings indicate that a small number of respondents reported significantly elevated levels of anxiety, with 2 females and 2 males falling into the "High" category, while 4 males showed "High" levels of depression. When it comes to stress, no respondents were reported at "High" levels. A moderate number of respondents exhibited "Above Average" levels, with 3 females and 2 males reporting slightly elevated anxiety, and 12 females and 6 males showing above-average stress levels. The majority of respondents fell within the "Average" range, with 32 females and 34 males reporting average levels of anxiety, 44 females and 3 males for depression, and 52 females and 3 males for stress. This endorses that most respondents experienced typical levels of anxiety, depression, and stress.

CONCLUSIONS

Based on the findings, out of the respondents, females exhibited a higher mean score of 9.78 with a standard deviation of 1.52 in terms of anxiety whereas the mean score of

Table 7. Levels of Anxiety, Depression and Stress in Hypothyroid subjects

	Anxiety		**Depression**		**Stress**		
Levels	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Z Score**
Extremely High	-	-	-	-	-	-	+2.01 & above
High	2	-	-	2	-	-	+1.26 to +2.00
Above Average	3	-	2	4	12	6	+0.51 to +1.25
Average	32	34	44	3	52	3	-0.50 to +0.50
Below Average	-	2	-	-	-	-	-1.25 to -0.51
Low	-	-	-	-	-	-	-2.00 to -1.26
Extremely Low	-	-	-	-	-	-	-2.01 & above

7.94 with a standard deviation of 0.86 was observed in case of depression when compared with males. In case of stress, males had a slightly higher mean score of 7.39 with a lower standard deviation of 0.95. Overall, the data assessed that most respondents experience average levels of anxiety, depression, and stress, with only a few reporting significantly elevated levels. There were notable differences between females and males in the distribution of responses, particularly for depression, where more females were in the higher categories compared to males.

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ASSESSMENT OF HEALTH AND QUALITY OF LIFE: VARIATIONS BETWEEN NATURAL AND INDUCED MENOPAUSAL WOMEN

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ABSTRACT

Menopausal health impacts among women vary. The research aimed to examine the problems of women with natural menopause and induced menopause in the year 2022-23.The evaluation of the study was on the basis of a self-prepared questionnaire and Menopause-Specific Quality of Life developed by Department of Family and Community Medicine, Sunnybrook Health Science Centre, University of Toronto, Canada in 1996 (MENQOL),the tool to evaluate the quality of life. About fifty sample each in natural menopause and induced menopause were chosen from various places in Kerala.The study opined that either the induced and natural menopause women had no significant relation with BMI. But the waist hip ratio pointed out that 20 per cent induced menopause women were at higher risk category than natural menopausal women (4%). Also, the physiological problems like diabetes (70%), dizziness (62%) and gastritis (60%), psychological problems like mood swings (100%), anxiety (66%), trouble sleeping (64%), sexual and genital problems like decreased libido (84%), itching (72%), vaginal dryness (60%) were high among induced menopausal women than natural menopause women. Menopause specific quality of life questionnaire showed that the quality of life at physical (flatulence-90%, aching in muscles and joints- 96%) and sexual domains (change in sexual desire-90%) affected mostly among induced menopause women**.**

Keywords: health, menopause, quality of life, women

INTRODUCTION

Most people in India, either ignore menopausal symptoms or don't pay attention to them. Menopause should be viewed as merely one step of a continuum of ages, not as the end of life. Prior health, reproductive, lifestyle, and ecological factors have a significant impact on a woman's health as she enters the menopausal stage.

Menopause marks the end of a woman's fertile life, and is an indicator of ageing.Regarding menopause, lack of awareness and leading ways to secure knowledge are some challenges that can be amplified by the facility of contradictory data.Menopause creates changes in the life pattern in multiple ways in their physical, emotional, social and financial factors.

Today we need for ongoing research on the social and biological factors influencing the menopausal experience so that we can develop better strategies to promote healthy

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ageing for women of all races and ethnicities. The information obtained from the research could be used to lessen the menopause-related problems and offer a foundation to arrange health care for menopausal women based on their necessities. Menopausal health is crucial for women's overall health and well-being. Understanding and addressing the physical, emotional, and hormonal fluctuations that happen during menopause helps in leading a healthier and more fulfilling life for women as they embrace this natural phase of life. Proper medical guidance, lifestyle adjustments, and self-care practices play vital roles in promoting menopausal well-being and ensuring women accepting the change with confidence and good health. The crrent research was carried to find out the variations in the effect of natural and induced menopause.

MATERIAL AND METHODS

Research design

The research was a cross sectional study. The area selected for the research was in different parts of Kerala as the number of women which affect the menopausal impacts were large. Also, the number of women who induce menopause due to cancer chemo-therapy, oophorectomy etc are increasing day by day.

Selection of sample

The sample were selected using a purposive sampling technique. Women who were > 45 years of age staying at homes and who agreed to contribute in the research were selected. The sample selected for the research consisted of 50 natural menopause and 50 induced menopause women. Purposive sampling refers to a set of non-probability sampling procedures through which sample are selected having common features necessary for the study. The designated method to purposive sampling used in each sample creates a way to the research design (Prior *et al.,*2020).

Selection of tool

The tool for the study was a self-prepared questionnaire to assess the health impact of natural and induced menopause. The Menopause-Specific Quality of Life Questionnaire (MENQOL)was used to evaluate the quality of life related to health issues among the post-menopausal women (Karmakar *et al.,* 2017). An inherent assum-ption of the MENQOL is that menopause causing symptoms interrupt emotional, physical, and social facets of a woman's life, which must be measured parallel with treatments.

Anthropometric assessments:

Anthropometric measurements (height, weight, hip circumference, waist circumference) were taken by the techniques detailed in Mini Nutritional Assessment guide (MNA guide). The weight (kg), height (m), waist circumference and hip circumference were measured. Anthropometric measurements are noninvasive quantitative measurements of the body. According to WHO (1995) anthropometry provides a valuable assessment of nutritional status in children and adults. The BMI and waist to hip ratio are measured and calculated. Body Mass Index (BMI) is a person's weight in kilograms (or pounds) divided by square of height in meters (or feet).

Interpretation of data

The investigator collected the data that was provided by the sample with the questionnaires. The total score of each subsection in the questionnaire was calculated and found out the percentage. The results were tabulated, analysed and interpreted. Analysis of data was done using Microsoft Office Excel 2010. Numerical variables were transformed into ordinal or nominal variables. Chi-square test was performed for qualitative variables. The associations were quantified as odds ratios with 95 per cent confidence intervals. P value less than 0.05 was regarded as statistically significant.

RESULTS AND DISCUSSION

Anthropometric measurements

Anthropometric measurements explain about the BMI and waist - hip ratio of the sample.

BMI of the sample

Table 1 describes the BMI of the sample.

The table gives the information about BMI of the sample. From the table 30 per cent natural menopause women were underweight, 42 per cent were normal,16 per cent were overweight and 12 per cent of them were obese. Regarding induced menopause 34 per cent of them were underweight, 38 per cent of them were normal, 22 per cent of them were overweight and 6 per cent of them were obese. The chi square static is 1.7and the p value is 0.637 which is not significant.

Waist - hip ratio of the sample

Table 2 shows the waist to hip ratio of the sample.

The table gives information about waist hip ratio of the sample. In natural menopause women 40 per cent were underweight,56 per cent were normal weight and 4 per cent of them were overweight or obese. While seeing induced menopause women 30 per cent of them were underweight or malnourished,50 per cent of them were normal and 20 per cent of them were overweight or obese. The study shows that induced menopause women were overweight than natural menopause women. The chi square static value is 6.22. The p value is 0.0446. Medications such as antidepressants and hormone treatments among some menopausal women promote weight gain(Stanford *et al.,* 2020).

Physiological problems

Many symptoms are related with the menopause, but the two that are usually the most significant and therefore most distressing to women are the hot flush, which often leads to insomnia, and vaginal dryness. These symptoms are associated with a decrease in oestrogen levels and are experienced by over 70 per cent of women. Most menopausal symptoms can be classified into either physical or psychological in nature (Santoro *et al.,* 2015).

Table 1. BMI of the sample N = 100

Categories of BMI (Kg/m²) *	Natural menopause		Induced menopause		Chi square static	p value
	Frequency	Percentage	Frequency	Percentage		
Underweight(<18.5)	15	30%	17	34%		
Normal (18.5- 24.9)	21	42%	19	38%	1.7	0.637
Pre-obesity(25- 29.9)	8	16%	11	22%		**NS
Obesity (>30)	6	12%	3	6 %		

*World Health Organization(2000)

* *Not Significant

Table 2. Waist to hip ratio of the sample N= 100

	Natural menopause N=50		Induced menopause N=50			
Waist hip ratio. ***(**Waist circumference /hip circumference**)**	**Frequ-ency**	**Perce-ntage**	**Frequ-ency**	**Perce-ntage**	**Chi square static**	**p value**
Low (<0.8)	20	40 %	15	30%	6.22	.0446**
Moderate (0.81 – 0.86)	28	56%	25	50%		
High (>0.86)	02	04%	10	20%		

* World Health Organization (2000)

* *Significant at p< .05

The Table 3 shows the physiological problems of the sample.

Among natural menopause women majority (78.00%) of them had hot flashes, followed by hypertension (64.00%), muscle pain (54.00 %), feelings of dizziness (56.00%) and similar number (52.00%) of respondents had both joint pain and diabetes, whereas, among induced menopause women, 74 per cent of them had hot flashes followed by

Table 3. Physiological problems N =100

Parameters	**Natural menopause n = 50**		**Induced menopause n = 50**	
Physiological problems	**Frequency***	**Percentage**	**Frequency***	**Percentage**
Hot flashes	39	78%	37	74%
Diabetes	26	52%	35	70%
Feeling of dizziness	28	56%	31	62%
Gastritis	26	52%	30	60%
Hypertension	32	64%	28	56%
Irritability	24	48%	26	52%
Joint Pain	26	52%	25	50%
Urinary problems	12	24%	24	48%
Muscle pain	27	54%	24	48%
Cold flashes	12	24%	20	40%
Heart palpitations	14	28%	20	40%
Heart beats slowly	16	32%	20	40%
Headache	10	20%	18	36%
Clammy feeling	8	16%	12	24%
Liver diseases	5	10%	3	6%
Asthma	0	0	1	2%

**Multiple choices*

diabetes (70.00%), feeling of dizziness (62.00%), gastritis (60.00%), hypertension (56.00%), irritability (52.00%) and joint pain (52.00 %).It is evident that induced menopause women undergo physiological problems than natural menopause women. In recent studies the menopause symptoms include symptoms like hot flushes and night sweats, sleep difficulties, fatigue, gastritis, urinary problems, palpitations, joint pains, thinning of nails, dryness of skin/eyes, and changes to skin and hair. It is observed that earlier symptom development in the transition signals a longer duration of bothersome symptoms(Santoro *et al.,*2015).

Psychological problems

The psychosocial and behavioural factors (e.g., social support, loss of interest in sex, stressful events) among women transitioning into menopause might be particularly susceptible to mood disturbances in general and depressive symptomology in particular (Cheng *et al.,* 2022).

Table 4 shows the psychological problems of the sample**.**

A major proportion of women experience psychological and cognitive symptoms during menopause, whether it occurs naturally or is induced. Among women undergoing natural menopause, 68 per cent reported experiencing mood swings, while 62 per cent faced heightened stress levels, 60 per cent struggled with sleep disturbances and had difficulties with cognitive functions, particularly in thinking clearly. Also, 50 per cent had loss of interest in activities. In contrast, women experiencing induced menopause seemed to report an even greater prevalence of such symptoms. Every woman in the group reported mood swings, while66 per cent experienced anxiety, trouble sleeping was affected for 64 percent,60 per cent found it challenging to concentrate, 56 per cent indicated a loss of interest and 52 per cent faced difficulties with clear thinking. Rao *et al.,* (2017) stated that depression and psychiatric problems were common in post-hysterectomy women.

Table 4. Psychological problems N =100

Parameters	Natural menopause n = 50		Induced menopause n = 50	
Physiological problems	**Frequency***	**Percentage**	**Frequency***	**Percentage**
Mood swings	34	68%	50	100%
Anxiety	21	42%	33	66%
Trouble sleeping	30	60%	32	64%
Difficulty in concentrating	18	36%	30	60%
Loss of interest	25	50%	28	56%
Difficulty in thinking	30	60%	26	52%
Stress	31	62%	33	44%
Crying spells	6	12%	20	40%

**Multiple Choices*

Table 5: Sexual and genital problems N= 100

Parameters	Natural menopause n = 50		Induced menopause n = 50	
Physiological problems	**Frequency***	**Percentage**	**Frequency***	**Percentage**
Sexual problems				
Decreased libido	37	74%	42	84%
Dyspareunia	19	38%	9	18%
Genital problems				
Itching	30	60%	36	72%
Vaginal dryness	35	70%	30	60%

**Multiple Choices*

Sexual and genital problems

Menopause is a natural and normal process, it can bring about various physical and emotional changes. Some women may feel symptoms like vaginal dryness, decreased libido, mood swings, and variations in bone density (Santoro*et al.,*2015). The reduce estrogen levels can also cause the vaginal issues, causing symptoms like vaginal dryness, itching, and discomfort during intercourse (Lethaby, 2016).

Table 5 shows the sexual and genital problems of the sample.

Among natural menopause 74 per cent of them had sexual problems of decreased libido. compared with induced menopause which was 84 per cent. In the case of genital problems, the results show that 60 per cent of natural menopause women had itching and 70 per cent had vaginal dryness and in induced menopause 72 per cent had itching and 60 per cent had vaginal dryness.

Assessment of quality of life (MENQOL)

Menopause is a physiological phase in women's life that can severely create an impact on the quality of life (QOL). Studies show that psychological symptoms were powerfully associated with menopausal women and have a significant impact on QOL of menopausal women than late postmenopausal women (Bashar *et al.,* 2017). Physical and physiological symptoms usually ago together in menopause and creates an impact on women's health and well-being (Senthilvel *et al.,* 2018).

Menopause, whether natural or induced, significantly impacts a woman's quality of life in various phases, including vasomotor, psychosocial, physical, and sexual aspects. The domain vasomotor shows that hot flashes were experienced by 78 per cent of women undergoing natural menopause, making it a prominent concern whereas among induced menopause groups 74 per cent experienced hot flashes.

In the psycho-social domain about 60 per cent reported feelings of nervousness or anxiety, being impatient with others was another common symptom, affecting 60 per cent of women with induced menopause. Natural menopause women had feelings of nervousness or anxiety affected by 64 per cent, while 52 per cent reported feelings of depression or being downhearted and poor memory was noted for 50 per cent.

Table 6: Quality of life N=100

Parameters	Natural menopause n = 50		Induced menopause n = 50	
Physiological problems	**Frequency***	**Percentage**	**Frequency***	**Percentage**
Vasomotor domain				
Hot flashes	39	78%	37	74%
Sweating	20	40%	24	48%
Night sweats	12	24%	20	40%
Psychosocial domain				
Feeling anxious or nervous	32	64%	30	60%
Feeling of wanting to be alone	32	64%	30	60%
Feeling depressed down or blue	26	52%	30	60%
Experiencing poor memory	25	50%	19	38%
Being impatient with other people	15	30%	20	40%
Accomplishing less than I used to	12	24%	20	40%
Being dissatisfied with personal life	5	10%	10	20%
Physical domain				
Aching in muscles and joints	48	96%	48	96%
Flatulence or gas pains	42	84%	45	90%
Decrease in physical strength	40	80%	45	90%
Feeling tired or worn out	35	70%	40	80 %
Difficulty sleeping	20	40 %	25	50%
Frequent urination	11	22%	25	50%
Feeling bloated	25	50%	28	36%
Drying skin	35	70%	15	30%
Involuntary leakage of urine	5	10%	15	30%
Low backache	13	26%	10	20%
Aches in back of neck or head	22	44%	10	20%
Weight gain	25	50%	10	20%
Increased facial hair	5	10%	6	12%
Sexual domain				
Change in sexual desire	40	80%	45	90%
Avoiding intimacy	30	60%	23	46%
Vaginal dryness during sexual intercourse	24	48%	20	40%

Multiple choices

The physical symptoms were highly common among women with induced menopause. Muscle aches were reported by women in both groups, about 96 per cent, whereas flatulence or gas pains and decreased physical strength were equally prevalent at 90 per cent for women with induced menopause and it was 84% and 80% respectively for women with natural menopause. A notable 80 per cent women with induced menopause felt chronically tired, 50 per cent experienced difficulty in sleeping and had frequent urination. Among women with natural menopause only 70 per cent women felt chronically tired, 40 per cent experienced difficulty in sleeping and 22 percent had frequent urination. With respect to weight gain and bloating, each affected 50 per cent of women in the natural menopause group but was comparatively less in the other group.

The sexual domain shows that changes in sexual desire were reported by 80 per cent in natural menopause women and 90% in induced groups, reflecting a significant impact on this aspect of life.

CONCLUSIONS

Many life challenges were faced during the menopausal period such as stress, age, loneliness, health conditions, diet changes, changes in working pattern etc. Study shows that most of the problems such as overweight (20%), physiological (60-74%), psychological (60-100%), sexual (84%) and genital (72%) were severe in induced menopause women when compared to natural menopause. The quality of life of them was found to be moderately high among induced menopause women mainly in the domains such as vasomotor (74%), psychosocial (60%) and sexual (60%). The study shows that the menopausal stage was a major part in the life of a woman. In the middle age stage, various complicated menopausal symptoms arose. Each middle-aged woman should need to be aware of the menopause stage and the various complications. Proper medications and check-ups were suggested to maintain the health of them.

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EXAMINING THE FACTORS AFFECTING FARMERS WILLINGNESS TO ADOPT AI-DRIVEN SMART FARMING TECHNOLOGIES FOR SUSTAINABLE BANANA CULTIVATION

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ABSTRACT

The present study explores the willingness of banana farmers in Theni district, Tamil Nadu, to adopt AI technology conducted in 2023. The analysis focuses on the socio-economic and demographic factors influencing the adoption of AI-ML technologies in banana cultivation, with a sample size of 260, analyzed using a multinomial logit model. However, many farmers are efficiently using AI-based mobile applications, soil spectra, drones for fertigation, etc. In Theni, the study tends to identify the reasons for the non-adoption of technologies among the other groups of farmers.The results of the variables like education (0.730), current use of precision farming tools (9.279), understanding of AI (13.18), use of updated irrigation methods (3.950), market price of banana (0.10), and skill (18.877), show a positive and significant effect on the likelihood of willingness to adopt AI technology in banana cultivation. At the same time, the age of the farmer (-0.146), male gender (-3.072), and area (-0.515) have a significant negative impact on the likelihood of AI adoption among farmers. Moreover, experienced farmers (-0.253) are still interested in following traditional farming rather than switching to innovative technologies. Innovation is long-termand gradually leads to enhanced profitability and quality production. Therefore, the integration of AI in banana cultivation emerges not only as a transformative technological advancement but as a key catalyst poised to revolutionize productivity, optimize resource allocation, elevate sustainable practices, etc.

Keywords: AI-ML, Banana, Smart farming, Sustainability, Theni

INTRODUCTION

Agrarian economies strive to secure livelihoods by fostering demand for agricultural goods in domestic and international markets. Ensuring an adequate food supply is a critical challenge with limited resources and a rapidly growing population. Emerging technologies like Artificial Intelligence (AI), Machine Learning (ML), the Internet of Things (IoT), and Big Data are transforming agriculture by creating innovative farming ecosystems (Javaid *et al.,* 2022; Goel *et al.,* 2021). These technologies enhance efficiency, address labor shortages, and optimize outputs by utilizing field-generated data for weather monitoring, soil testing, and seed treatment (Javaid *et al.,*

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Table 1: Variables Used for the Analysis of Willingness on Adopting AI

Variables	Categories	Description
Willingness to Adopt (Dependent Variable)	Yes, if it outweighs the concern/Yes/ No, prefer traditional farming/Undecided	If it outweighs the concern, the farmer is willing to adopt AI technology only if it eliminates the risks or problems caused by traditional farming methods.Yes: It reflects the farmers' willingness to take a chance and invest in AI without pointing out the future benefits derived from the same.No, I prefer traditional farming—those farmers who do not believe in modern farming techniques and are happy with what they do. Undecided: Farmers who are confused between AI and traditional farming may be confused due to a lack of knowledge.
Irrigation	Drip Irrigation/ Sprinkler/ Channel Irrigation/ Surface Irrigation	The type of irrigation followed by the farmer.
Market Price of Banana	Rs Per kg	The average market price of a banana in Theni
Skill	Skilled/ Unskilled	Whether the farmer is skilled or not, new agricultural technologies
Experience	In years	Farming experience
Description of Underst-anding of AI	Very Limited/ Limited/ Moderate/Extensive	How far does the farmer generally know about the AI tools
Age	In years	Age of the farmer
Gender	Male/ Female	Gender of the farmer
Education qualification	High school/12th/ Degree/Diploma/Post-Graduation	Education qualification of the farmer (all the farmers completed primary education)
Technology currently using	Conventional Farming/ Precision Farming/ Neutral Farming	Which is the existing farming method used by the farmer.
Awareness of AI in agriculture	Yes/ No	Whether the farmer is aware of the usage of AI in the agriculture sector
The area under cultivation of banana	In acres	The area is owned by the farmer and is used exclusively for banana cultivation.
General Awareness of AI	Yes/ No	Does the farmer have a general awareness of AI

2022). India has increasingly adopted smart agricultural technologies to improve productivity, double farmers' income, and ensure food security for its growing population. Among crops, bananas are nutritionally rich and globally significant, with world production reaching 116,781,658 (000 MT) in 2020-21.

Tamil Nadu, particularly the Theni district, has emerged as a frontrunner in integrating IoT-based solutions in banana cultivation. The farmers are highly motivated to cultivate bananas instead of other tropical crops like paddy, which is more remunerative and profitable in Theni (Sivarajah, 2022). These include drones for fertilizer and pesticide spraying under the Sub-Mission on Agricultural Mechanization (SMAM) project, mobile applications like Fasal agri-tech for pest and disease management, and soil testing technologies like Soil Spectra for real-time soil analysis. Additionally, the Tamil Nadu Supply Chain Management (TNSCM) project facilitates end-to-end traceability, enhancing the export potential of value-added banana products. Theni has gained prominence through its focus on cultivating the Grand Naine banana variety for international markets, aligning with initiatives like "One District One Product" (ODOP) and "Districts as Export Hubs". These programs aim to unlock the district's export potential, create employment opportunities, and promote rural entrepreneurship, contributing to the vision of AtmaNirbhar Bharat.

This study examines the factors influencing farmers' willingness to adopt innovative farming technologies in banana cultivation in Theni, Tamil Nadu. By understanding their accessibility and motivation to adopt IoT-based innovations, the study seeks to contribute to the broader goal of achieving sustainable agricultural practices and enhancing the global competitiveness of India's banana sector.

MATERIAL AND METHODS

The factors affecting the willingness of the farmers to adopt innovative farming technologies in their farmlands for banana cultivation were analyzed using qualitative response models, i.e., the multi-nominallogit model. For this, the following variables are used:

Econometric Methodology

The multinomial logit model is used in the present study as it is suitable for analyzing categorical dependent variables with more than two outcomes. The multi-nominal logit model is used extensively to understand individuals' behavioral choices. The present study uses this model to examine the factors influencing farmers' willingness to adopt innovative farming technologies in banana cultivation by categorizing their willingness into multiple choices or levels.The model can calculate the probability of farmers' showing their desire to adopt AI technologies through a utility function. The likelihood that n^{th} respondent chooses i^{th} willingness to adoption behaviour is

$$P_n(i) = Prob\big(U_{ni} \geq U_{nj}, J \in J_n, i \neq j\big) \text{--}(1)$$

$$= Prob\,(V_{ni} + \varepsilon_{ni}\,, j \in J_n\,,\ i \neq j) \text{--}\ (2)$$

$$= Prob\,(V_{ni} + \varepsilon_{ni} \geq \max\,(V_{ni} + \varepsilon_{ni}) \text{---}\ (3)$$

Where n^{th}respondent chooses the effect of i^{th} willingness to adopt AI technology as U_{ni}

V_{ni} is βX_{nk}

ε_{ni} Is the random white noise error term

X_{nk} is the K factor which affects the nth respondent's choice

β is the parameter to be estimated

According to th e results in Table 2, the following variables are explained based on their significant effect on the willingness to adopt AI technologies. The table is presented based on the three thresholds- Threshold 1 between Yes, if outweighs concern vs undecided category; Threshold 2 between Yes & Undecided category; Threshold 3 between No prefer traditional farming vs Undecided.

A confusion matrix is a tabular representation used to evaluate the performance of a classification model by comparing its predicted labels with the actual labels. It categorizes predictions into four groups: True Positives (TP), True Negatives (TN), False Positives (FP), and False Negatives (FN). This method helps identify correct and incorrect predictions, offering valuable insights into the model's accuracy, errors, and effectiveness across different classes in the dataset.

A word cloud visualization is a technique for visually representing textual data by displaying words in varying sizes, where more prominent words signify higher frequency or significance. This method creates a cloud-like arrangement, emphasizing the most commonly occurring terms in a dataset, making identifying key themes and patterns easier.

RESULTS AND DISCUSSION

Table 2 offers key insights into the factors affecting farmers' willingness to adopt AI technology under different choices. For the category "Yes, if it outweighs concern" versus the undecided farmers, results show that age negatively impacts willingness, with each additional year reducing the probability by 0.023 units, though statistically insignificant. Gender also appears insignificant, as male farmers are 1.718 times less likely to consider adopting AI than females. Educational qualifications, however, show a significant effect—farmers with 12th-grade, degree, and diploma qualifications are more likely to embrace AI compared to those with high school education, with 0.34, 3.79, and 2.11 units, respectively, highlighting the positive role of higher education in fostering adoption. Precision farming significantly enhances willingness, with a 3.75 units higher likelihood than conventional methods. However, more extensive landholdings reduce the probability, with a one-acre increase lowering the odds by 0.618 units. General awareness about AI and its agricultural applications remains insignificant, though understanding its potential benefits increases the probability by 0.97 units. Farmers with extensive, moderate, or limited knowledge of AI have a significantly higher likelihood (13.18, 9.66, and 10.1 times, respectively) of adopting AI than those with minimal knowledge.

Additionally, advanced irrigation methods such as drip and sprinkler systems positively influence willingness, significantly increasing log odds compared to surface irrigation. Among the benefits, improved pest management, resource efficiency, and increased yield motivate farmers to adopt AI, with skilled farmers showing a notable likelihood of 6.44 times higher than unskilled workers. Farming experience, however, remains insignificant, with only a slight increase in probability.

For the "Yes" versus undecided threshold, age has a significant negative impact, indicating younger farmers are more likely to adopt AI, with each additional increase

Table 2: Multi-nominal Logit results for different Threshold Values

		Threshold 1		Threshold 2		Threshold 3	
Variable	**Categories**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**
INTERCEPT		-25.487	0.0000**	-19.210	0.000**	22.469	0.0417**
Age	-	-0.0238	0.5662	-0.146	0.0026**	0.1241	0.1044
Gender	Male	-1.7183	0.1779	-3.072	0.0213**	-0.3862	0.7883
Education	12th	0.3400	0.8193	2.704	0.2003	4.0945	0.0285**
	Degree	3.7989	0.0436**	5.976	0.0124**	-3.609	0.1960
	Diploma	2.1153	0.2381	3.2940	0.1592	2.003	0.411
	Post-Graduation	0.0843	0.9708	0.730	0.792	-13.560	0.0000**
Technology	Precision	3.759	0.002**	9.279	0.000**	-12.859	0.0000**
	Neutral	2.6854	0.0620	9.598	0.0000**	4.363	0.0103**
Area	-	-0.6181	0.004**	-0.515	0.0236**	-0.119	0.7407
Awareness on AI	Yes	-1.225	0.3194	-4.730	0.0000**	-0.9423	0.3687
Description on understanding of AI	Extreme	13.1843	0.000**	2.306	0.3194	-1.5440	0.4201
	Moderate	9.6611	0.000**	-3.044	0.010**	-5.387	0.3108
	Limited	10.103	0.000**	-2.510	0.010**	-2.261	0.010**
Awareness of AI in Agri	Yes	-1.225	0.3194	-4.7303	0.000**	-0.9423	0.3682
Irrigation	Drip	3.0950	0.046**	2.8592	0.0831	0.0912	0.9691
	Sprinkler	1.653	0.5206	2.1568	0.41326	-0.989	0.746
	Channel	4.2709	0.027**	4.0628	0.0600	-1.637	0.4915
Market Price	-	0.110	0.219	0.1010	0.2772	-0.653	0.0181**
Awareness on potential benefits of AI	Yes	0.9730	0.3717	1.0052	0.3785	4.055	0.023**
Skill	Yes	6.4452	0.006**	18.877	0.000**	-8.496	0.000**
Experience	-	0.0862	0.1804	0.0839	0.223	-0.2538	0.048**

Source: Authors estimation using primary data in age reducing willingness by 0.146 units. Educational qualifications again play a pivotal role, with degree holders being the most likely to adopt AI, followed by diploma and 12th-grade farmers, compared to high school graduates. Precision and neutral farming methods foster higher probabilities of adoption, with significant 9.27 and 9.59 units, respectively, over conventional practices. More extensive landholdings again show a negative effect, with a one-acre increase lowering the probability of adoption by 0.51 units. Awareness variables remain insignificant, but farmers with extensive knowledge of AI have a 2.03 times higher likelihood of willingness. Irrigation methods and the market price of bananas show no considerable effect on willingness. However, skilled farmers demonstrate a significant possibility of adopting AI, with a probability of 18.87 units compared to unskilled farmers. Among benefits, increased crop yield emerges as an essential driver, raising the likelihood of willingness by 5.26 units. Farming experience contributes positively, with a one-year increase raising the probability of adopting AI.

For the "No, prefer traditional farming" versus undecided threshold, older farmers are more likely to prefer traditional practices, with each additional year increasing the probability by 0.12 units. Male farmers are 3.07 times less likely than females to stick to conventional farming, though this remains insignificant. Educational qualifications reduce the likelihood of preferring traditional agriculture, with postgraduates being the least likely to continue traditional methods. More extensive landholdings discourage traditional farming, as each additional acre reduces the probability by 0.119 units. Whether extensive, moderate, or limited, knowledge about AI decreases the likelihood of sticking to traditional practices, with significant reductions of 1.54, 5.38, and 2.26 times, respectively, compared to minimal knowledge. Irrigation methods have no substantial impact. Awareness of AI's benefits also reduces the probability of traditional farming, especially for benefits like pest management and yield improvement. Skilled farmers are significantly less likely to prefer traditional methods, with a probability of 8.49 units, and experienced farmers are also more inclined toward modern practices, with a one-year increase in experience reducing the probability by 0.25 units.

The study identifies the socio-economic and demographic characteristics of banana farmers willing to adopt AI-based technologies. The higher the age, the lesser the probability of farmers adopting smart farming in banana cultivation (Chuchird *et al.*, 2017). Female farmers were more inclined towards adopting AI technologies than male farmers (Dissanayake *et al.*, 2022). Higher education positively influences willingness to adopt AI technology (Worku, 2019). Farmers holding higher education – particularly degrees/ diplomas- are significantly more likely to adopt AI in banana cultivationthan those with lower education qualifications. Farmers already using precision farming showed a higher probability of adopting AI technologies,which is statistically significant compared to those using conventional cultivation methods. Larger landholders were less likely to adoptinnovative farming (Li *et al.*, 2023). They often rely on traditional methods that have worked for them over time and may perceive AI adoption as unnecessary or too risky. Additionally, the higher upfront costs and complexity of implementing smart technologies across larger areas could deter them compared to smallholders seeking efficiency gains. Farmers were more willing to adopt AI in banana cultivation, mainly when there was a shift in choice from surface irrigation to drip and sprinkler irrigation. Skilled farmers were more likely to adopt the technology than unskilled farmers. The higher the experience in banana cultivation, the lower the chances for adopting

AI, giving more preference to traditional farming (Olatade *et al.*, 2016). The market price of bananas can significantly affect farmers' willingness to adopt AI technologies, as higher prices incentivize farmers to invest in advanced methods like AI to maximize profits.In contrast, price reductions discourage adoption by limiting their financial capacity and perceived return on investment. In Theni, a one-unit price increase decreases the likelihood of traditional farming by 0.65 units, highlighting a shift toward modern practices driven by better market prices.The negative relationship between AI awareness and the possibility of adoption could indicate that farmers aware of AI's complexities, costs, or limitations in agriculture may perceive it as less practical or beneficial for their specific needs, leading to hesitation in adopting smart technologies. This highlights the need for better-targeted awareness campaigns emphasizing AI's tangible benefits and ease of use in farming.

The confusion matrix further shows the actual and predicted results into different outcomes (Table 3). The result suggests that 17 among the total 240 were predicted correctly, belonging to the Undecided category. 83, 60, and 35 observations are predicted trueat the 'Yes, if outweighs concern,''Yes' and 'No, prefer traditional farming' categories, respectively. The rest were predicted as false. The accuracy or success rate of the model was tested. Accuracy was calculated at 81.25 percent. Therefore, the model's error ratewas 1- Accuracy, i.e., 18.75% is the error rate.

A word cloud shows the suggestions given by the farmers that could help them adopt AI-ML smart farming technologies in their farmlands. The word cloud illustrates the precise form of representing farmers' recommendations/ suggestions to ensure the practical possibilities of adopting smart farming technologies in future. The word having the highest weight is"Support" followed by the words – "Government", "technical", "intermediaries", "subsidies", and "financial". It suggests that farmers expect support from the Government for incentives and other policies that promote and support the adoption of smart farming technologies. Affordability plays a vital role in deciding the adoption of these technologies, behind why farmers expect Government (Jabbari *et al.*, 2023) and cooperative institutions to provide loans, subsidies, and other financial support (Dong *et al.*, 2023). Access to technical support and trainingfrom respective authorities is crucial for farmers who encounter issues or fear in

Table 3: Confusion matrix

Actual class/ classified data	Predicted-Class/ Reference data: Unde-cided	Yes, if it outweighs the concern	Yes	No, prefer traditional farming
0 (Undecided)	**17 (6.54%)**	6 (2.31%)	2 (0.77%)	1 (0.38%)
1 (Yes, if it outweighs the concern)	3 (1.15%)	**83 (31.92)**	17 (6.54%)	0 (0%)
2 (Yes)	1 (0.38%)	14 (5.38%)	**60 (23.08%)**	0 (0%)
3 (No, prefer traditional farming)	1 (0.38%)_	0 (0%)	0 (0%)	**35 (13.46%)**

Source: Authors estimation using primary data
Note: Frequency Percentage in parenthesis

Figure 1. Word Cloud Visualization of Farmers' Suggestion to make improvements in the agriculture sector in Theni

Source: Author's representation

technology usage (Li *et al.*, 2023). Farmers consider intermediaries as the biggest reason for their limited access to AI technologies (in terms of distribution rights), delayed adoption (they slow down the process), conflict of interest, complex supply chain, limited accountability etc. In addition to this, farmers suggest improving internet connectivity in rural Theni for ensure better adoption of techniques requiring internet connectivity, and the operations through mobile devices will be highly practical. The farmers are likely to ensure with better market planning and better prices for their product before investing in such technologies.

CONCLUSIONS

The study establishes that AI adoption in agriculture is influenced by a combination of demographic, economic, and policy-driven factors. age negatively impacts adoption, with younger farmers exhibiting a higher willingness to embrace AI. Education plays a crucial role, with farmers holding higher qualifications (diploma, degree) being significantly more likely to adopt AI (up to 3.79 times more likely than high school graduates). Precision farming techniques enhance willingness by 3.75 units, while larger landholdings reduce the probability of adoption (-0.618 units per acre).

The classification results (Table 3) indicate that the model effectively predicts adoption patterns among farmers, demonstrating its robustness. Among those who are willing to adopt AI if their concerns are addressed, the model correctly predicts 83 farmers (31.92%), while 60 farmers (23.08%) are accurately classified as definite adopters. Additionally, 35 farmers (13.46%) who prefer traditional farming were correctly identified.The minimal misclassification, such as 6 farmers (2.31%) from the undecided group being classified under 'Yes, if it outweighs concerns,' further supports the model's effectiveness in predicting AI adoption. Figure 1 (Word Cloud) reinforces the role of government support, technical assistance, and financial incentives in driving AI adoption. The prominence of terms like "subsidies," "technical support," and "intermediaries" suggests that policymakers should focus on improving AI accessibility, training, and financial assistance for smallholders. Overall, the findings suggest that targeted policy interventions, including subsidies for AI tools, skill development programs, and better connectivity in rural areas, are essential to drive adoption. Addressing concerns related to cost, accessibility, and ease of use can further enhance farmers' willingness to integrate AI, ultimately contributing to a more efficient and resilient agricultural sector.

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EVALUATING MANGO VALUE CHAINS: PRICE SPREAD, MARKETING EFFICIENCY AND CONSTRAINTS IN CHITTOOR DISTRICT, ANDHRA PRADESH

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ABSTRACT

The study conducted during 2024-25 in Chittoor district, Andhra Pradesh aimed at identification of various actors and activities involved in mango value chain for processing varieties along with assessment of price spread, efficiency in marketing and constraints of the actors involved. The sample size included 150 farmers and 30 intermediaries. The analysis employed value chain mapping, price spread analysis and Garrett techniques. The study identified three distinct value chains that included direct selling to processors, selling through ramp traders and selling to pre-harvest contractors. Among these, value chain 1reflecting farmers selling directly to processors was found most efficient and advantageous, offering the highest marketing efficiency (0.56) and yielding a greater sharefor producers to an extent of 55.88. Additionally, the Garrett ranking revealed that key challenges encountered by pre-harvest contractors, ramp traders, and processors across these value chains were high market price fluctuation, lack of timely payments and high requirements for working capital respectively.

Keywords: Mango value Chain, Value chain mapping, efficiency, price spread, constraints

INTRODUCTION

After China, India is the world's largest producer of fruits and vegetable production.The country holds the top global rank in the production of bananas, mangoes (including mangosteens and guavas), and papayas, contributing 25.56%, 44.46% and 38.64%, respectivelyto the world's total production. Mango (*Mangiferaindica* L.), widely cultivated tropical fruit, is a member of the cashew family, *Anacardiaceae*. States such as Karnataka, Uttar Pradesh, Andhra, Telangana Bihar,and West Bengal states are principal mango-growing regions in India. Andhra Pradesh and Uttar Pradesh states leadin mango cultivation area, accounting for 16.56 per cent and 13.42 per cent respectively. Uttar Pradesh and Andhra Pradesh occupies the largest production with a share of 25.76 per centand 22.10 per cent respectively (Department of Agriculture and Farmers Welfare, 2024).

Mango processing is a vital segment of the fruit's value chain, with significant processing activity concentrated in the Krishnagiri district of Tamil Nadu and erst while

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Chittoor district in Andhra Pradesh. These regions house around 65 processing units, with Alphonso and Totapuri mangoes being the primary varieties used in processing (Agricultural and Processed Food Products Export Development Authority, Ministry of Commerce and Industry, 2024). The erstwhile Chittoor district alone accounts for 1.12 lakh hectares of mango cultivation, producing approximately 15.50 lakh tonnes annually. The Totapuri (Banglora) variety is predominantly used by the pulp industry (Sowmya *et al.,* 2022). Processed mango products such as juices, purees and dried slices have witnessed increased demand in domestic and international markets. However, processors operate at only about 40% capacity due to several challenges, including raw material shortages, the lack of suitable varieties for processing, poor quality of raw materials, high working capital requirements and competition from fresh produce buyers.

Despite India's leadership in mango production, farmers and processors face multiple challenges. Price fluctuations, driven by the seasonal nature of mango production, pose a major risk, while limited access to credit, markets and timely market information limiting timely investment in better practices. Labour shortages and high pest and disease infestation further escalate production costs. Moreover, middlemen exploitation, trader cartels, and policy-related inefficiencies contribute to low price realization, widening the price spread and creating marketing inefficiencies (Kumaresh and Sekar, 2013; Saripalle, 2019; Badar and Ahmad, 2021). These challenges necessitate for a well-structured and integrated value chain that enhances market efficiency, reduces post-harvest losses while also ensuring higher prices for mango growers and processors. Alternative marketing channels have also emerged to strengthen farmers' bargaining power, ensure better prices, and enhance supply chain transparency.

Value chain refers to set of actors and activities involved in bringing a product from production stage to the final consumer and its final disposal. The actors in the mango value chain for processing varieties in India include nursery producers, fresh mango producers, harvesters, assemblers, processors, traders and exporters. These actors engage in a series of inter connected activities to bring the farm produce to final consumers. In the process, each actor relies on others in the value chain to ensure an efficient flow of produce. Understanding these interdependencies play a vital role in improving responsiveness and competitiveness within the mango value chain.Value chain analysis enables the assessment of the actors, their relationships, factors influencing the industry performance, identifying and addressing the constraints to enhance efficiency, productivity and competitiveness of an industry. In this context, the study focuses on evaluating mango value chains for processing varieties in erstwhile Chittoor district in state of Andhra Pradesh with the following objectives.

i. To map value chains of mangoes associated with processing varieties

ii. To evaluate the efficiency of different marketing channels for processed mango processing.

iii. Identifying the constraints encountered by various actors in mango value chains.

Till date, studies on mango have primarily focused on economic analysis, price spread, and marketing efficiency for table varieties. Although some research has explored farmer challenegs, a comprehensive examination of all actors involved in the mango value chain, from production to end-use, remains lacking. Existing studies predominantly concentrate on fresh mangoes and do not provide an in-depth assessment of value chain efficiency, price spread, and market linkages in the processing segment. Moreover, previous studies lack integrated approach regarding perspectives of key stakeholders across the value chain. This study seeks to fill this gap by offering a holistic analysis of the mango value chain, specifically for processing varieties, evaluating marketing channels, and identifying the challenges faced by stakeholders to enhance efficiency and market outcomes.

MATERIAL AND METHODS

Chittoor district was selected for this study purposively due to its prominent position in mango production within Andhra Pradesh. The district's top five mango-producing mandals were purposively selected. Within these mandals, three villages with largest area from each mandal were selected, leading to a total of 15 villages. A random sample of 10 mango-growing farmers were selected from each selected village, totaling 150 farmers as the sample. Additionally, 30 intermediaries including 8 pre-harvest contractors, 10 ramp traders, and 12 processors were selected using the snowball sampling technique. Thus, the study constituted a sample of 150 farmers and 30 intermediaries. Both the farmers and intermediaries were interviewed to gather data on mango value chains, value addition activities, marketing costs, and constraints within these chains. The information obtained was analyzed using value chain mapping, price spread analysis, Acharya's marketing efficiency approach, and Garrett ranking technique. The collected data pertains to the period of June and July months of 2024.

Price Spread

It is the difference between the price paid by the consumer and the price received by the producer for an equivalent quantity of produce. It is calculated by using below formula.

Price Spread=Consumer Price-Producer Price

Producer's share in consumer rupee

It represents the percentage of the final retail price that goes to the producer. It is evaluated by using the below formula. It is calculated usig the following formula.

Producer's Share (%)=(Consumer Price/ Producer Price)×100

Marketing Efficiency

Marketing efficiency of value chains was calculated by using Acharya's formula (2003).

Marketing Efficiency (ME)= Producer Price/(Marketing Costs+ Marketing Margin)

Garrette ranking

It is a statistical technique used to rank constraints faced by various actors in value chains based on their significance as perceived by respondents in the survey.Garrett's formula is given by,

Percent position = $100\times (R_{ij}-0.5)/N_j$

Where,

R_{ij} : Rank given for i^{th} factor by j^{th} individual

N_j : Number of factors ranked by j^{th} individual

RESULTS AND DISCUSSION

Mapping of value chains and the value chain analysis of mango processing varieties:

In Chittoor district, the mango value chain for processing varieties includes mango growers, pre-harvest contractors, input suppliers, financial institutions, horticulture departments and processing units. Post-cultivation, the value chain includes aggregation and marketing managed by ramp traders and processors, who enhance the value of mangoes for both domestic and international markets. Farmers primarily sell processing varieties, such as Totapuri, to processors, pre-harvest contractors and traders. The marketing efficiency of three major value chains used by these farmers has been evaluated and the results aredetailed below.

Value chain 1:

Farmers → Processors → Domestic/ international buyers

Mango-growing farmers focused primarily on cultivating and harvesting mangoes. After harvest, produce is sold directly without middlemen to nearby processing units, received a net price of Rs.24596 per tonne (Table 1). The processing units then added value by converting the raw mangoes into pulp, concentrates and mango drinks, which were sold to domestic beverage companies or exported to international buyers. In this value chain, processors received a margin of 18.98 per cent from domestic sales, while the producer's share accounted for 55.88 per cent of the final consumer price. (Sowmya *et al*., 2022)

Value chain 2:

Farmers → Ramp Traders → Processors → Domestic/international buyer

In this value chain, farmers sell their output to ramp traders, received a net price of Rs.22,222 per tonne (Table 1). After purchasing the produce, ramp traders promptly loaded it onto large vehicles, such as lorries, using ramps which is then transported to processing units, while also bearing the costs associated with loading and transportation. These traders typically sold the produce to domestic or out-of-state processors, earned a margin of 2.18 per cent of final consumer's price. Once the mangoes purchased from the traders, the processing units added value by converting them into pulp, concentrates and mango drinks, which were then sold to domestic beverage companies or exported to international buyers. In this value chain, processors achieved a margin of 19.83 per cent from domestic sales, while the producer's share accounted for 50.49 per cent of consumer price.(Sowmya *et al*., 2022)

Value chain 3:

Farmers → Pre-harvest → contractors → Processors Domestic/ international buyer

In this case, farmers sold mango orchards to pre-harvest contractors (PHCs) for an agreed-upon price of Rs.12611(Table 1) per cent which represents approximately 28.65 per cent of price paid by consumers, thereby stepped away from any further involvement in the marketing process. Once the PHCs take over the orchards, they take complete responsibility of maintenance and covered all related costs. After harvesting, the PHCs sold the produce directly to nearby processing units, resulting in earning a margin of 8.01 per cent of consumer purchase price. The processing units then added value by converting the mangoes into pulp, concentrates and mango drinks, which were sold to domestic beverage companies or exported to international buyers. In this value chain, processors achieved a margin of 21.02 per cent from domestic sales, while the producer's share accounted for 28.65 per cent of the final consumer price. (Ravi *et al.,* 2023)

The results revealed that the price spread across three value chains were Rs.19417,Rs.21791 and Rs.31402 respectively. Higher efficiency in the value chain is reflected through smaller gap between the consumer purchase price and producer

Table 1. Marketing costs, margins, price spread, producer's share and marketing efficiency of mango processing variety

		Processing variety					
		Value chain 1		Value chain 2		Value chain 3	
S.No	Actor	Cost per tonne (Rs.)	% in CP	Cost per tonne (Rs.)	% in	Cost per tonne (Rs.)	% in CP
1	**Farmer**						
	Producer's Sale price	26526	60.27	23750	53.96	12611	28.65
	Total MC	1930	4.39	1528	3.47	0	0.00
	Producer's net price	24596	55.88	22222	50.49	12611	28.65
2	**Pre-harvest contractor**						
	Purchasing price					12611	28.65
	Total MC					9490	21.56
	Margin					3524	8.01
	Sale price					25625	58.22
3	**Ramp trader**						
	Purchasing price			23750	53.96		
	Total MC			1440	3.27		
	Margin			960	2.18		
	Sale price			26150	59.41		
4	**Processor**						
	Purchasing price	26526	60.27	26150	59.41	25625	58.22
	Total MC	9135	20.76	9135	20.76	9135	20.76
	Margin	8352	18.98	8728	19.83	9253	21.02
	Domestic sale price	44013	100	44013	100	44013	100
	International price	57216		57216		57216	
	PS (Price Spread)	**19417**		**21791**		**31402**	
	P's S (Producer's Share) (%)	**55.88**		50.49		28.65	
	ME (Marketing Efficiency)	**0.56**		0.50		0.29	

·MC – marketing costs (maintenance costs, harvesting costs, loading costs, unloading costs, transportation costs and processing costs)

Table 2. Constraints faced by the pre-harvest contractors in mango value chain

S.No.	Constraints	Garrett score	Rank
1	High market price fluctuations	79	I
2	Weather uncertainty	71.25	II
3	Lack of negotiation power	61.75	III
4	Labor shortage	61	IV
5	Unsupportive government policies	48.5	V
6	Less support from financial institutions	46.5	VI
7	Lack of processing units support	41	VII
8	Lack of storage facilities	34.875	VIII
9	Insufficient transport facilities	33.375	IX
10	Lack of timely payments	20.75	X

received price. Among the three, Value Chain 1 proved to be higher efficient, given its lower price spread. The producer's share of the consumer's rupee was 55.88 per cent, 50.49 per cent and 28.65 per cent for the three value chains, respectively. Value Chain 1 had higher producer share, making it the most efficient (Kalidas and Ravikumar. 2024). In general, a value chain with lower value-added costs and margins is considered more efficient in marketing. Therefore, Value Chain 1, indicating farmers selling their produce directly to processors, demonstrated the highest marketing efficiency, resulting in a greater share for producers and making this chain the most advantageous for farmers.

Constraints of pre-harvest contra-ctorsin mango value chain

Results in Table 2. indicates the first major constraint faced by pre-harvest contractors in the study area was higher market price fluctuations (79) as the prices changes day to day and price was fixed by the union of processors. The second constraint encountered was weather uncertainties leading to lesser yields(71.25). Other notable constraints included lack of negotiation power with the farmers (61.75) as large farmers

Table 3. Constraints of ramp traders in mango value chain

S.No.	Constraints	Garrett score	Rank
1	Highmarket price fluctuations	77.6	I
2	Lack of timely payments	65.8	II
3	Competition from other players in the market	59.2	III
4	Lack of adherence to promised agreements due to better prices offered by other players in market	50.2	IV
5	Lack of processing units support	46.8	V
6	Less support from financial institutions	39.8	VI
7	Inadequate transport	38.2	VII
8	Inadequate storage	22.4	VIII

Table 4. Constraints faced by the processors in mango value chain

S.No.	Constraints	Garrett score	Rank
1	High requirements for working capital	80	I
2	Shortage of labor for processing activities	66.67	II
3	Unavailability of high-quality raw materials	63	III
4	High interest rates on loans	56.08	IV
5	Unsupportive government policies	52.58	V
6	Shortage of skilled labor	48.67	VI
7	Less support from financial institutions	42.33	VII
8	Non upgradation to advanced technologies	36	VIII
9	Market competition from other processing firms	34.67	IX
10	Frequent electricity supply disruptions	18	X

demand high prices and shortage of labor for harvesting and marketing activities (61).

Constraints of Ramp traders in mango value chain:

Table 3. also indicates thathigher market price fluctuations (77.6) identified as major challenge by ramp traders driven by daily price changes and the influence of processor unions in setting prices. This is followed with payments delays from buyers (65.8), as processing units often make payments late. Additional challenges included competition from other players in market (59.2) and a lack of adherence from suppliers to agreed-upon terms (50.2) often due to higher prices offered by competitors.

Constraints of processors in mango value chain:

Table 4. indicates that, the primary challenge encountered by processors was the high requirement for working capital (80), driven by increasing raw material costs and higher labor costs. The next constraint was a shortage of labor for processing activities (66.67), attributed to the presence of multiple processing units in the area. Other notable constraints included the unavailability of high-quality raw materials (56.08) and high interest rates onloans (52.58). (Sowmya *et al.*, 2022 and Wie and Aido, 2017)

CONCLUSIONS

The study conducted in Chittoor district of Andhra Pradesh with regard to mango processing varietiesrevealed that among the three identified mango value chains, direct selling to processors (Value Chain 1) is identified as the most efficient cannel, offering the highest marketing efficiency (0.56) and the greatest share for farmers to an extent of 55.88.The major constraints faced by pre-harvest contractors include high market price fluctuations and weather uncertainty, while that of ramp traders were high market price fluctuations and lack of timely payments from processors and processors have been facing major significant constraints related to high requirements for working capital and shortage of labour for processing activities. These challenges hinder the overall efficiency and profitability of the mango value chains, indicating a need for targeted interventions to address these issues and improve the value chain's performance.

RECOMMENDATION

Improving the mango value chain for processing varieties requires a multi-faceted approach. This includes establishment of efficient price dissemination mechanism and expanding alternate market access through eNAM along with facilitating logistic services for institutional and large buyers located at distant markets. Furthermore, enhancing access to value chain finance for farmers, middlemen and processors, promoting mango FPOs and addressing infrastructural bottlenecks through them followed with enhancing technology adoption at farmer level to increase yields and mitigate climate risk will significantly enhance the efficiency of mango value chain in the study area.

POLICY IMPLICATIONS

As price fluctuations is identified a major challenge in the mango value chain, the government should establish an efficient market intelligence system to disseminate real-time price information. This can be achieved by setting up kiosks near marketplaces and at the village level. Strengthening the integration of logistics service providers and institutional buyers through the eNAM "Platform of Platforms" will not only improve price discovery but also enhance access to other markers for mango farmers. The government should promote formation of mango FPOs in high-production clusters to enhance farmers' bargaining power. Additionally, facilitating infrastructure development such as cold storage and ripening chambers, through these FPOs will help mitigate price fluctuations and reduce post-harvest losses. Expanding institutional credit through relaxations of norms along side with state support to mango processing units in identified clusters will address their working capital needs, ensuring timely payments to farmers and supporting the growth of the processing industry. Through a Public-Private Partnership (PPP) model involving state agricultural departments and agri-startups, the government should encourage farmers to adopt technologies such as IoT, helping farmers for informed decision making while also effectively mitigating risk associated climate variability. To protect mango farmers from price volatility, the government should introduce alternative price guarantee mechanisms for crops not covered under MSP. A price assurance system similar to the sugarcane model can help shield farmers from trader cartels and unpredictable market fluctuations

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PROFILE, KNOWLEDGE AND ADOPTION OF CRITICAL INTERVENTIONS OF MAJOR CROPS AMONG DRYLAND FARMERS IN PRAKASAM DISTRICT OF ANDHRA PRADESH

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ABSTRACT

The current study was conducted to examine the profile, knowledge, and adoption of key interventions among dryland farmers in the Prakasam district of Andhra Pradesh in 2021.An *ex-post facto* research design was used for the study, and a sample of 120 dryland farmers was selected.The results revealed that most farmers were middle-aged (43.33%) or older (45%), with 31.67% being illiterate or having only primary or high school education. Small-scale farmers (56.66%) dominated, and land holdings had decreased due to family divisions. While a majority of farmers had medium (63.33%) to high (19.17%) farming experience, yields in redgram were low (37.5%) and medium in cotton (71.67%), primarily due to climatic challenges and limited irrigation. The majority (55%) had medium annual incomes, supplemented by livestock. Extension contact, media exposure, and information-seeking behaviors were generally medium, with farmers depending on local sources for advice, especially during droughts. Knowledge levels on farming interventions were predominantly medium to high, with 60% of farmers showing medium knowledge on redgram and 68.33% on cotton. Adoption rates were also moderate, with 63.33% adopting redgram interventions and 70% adopting cotton interventions to a medium extent. A significant correlation was found between farmers' knowledge and adoption levels, with education playing a key role in both. Moreover, the study revealed a strong positive correlation between education and the adoption of improved farming practices for both crops. Key variables such as land holding, annual income, extension contact, and irrigation status were positively correlated with knowledge and adoption, while age and farming experience had negative correlations. The study emphasizes the need for targeted agricultural policies, enhanced extension services, and improved irrigation infrastructure to improve productivity and prevent rural-to-urban migration.

Keywords: Credit orientation, Dryland, Information seeking behaviour, Risk preference.

INTRODUCTION

According to the FAO (2000), drylands are defined as areas with a length of growing period (LGP) between 1 and 179 days, encompassing regions that are climatically categorized as arid, semi-arid, and dry sub-humid. Based on the FAO's Global Agro-Ecological Zones (GAEZ) modelling system (FAO, 2020), drylands accounted for 43.20% of the world's total area in 2020, with

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projections indicating an increase to 44.20% by 2050. Rainfed agro-ecosystems play a significant role in Indian agriculture, spanning 80 million hectares across arid, semi-arid, and sub-humid climatic zones, and making up around 57% of the net cultivated land. These areas support 40% of the human population and 60% of the livestock population. Approximately 70% of the rural population resides in rainfed regions, with their livelihoods closely tied to the success or failure of crops (Rao *et al*., 2016). Climate change can amplify existing conflicts by putting additional strain on already vulnerable ecosystems and communities, pushing them beyond their ability to cope. This often leads to heightened tensions over access to and use of natural resources (IPCC, 2019). The productivity of rainfed agriculture remains low due to a combination of biophysical challenges and socio-economic factors (Rao *et al*., 2016).The adoption of moisture conservation technologies by farmers could enhance dryland crop yields, increase farm income, and improve livelihoods. Moreover, utilizing every bit of rainfed land through the implementation of highly efficient technologies is crucial to meet the demands of the growing global population (Kaur *et al*., 2022).

The Commission on Inclusive and Sustainable Agricultural Development of Andhra Pradesh (2016) report reveals that, of the 645 non-urban mandals in the state, 129 are classified as severely resource-deprived. These mandals are mainly concentrated in Anantapuramu (51), Kurnool (30), Kadapa (24), and Prakasam (18). Notably, 64.30% of these resource-deprived mandals are located in the Rayalaseema and Prakasam district. Prakasam is considered highly vulnerable to climate change due to the increasing frequency of droughts and erratic monsoons. With more than 60% of the area relying on rainfed farming, sustaining livelihoods in the district is a significant challenge (NABARD, 2021). Additionally, Prakasam has the largest dryland area among the coastal districts of Andhra Pradesh. This situation calls for a study to assess the socio-economic status, knowledge, and adoption rates of dryland farmers in the district. The study aims to explore their understanding and application of improved rainfed practices, which are crucial for their livelihoods. Based on the findings, recommendations will be provided to enhance their knowledge and promote greater adoption of these practices.

MATERIAL AND METHODS

The study was carried out in Prakasam district, Andhra Pradesh, in 2021, using an *Ex-post facto* research design. Four mandals within the district were chosen, and two villages from each mandal were randomly selected *viz*., Annampalli and Racherla from Racherla mandal, Sanjeevarayunipeta and Kommunuru from Giddalurmandal, Konapalli and Singarapalli from Bestavaripeta mandal, and Darimadugu and Bodapadu from Markapur mandal. Fifteen farmers were randomly selected from each of the chosen villages using a simple random sampling method, resulting in a total of 120 farmers.The assessment of farmer’s knowledge used a standardized test with measures like difficulty index, discrimination index, and point-biserial correlation. Responses were scored binary, with 1 for correct answers and 0 for incorrect answers. The maximum possible score for redgram knowledge was 28, and for cotton, it was 35. The scoring pattern for the adoption of critical interventions in cotton and redgram was based on a binary system, where farmers were scored 1 for adopting a particular practice and 0 for non-adoption. The scores for each item were calculated by adding the weights of the items for both knowledge and adoption. Using the resulting scores, farmers were classified into three categories based on the mean and standard deviation. Critical interventions included off-season tillage, improved high-yielding and drought-tolerant varieties, soil moisture conservation practices like ridges and furrows, green manuring, intercropping, and integrated pest management. Adoption of water-saving technologies like micro-irrigation, along with timely sowing, recommended seed rates, spacing, and nutrient management practices, were also assessed. These interventions aim to optimize crop yield, reduce water usage, and mitigate the adverse effects of drought, pests, and poor soil conditions.The Primary data were collected using a pre-tested interview schedule, and statistical methods such as the arithmetic mean, standard deviation, frequencies, percentages, and chi-square test, Phi, Cramer's V, Spearman rank correlation and Pearson correlation coefficient were employed for analysis. Cramer's V was used to assess the strength of association between categorical variables, providing insight into the strength of the relationship.Spearman's rank correlation was used to measure the strength and direction of the relationship between ordinal variables. The Pearson correlation coefficient was employed to evaluate the linear relationship between continuous variables, thereby quantifying the strength and direction of these relationships.

RESULTS AND DISCUSSION

Profile Analysis

The dryland farmers were categorized into different groups based on their profiles, and the results are shown in Table 1.

Most farmers were older (45%) or middle-aged (43.33%), actively engaged in farming. Younger farmers (11.67%), despite their education, were hesitant to farm due to low profitability and frequent droughts, seeking jobs elsewhere. About 31.67 per cent of farmers were illiterate. High school (25%) and primary school (15%) were the next most common educational levels. Graduates (11.67%) often chose farming due to limited job opportunities.The majority were small farmers (56.66%), followed by medium-sized farmers (25%). Land holdings have declined due to family divisions.Most farmers had medium (63.33%) or high (19.17%) farming experience levels, entering farming young due to limited educational opportunities.Over one-third (37.50%) experienced low yields in redgram, and 71.67 per cent achieved medium yields in cotton. Climatic challenges and limited irrigation contributed to these results.Most belonged to medium annual income groups (55%), with diversification into activities like goat rearing and dairy supplementing income.

Nearly two-thirds (65%) had medium extension contact, relying heavily on Agricultural Extension Officers and input dealers for information.Medium exposure (70%) was common, with farmers using electronic media for agricultural information.Nearly two-thirds (65%) exhibited medium information-seeking behavior, relying on local sources due to recurring droughts and crop failures.The majority (60%) had medium levels of social participation, often engaging in farmer interest groups and Vyavasaya Sanghalu for collective benefits. Over three-fourths (76.67%) had medium credit orientation, often accessing loans from banks or cooperatives. Most of the respondents (63.33%) exhibited medium risk preference, reflecting the inherent risks of dryland farming.Over three-fourths (78.33%) had poor irrigation status, highlighting the need for community-based awareness campaigns on farm pond construction.Over half (58.33%) of them had medium economic orientation, prioritizing minimizing crop losses over profit maximization. Half (50%) had medium decision-making ability, often relying on peers due to

Table1.Distribution of dryland farmers according to their profile (n=120)

S.No.	Independent variables	Category	Respondents Frequency	Respondents Percentage
1.	Age	Young age (35 and below)	14	11.67
		Middle age (36 to 55 years)	52	43.33
		Old age (56 years and above)	54	45.00
2.	Education	Illiterate	38	31.67
		Can read and write only	0	0.00
		Primary school	18	15.00
		Middle school	10	8.33
		High School	30	25.00
		Intermediate	10	8.33
		Graduate & above	14	11.67
3.	Land holding	Marginal farmers	08	6.67
		Small farmers	68	56.66
		Medium farmers	30	25.00
		Semi-medium farmers	06	5.00
		Large farmers	08	6.67
4.	Experience in	Low (< 17.69)	21	17.50
	dryland farming	Medium (17.69-46.24)	76	63.33
	$\bar{X}$= 31.97 ó = 14.28	High (>46.25)	23	19.17
5.	Yield Redgram	Low (< 2.032)	45	37.50
	$\bar{X}$= 2.97	Medium (2.032-3.908)	43	35.83
	ó = 0.938	High (>3.908)	32	26.67
	Cotton	Low (< 2.814)	20	16.67
	$\bar{X}$= 4.08	Medium (2.814-5.346)	86	71.67
	ó = 1.266	High (>5.346)	14	11.66
6.	Annual income	Low (< Rs.50000)	20	16.66
		Medium (Rs.50000-100000)	66	55.00
		High (>Rs.100000)	34	28.34
7.	Extension contact	Low (< 8.29)	22	18.33
	$\bar{X}$= 12.18 ó = 3.89	Medium (8.29-16.07)	78	65.00
		High (>16.07)	20	16.67
8.	Mass media	Low (< 0.81)	14	11.67
	exposure	Medium (0.81-6.41)	84	70.00
	$\bar{X}$=3.61 ó =2.80	High (>6.41)	22	18.33

S.No.	Independent variables	Category	Respondents	
			Frequency	Percentage
9.	Information seeking behaviour $\bar{X}$=6.35 ó =2.95	Low (< 3.40)	22	18.33
		Medium (3.40-9.30)	78	65.00
		High (>9.30)	20	16.67
10.	Social participation $\bar{X}$=1.07 ó =0.80	Low (< 0.27)	18	15.00
		Medium (0.27-1.87)	72	60.00
		High (>1.87)	30	25.00
11.	Credit orientation $\bar{X}$=3.28 ó =1.46	Low (< 1.82)	8	6.67
		Medium (1.82-4.74)	92	76.67
		High (>4.74)	20	16.66
12.	Risk preference $\bar{X}$=17.61ó =3.60	Low (< 14.01)	24	20.00
		Medium (14.01-21.21)	76	63.33
		High (>21.21)	20	16.67
13.	Irrigation status $\bar{X}$=8.01 ó =1.64	Poor (< 6.37)	94	78.33
		Fair (6.37-9.65)	24	20.00
		Good (>9.65)	2	1.67
14.	Economic orientation $\bar{X}$=18.45 ó =4.34	Low (< 14.11)	26	21.67
		Medium (14.11-22.79)	70	58.33
		High (>22.79)	24	20.00
15.	Decision making ability $\bar{X}$=20.30 ó =6.25	Low (< 14.05)	32	26.67
		Medium (14.05-26.55)	60	50.00
		High (>26.55)	28	23.33
16.	Cropping pattern $\bar{X}$ =3.31 ó =0.91	Poor(< 2.40)	60	50.00
		Fair (2.40-4.22)	46	38.33
		Good (>4.22)	14	11.67

challenges like dry spells.Half (50%) had poor cropping patterns, with limited irrigation affecting their choices. These findings align with the previous studies conducted by Naik *et al.* (2015), Bankey *et al.* (2012), Praveenbabu (2014), Siddeswari (2015), and Devi (2019).

Level of Knowledge of Dryland Farmers on Critical Interventions in Redgram and Cotton

Table 2 illustrates the distribution of respondents based on their level of knowledge regarding critical interventions in redgram and cotton. The data revealed that the majority (60.00% for redgram and 68.33% for cotton)

Table 2. Distribution of Dryland Farmers Based on Their Knowledge Level of Critical Interventions in Redgram and Cotton (n=120)

S.No.	Category	Redgram		Cotton		Chi-square value ($\div^2$)	Phi (ö)	Cramer's V
		f	%	f	%			
1.	Low	23	19.17	18	15.00	68.403** (0.0001)	.068** 1(0.0001)	0.755** (0.0001)
2.	Medium	72	60.00	82	68.33			
3.	High	25	20.83	20	16.67			
	Total	**120**	**100**	**120**	**100.00**			
	Mean	16.16	18.60					
	S.D.	5.95	6.99					

Values in parentheses represent the significance level (sig.)
** Sig. at 5% level; f: Frequency; %: Percentage

had a medium level of knowledge, followed by those with high (20.83% for redgram and 16.67% for cotton) and low (19.17% for redgram and 15.00% for cotton) levels of knowledge, respectively.

It is clear from the above findings that most of the farmers had medium to high levels of knowledge on critical interventions of redgram and cotton. Many of the farmers in the study area were well experienced in farming and had medium level of extension contact. Moreover, the dryland farmers were often exposed to droughts and experienced crop losses due to which they invariably depend on different information sources for gaining knowledge on critical interventions so as to minimize the crop losses. Hence, many of the farmers had medium to high level of knowledge. Similar findings were reported by Rai and Singh (2010), Tidke *et al*., (2012) and Kumar (2019).

The results indicate a significant association between the category distribution of farmers and the type of crop they cultivate, as evidenced by the Chi-square value of 68.403, which is highly significant (p = 0.0001). This implies that the differences in the distribution of farmers across the Low, Medium, and High categories for Redgram and Cotton are not due to random chance.

Extent of Adoption of Critical Interventions in Redgram and Cotton by Dryland Farmers

Table 3 shows the distribution of respondents based on their extent of adoption of critical interventions in redgram and cotton. The data revealed that the majority (63.33% for redgram and 70.00% for cotton) of dryland farmers adopted the critical interventions to a medium extent, followed by those who adopted to a high extent (21.67% for redgram and 18.33% for cotton) and to a low extent (15.00% for redgram and 11.67% for cotton), respectively.

In the study area, most of the farmers are middle aged and experienced in dryland farming. Apart from this, they were in contact with extension personnel and utilized different information sources for suggestions in agriculture. Further, the cluster demonstrations and on farm demonstrations conducted by KVK scientists also had an impact on adoption of

Table 3. Distribution of Dryland Farmers Based on Their Extent of Adoption of Critical Interventions in Redgram and Cotton (n=120)

S.No.	Category	Redgram		Cotton		Chi-square value (χ^2)	Phi (φ)	Cramer's V
		f	%	f	%			
1.	Low	18	15.00	14	11.67	27.078**	0.672**	0.475**
						(0.0001)	(0.0001)	(0.0001)
2.	Medium	76	63.33	84	70.00			
3.	High	26	21.67	22	18.33			
	Total	**120**	**100**	**120**	**100.00**			
	Mean	14.00	16.81					
	S.D.	5.27	6.19					

Values in parentheses represent the significance level (sig.)
** Sig. at 5% level; f: Frequency; %: Percentage

critical interventions by the farmers. Hence, majority of the farmers adopted the critical interventions to a medium to high extent. Similar findings were reported by Mukundarao *et al.* (2015) and Kumar (2019).

The analysis reveals a significant association between the type of crop (Redgram or Cotton) and the distribution of farmers across different adoption levels. The Chi-square value of 27.078 indicates a highly significant relationship (p = 0.0001). The Phi coefficient of 0.672 suggests a strong association, further supported by Cramer's V value of 0.475, indicating a substantial effect size.

Based on the above findings, it is clear that crop-specific interventions are necessary to enhance farmers' adoption of critical practices.The significant relationship between the type of crop and the levels of knowledge and adoption among farmers suggests that tailored approaches will be more effective. For instance, targeted training programs and resources for Redgram and Cotton farmers can address specific challenges and leverage opportunities unique to each crop, thereby improving overall agricultural productivity and sustainability.

The table 4 shows a strong positive correlation between education and both the

Table 4. Spearman's rank correlation between education with their level of knowledge& extent of adoption of critical interventions in redgram and cotton(n=120)

S.No.	Profile	Level of knowledge		Extent of Adoption	
		Spearman's rho (redgram)	Spearman's rho (Cotton)	Spearman's rho (redgram)	Spearman's rho (Cotton)
X_2	Education	0.729** (0.000001)	0.756** (0.000001)	0.654** (0.000001)	0.668** (0.000001)

Values in parentheses represent the significance level (sig.)
** Sig. at 5% level; * Sig. at 1% level

Table 5. Pearson correlation between the profile of dryland farmers with their level of knowledge & extent of adoption of critical interventions in redgram and cotton (n=120)

S.No.	Profile	Level of knowledge		Extent of Adoption	
		'r' value (redgram)	'r' value (Cotton)	'r' value (redgram)	'r' value (Cotton)
X_2	Education	-	-	-	-
X_3	Land holding	0.426**	0.291*	0.319*	0.437**
X_4	Experience indrylandfarming	-0.427**	-0.302*	-0.317*	-0.310*
X_5	Yield	0.558**	0.449**	0.520**	0.621**
X_6	Annual income	0.559**	0.480**	0.549**	0.654**
X_7	Extension contact	0.436**	0.256*	0.573**	0.606**
X_8	Mass media exposure	0.478**	0.456**	0.639**	0.692**
X_9	Information seeking behavior	0.611**	0.514**	0.720**	0.752**
X_{10}	Social participation	0.611**	0.528**	0.773**	0.723**
X_{11}	Credit orientation	0.552**	0.464**	0.532**	0.502**
X_{12}	Risk preference	0.597**	0.450**	0.583**	0.642**
X_{13}	Irrigation Status	0.345**	0.221**	0.266*	0.150
X_{14}	Economic orientation	0.680**	0.611**	0.590**	0.636**
X_{15}	Decision making ability	0.767**	0.688**	0.694**	0.750**
X_{16}	Cropping pattern	0.271*	0.273*	0.197	0158

** Sig. at 5% level; * Sig. at 1% level

level of knowledge and the extent of adoption of cultivation practices for redgram and cotton. For redgram, the correlation with knowledge it's "r" = 0.729, and for cotton, it's "r" = 0.756. Regarding adoption, the correlation it's "r"= 0.654 for redgram and "r" = 0.668 for cotton. These results suggest that higher education levels are linked to increased knowledge and adoption of improved cultivation techniques for these crops. A similar trend was observed in the study by Thiyagarajan (2011).

The variables like age and experience in dryland farming have negative and significant relations with the level of knowledge and extent of adoption in both cotton and redgramat 1 to 5 per cent level of significance. On the other hand, variables such as land holding, yield, annual income, extension contact, mass media exposure, information-seeking behavior, social participation, credit orientation, risk preference, irrigation status, economic orientation, and decision-making ability are positively correlated with both knowledge and adoption for redgram and cotton at 1 to 5 per cent level of significance. However, cropping pattern shows only a weak positive correlation with knowledge and no significant relationship with adoption, suggesting it may slightly increase knowledge without significantly impacting adoption.Similar findings were reported by Thiyagarajan (2011), Dhepe (2014), Meena (2014), Sumit and Rajesh (2017), Kandasamy *et al.,* (2022).

CONCLUSIONS

Since most of the dryland farmers belonged to medium category of selected independent variables it should be necessary to enhance desired socio-economic status of dryland farmers through various research, extension and policy interventions in the study area.Despite possessing a moderate to high level of knowledge regarding critical interventions in dryland farming, the resource-poor nature and diminishing sustainability of these areas compel the next generation of farming families to migrate to urban areas. Consequently, a majority of farmers fall within the middle-aged to elderly demographic. Both pull and push factors contribute to this migration phenomenon, resulting in a notably high migration rate. It is imperative for governments to address this concern by formulating policies aimed at retaining rural populations, as failure to do so poses a significant threat to food security. Governmental policies should prioritize the provision of essential resources to mitigate drought effects, funding research for the development of location-specific, cost-effective micro-irrigation technologies, and enhancing crop insurance mechanisms.

The analysis reveals a strong and significant relationship between the type of crop and the farmers' distribution across different categories. Understanding these patterns can help in designing targeted agricultural policies and support systems for farmers based on the crops they cultivate.

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REVIVAL OF MILLETS INTRODUCTION IN PUBLIC DISTRIBUTION SYSTEM- IMPROVING ACCESSIBILITY AND CONSUMPTION

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ABSTRACT

The study was conducted in 2023 to investigate the integration of millets into India's Public Distribution System (PDS) and evaluate the feasibility and impact of incorporating millets into the PDS across South India, particularly in states like Telangana, Tamil Nadu, Karnataka, Kerala, and Andhra Pradesh. The distribution of millet grains under PDS has increased significantly in states having millet programs. The findings reveal that states implementing millet initiatives have witnessed a notable increase in consumption within the PDS framework. Karnataka emerged as a leader in millet distribution, with approximately 35% of total consumption, followed by Tamil Nadu (25%) and Andhra Pradesh (23%). Advancing millet cultivation and promoting nutrition education programs is vital to support millets acceptability and consumption to a greater population in the country. The successful implementation of millet inclusion in PDS could serve as a model for other nations aiming to address similar challenges in food security and nutrition.

Keywords:millets, mid-day meal, nutrition security, pubic distribution scheme.

INTRODUCTION

With 83% of Asia's millet production area and approximately 41% of the world's production in 2020, India is the world's largest producer of millet. A variety of small-grained, dryland cereals, such as foxtail, barnyard, and fonio, are grouped together as millets. Millets are a wonderful source of important nutrients because they are whole grains. Asia and Africa are the main growing regions for millet, with India leading the way in production, followed by Nigeria, Niger, and China. In many regions of Asia and Sub-Saharan Africa, they remain a traditional staple crop, having been among the earliest plants to be domesticated (Sheethal *et al*., 2022).

These crops, are rooted in ancient cultures and ancestral traditions, and also possess long survived harsh growing conditions. Their climate resilience and adaptability offer opportunities for strengthening food security and bolstering economic growth. India celebratedthe "international year of millets" in 2023, awareness on millets has grown among the consumers. Pesticides or fertility promoters are not required for millets to grow healthily and produce a decent crop. Additionally, millets have a number of morpho-physiological, molecular, and biochemical traits that give them a higher resilience to environmental stress

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compared to other cereals (Bandyopadhyay *et al.,* 2017).

India's public distribution system is the largest food security programme in the world, which covers nearly 60% of the population and costs Rs 1.45 trillion— close to 1.4% of the national income(Kumar and Bathla, 2017).The Public Distribution System (PDS) in the country facilitates the supply of food grains to the poor at a subsidized price. However, doubts have been raised about the efficacy and cost-effectiveness of the PDS, especially in the light of the growing food subsidy and food stocks(Bommy and Maheswari, 2016).

Subsequently sorghum is highly valued in the areas where it is mostly cultivated and in urban areas it is referred to healthy food, integration of this millet into the public distribution system (PDS) as an alternative to grains such as wheat and rice provides numerous health benefits(Rao *et al*., 2007).The present study is to determine and evaluate for the possible advantages and challenges of millets inclusion in the Public Distribution System (PDS) as a means of ensuring food and nutrition security.

MATERIAL AND METHODS

As the study aims at inclusion of millets in the Public Distribution Systems (PDS)of South India. This study covered Telangana, Tamilnadu, Karnataka, Kerala and Andhra Pradesh states.

The data was collected from the official websites of Public Distribution System of each state*viz.,*https://www.tnpds.gov.in (Tamilnadu), https://www.civilsupplies.telangana.gov.in/ (Telangana), https://ahara.kar.nic.in/Home/EServices (Karnataka), https://aepos.ap.gov.in/ (Andhra Pradesh) and https://civil supplies kerala.gov.in/ (Kerala)

The data was collected in the year 2023 for a period of 6 months (January-July) by sending a questionnaire to the respective public distribution systems of the selected state governments to consider the International year of Millets and its promotion of Millets in India.

The study was carried out on the inclusion of millets in Public Distribution programs, by eliciting data/ information on the type of products distributed, type of meal provided, venue of product distribution etc., The collected data has been analysed by using frequencies, percentages and represented as Tables.

The study was developed by incorporating information from many stakeholders and secondary research (particularly the Civil Supplies Department) working on millets. These millets recommendations document comprehensively addresses an abundance of topics like the State missions and programs with the objective advancing millets; Table 1 reflects a growing recognition of millets as vital for nutritional security and agricultural sustainability in India. Through these initiatives, the government aims to revitalize millet production, enhance farmer incomes, and promote healthier dietary practices among its population.

1.1 Role of PDS in Ensuring Food security through millets:

Karnataka state pioneered in bringing millets under its public distribution system after the role out of the national food security act of 2013. Through the MSP system, the state started to procure millets from the farmers and started distributing it through the public distribution system. However, it is to be noted that the area and production of millets in the state was witnessing a continuous decline on par with the national trend of the same for the last few decades (Gowda *et al.,* 2022). Along with the fall in area under millets, it is to be noted that the profitability also witnessed a drastic decline in the last decade. A reflection

Table 1. Timeline of policy initiatives related to millets by Government of India. (Source: NITI Aayog)

Year	Policy Interventions
2012	* Launched under the **Rashtriya Krishi Vikas Yojana (RKVY)** with an outlay of ¹ 300 crore. * Aimed to enhance millet production, processing, and value addition across 16 states, targeting areas with low productivity compared to national averages
2013	The NFSA included provisions for coarse grains, which encompass millets, thereby recognizing their importance in food security.
2017	NITI Aayog released the National Nutrition Strategy, recommending the strengthening of cereal productivity, including millets, to improve nutritional outcomes in India
2018	* Millets were officially designated as Nutri-Cereals by the government, emphasizing their nutritional benefits. * The year was declared the National Year of Millets, promoting awareness and consumption
2018-2019	Launched under the National Food Security Mission (NFSM) with a budget of ₹ 300 crore to increase millet production and consumption
2021	* Government of India revises its Guidelines for procurement, allocation, distribution and disposal of coarse grains to enhance their availability in public distribution systems. * Organizations like the Food Corporation of India (FCI) works as the main storage unit in various states. * United Nations General Assembly approved India's proposal to observe **2023 as the International Year of Millets** (IYM), highlighting global efforts to promote these grains
2023	* Global Millets Conference: Prime Minister Narendra Modi inaugurated the **Global Millets Conference**, marking India's leadership in promoting millets globally * This event included the unveiling of a postal stamp and currency coin dedicated to IYM

Having spelt out the schemes of the various state governments to introduce millets, let us focus on the role of Public Distribution System of this decline is also evidently visible in the consumption pattern of millets in among the poor sections of the society in both rural and urban areas. People think that if the increased supply of millets is at the expense of reduced quantities of rice it does not worth taking more millets. Another reason is that millets can grow in marginal lands and hence can be cultivated easily unlike rice.

The Cabinet Committee on Economic Affairs (CCEA) chaired by the Hon'ble Prime Minister Shri Narendra Modi has approved the increase in the Minimum Support Prices (MSP) for all mandated Kharif Crops which includes the major millets (Sorghum, Pearl millet and Finger Millet) for Marketing Season 2023-24.

Table 2 depicts the MSP of the millets by the Government of India, for Marketing Season 2023-24, to ensure remunerative prices to the growers for their produce and to encourage crop diversification, as provided in the table below:

Statistical analysis

From the secondary data collected on the inclusion of millets in Public Distribution Systems (PDS) of various states,Analysis of variance (ANOVA) was carried out to determine the results, which were expressed as mean ± standard deviation with a 95% confidence level. Software from the commercial statistical package SPSS (IBM statistics 22) was used to analyze the data.

RESULTS AND DISCUSSION

2.1 Millets in the Public Distribution System (PDS)

The millets initiative of the Indian states from farm to plates is laudable. Millets are the focus of a larger discussion that addresses food security, nutritional adequacy, and food systems sustainability in the world. India, being the largest producer of the nutri-cereals, has the potential to become the global leader in promoting millets. In India there should be a two-prolonged approach that can address demand side and supply side of the millet economy parallelly. On the supply side, increasing productivity, reducing production costs, promoting value addition, and strengthening PDS will help gradually. Considering the local diversity of millet markets and the layers of its associated challenges, state specific and regionally organized interventions will be more fruitful in fostering a strong Millet Economy in the long run(Rahman, 2014).

Table 2. Increase in MSP of Millets from 2017-18 to 2023-24 (Rs. per quintal)

S.No	Year/Crops	Ragi	Bajra	Jowar (Hybrid)	Jowar (Maldandi)
1.	2017-18	1900	1425	1700	1725
2.	2018-19	2897	1950	2430	2450
3.	2019-20	3150	2000	2550	2570
4.	2020-21	3295	2150	2620	2640
5.	2021-22	3377	2250	2738	2758
6.	2022-23	3578	2350	2970	2990
7.	2023-24	3846	2500	3180	3225

Source: Researcher's calculations based on the secondary data

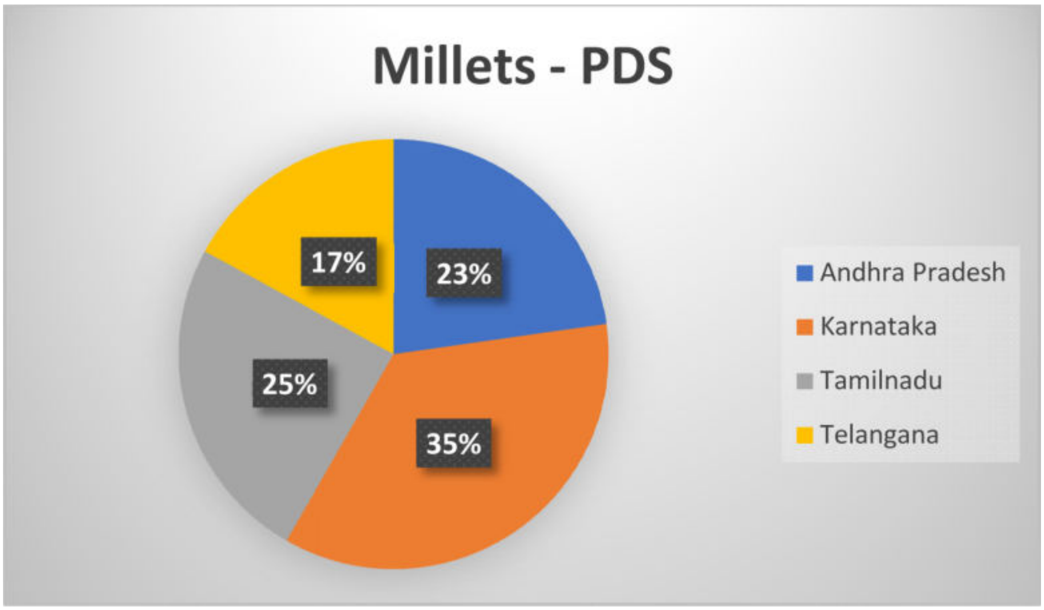

Figure 1. Distribution of millets in inclusion of the states

Through regulating the cost of necessities like grains and pulses, the Public Distribution System manage to include people's dietary habits and selections. The Indian government has started to encourage millet production and distribution through public systems, realizing the nutritional benefits of millets and the need to help millet growers (Samal and Mishra, 2020). Figure 1 elicits the distribution of millets in the Southern states of India. Highest consumption is observed in the Karnataka state (35%) followed by Tamilnadu (25%), Andhra Pradesh (23%) and Telangana (17%).

2.4 State Millet Missions Framework-Mechanisms to Revamp Public Distribution System (PDS)

The replication of millet farming practices in India can be explored through the successful framework set concisely according to the state prevalence rate of the millets production. Many Indian states have implemented millet promotion programs or missions,The data is compiled from the policy documents, and research articles related to these state-level initiatives which includes information on the objectives, outcomes, and challenges faced by the missions.Table 3 illustrate about the production of millets in tonnes, and its marginal effect in the distribution in the public distribution system (PDS). The Karnataka state (34.8) having the highest overall production of all the major millet crops and Andhra Pradesh state (14.9) the lowest in the overall production of the millet crops.

2.2 Distribution of Millets- Processing

Awareness of cultivation and consumption of millets to the farmer organizations and to the self-help groups has resulted in bringing millets back for larger production area. Given below are the reasons to improve the affordability and accessibility:

· Emphasis on local production, location-specificity, decentralization, and giving Farmer Producer Organizations play a prominent role. Because it was dispersed, less storage space is needed.

· Emphasised jobs and industrialization in rural areas Overall, the project region has

Table 3. Production (tons) of millets and sorghum per state in 2021–2022 and their marginal effect of distribution in the Public Distribution System schemes of the state.

S.No.	Selected State	Production of finger millet per state	Production pearl millet of per state	Production of sorghum per state	Production of the three crops per state	Marginal for the PDS distribution in the state	p-value
		('000 tons)	('000tons)	('000 tons)	('000 tons)		
1.	Karnataka	18.07	2.21	14.52	34.8	(0.0187)	0.000
2.	Tamil Nadu	3.49	1.82	6.02	23.13	0.0068	0.100
3.	Telangana	0.01	5.06	18.85	23.92	(0.0041)	0.200
4.	Andhra Pradesh	0.77	2.75	11.17	14.94	(0.0166)	0.000

seen the following effects: A rise in farmers' interest in growing millet, with more of them requesting supplies of the seed during the Rabi season so they can plant millet for their own use as well as to sell to nearby millet processing companies.

· Figure 2 depicts the millet flour milling at a Primary Processing centre in Telangana state, from where the ragi flour is processed, packed and distributed to the government schools and supply to the ration shops

Figure 2. Primary Processing (Milling) of Ragi, in Telangana State

2.3 Millet consumption during different meals of the day

In the context of the Mid Day Meal programs, the importance of diversifying the food items provided to schoolchildren. Traditional grains like rice and wheat, while staple components, may lack certain essential nutrients found abundantly in millets. Incorporating millets into the MDM menu can lead to improved nutritional outcomes, addressing prevalent deficiencies in iron, zinc, and other micronutrients. Moreover, the processing of millets into palatable and easily consumable forms can play a crucial role in increasing their acceptability among children. The food meals with inclusion of millets in their daily diet provided in the form of Breakfast, Lunch and Evening snacks this enhances the integration of millets into the Mid-Day Meal programs for enhanced nutritional impact and improved overall health outcomes for school children.

Central Government requested all the Indian state governments to explore the introduction of millets under PM POSHAN Scheme preferably in the districts where eating millets is a culturally accepted food habit. It is suggested to introduce millets-based menu weekly once and emphasize on millet-based recipes by conducting cooking competitions (ICRISAT, 2016).

The consumption form of millets in the Public Distribution Systems (PDS) are given

Table 4. Recipes given in the public distribution system (PDS) schemes

S.No.	Item	Qty/ day	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrate (g)
Breakfast						
1	Millet Khichdi	50 g	142.60	5.98	1.55	52.09
2	Ragi Dosa	35 g	207.87	4.3	5.2	36
Lunch						
3	Millet Pulao	70 g	199.05	6.21	6.81	62.45
Snacks						
4	Ragi Laddu	25 g	294.00	7.95	7.50	69.32
5	Millet Chikki	25 g	185.02	6.4	5.5	60.54
	Mean ± SD		**205.7 ±55.35**	**6.16±1.29**	**5.31±2.3**	**56.08±12.7**

in the form of various recipes as discussed in Table 5, On the whole the millet meal distribution provides a nutrition for an individual with an average of Energy (205 kcal), Protein (6.1g), Fat (5.3g), Carbohydrate (56g) meeting the average daily requirements of my plate balanced diet recommended by National Institute of Nutrition (Hemalatha, 2023)

CONCLUSIONS

Notable inferences from the given findings that the country's focus on improving millet production through state-specific missions has been critical, with Karnataka leading the way in millet production (34.8 thousand tons), while states like Andhra Pradesh lag behind with lower production (14.94 thousand tons). However, the marginal effect of millet distribution in PDS schemes, as shown in the data, demonstrates that states like Karnataka and Andhra Pradesh have significant room for improvement in making millets more widely available through public systems.The average energy content of meals in the PDS scheme stands at 205 kcal, with a balanced amount of protein (6.16g), fat (5.31g), and carbohydrates (56.08g), meeting the daily dietary requirements.The incorporation of millets into the Mid-Day Meal (MDM) programs has also shown promise in improving the nutritional outcomes for school children. As millets are being introduced into school programs and other PDS schemes, it is clear that ongoing efforts to increase awareness, improve processing, and expand distribution systems will be key to the long-term success of the millet economy.

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LIVESTOCK INVESTMENT AND ITS IMPACT ON FARM INCOME AMONG MIXED FARMERS IN NAGALAND

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ABSTRACT

The study estimates the pattern of livestock investment and its impact on farm income among mixed farmers of Nagaland. Additionally, the study also incorporates other livelihood assets owned by livestock farmers to identify the extent of their influence on farm income. The primary data pertains to the year 2020-21, collected through a multi-stage sampling technique conducted in Peren district of Nagaland, known as the “Green District of Nagaland” because of high diversity of flora and fauna offering significant potential abundant grazing areas. Information from 197 mixed farmers were collected to generate and interpret results. On average, farm households invest ₹ 38,293.75 annually in livestock, which constitutes about 27.75 per cent of total agricultural investment, with livestock contributing 40.33 per cent to total farm income. By farm size, the proportion of livestock investment in total farm investment was lower for marginal (29.27 per cent) and small farmers (21.79 per cent) than for medium farmers (33.64 per cent). Consequently, medium farmers earn a more significant proportion of income from livestock (46.03 per cent). Regression analysis results revealed that livestock investment, farm size, level of farmers participation in livestock management, and number of animals have positive impact on farm business income.The study suggests that there is catalyst for appropriate and higher government investment in agriculture and livestock operations by incorporating traditional knowledge and experience with the latest technologies.

Keywords: Farm income, Investment, Livelihood assets, Mixed farming, Multiple linear regression model

INTRODUCTION

India is an agrarian-based economy, where farmers are the backbone of the economy. For farming households, animal husbandry is crucial in generating additional income. Livestock has thus become a key component of the growing and changing agricultural sector in India. According to the Central Statistical Organization (CSO, 2019), within the agriculture sector, animal husbandry has emerged in recent years as the fastest-growing subsector. Agricultural growth has been significantly driven by the expansion of this subsector. Animal husbandry is significantly contributing to the agricultural sector and overall GDP. As of 2021-22, the livestock sector accounts for 30.19 per cent of Gross Value Added (GVA) in agriculture and

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allied sectors, increased from 24.38 per cent in 2014-15. The sector's overall contribution to national GVA stood at 5.73 per cent (Press Information Bureau, 2023).

Both the agriculture and livestock sectors are highly coordinated and work well together. This underscores the importance of integrated or mixed farming, where livestock rearing is combined with crop cultivation to boost farm income. This practice is especially prevalent among marginal and small farmers in India, with over 62 per cent of these households directly engaged in livestock sector (Das *et al.*, 2020). Integrated crop-livestock systems can improve resource use efficiency and sustainability.

Livestock forms an integral part of farming community in Nagaland, serving not only as source of meat protein but also a major source for sustaining livelihoods by supplementing income, employment, and food security. Since time immemorial, livestock have been symbolic of health and wealth of a Naga family (Singh *et al.*, 2019). However, despite having significant potential for developing animal husbandry and its importance for enhancing farmers' livelihood sustainability, yet the State struggles to fulfill the growing demand for animal products. GoN (2022-23) reveal that, the State produced about 45 per cent of its total requirement of animal products, resulting in 55 per centshortfall that necessitates importing products worth ¹ 211.94 crores. This situation highlights an urgent need for an increase in livestock investment.

In 2022-23, the total revenue expenditure on animal husbandry and dairy development in Nagaland was ¹ 10,995.5 lakhs, that accounts for 13.62 per cent of expenditure in agriculture and allied sectors. However, its share in overall development expenditure was only 1.49 per cent. For capital expenditure, animal husbandry received ¹ 300 lakhs, which constituted 2.56 per cent of expenditure in agriculture and allied sectors and 0.11 per cent of total development expenditure (RBI, 2023).

Considering the critical role of livestock sector investment in mixed farming and its substantial contribution to the income of rural farmers, it is essential to conduct in-depth farm-level research, aiming to increase income from farm-related activities and improve the living conditions of rural communities.

MATERIAL AND METHODS

Primary data was collected through a sample survey that pertains to the year 2020-21, purposively conducted in Peren district of Nagaland. Multi-stage random sampling technique was employed to select blocks, villages, and farm households. In first stage, two circles, Jalukie and Peren, were selected from four circles in the Peren district. In second stage, two villages from each circle were selected, totaling to four villages. In third stage, 50 farm households were selected from each village at random, resulting intotal of 200 farm households. Ultimately, data from 197 households that practice mixed farming (both crop and livestock farming) were processed and analyzed to generate the results. Households were further stratified into three farm size categories based on land holdings: marginal farmers (up to 2.5 acres), small farmers (2.51 to 5.0 acres), and medium farmers (5.0 to 25 acres).

Multiple linear regression model was used to examine impact of livestock investment and other livelihood assets on farm income. For this purpose, regression model was defined as,

$$Y_i = b_0 + \Sigma\, b_j X_{ij} + u_i \qquad (j = 1 \text{ to } 6)$$

Where,

Y= Farm income (¹ '000)

X_1= Farm holding (in acres)

X_2=Educational level of household head (in years)

X_3= Level of farmers' participation in livestock management (in numbers)

X_4=No of livestock population (in numbers)

X_5= Working age household members (in numbers)

X_6=Livestock investment ((¹ '000)

b_0 is the intercept and u_i is error term

RESULTS AND DISCUSSION

Table 1 indicates that most of mixed farmers (crop and livestock) were smaller farmers with land holdings of less than 5 acres, that accounts for 80.20 per cent of total household. While medium farmers accounts for 19.80 per cent only and there were no large farmers. For the sample average, the farm size was estimated at 3.12 acres. Breaking it down by farm size categories, the average land holding was 1.31 acres for marginal farmers, 2.99 acres (small farmers), and 7.22 acres (medium farmers).

Regarding the farmers' educational level, the average years of schooling was 8.19 years for the sample total households. By farm size categories, medium and small farmers have the highest average years of schooling at 8.13 years each, while marginal farmers have lowest (7.43 years). For livestock management activities, including breeding, purchasing, animal traction, sale of animal by-products, livestock business, vaccination, and access to veterinary hospitals, a livestock keeper was involved in an average of 3.07 activities in total households. By farm size categories, marginal farmers engaged in 2.83 activities on average, small farmers in 3.07 activities, and medium farmers in 3.56 activities. Larger farmers were engaged in more livestock management activities than the smaller farmers.

The average number of animals per household, including cows, buffaloes, mithun, poultry, pigs, and goats, was 17.84 in the sample total. While is was 7.61 for marginal farmers, 10.60 for small farmers, and 53.51 for medium farmers. The working-age population (14-64 years) per household was estimated at 4.16 individuals in the sample total. Small farmers had highest number of working-age members estimated at 4.53, followed by medium farmers at 4.28 and marginal farmers at 3.76 per household.

Farm income include income from crop production, plantation, livestock, and wages. A significant difference in average annual income from farm-related activities was observed among the farm size. Annual average

Table 1: Livelihood assets and farm income among livestock farmers

Livelihood assets	Marginal (n=83)	Small (n=75)	Medium (n=39)	All size (n=197)
Farm size (acre)	1.31	2.99	7.22	3.12
Education (years)	7.43	8.13	8.13	8.19
Livestock management activities(numbers)	2.83	3.07	3.59	3.07
Animals (numbers)	7.61	10.60	53.51	17.84
Working age population (numbers)	3.76	4.53	4.28	4.16
Farm income (rupees)	142545.18	241090.53	413199.74	233643.81

Source: Field survey 2020-21

income from farm was estimated at ¹ 233643.81 in the sample total. Medium farmers, by virtue of larger farm size, obtain higher farm income (¹ 413199.74) than the small (¹ 241090.53) and marginal farmers (¹ 142545.18).

Investment Pattern and Livestock Income

An analysis of investment patterns in livestock enterprises is depicted in Table 2. In the sample area, an average farm household invest ₹ 38,293.75 annually in livestock, which constitutes about 27.75 per cent of total investment in agriculture, with livestock contributing 40.33 per cent to total farm income. Among various livestock items, approximately 47.00 per cent of total livestock investment was in piggery, followed by buffalo/mithun at 34.95 per cent. Piggery is a mainstay of livestock farming due to the tribal people's high preference for pork (Singh and Mollier, 2016). Other items, such as cows and poultry, accounted for 12.20 and 5.66 per cent, respectively.

The share of contribution varied with farm sizes. For marginal and small farmers, piggery contributed the highest share of livestock investment at 58.16 and 52.07per cent, followed by buffalo/mithun at 20.39 and 23.21per cent, respectively. For medium farmers, buffalo/mithun constituted the highest share at 51.55per cent, followed by piggery at 37.21per cent. Average total investment in livestock was highest for medium farmers at ₹ 83,850, compared to ₹ 33,198.68 for small farmers and ₹ 21,351.18 for marginal farmers.

It was observed that livestock investment for medium farmers was 3.5 times higher than their smaller counterparts. And additionally, proportion of livestock investment to total farm investment is higher for medium farmers (33.64 per cent). This results a higher percentage of income for medium farmers(46.03 per cent) as compared to marginal and small farmers (40.52 and 35.13 per cent, respectively). This highlights the importance of livestock investment for generating higher income among mixed farmers.

Table 2: Investment in Livestock Enterprise by the Farm Sizes

Items	Marginal (n=83)		Small (n=75)		Medium (n=39)		All size (n=197)	
	Per farm (Rs)	Per cent	Per farm (Rs)	Per cent	Per farm (Rs)	Per cent	Per farm (Rs)	Per cent
Cow	3670.59	17.19	6506.67	19.60	3350	4.00	4670	12.20
Buffalo/Mithun	4352.94	20.39	7706.67	23.21	43225	51.55	13385	34.95
Poultry	910	4.26	1512	4.55	6077.5	7.25	2169.25	5.66
Piggery	12417.65	58.16	17286.67	52.07	31197.5	37.21	17999.5	47.00
Goat	0	0.00	186.67	0.56	0	0.00	70	0.18
Total livestock investment	21351.18 (29.27)	100.00	33198.68 (21.79)	100.00	83850 (33.64)	100.00	38293.75 (27.75)	100.00
Livestock Income	57762.05 (40.52)		84694.53 (35.13)		190207.44 (46.03)		94235.69 (40.33)	
Total farm investment	72956.48		152312.7		249286.3		137981	

Source: Field survey 2020-21
Note: Figures in brackets represent percentages of farm total investment and income.
Livestock investment includes cost on purchase of animals, fodder, and animal care
Livestock income includes gross value of output and income from dairy and others

Impact of Livestock Investment on Farm Income

The study considers livestock investment and livelihood assets that are likely to influence farm income, such as farm size, education level, participation in livestock management, number of animals, and the working-age population in the household.

The R^2 value for the district (overall) reveals that 85 per cent of variability in farm income was explained by the model, implying a strong correlation between farm income and investment in livestock and other factors. For marginal, small, and medium farmers, the values are 68 per cent, 73 per cent, and 85 per cent, respectively, indicating relatively strong relationships between the dependent and independent variables. The F-test indicates that independent variables had a significant effect on the dependent variables simultaneously. Table 3 shows that the F-test was significant at a 1 percent level among all sizes, marginal, small, and medium farmers.

The regression analysis result shows that the value of coefficient for livestock investment was 1.383 for the district (overall), which was positive at a 1 per cent significant level. This suggests that, keeping other things constant, investment in livestock had positive influence on farm income. A ₹1000 increase in livestock investment will increase farm income by ₹1383. Similarly, by the farm sizes, for the marginal,

Table 3: Factors affecting farm income by the size of holdings

Variables	Marginal (n=83)	Small (n=75)	Medium (n=39)	All size (n=197)
Constant	37.407**	-31.459	206.148**	59.994***
	(2.07)	(0.63)	(2.55)	(3.29)
Farm size (acre)	44.192***	54.641***	0.319	19.274***
	(6.47)	(4.14)	(0.04)	(8.76)
Education (years)	-0.080	2.757	2.121	1.209
	(0.07)	(1.22)	(0.48)	(0.90)
Livestock management activities (numbers)	9.140*	8.083	12.357	12.900***
	(1.68)	(1.19)	(0.82)	(2.66)
Animals (numbers)	-0.131	1.715**	0.403***	0.338***
	(0.22)	(2.19)	(3.12)	(4.46)
Family working members (numbers)	-5.126**	-4.743	-6.566	-3.244
	(2.17)	(1.33)	(0.90)	(1.37)
Livestock Investment (rupees in '000)	1.483***	1.397***	1.319***	1.383***
	(7.31)	(6.36)	(4.71)	(11.15)
R^2	0.676	0.730	0.852	0.847
Standard error	36.209	50.619	95.089	62.551
F value	26.372***	30.704***	30.629***	175.129***

***, ** and *: Significant at 1, 5 and 10 percent levels, respectively.
Figures in the brackets represent the t-value

small and medium farmers, livestock investment was found to be positive at 1 percent significant level, respectively, on which a ₹1000 increase in livestock investment will increase farm income by ₹1483, ₹1397 and ₹ 1319, respectively. This implies that a unit increase in livestock investment will enable farmers to produce and sell more animal products and thereby increase farm income, irrespective of farm size. The result was similar to Baidoo *et al.*(2016b).

The size of farmland owned by livestock farmers positively impacts the farm income for the district (overall), marginal and small farmers at 1 percent significant level but for medium farmers, the relationship was insignificant. For the district (overall), by increasing agricultural land by an acre, livestock farmers can increase the farm income by ₹ 19000. Similarly, an acre increase will have a significant increase in farm income for the marginal and small farmers. These findings were in line with a study made by Akouegnonhou and Demirbas, (2021) that if farm size increases, the farm income source also tends to increase.

Level of farmers participation in different livestock management activities has positive influence on farm income at 1 percent significant level. Among farm size categories, this was found positive among the marginal farmers at 10 percent significant level. This finding could be associated with the fact that many Nagas, particularly those living in rural areas, depend on the ownership and management of livestock not just as source of income but also as a crucial aspect of their cultural and social identities (Khongsai, 2023). Hence, by self-employing and engaging in different livestock management activities, farmers depend heavily on income earned from livestock farming. In this way, maximum efforts are put in by the farmers, especially among the smaller farmers, to capitalize on availability of resources by increasing the level of farmers participation in livestock management.

Number of animals owned by a livestock farmer has positive impact on income of farmers at 1 percent significant level for the district. Moreover, by farm size categories for small and medium farmers, it was positive at 5 and 1 percent significant levels, respectively. As expected, number of animals positively affects livestock gross margins and thereby increases the share of income sources from farm-related activities. In study area, piggery was the first choice of the farming household as it has high market demand, and next was buffalo, which animal was used in plowing the farm.

CONCLUSIONS

The present analysis shows significant insights into the patterns of livestock investment and their impact on farm income among mixed farmers in the Peren district of Nagaland. Notably, higher investments in livestock were positively associated with increased farm income, particularly for medium farmers who invest substantially 3.5 times more than their smaller counterparts. The regression analysis indicates that each unit increase in livestock investment leads to a substantial increase in farm income i.e., a ₹ 1000 increase in livestock investment will increase farm income by ₹1383 and by farm sizes, it is[1] 1483, ₹ 1397 and ₹ 1319 for the marginal, small and medium farmers, respectively. Additionally, an acre increased in agricultural land positively influences income by ₹ 44,192 and ₹ 54,641for marginal and small farmers particularly, while an increased in level of farmers' participation in livestock management and number of animals owned also significantly contribute to income by ₹ 12,900 and ₹ 338, respectively. Overall, the findings highlight the importance of livestock investment for enhancing income and livelihood opportunities in rural communities.

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