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RESPONSE OF PHOSPHORUS AND BORON LEVELS ON GROWTH, YIELD, AND QUALITY OF CHICKPEA (*CICER ARIETINUM* L.)

RITIK GARG and SANJAY LILHARE

Department of Agronomy, AKS University,
Sherganj, Satna - 485001 (M.P.), India

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ABSTRACT

A field experiment was conducted during the *Rabi* season of 2023-2024 at the Research farm, Department of Agronomy, AKS University, Satna, Madhya Pradesh, to evaluate the effects of phosphorus and boron on chickpea (variety JG-63) growth, yield, and quality. The study employed a Factorial Randomized Block Design with two factors and three replications. There were four levels of Phosphorus i.e., Control, 30 kg P_2O_5ha^{-1}, 40 kg P_2O_5ha^{-1}and 50 kg P_2O_5ha^{-1} and three levels of boron i.e., 1.5 kgha ^{1}, 2.5 kg ha-1 and 3.5 kg ha^{-1}. Results indicated that applying 50 kg P_2O_5 ha^{-1} + 3.5 kg Boron ha^{-1} significantly enhanced plant height (43.57 cm), number of branches (18.20), root nodules (22.00). Furthermore, yield attributes, grain yield (2492.81 kg ha^{-1}), stover yield (4115.56 kg ha^{-1}), and protein content (22.13 %) were also highest with the same treatment combination. Economically, the application of 50 kg P_2O_5 ha^{-1} + 3.5 kg Boron ha^{-1} registered the highest benefit-cost ratio (4.16:1) and net monetary returns (^{1} 1,07,275.35 ha^{-1}) as compared to other doses.

Keywords: Boron, factorialgro wth, chickpea, phosphorus, yield

INTRODUCTION

Chickpea (*Cicer arietinum* L.) stands out as an important pulse crop, traditionally cultivated during the *Rabi* season in India and primarily grown in semi-arid and warm temperate regions worldwide, where temperatures range from 20 to 30 degrees Celsius. Belonging to the *Leguminaceae* family, chickpea boasts a protein content, nearly three times higher than that of cereals, making it the top protein-yielding grain legume. It can fix 140 kg of nitrogen per hectare during a growing season (Harsha, 2022). In India, chickpea was cultivated in an area of 10.74 million ha with a production of 13.54 million tonnes and average productivity was 1261 kg ha^{-1} in 2021-22 (AIRCP Report, 2022-23). Madhya Pradesh, Rajasthan, Maharashtra, Karnataka and Uttar Pradesh are the main chickpea-growing states in the country (AICRP Report, 2022-23). It is highly nutritious legume, offering a variety of essential nutrients. A 100g serving of cooked chickpeas contains 164 calories, 8.9g of protein, 27.4g of carbohydrates (including 7.6g of fiber), and 2.6g of fat, with minimal saturated fat. With their high fiber content and low

***Corresponding Author E-mail**: ritikgarg8008@gmail.com; Part of M.Sc. thesis submitted to AKS University Sherganj, Satna, M.P.

glycemic index, chickpeas benefit digestive health, regulate blood sugar, and provide long-lasting satiety. The combination of protein, fiber, and micronutrients makes chickpeas an excellent choice for a plant-based diet.

An adequate supply of phosphorus to plants accelerates their maturation, enhances nodulation and pod development rates, and promotes shoot hardiness. Phosphorus also plays a crucial role in improving overall plant quality, regulating photosynthesis, and governing various physico-biochemical processes. Given its role in fostering root development, phosphorus application becomes essential, particularly for crops cultivated under rainfed conditions. The application of Phosphorus 60 kg ha^{-1} + PSB produced higher plant height (52.56 cm), No. of nodules/plant (23.03), dry weight (8.19g), No. of pods/plant (30.90), No. of seeds/pod (1.53), seed yield (2570.74 kg ha^{-1}) and stover yield (3583.33 kg ha^{-1}) in chickpeas (Lalrinzuali *et al*., 2023).

Boron deficiency leads to flower drop and subsequently poor pod development in chickpeas, resulting in diminished yields. Boron plays a crucial role in the synthesis of amino acids and proteins, as well as in regulating carbohydrate metabolism and the mechanism of root growth. It is also essential for the translocation of sugars and phosphorus and aids in the absorption of nitrogen while facilitating the formation of nodules (Singh *et al*., 2015). The application of Boron 2 kg ha^{-1} + Gibberellic acid 30 ppm recorded significantly higher Plant height (56.6 cm), Plant dry weight (45.7 g/plant), number of nodules per plant (11.7). Significantly maximum number of pods per plant (31.60), number of seeds per pod (2.53), Seed yield (1103.90 kg ha^{-1}) (Vaishnavi U Nair *et al.,* 2024). Hence the present research was formulated to study on the response of phosphorus and boron levels on growth, yield, and quality is essential to determine the optimal nutrient requirements for healthy plant development. It helps enhance crop productivity and quality, ensures efficient use of fertilizers, reduces environmental impact, and supports sustainable agricultural practices tailored to specific soil and crop needs

MATERIAL AND METHODS

The field experiment was conducted at the Research Farm, Department of Agronomy, AKS University, Sherganj, Satna (M.P.) during the *Rabi* season of 2023-2024. The experimental site is situated in the semi-arid region of Satna district, at an elevation of approximately 315 meters above sea level. It lies in the northern part of Madhya Pradesh, between a latitude of 24.34°N and a longitude of 80.49°E. The soil of the experimental field has a sandy clay loam texture. It is neutral in reaction (pH 7.45), with medium organic carbon content (0.61 %), available nitrogen (220.34 kg/ha^{-1}), available phosphorus (15.84 kg ha^{-1}), and available potassium (214.63 kg ha^{-1}). The experiment was designed as a Factorial Randomized Block Design with two factors and three replications, consisting of 36 plots. There were four levels of Phosphorus i.e., Control (00 kg P_2O_5 ha^{-1}) (P_0), 30 kg P_2 / ha^{-1} (P_1), 40 kg P_2O_5 / ha^{-1} (P_2) and 50 kg P_2O_5 / ha^{-1} (P_3) and three levels of boron i.e., 1.5 kg / ha^{-1} (B_1), 2.5 kg / ha^{-1} (B_2) and 3.5 kg / ha^{-1} (B_3). A total of twelve treatment combinations were drawn from the treatments of phosphorus and boron i.e. 00 kg P_2O_5 ha^{-1} + 1.5 kg B ha^{-1} (T_1 - P_0 B_1), 00 kg P_2O_5 ha^{-1} + 2.5 kg B ha^{-1} (T_2- P_0 B_2), 00 kg P_2O_5 ha^{-1}+ 3.5 kg B ha^{-1}(T_3 - P_0 B_3), Application of 30 kg P2O5 ha^{-1} + 1.5 kg Boron ha^{-1} (T_4 – P_1 B_1), Application of 30 kg P2O5 ha^{-1} + 2.5 kg Boron ha^{-1} (T_5- P_1 B_2), Application of 30 kg P2O5 ha^{-1} + 3.5 kg Boron ha^{-1} (T_6 – P_1 B_3), Application of 40 kg P2O5 ha-1 + 1.5 kg Boron ha^{-1} (T_7 – P_2 B_1), Application of 40 kg P2O5 ha^{-1} + 2.5 kg Boron ha^{-1} (T_8 – P_2 B_2), Application of 40 kg P2O5 ha^{-1} + 3.5 kg Boron ha^{-1} (T_9 – P_2 B_3), Application of 50 kg P2O5 ha^{-1} + 1.5 kg Boron ha^{-1} (T_{10} – P_3 B_1), Application of 50 kg P2O5 ha^{-1} + 2.5 kg Boron ha^{-1} (T_{11} - P_3 B_2), Application of 50 kg P2O5 ha^{-1} + 3.5 kg Boron ha^{-1}(T_{12} - P_3 B_3). Each plot measured 5 m × 3 m, and the main irrigation channel had a width of 1 m. The chickpea variety JG-63 was used for the experiment, with a seed rate of 80 kg h^{-1} Before sowing, the seeds were treated with Carbendazim 50% WP @ 2 g/kg seed followed by seed inoculation with liquid *Rhizobium* culture @ 10 ml/kg seed. The recommended doses for nitrogen and potassium were each set at 20 kg ha^{-1}. Phosphorus and boron were applied according to the specific treatment plans. Urea, Single Super Phosphate, Muriate of Potash, and Borax were used as sources of nitrogen, phosphorus, potassium, and boron, respectively. Each fertilizer i.e., nitrogen, phosphorus, potassium and boron were applied in each plot as basal at the time of sowing as 100 % fertility levels. Fertilizers were applied by placement i.e., 5 cm away from the seed row and of 5 cm below the seed zone. The data, procured on various growth characters (Plant height, number of branches and root nodules per plant), yield attributes (Number of pods per plant and number of seeds per pod), grain and stover yield), were subjected to statistical analysis using the standard method of Analysis of Variance.

RESULTS AND DISCUSSION

The data specified on Table 1, 2 and 3 revealed that there was a significant improvement in the growth characteristics, yield, protein content and profitability of chickpea due to different phosphorus and boron levels.

Growth Characters

An appraisal of the data in Table1 indicates that the application of treatment P_3B_3(Phosphorus @ 50 kg ha^{-1}+ Boron @ 3.5 kg ha^{-1}) brought significant enhancement in the plant height of chickpea which was 47.53 cm. However, the lowest plant height (36.49 cm) was measured under treatment P_0B_1 (Control + Boron @ 1.5 kg ha^{-1}). The enhancement in plant height under P_3B_3 was to the tune of 30.25 % over P_0B_1.

A critical examination of the data in Table 1 indicates that the application of treatment P_3B_3 (Phosphorus @ 50 kg ha^{-1} + Boron @ 3.5 kg ha^{-1}) brought significant enhancement in the number of branches per plant of chickpea which was 18.20. However, the lowest number of branches per plant (13.47) was noted under treatment P_0B_1 (Control + Boron @ 1.5 kg ha^{-1}). The enhancement in number of branches per plant under P_3B_3 was to the tune of 35.11 % over P_0B_1.

Data arranged in Table 1 manifests that the application of treatment P_3B_3 (Phosphorus @ 50 kg ha^{-1} + Boron @ 3.5 kg ha^{-1}) brought significant enhancement in the number of root nodules per plant of chickpea which was 22.00. However, the lowest number of root nodules per plant (15.87) was noted under treatment P_0B_1 (Control + Boron @ 1.5 kg ha^{-1}). The enhancement in number of root nodules per plant under P_3B_3 was to the tune of 38.63 % over P_0B_1.

Sabur and Abdus (2020) found that boron application at 1.5 kg ha^{-1} showed higher results on branch $plant^{-1}$ (25.17), pod length (1.75cm), effective pods $plant^{-1}$ (40.96), total pods $plant^{-1}$ (47.03), seed per pod (1.93), 1000-grain weight (153.45 g), grain yield (2.19 t ha^{-1}) and straw yield (2.37 t ha^{-1}) over no boron application. Naik, (2012) Observed that the application of 50 kg $P_2O_5 ha^{-1}$ recorded significantly 14.7 and 33.7 per cent higher grain yield (1808 kg ha^{-1}) of Kabuli chickpea than the application of 25 kg P_2O_5 ha^{-1} (1577

Table 1. Growth characters of chickpea as influenced by levels of phosphorus, boron and their interaction.

Treatments	Plant height	Number of (cm) branches per plant	Number of root nodules per plant
Control + 1.5 kg B ha^{-1}	36.49	13.47	15.87
Control + 2.5 kg B ha^{-1}	36.89	13.73	16.73
Control + 3.5 kg B ha^{-1}	37.10	13.80	17.07
Application of 30 kg P_2O_5 ha^{-1} + 1.5 kg Boron ha-1	36.79	13.93	16.67
Application of 30 kg P_2O_5 ha^{-1} + 2.5 kg Boron ha^{-1}	37.55	14.07	17.73
Application of 30 kg P_2O_5 ha^{-1} + 3.5 kg Boron ha^{-1}	37.40	14.27	20.20
Application of 40 kg P_2O_5 ha^{-1} + 1.5 kg Boron ha^{-1}	37.25	14.73	19.07
Application of 40 kg P_2O_5 ha^{-1} + 2.5 kg Boron ha^{-1}	38.32	14.80	20.93
Application of 40 kg P_2O_5 ha^{-1} + 3.5 kg Boron ha^{-1}	41.03	15.60	21.13
Application of 50 kg P_2O_5 ha^{-1} + 1.5 kg Boron ha^{-1}	40.35	16.00	21.87
Application of 50 kg P_2O_5 ha^{-1} + 2.5 kg Boron ha^{-1}	42.35	17.47	21.60
Application of 50 kg P_2O_5 ha^{-1} + 3.5 kg Boron ha^{-1}	43.57	18.20	22.00
S.Em±	0.50	0.28	0.49
C.D. (P=0.05)	1.47	0.82	1.44

kg ha^{-1}) and control (1352 kg ha^{-1}). significantly Higher N, P and K uptake was recorded with the application of 50 kg P_2O_5 ha^{-1} (64.55 kg N, 28.82 kg P_2O_5 and 37.89 kg K_2O ha^{-1}) than with 25 kg P_2O_5 ha^{-1} and control. Similar results were reported by Kumar *et al*. (2023) and Embadwar *et al*., (2023).

Yield attributes and yield

Maximizing economic yield is the primary goal of an agronomist. Key yield attributes, such as the number of pods per plant, grains per pod, and grain and stover yield per hectare, significantly influence the overall productivity of a crop.

Table 2. Yield attributes, yield and protein content of chickpea as influenced by levels of phosphorus, boron and their interaction.

Treatments	Number of pods per plant	Number of seeds per pod	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Protein content (%)
Control + 1.5 kg B ha^{-1}	36.80	1.07	1263.14	2724.99	18.46
Control + 2.5 kg B ha^{-1}	38.80	1.13	1329.02	3337.66	19.02
Control + 3.5 kg B ha-1	39.27	1.33	1546.80	3512.61	19.12
Application of 30 kg P2O5 ha^{-1} + 1.5 kg Boron ha^{-1}	38.87	1.27	1539.24	3389.50	19.04
Application of 30 kg P_2O_5 ha^{-1} + 2.5 kg Boron ha^{-1}	39.33	1.33	1555.44	3704.47	19.63
Application of 30 kg P_2O_5 ha^{-1} + 3.5 kg Boron ha^{-1}	40.87	1.40	1765.66	3738.67	19.70
Application of 40 kg P_2O_5 ha^{-1} + 1.5 kg Boron ha^{-1}	39.53	1.33	1608.72	3788.34	20.30
Application of 40 kg P_2O_5 ha^{-1} + 2.5 kg Boron ha^{-1}	42.27	1.53	1849.90	3804.54	20.36
Application of 40 kg P_2O_5 ha^{-1} + 3.5 kg Boron ha^{-1}	44.80	1.73	2088.56	3858.90	20.50
Application of 50 kg P_2O_5 ha^{-1} + 1.5 kg Boron ha^{-1}	43.47	1.67	1964.73	3668.11	20.60
Application of 50 kg P_2O_5 ha^{-1} + 2.5 kg Boron ha^{-1}	47.20	1.93	2221.03	3987.05	21.24
Application of 50 kg P_2O_5 ha^{-1} + 3.5 kg Boron ha^{-1}	49.73	2.07	2492.81	4115.56	22.13
S.Em±	0.62	0.10	47.16	57.44	0.17
C.D. (P=0.05)	1.82	NS	138.32	168.47	0.50

An appraisal of the data in Table 2 indicates that the application of treatment P_3B_3 (Phosphorus @ 50 kg ha^{-1}+ Boron @ 3.5 kg ha^{-1}) brought significant enhancement in the number of pods per plant of chickpea which was 49.73. However, the lowest number of pods per plant (36.80) was noted under treatment P_0B_1 (Control + Boron @ 1.5 kg ha^{-1}). The enhancement in number of pods per plant under P_3B_3 was to the tune of 35.14 % over P_0B_1.

A critical examination of the data in Table 2 indicates that the application of different phosphorus and boron levelscould not bring any significant enhancement in the number of seeds per pod of chickpea. It islikely due to the genetic characteristics of the cultivar, as such traits are often determined by genetic factors.

Data arranged in Table 2 manifests that the application of treatment P_3B_3 (Phosphorus @ 50 kg ha-1+ Boron @ 3kg ha^{-1}) brought significant enhancement in the grain yield of chickpea which was 2492.81 kg ha^{-1}. However, the lowest grain yield (1263.14 kg ha^{-1}) was noted under treatment P_0B_1 (Control + Boron @ 1.5 kg ha^{-1}). The enhancement in grain yield under P_3B_3 was to the tune of 97.35 % over P_0B_1. The higher yield attributes under P_3B_3 treatments might be responsible for the greater grain yield.

The data in Table 2clearly shows that the application of treatment P_3B_3 (Phosphorus @ 50 kg ha^{-1} + Boron @ 3.5 kg ha^{-1}) brought significant enhancement in the stover yield of chickpea, which was 4115.56 kg ha^{-1}. However, the lowest stoveryield (2724.99 kg ha^{-1}) was noted under treatment P_0B_1 (Control + Boron @ 1.5 kg ha^{-1}). The enhancement in stoveryield under P_3B_3 was to the tune of 51.03 % over P_0B_1.

Badini (2015) evident that application of phosphorus @ 55 kg ha^{-1} brought significant effect on days taken to flowering, pods $plant^{-1}$ (44.50), seeds $plant^{-1}$ (49.33), pod length (1.38 cm), test weight (215.12 g) and seed yield (1691.21 kg ha^{-1}) as compared to phosphorus level of 45 kg, 35 kg, 25 kg and 15 kg ha^{-1}. Similar results were reported by Shukla *et al*. (2017) & Reddy and Umesha (2022).

Protein Content

A critical examination of the data in Table 2 indicates that the application of treatment P_3B_3 (Phosphorus @ 50 kg ha^{-1} + Boron @ 3.5 kg ha^{-1}) brought significant enhancement in the protein content in grains of chickpea, which was 22.13 %. However, the lowest protein content (18.46 %) was noted under treatment P_0B_1 (Control + Boron @ 1.5 kg ha^{-1}). The enhancement in protein content under P_3B_3 was to the tune of 19.88 % over P_0B_1.

Boron plays a crucial role in the synthesis of amino acids and proteins, as well as in regulating carbohydrate metabolism and the mechanism of root growth. It is also essential for the translocation of sugars and phosphorus and aids in the absorption of nitrogen while facilitating the formation of nodules (Singh *et al.,* 2015) Legume crops particularly demand ample boron compared to other field crops, as it is indispensable for the proper development of their reproductive organs. Insufficient boron levels can induce sterility in plants by causing abnormalities in reproductive tissues, hampering pollen germination, and consequently increasing flower drop while reducing fruit yield (Subasinghe *et al.,* 2003).

Economics

Evaluating the economics of the treatments is essential for making sound recommendations. Even the most effective treatment can become impractical if the production and input costs are too high. An appraisal of the data in Table 3 indicates that the application of treatment P_3B_3 (Phosphorus @ 50 kg ha^{-1} + Boron @ 3.5 kg ha^{-1}) brought significant enhancement in the gross return of chickpea which was ¹ 1,41,222 ha^{-1}. However, the lowest gross return (¹ 72,839 ha^{-1}) was measured under treatment P_0B_1 (Control + Boron @ 1.5 kg ha^{-1}). The enhancement in gross return under P_3B_3 was to the tune of 93.88 % over P_0B_1.

A critical examination of the data in Table 3 indicates that the application of treatment P_3B_3 (Phosphorus @ 50 kg ha^{-1} + Boron @ 3.5 kg ha^{-1}) brought significant enhancement in the net return of chickpea which was ¹ 1,07,275 ha^{-1}. However, the lowest net return (¹ 42,030 ha^{-1}) was noted under treatment P_0B_1 (Control + Boron @ 1.5 kg ha^{-1}). The enhancement in net return under P_3B_3 was to the tune of 155.24 % over P_0B_1.

Table 3. Economics of chickpea as influenced by levels of phosphorus, boron and their interaction.

Treatments	Gross returns (ha^{-1})	Net returns (ha^{-1})	B:C ratio
Control + 1.5 kg B ha^{-1}	72839	42030	2.37
Control + 2.5 kg B ha^{-1}	77579	46334	2.49
Control + 3.5 kg B ha^{-1}	89547	57866	2.83
Application of 30 kg P_2O_5 ha^{-1} + 1.5 kg Boron ha^{-1}	88898	56729	2.77
Application of 30 kg P_2O_5 ha^{-1} + 2.5 kg Boron ha^{-1}	90392	57787	2.78
Application of 30 kg P_2O_5 ha^{-1} + 3.5 kg Boron ha^{-1}	101675	68634	3.08
Application of 40 kg P_2O_5 ha^{-1} + 1.5 kg Boron ha^{-1}	93402	60780	2.87
Application of 40 kg P_2O_5 ha^{-1} + 2.5 kg Boron ha^{-1}	106301	73243	3.22
Application of 40 kg P_2O_5 ha^{-1} + 3.5 kg Boron ha^{-1}	119142	85648	3.56
Application of 50 kg P_2O_5 ha^{-1} + 1.5 kg Boron ha^{-1}	112154	79079	3.40
Application of 50 kg P_2O_5 ha^{-1} + 2.5 kg Boron ha^{-1}	126466	92955	3.78
Application of 50 kg P_2O_5 ha^{-1} + 3.5 kg Boron ha^{-1}	141222	107275	4.16
S.Em±	2548	2548	0.08
C.D. (P=0.05)	7473	7473	0.24

Data arranged in Table 3 manifests that the application of treatment P_3B_3 (Phosphorus @ 50 kg ha^{-1} + Boron @ 3.5 kg ha^{-1}) brought significant enhancement in the B:C ratio of chickpea which was 4.16. However, the lowest B:C ratio (2.37) was noted under treatment P_0B_1 (Control + Boron @ 1.5 kg ha^{-1}). The enhancement in the B:C ratio under P_3B_3 was to the tune of 75.53 % over P_0B_1.

Kumar *et al., 2022* evident that the maximum seed and stover yield (18.9 and 29.6 q ha^{-1}), protein content, gross returns (81.6 × 103 ¹ ha^{-1}), net returns (53.7 × 103 ¹ ha^{-1}) and B: C ratio (1.94) were noticed under 60 kg P_2O_5 ha^{-1} as compared to the control plot. They further reported that maximum NPK uptake by seed (63.8, 7.49 and 26.5 kg ha^{-1}) and stover (44.5, 5.31 and 81.6 kg ha^{-1}) was also recorded under 60 kg P_2O_5 ha^{-1}as compared to the control plot. Similar findings were documented by Jaiswal and Tomar(2022)

CONCLUSIONS

From the summarization of the result, Phosphorus application @ 50 $kgha^{-1}$ registered the highest growth and yield attributes. Furthermore, higher grain yield (2226 $kgha^{-1}$), protein content (21.32 %) and B:C ratio (3.78:1) were also higher under the same treatment. Boron@ 3.5 $kgha^{-1}$ proved superior in terms of growth, yield attributes and yield (1973 $kgha^{-1}$) of chickpea. A higher protein content (20.36 %) and B:C ratio (3.41:1) were also obtained under the same boron level. Regarding the interaction effect, the application of 50 kg P_2O_5 ha^{-1} in combination with 3.5 kg B ha^{-1} produced superior results in terms of growth, yield attributes and yield (2492 $kgha^{-1}$) of chickpeas. Additionally, under the same treatment combination, a greater B:C ratio (4.16:1) and protein content (22.13%) were attained. In light of the current agroclimatic conditions in the area, the chickpea crop should be fertilized with phosphorus at a rate of 50 $kgha^{-1}$ and boron at a rate of 3.5 $kgha^{-1}$ for optimal results.

The balanced application of phosphorus and Boron at the time of sowingat 5 cm away from the seed row and of 5 cm below the seed zoneensures optimal metabolic activity, better reproductive success, and improved nutrient use efficiency. Therefore, integrated nutrient management involving both phosphorus and Boron is essential for maximising chickpea productivity, especially in nutrient-deficient or marginal soils.

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IDENTIFICATION OF THERMOTOLERANT LINES IN RICE (*ORYZA SATIVA* L.) USING STRESS INDICES

VASANTHA CH, RAMANA RAO PV, SATISH Y and VERONICA N

Department of Genetics and Plant Breeding, Agricultural college
Bapatla-522 101, Andhra Pradesh, India

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ABSTRACT

Stress from high temperatures is a significant environmental factor influencing crop yield. A diverse set of rice germplasm consisting of 48 genotypes (released rice varieties, advanced breeding lines along with tolerant (Nagina 22) and susceptible (Vandana) checks) was grown at two different conditions (Control and Heat stress conditions) in *Kharif* 2023 Under heat stress conditions, the genotypes showed a significant reduction in grain yield.Yield-based indices were computed using grain yield data collected under control and heat stress conditions. The Stress Tolerance Index (STI), Geometric Mean Production (GMP), Mean Production (MP), Yield Index (YI), Heat Index (HI), and Modified Stress Tolerance (K1STI and K2STI) were all positively and significantly correlated with yield under control and high temperature stress conditions, making them suitable indices for screening rice genotypes under high temperature conditions. Highest correlation was observed in STI, GMP, and MP with Ys (Yield under heat stress)under both control and heat stress conditions.The genotypes IET 28960, MTU 1153, MTU 1156, N 22, NLR 3778, L 663 and MTU 1290 highest mean rank and a lower standard deviation of rank, hence they can be identified as heat tolerant genotypes.

Keywords: Rice, High temperature, Stress indices, Correlation, Heat tolerance, Grain yield

INTRODUCTION

Rice (*Oryza sativa* L.) is a globally important cereal plant, and as a primary source of food it accounts for 35–75% of the calorie intake of more than 3 billion humans. An increase in food production by 70% is necessary to meet the dietary requirements of the expected 9 billion population by 2050 (Bita and Gerats, 2013). Rice is the primary food source for nearly half of the world's population, accounting for 21% of total global caloric intake. Rice cultivation accounts for 11% of the total cultivated land area worldwide. Global rice consumption is expected to rise from 480 million tons in 2014 to nearly 550 million tons by 2030 (Yuan *et al*., 2021). Abiotic stress conditions pose a significant challenge to modern agriculture, leading to substantial crop failure and productivity losses ranging from 50-80%. One significant environmental factor influencing crop growth and yield is high temperature stress (Yang *et al*., 2017). Rice yield is estimated to decrease by up to 10%

*Corresponding authors e-mail - vasanthach98@gmail.com; Part of M. Sc thesis submitted to Acharya N.G. Ranga Agricultural University, Guntur, Andhra Pradesh.

with every 1°C increase in land surface temperature (Peng *et al*., 2004).Rice plants are particularly sensitive to temperature stress during reproductive growth and maturation, and when exposed to high temperatures, it significantly affects development and yield(Lawas *et al.,* 2019, Chen *et al.,* 2020). High temperatures during grain filling can decrease rice yields by 50%(Sreenivasulu *et al*., 2015). It can also cause failure of grain filling in rice by affecting the accumulation of starch granules, eventually resulting in yield losses (Impa *et al*., 2021).Therefore,to mitigate the reduction in yield caused by high temperatures, the development and cultivation of new thermotolerant crop varieties has emerged as an important strategy for sustainable agriculture. Stress indices based on yield loss when grown under stress conditions compared to normal conditions have been used for screening stress-tolerant genotypes for many abiotic stresses (Khodarahmpour *et al.,* 2011).

MATERIAL AND METHODS

The present investigation was conducted in *Kharif* 2023 at Regional Agricultural Research Station, Maruteru with forty-eight rice genotypes.The experiment was set up in alpha lattice design with a spacing of 20x15 cm. Recommended dose of Nitrogen (N), Phosphorus (P) and Potassium (K) applied. All recommended practices for irrigated transplanted rice were followed one set of genotypes was grown under ambient conditions (control) and another set of genotypes was grown under high temperature stress by enclosing a polythene sheet at panicle initiation stage (PI). The data in the polyhouse was recorded using a data logger (RC-4HC) installed inside the polyhouse. During cropping season, the ambient mean monthly maximum temperature was 30.7° C and mean monthly minimum temperature was 24.8°C. However, during the stress imposition period (from panicle initiation to maturity), the mean maximum temperature in ambient conditions was 30.6 °C, and the mean minimum temperature was 24.3°C. During this period, the mean maximum temperature inside the polyhouse was 35.0 °C, while the mean minimum temperature was 27.9 °C. The mean maximum and minimum temperatures increased by 4.4°C and 2.3°C, respectively, under the polyhouse. At physiological maturity, panicles from each plant in both stress and non-stress conditions were harvested, sun dried, threshed, and cleaned, and grain weight was measured and expressed in grams per plant.Spikelet fertility was worked out as number of filled grains/ total number of grains x 100 and expressed in percentage.

Yield based indices

Based on grain yield under control (Yp) and grain yield under stress (Ys) heat-tolerant indices were computed *viz*., Stress Susceptibility Index (SSI), Relative Heat Index (RHI), Stress tolerance index (STI), Geometric Mean Production (GMP), Mean Production (MP), Yield Index (YI), Heat resistance index (HI), Yield Stability Index (YSI), Stress Susceptibility Percentage Index (SSPI) and Modified stress tolerance (K1STI and K2STI) (Moosavi *et al*., 2008; Farshadfar and Sutka, 2002).To identify a suitable screening index, a correlation between grain yield under control and stress conditions and the calculated yield-based indices was performed in Microsoft Excel.

The indices were computed based on the formulas given below

SSI= $(1-(Ys/Yp)/(1-(\overline{Y}s/\overline{Y}p)$

RHI= $(Ys/Yp)/(\overline{Y}s/\overline{Y}p)$

STI= $Ys \times Yp/(\bar{Y}p^2)$

GMP= $\sqrt{YS \times YP}$

Table 1. Tolerant and susceptibility indices of rice genotypes under high temperature conditions.

Entry	SSI	RHI	STI	GMP	MP	YI	HI	YSI	SSPI	K1STI	K2STI
IET 29859 (New Delhi)	1.53	0.84	0.75	13.02	13.33	0.90	0.58	0.64	19.19	1.16	0.82
IL 19019	1.29	0.91	0.71	12.71	12.91	0.92	0.64	0.70	15.15	1.02	0.85
IL 19020	1.12	0.96	0.82	13.63	13.79	1.01	0.75	0.74	13.74	1.11	1.03
IL 19021	1.51	0.85	0.48	10.41	10.65	0.73	0.47	0.65	15.00	0.74	0.53
IL 19022	0.97	1.01	0.82	13.63	13.74	1.04	0.80	0.77	11.62	1.06	1.08
IL 19024	0.82	1.06	0.61	11.71	11.77	0.91	0.74	0.81	8.18	0.75	0.83
IL 19185	1.15	0.95	0.83	13.73	13.89	1.02	0.75	0.73	14.24	1.14	1.04
IL 19198	0.76	1.07	0.74	12.89	12.95	1.01	0.83	0.82	8.38	0.89	1.02
IL 19202	0.93	1.02	0.84	13.79	13.89	1.06	0.83	0.78	11.21	1.07	1.12
IL 19211	0.48	1.16	0.79	13.37	13.39	1.09	0.97	0.89	5.25	0.89	1.19
IL 19247	0.92	1.03	0.68	12.43	12.52	0.95	0.75	0.79	9.90	0.87	0.91
IL 19396	0.91	1.03	0.85	13.89	13.98	1.07	0.84	0.79	11.01	1.08	1.14
JB 680-2 (Hyderabad (AICRIP))	1.99	0.70	0.39	9.40	9.85	0.60	0.32	0.54	19.60	0.72	0.36
JB 683-1 (Hyderabad (AICRIP))	0.89	1.03	0.86	13.91	14.00	1.07	0.85	0.79	10.69	1.08	1.15
JB 687-3 (Hyderabad (AICRIP))	1.23	0.93	0.76	13.11	13.29	0.96	0.69	0.72	14.65	1.06	0.92
JB 689-1 (Hyderabad (AICRIP))	1.01	1.00	0.80	13.44	13.56	1.02	0.78	0.77	12.02	1.04	1.04
JBC 159-11	1.06	0.98	0.71	12.71	12.83	0.95	0.72	0.75	12.02	0.95	0.91
Krishna hamsa (Hyderabad)	0.92	1.02	0.97	14.83	14.94	1.14	0.89	0.79	11.92	1.24	1.30
MTU 1153 (Maruteru)	0.70	1.09	0.85	13.90	13.95	1.10	0.92	0.84	8.18	1.02	1.21
MTU 1156 (Maruteru)	0.51	1.15	0.85	13.84	13.86	1.13	0.99	0.88	5.76	0.96	1.27
MTU 1273 (Maruteru)	1.16	0.95	0.66	12.23	12.38	0.90	0.66	0.73	12.83	0.90	0.82
MTU 1290 (Maruteru)	0.72	1.09	0.85	13.87	13.92	1.10	0.91	0.83	8.38	1.02	1.20
MTU 1293 (Maruteru)	1.61	0.81	0.77	13.21	13.58	0.90	0.57	0.63	20.81	1.23	0.82
N-22 (Meerut)	1.03	0.99	1.03	15.25	15.39	1.15	0.88	0.76	13.95	1.35	1.32
NLR 3776 (Nellore)	0.96	1.01	0.55	11.11	11.20	0.85	0.66	0.78	9.35	0.70	0.72
NLR 3778 (Nellore)	1.04	0.99	1.01	15.09	15.23	1.14	0.87	0.76	13.84	1.32	1.30
CO-51 (Coimbatore)	1.02	0.99	0.92	14.40	14.53	1.09	0.83	0.76	13.03	1.20	1.18
NLR 3775 (Nellore)	1.27	0.92	0.68	12.43	12.62	0.90	0.64	0.71	14.44	0.97	0.82
NLR 3768 (Nellore)	1.33	0.90	0.49	10.57	10.75	0.76	0.53	0.69	12.99	0.71	0.58
IET 28954 (New Delhi)	0.98	1.01	0.71	12.65	12.76	0.96	0.74	0.77	10.91	0.92	0.93
IET 28960 (New Delhi)	0.48	1.16	1.08	15.65	15.68	1.28	1.14	0.89	6.16	1.22	1.63
L 648 (Maruteru)	0.58	1.13	0.71	12.63	12.67	1.02	0.88	0.87	6.06	0.82	1.04
L 663 (Maruteru)	0.97	1.01	0.98	14.90	15.02	1.14	0.88	0.78	12.63	1.26	1.29
MTU 2897-35-1-1(Maruteru)	0.66	1.10	0.81	13.53	13.58	1.08	0.91	0.85	7.47	0.96	1.16
JGL 24423 (Jagityal)	1.18	0.95	0.89	14.15	14.33	1.04	0.76	0.73	15.15	1.22	1.09
KNM 733 (Kunaram)	0.61	1.12	0.80	13.45	13.48	1.08	0.92	0.86	6.87	0.93	1.16
KNM 1638 (Kunaram)	0.76	1.07	0.79	13.39	13.45	1.05	0.87	0.82	8.69	0.96	1.11
NLR 3648 (Nellore)	0.67	1.10	0.72	12.76	12.80	1.01	0.86	0.84	7.17	0.85	1.03
MTU 2896-58-1-1(Maruteru)	0.55	1.13	0.70	12.56	12.59	1.01	0.88	0.87	5.76	0.80	1.03
NDLR 24 (Nandyal)	0.89	1.03	0.84	13.81	13.91	1.06	0.84	0.79	10.72	1.06	1.13
NDLR 26 (Nandyal)	1.02	0.99	0.55	11.17	11.27	0.84	0.64	0.76	10.10	0.72	0.71
NDLR 25 (Nandyal)	0.78	1.07	0.84	13.75	13.82	1.08	0.88	0.82	9.09	1.02	1.16
SAL 10(Cuttak)	0.93	1.02	0.84	13.75	13.85	1.05	0.83	0.79	11.11	1.06	1.11
PR 126(Ludhiana (PAU))	1.06	0.98	0.84	13.74	13.88	1.03	0.78	0.75	12.93	1.11	1.07
RNR 15048 (Rajendranagar)	1.50	0.85	0.99	14.97	15.31	1.05	0.68	0.65	21.38	1.52	1.10
Pusa Samba 1850 (New Delhi)	1.40	0.88	0.62	11.88	12.11	0.84	0.57	0.68	15.66	0.92	0.71
Vandana (Cuttak)	1.32	0.90	0.50	10.67	10.85	0.77	0.54	0.70	13.00	0.72	0.59
MTU 1010 (Maruteru)	0.75	1.07	0.88	14.07	14.14	1.11	0.91	0.83	8.99	1.06	1.22

MP= $(Ys + Yp)/2$

YI= $(Ys)/(\overline{Y}s)$

HI= $(Ys \times ((Ys/Yp))/ \overline{Y}S$

YSI= Ys/Yp

SSPI= $Yp - Ys/2(\overline{Y}p)) \times 100$

K1STI= $Yp^2/\ \overline{Y}p^2$ and K2STI= $Ys^2\ /\overline{Y}s^2$

In the above formulae, Ys, Yp, $\overline{Y}s$ and $\overline{Y}p$ represent yield under high temperature stress, yield under control for each genotype, mean yield in high temperature stress and control conditions for all genotype, respectively. The genotypes were ranked according to each index in such a way that a good performing genotype was given the highest rank.

Statistical analysis:

Two-way analysis of variance (ANOVA) was carried out using the open source software R (R Core Team, 2012) and the Agricolae package (de Mendiburu, 2012). The statistical significance of the parameter means was tested using Fisher's LSD test.

RESULTS AND DISCUSSION

Grain Yield(g/plant) and Spikelet fertility(%)

The genotypes RNR 15048 (18.5 g) recorded the greatest grain yield per plant followed by N-22 (17.5 g) and NLR 3778 (17.3 g) under the control conditions while under the elevated temperature stress conditions the genotypes IET 28960 (14.8 g), NLR 3778 (13.2g) and L663 recorded highest grain yield (13.1g).Further, the genotypes NLR 3776 (12.6 g)recorded lowg rain yield under control conditions followed by NLR 3768 (12.7 g), JB 680-2 (12.8 g) and NDLR 26 (12.8 g) and Vandana (12.8). During heatstress conditions lowest grain yield was observed in JB 680-2 (6.9 g) followed by IL 19021(8.4), NLR 3768 (8.8) and Vandana (8.9 gAll of these genotypes showed a highly susceptible reaction to heat stress(Fig1.).High temperatures during the reproductive period decrease seed set. Under controlled conditions, the genotype RNR 15048 (93.1 %) had highest spikelet fertility which was comparable to that of the tolerant control N22 (92.2 per cent). Meanwhile, the genotypes with the highest spikelet fertility during heat stress were MTU 1153 (85.2%), N-22 (84.9%) and MTU 1156 (84.8%) and MTU 1290 (84.5%). Under the elevated temperature stress conditions, the genotype IL 19021(67.0%) recorded least spikeletfertility followed by Vandana (68%) (Fig2.). These genotypes also exhibited highly susceptible reaction to heat stress.The genotype MTU 1153 (6.6 %) showed the lowest drop in spikelet fertility after

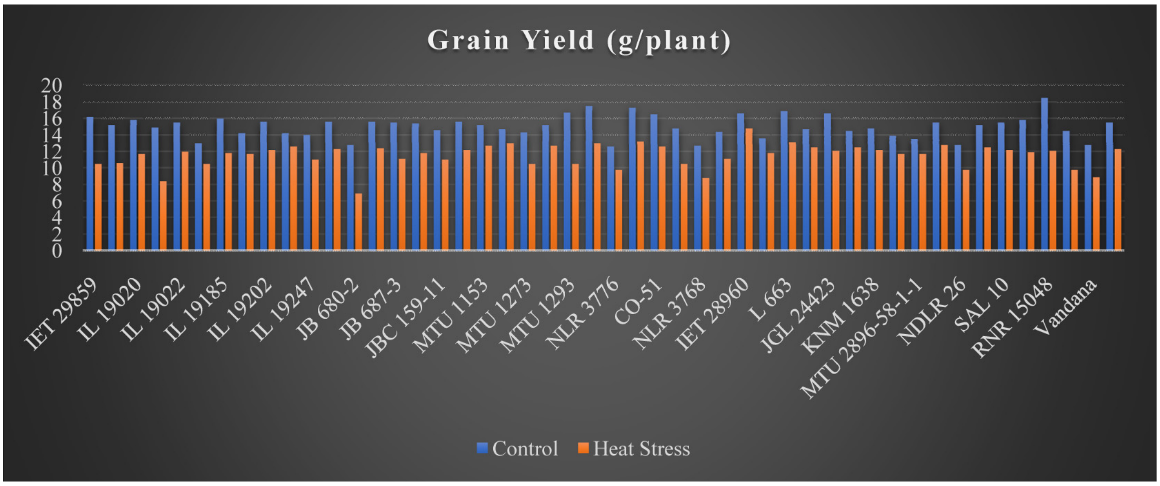

Fig 1.Impact of high temperatures on grain yield (g/plant) in rice genotypes

imposition of heatstress, followed by MTU1156 (7.9%), N-22(7.9%),MTU 1293 (8.0%) and MTU 1290 (8.3 %) and these genotypes could be identified as heat stress-tolerant. Besides, MTU 2897-35-1-1 showed the largest drop in spikelet fertility (25.9%)followed by JGL 2443(24.4) and L 648(24.3%).The data analysis revealed that IET 28960 had the lowest reduction (10.8%). Meanwhile, the highest reduction (46.0%) was recorded in JB 680-2.

Performance of cultivars based on tolerance indices

Stress Susceptibility Index (SSI) values indicating the degree of susceptibility was highest in JB680-2 (1.99), MTU 1293 (1.61), IET 29859 (1.53), and IL 19021 (1.51) and lowest was in IL 19211(0.48), IET 28960 (0.48), MTU 1156 (0.51) and MTU 2896-58-1-1 (0.55) (Table 1).Relative Heat Index(RHI) varied from 0.70 (JB680-2) to 1.16 IET 28960 and IL 19211. High RHI was noted in IL 19211(1.16), IET 28960 (1.16), MTU 1156 (1.15) and L 648 (1.13). Low values for RHI was noted in JB680-2 (0.70), MTU 1293(0.81), IET 29859 (0.84) and IL 19021 (0.85).Stress Tolerance Index(STI) was maximum in IET 28960 (1.08), N22 (1.03), NLR 3778 (1.01) and RNR 15048 (0.99). Minimum STI was recorded in JB680-2 (0.39), IL 19021 (0.48), NLR3768 (0.49) and Vandana (0.50).Geometric Mean Production (GMP) ranged from 9.40 (JB680-2) to 15.65 (IET 28960). It was highest in IET 28960 (15.70), N22 (15.25), NLR 3778 (15.09) and RNR 15048 (14.97). Lowest was in JB680-2 (9.40), IL 19021 (10.40), NLR3768 (10.57) and Vandana (10.67).Mean Production (MP)was recorded maximum in IET 28960 (15.70), N-22 (15.40), RNR 15048 (15.31) and NLR 3778 (15.23). Minimum MP was in JB 680-2 (9.85), IL 19021 (10.65), NLR3768 (10.75), and Vandana (10.85). Yield Index (YI) the rice genotype with high values of Yield index (YI) is suitable for heat condition.Highest values of YSI was noted in IET 28960 (1.28), N-22 (1.15), Krishna hamsa (1.14), NLR 3778 (1.14) and L 663 (1.14). Lower YI was in JB 680-2 (0.60), IL19021 (0.73), NLR 3768 (0.76) and Vandana (0.77). Heat Resistance Index (HI) ranged from 0.32 (JB680-2) to 1.14 (IET 28960). Maximum HI was observed in IET 28960 (1.14), MTU 1156 (0.99) and IL 19211 (0.97), MTU 1153 (0.92) and KNM 733 (0.92). Minimum HI was recorded in JB680-2 (0.32), IL 19021 (0.47), NLR 3768 (0.53) and Vandana (0.54).Yield Stability Index (YSI), maximum values are the better indication of the superior performance of genotypes under heat stress environment. Yield Stability Index,maximum was observed in IL 19211 (0.89), IET 28960 (0.89), MTU 1156 (0.88), and MTU 2896-58-1-1 (0.87). Lower values were noted in JB680-2 (0.54), MTU 1293 (0.63) IET 28959 (0.64) and IL19021 (0.65) and RNR 15048 (0.65).Stress Susceptibility Percentage Index (SSPI) maximum was in, RNR 15048 (21.38), MTU 1293 (20.81), JB680-2 (19.60) and IET 28959 (19.19). However, minimum values were in IL 19211 (5.25), MTU 1156 (5.76), MTU-2896-58-1-1 (5.76) and L 648 (6.06). Modified stress tolerance (K1STI and K2STI) showed highest in RNR 15048 (1.52), N-22 (1.35), NLR 3778 (1.32) and L 663 (1.26). NLR 3776 (0.70), NLR 3768 (0.71), JB680-2 (0.72), NDLR 26 (0.72) and Vandana (0.72) recorded lowest K1STI. Maximum values for K2STI were noted in IET 28960 (1.63), N-22 (1.32), Krishna hamsa (1.30), NLR 3778 (1.30) and L 663 (1.29) andthe lowest was observed in JB680-2 (0.36), IL 19021 (0.53), NLR 3768 (0.58) and Vandana (0.59).

Correlation analysis

The correlation analysis between grain yield under heat stress (Ys), grain yield under control (Yp), and other tolerance and susceptibility indices revealed a negative but

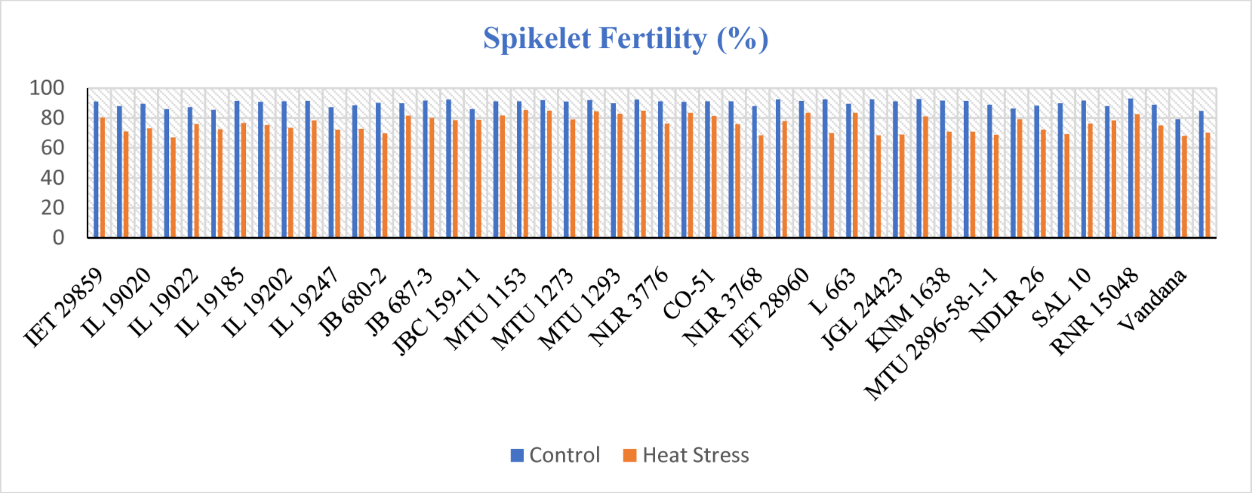

Fig.2. Impact of high temperature on spikelet fertility in rice genotypes

statistically significant correlation between SSI and Ys. A significant but negative correlation was discovered between SSPI and Ys. Given their strong and positive correlation with Ys, the remaining indices RH, STI, GMP, MP, YI, HI, YSI, and K1STI and K2STI could be regarded as useful selection indicators. Under both control and heat stress conditions, STI, GMP, and MP had the strongest correlation with Ys. (Table 2.)

Ranking method

The genotypes IET 28960, MTU 1153, MTU 1156, N 22, NLR 3778, L 663 and MTU 1290 had the highest mean rank and a lower standard deviation of rank, hence they can be identified as heat tolerant genotypes. Genotypes *viz*., JB 680-2, NLR 3768, IL19021 and Vandana are susceptible to high temperature stress as they recorded lower mean rank (Table 3). Yield and yield components were known to be effective for evaluation of genotypes under stress conditions and computing the yield-based indices essential to identify the tolerant genotypes. Yield-based indices have been used for screening large germplasm of many crops for abiotic stresses include drought, salinity and high temperature.

A positive correlation between the indices MP, GMP and Ys, Yp was reported by Toorchi *et al*. (2012). A positive and significant relationship between GMP, MP and STI and Ys was reported by Khalili *et al*. (2012) and these indices were used to identify the tolerant genotypes. In the present study, also a highly positive significant correlation was obtained and hence the genotypes possessing a higher GMP, MP and STI can be categorized as tolerant. Ilker *et al*. (2011) have reported that indices MP, GMP and STI are suitable to select high yielding wheat genotypes in both stress and non-stress conditions. Similarly, Veronica *et al*. (2021) reported that indices MP, GMP and STI are suitable to select high yielding genotypes in rice under both control and heat stress conditions. Mazal (2021) reported in rice the heat tolerant index (HTI) and meanproductivity (MP) index had the highest correlation with yield under both the conditions.

The correlation analysis revealed that the negative correlation of tolerance index and stress susceptibility percentage index with the grain yield of genotypes under heat stress condition (Ys) and a highly positive correlation of stress tolerance index, mean productivity, geometric mean, harmonic mean, and mean relative performance with grain yield (Yp and

Table 2. Correlation coefficient between Yp, Ys and tolerance or susceptibility indices in rice genotypes

	Yp	Ys	SSI	RH	STI	GMP	MP	YI	HI	YSI	SSPI	K1STI	K2STI
Yp	1.00												
Ys	0.66***	1.00											
SSI	0.05	-0.71***	1.00										
RH	-0.05	0.71***	-1.00	1.00									
STI	0.89***	0.93***	-0.41	0.41	1.00								
GMP	0.88***	0.94***	-0.43	0.43	1.00	1.00							
MP	0.91***	0.92***	-0.37	0.37	1.00	1.00	1.00						
YI	0.66***	1.00***	-0.71	0.71	0.93	0.94	0.92	1.00					
HI	0.37**	0.94***	-0.90	0.90	0.75	0.77	0.72	0.94	1.00				
YSI	-0.05	0.71***	-1.00	1.00	0.41	0.43	0.37	0.71	0.90	1.00			
SSPI	0.37**	-0.45***	0.94	-0.94	-0.10	-0.12	-0.06	-0.45	-0.73	-0.94	1.00		
K1STI	1.00***	0.64***	0.07	-0.07	0.88	0.87	0.90	0.64	0.35	-0.07	0.39	1.00	
K2STI	0.66***	0.99***	-0.70	0.70	0.93	0.94	0.91	0.99	0.94	0.70	-0.45	0.65	1.00

** indicates Significance at 0.01 level, *** indicates Significance at 0.001 level

Table 3. Rank, rank mean and standard deviation of ranks (SDR) of heat tolerance and susceptibility indices in rice genotypes.

Entry	SSI	RH	STI	GMP	MP	YI	HI	YSI	SSPI	K1STI	K2STI	MEAN	STD
IET 29859	3	3	18	18	19	7	6	3	3	39	7	11	11.2
IL 19019	7	7	15	15	16	12	9	7	6	23	12	12	5.2
IL 19020	14	14	28	28	28	18	17	14	13	37	18	21	8.0
IL 19021	4	4	7	7	7	6	5	4	5	15	6	6	3.1
IL 19022	24	24	27	27	27	25	23	24	23	28	25	25	1.8
IL 19024	31	31	6	6	6	11	14	31	38	6	11	17	12.6
IL 19185	13	13	29	29	33	21	16	13	11	38	21	22	9.4
IL 19198	33	33	17	17	17	17	27	33	36	12	17	24	8.8
IL 19202	26	26	33	33	34	29	25	26	24	33	29	29	3.8
IL 19211	48	48	21	21	20	36	45	48	48	11	36	35	14.0
IL 19247	29	29	9	9	9	13	18	29	29	10	13	18	9.2
IL 19396	30	30	36	36	37	30	29	30	26	35	30	32	3.6
JB 680-2	1	1	1	1	1	1	1	1	2	3	1	1	0.6
JB 683-1	15	15	45	45	46	42	28	15	8	47	42	32	15.5
JB 687-3	10	10	19	19	18	15	12	10	9	29	15	15	6.0
JB 689-1	21	21	23	23	23	22	20	21	20	27	22	22	2.0
JBC 159-11	16	16	14	14	15	14	13	16	21	17	14	15	2.2
Krishna hamsa	25	25	44	44	44	43	33	25	19	45	43	35	10.1
MTU 1153	43	43	42	42	41	47	47	43	41	34	47	43	3.7
MTU 1156	46	46	34	34	31	41	46	46	47	19	41	39	8.8
MTU 1273	12	12	8	8	8	8	11	12	17	13	8	11	2.9
MTU 1290	38	38	35	35	35	37	42	38	37	25	37	36	4.2
MTU 1293	2	2	20	20	24	9	4	2	1	43	9	12	13.2
N-22	39	39	37	37	36	38	43	39	39	24	38	37	4.7
NLR 3776	22	22	4	4	4	4	10	22	30	2	4	12	10.2
NLR 3778	36	36	38	38	38	40	41	36	33	30	40	37	3.2
CO-51	19	19	41	41	42	35	26	19	14	40	35	30	10.8
NLR 3775	8	8	10	10	11	10	7	8	10	21	10	10	3.8
NLR 3768	6	6	2	2	2	2	2	6	18	1	2	4	4.9
IET 28954	23	23	13	13	13	16	15	23	27	14	16	18	5.1
IET 28960	47	47	48	48	47	48	48	47	44	41	48	47	2.2
L 648	44	44	12	12	12	23	34	44	45	8	23	27	15.2
L 663	28	28	43	43	43	45	38	28	22	44	45	37	8.7
MTU 2897-35-1-1	41	41	25	25	26	32	40	41	40	18	32	33	8.3
JGL 24423	11	11	40	40	40	26	19	11	7	42	26	25	13.8
KNM 733	42	42	24	24	22	33	44	42	43	16	33	33	10.2
KNM 1638	34	34	22	22	21	27	32	34	34	20	27	28	5.9
NLR 3648	40	40	16	16	14	19	30	40	42	9	19	26	12.6
MTU 2896-58-1-1	45	45	11	11	10	20	36	45	47	7	20	27	16.6
NDLR 24	35	35	39	39	39	39	39	35	31	31	39	36	3.2
NDLR 26	20	20	5	5	5	5	8	20	28	4	5	11	8.8
NDLR 25	32	32	32	32	29	34	35	32	33	26	34	32	2.5
SAL 10	27	27	31	31	30	28	24	27	25	32	28	28	2.6
PR 126	17	17	30	30	32	24	21	17	16	36	24	24	7.1
RNR 15048	9	9	47	47	48	44	22	9	4	48	44	30	19.2
Pusa Samba 1850	37	37	26	26	26	31	37	37	35	22	31	31	5.6
Vandana	5	5	3	3	3	3	3	5	15	5	3	5	03.5
MTU 1010	18	18	46	46	45	46	31	18	12	46	46	34	14.5

Ys) under both conditions, helped accurately identify the desirable genotypes in wheat (Lamba *et al*., 2023). Kumar *et al*. (2024) reported that grain yield (Ys) showed negative association with SSI, RSI and RED and significant positive correlation with the indices viz., STI, YI, MP, GMP and HM. Hence these indices could be regarded as the best selection indicators for heat stress tolerance.

CONCLUSIONS

In this experiment, the most effective stress tolerance indices for identifying tolerant rice genotypes under high temperature conditions were STI, GMP, MP, YI, HI, K1STI, and K2STI, which were significantly correlated under both Yp and Ys. When large amounts of germplasm are available, these yield-based indices can help with preliminary screening for high temperature tolerant genotypes.

The genotypes IET 28960, MTU 1153, MTU 1156, N 22, NLR 3778, L 663 and MTU 1290 highest mean rank and a lower standard deviation of rank, hence they can be identified as heat tolerant genotypes. The correlation coefficient results revealed a significant and positive association between spikeletfertility and grain production under elevated temperature stress.Under the elevated temperature stress conditions the genotypes IET 28960, MTU 1153, MTU 1156, N 22, NLR 3778, L 663 and MTU 1290 identified as tolerant to heat stress as they recorded highest spikelet fertility.

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DETECTION OF *CRY*1AC AND *CRY*2AB PROTEINS WITH ELISA AND PCR TECHNIQUES IN TRANSGENIC COTTON (*GOSSYPIUM HIRSUTUM* L.)

RANI CHAPARA, N. CHAMUNDESWARI, L. RAJESH CHOWDHARY, CH. NAGAJYOTHI, B. SREEKANTH, V. MANOJ KUMAR, S. RAJAMANI and M. JAMES

Department of Genetics & Plant Breeding, Regional Agricultural Research Station, Acharya N.G. Ranga Agricultural University, Lam, Guntur – 522034.

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ABSTRACT

To develop BGII hybrids/varieties, the elite lines which were proven for high yield with jassid resistance were selected and converted under BGII background for further usage in BGII hybrid development programme. Hence, the study was aimed to detect the presence of *Cry*1Ac and *Cry*2Ab proteins/genes through qualitative ELISA, PCR techniques and to select the homozygous population from the segregating generations consisting of 1663 samples from different segregating generations as well as from stabilized populations from OYT/PYT/AYT yield trials. The study revealed that out of 9125 samples, 8760 (96%) of samples showed the presence of *cry* 1Ac and *cry* 2Ab proteins in the transgenic leaf samples and also demonstrated that the technique of ELISA for identification of c*ry* 1Ac and c*ry* 2Ab proteins is quite handy and easily adoptable. Using PCR technique, the zygosity status of the samples were known for c*ry*1Ac and c*ry*2Ab genes; used for selection and advancement to next generations in the breeding programme.

Keywords: Cotton (*G.hirsutum* L.), c*ry*1Ac, c*ry*2Ab, ELISA, PCR and Primer

INTRODUCTION

Till date no GM crop/products are allowed in India to be marketed. However, Bt-cotton is the only transgenic crop, approved for commercial cultivation in India. In India, since 2002 the cultivation of Bt cotton hybrids consisting of the *Cry*1Ac gene (BG I with the event MON 531 developed by Monsanto company) played a vital role in the effective control of boll worms like *Helicoverpa armigera* (Hubner), *Erias vitella* (Hubner) and *Pectinophora gossypiella* Saunders) (Naik *et al*., 2018, Arain *et al*., 2021 Likhitha *et al*., 2023). To maintain delay bollworm resistance to BGI, second-generation Bt cotton, BGII with the event MON 15985 was developed by Monsanto company that expressed two *Cry* toxins (*Cry*1 Ac and *Cry*2Ab) and was commercialized in India (2006), occupied > 95 per cent of traditional non-Bt cotton cultivation in India (Kumar *et al*., 2015, Venugopalan and Reddy, 2017). This invention protected the cotton crop from bollworms and lead to reduced pesticide usage up to 20 to 40% whereas in past five to six years pink bollworm became a menace (Kranthi, 2016 and Naik *et al*., 2018). Hence, plant breeders focussed more on developing BGII cotton varieties as it is

Corresponding author: ranichapara@angrau.ac.in

providing resistance to the pests *Helicoverpa armigera* (Hubner) and *Erias vitella* (Hubner). To identify the trait positive plants in segregating generations and to select the homozygous samples ELISA followed by PCR techniques are very much effective while breeding for BGII cotton elite lines with high yield and resistance biotic stresses especially boll worms. The ELISA technique includes the identification of proteins produced by the introduced trait gene through the detection of its specific antibody, such as by Enzyme Linked Immunosorbent Assay (ELISA) (Dohare and Tank, 2014; Khetarpal and Kumar, 2017), while second technique employs the identification of specific DNA sequence used for gene modification by Polymerase Chain Reaction (PCR) (Hussain *et al*., 2014; Cheema *et al*., 2016). Based on the above advantages the research work was proposed to test the BC_3F_4 generation lines developed through back cross breeding as well as homozygous populations from different yield trials'

MATERIAL AND METHODS

Sample preparation for Qualitative assay:

Leaf sample preparation: Taken 3 leaf disc in 2 mL centrifuge tube and then added 1 autoclaved stainless-steel bead to the tube. After that dipped all the sample tubes in liquid nitrogen for 10 min. Added 500 µL of 1X Extraction Buffer to the tube. Proceed all the tubes for crushing on tissue homogenizer for 30 sec. Transferred all the content from 2 mL tube to 1.5 mL tube followed by centrifugation of all the tubes at 10000 RPM for 10 min. at 4 ºC. Kept all the tubes to 4 ºC until use.

Protocol for Qualitative Assay:

Added 50 µL leaf sample extract to the precoated plate followed by 50 µL Conjugate was added. Later 50 µL of Blank, Controls, to respective wells were added. Incubated the plate at room temperature for 45 minutes. Decantated the content from the plate after incubation. Washed the plate 4 times and pat dry the plate after last wash . Added 100 µL of Substrate to the plate. Incubate the plate at room temperature for 15 min. strictly in dark. Added 100 µL of Stop solution to the plate . Measured the absorbance at 450 nm using an ELISA plate reader (Multiskan FC ESW version 1.01.16, make Thermofisher). The absorbance of a blank well must be subtracted from absorbance values of samples and controls. Optical density (OD) values were used to determine the presence or absence of a specific antigen or antibody in a sample. The OD of the wells is then measured using a microplate reader at a specific wavelength, typically 450 nm for most ELISA. The OD value is a measure of the intensity of the color developed in each well.

Assay Acceptance Criteria and Interpretation:

The OD value of blank well should be below 0.200 for cry1Ac and 0.250 for cry2Ab. Subtracted the OD value of blank from all samples including positive and negative control. The mean OD value of negative control(s) should be below 0.150. If negative control showed negative (minus) readings then considered that reading as zero. The OD value of 2 positive controls should be within 15% of each other. Mean OD value of positive control should be at least 0.50. The cutoff value was calculated by adding the mean O.D. of negative control to the numerical value 0.2 for cry1Ac detection and 0.1 for cry2Ab detection. The positive sample are the one the samples showing absorbance above cutoff value while the samples showing absorbance below cutoff value ate negative samples.

DNA Extraction Procedure:

DNA extraction was performed using CTAB method as suggested by (Doyle & Doyle 1990). Two to three punches of leaf sample in

PCR Method to detect *cry*1Ac and *cry*2Ab zygosity status:

The PCR analysis carried out in a proflex thermal cycler, Thermofisher, U.S.A. A total reaction volume of 20 µl was prepared using the following protocol

Event/ Trade Name	Genes	PCR Primers	PCR Reaction Conditions		Source
MON531	*cry*1Ac	SQ95 (1075 bp) SQ525 SQ524 (810bp)	Each primer concentration (1µM)	0.4 µl of 0.2 µM concentration	GMO METHODS
			dNTP mix (10mM) 10x Reaction Buffer (with MgCl2) Taq	0.4 µl 2µl 1µl	
			Template DNA	50 ng	
			DD water	10.4 µl	
MON15985	*cry*2Ab	ESQ119 (1056bp) SQ121 SSQ120 (1760bp)	Each primer concentration (1µM)	0.4 µl of 0.2 µM concentration	GMO METHODS
			dNTP mix (10mM) 10x Reaction Buffer (with MgCl2) Taq	0.4 µl 2µl 1µl	
			Template DNA	50 ng	
			DD water	10.4 µl	

2 mL centrifuge tubes were collected and kept all sample tubes in ice. Added small and big sized steel beads to each tube and then placed all the sample tubes in tray and dumped them in container containing Liquid Nitrogen and left it in container for 10 minutes. After 10 minutes, took out the tray and proceeded to crushing for 1 minute on machine crusher. Added 850 µL of prewarmed CTAB Buffer (having 300 µL of beta mercaptoethanol to 10 mL of CTAB Buffer) to all the tubes as soon as possible (before sample thawing). Shook the tubes well so as to mix the content. After that all the contents were transferred to new 2 mL centrifuge tubes and incubated all the tubes to 65°C for 1 hour (Inverted the tubes occasionally). Later added 850 µL of Chloroform: Isoamyl Alcohol (24: 1) to the tube sand inverted properly for 10-15 times and centrifuge all the tubes at 9000 RPM for 20 min. at room temperature. In a new 1.5 mL centrifuge tube supernatant was taken and added 10 µL of RNAse enzyme (10mg/mL stock) to all the tubes. Incubated the tubes at 37°C for 20 minutes. Later added Chloroform: Isoamyl Alcohol (24: 1) in ratio equivalent to volume of supernatant. Invert the tubes properly for 10 to 15 times and centrifuged all the tubes at 9000 RPM for 20 minutes at room temperature. Took the supernatant

Number of Cycles	Settings (°c) of Proflex PCR	Time
1	94	3 minutes
38	94	15 seconds
	60	30 seconds
	72	1 minute
1	72	5 minutes

The expected band size of the amplicons was as follows:

Amplicon name	Expected band size (bp)
Non-transgenic cotton	1075
531 homozygous cotton	810
531 heterozygous cotton	1075 and 810

The expected band size of the amplicons was as follows:

Amplicon name	**Expected band size (bp)**
Non-transgenic cotton	1050
15985 homozygous cotton	1760
15985 heterozygous cotton	1050 and 1760

(approximately 410 µL) in new 1.5 mL centrifuge tubes and the added 2.5 volumes of prechilled absolute ethanol. Kept all the tubes in -20°C for 10 min (or overnight). The next day centrifuged all the tubes at 9000 RPM for 20 minutes at room temperature. After that discarded the absolute ethanol and added 500 µL of 70% Ethanol. Tapped the pellet of DNA in each tube well. Centrifuged all the tubes at 10000 RPM for 20 min. at room temperature and discarded the 70% Ethanol without disturbing the pellet followed by added 500 µL of 70% Ethanol. Tapped the pellet of DNA in each tube well and centrifuged all the tubes at 10000 RPM for 15 min. at room temperature and discarded the 70% Ethanol without disturbing the pellet. After that air dried the DNA pellet in DNA Concentrator (Eppendorf make) set at 37°C for 15 minutes. Added approximately 100 µL of TE buffer and dissolved the DNA well in all the tubes and kept all the tubes at -20°C for long term storage.

The sequences of primers for, MON531 for cry1Ac and MON15985 for cry2Ab were recovered from the GMO Detection Method Database (GMDD; www.gmdd.shgmo.org).

The Proflex PCR (make: Thermofisher) was used to perform the PCR and the following were the PCR conditions https://patents.google.com/patent/WO2002016588A3/en :

Agarose gel electrophoresis

Eight ìl of PCR products (including PCR amplification products, positive and negative controls) were electrophoresed on 3% agarose gel containing 2 ìl DNA safe stain at 80 Voltage in 1× TBE (Himedia make) running buffer (containing 600 ml dH_2O, 48.4 g Tris base, 11.42 ml glacial acetic acid and 40 ml EDTA

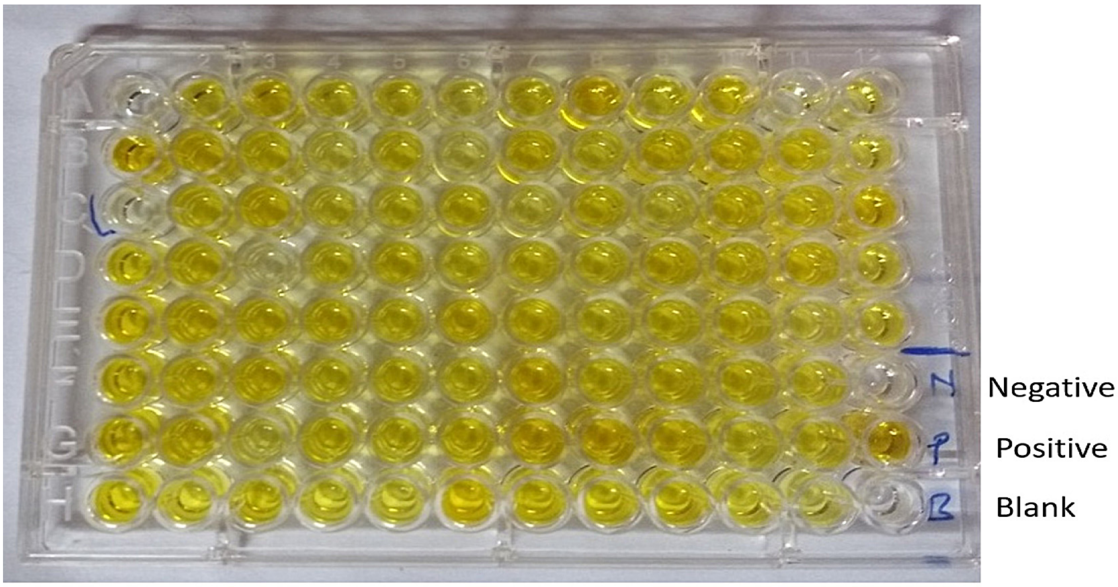


Figure 1. Detection of *Cry*1Ac proteins in cotton leaf samples through qualitative ELISA

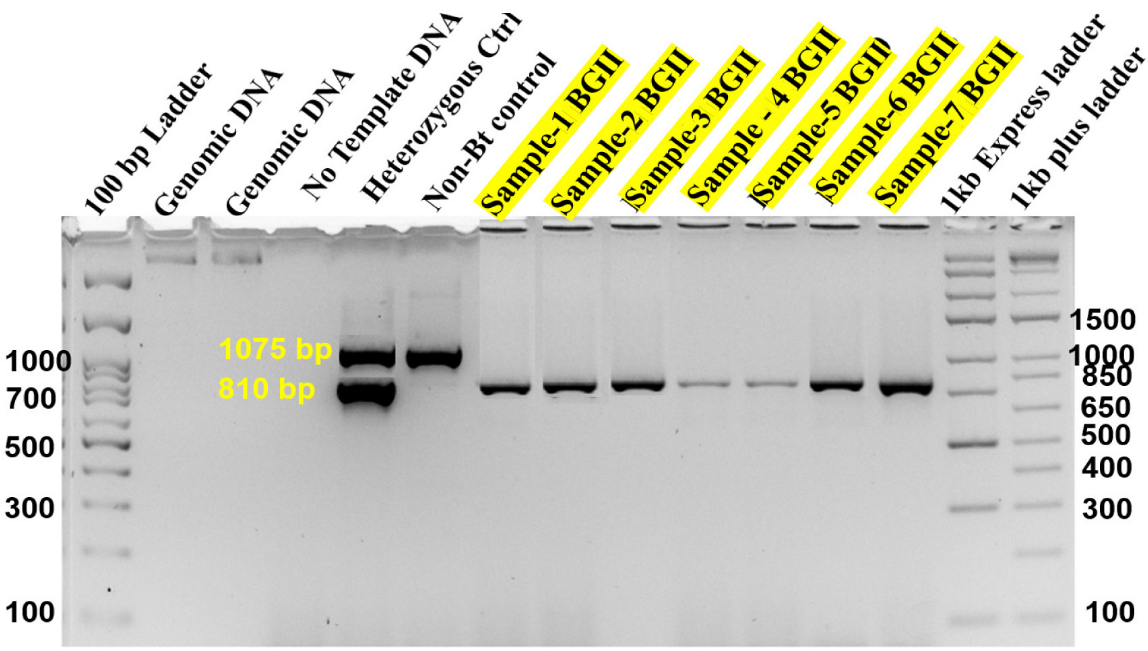


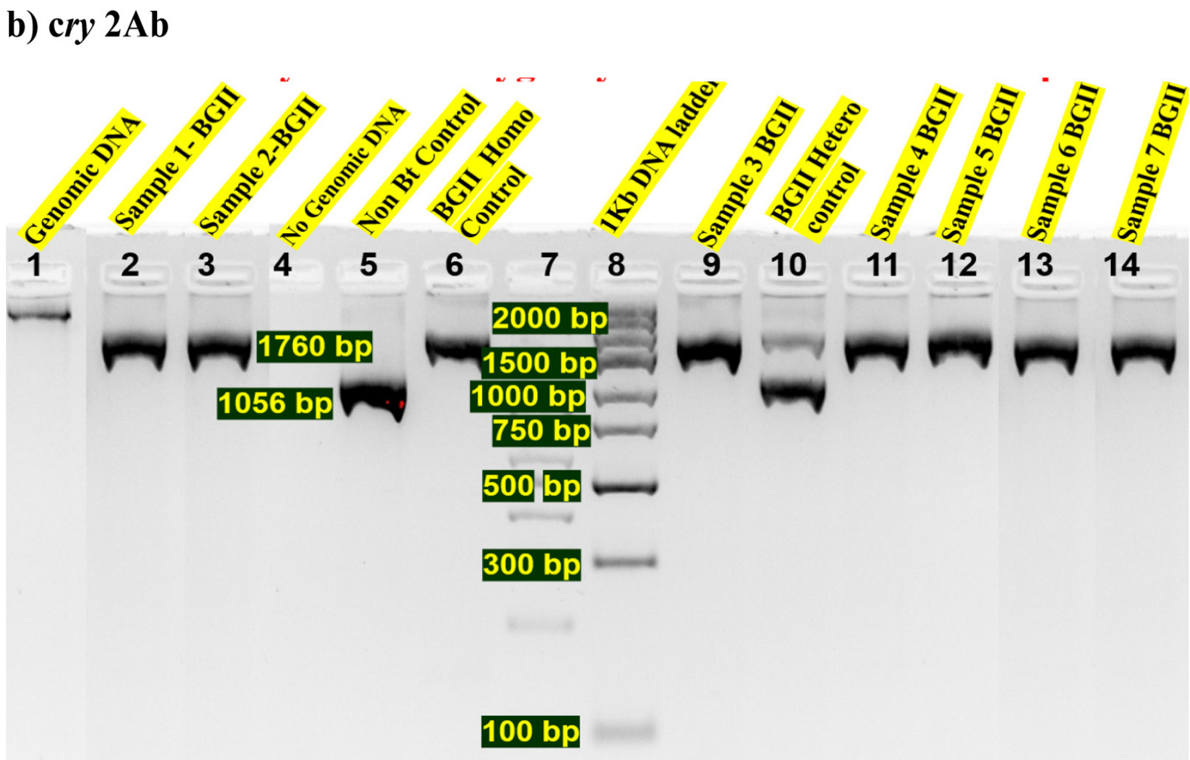
Figure 2. Detection of *cry* genes homozygosity status in cotton leaf samples. a) *cry* 1Ac

(0.5 M), PH 8.0, then dilute with dH2O to obtain a final volume of 1 L) for 60 min. 4 ìl of 100 bp DNA ladder was used as a reference marker. DNA fragments were separated through a gel based on size and then visualized using chemidoc (Thermofisher make).

RESULTS AND DISCUSSION

From different yield trials like OYT (2208 samples), PYT (2004 samples), AYT (1465 samples), uniform bulks (3448 samples) and segregating generation of BC_3F_4 (957 samples) were tested for confirmatory study of *cry*1Ac

b) *cry* 2Ab



and *cry*2Ab proteins in cotton leaf samples. The ELISA plates were prepared with blank, positive and negative controls as shown in Figure 1. The mean absorbance values were detected using ELISA reader, Multiskan FC ESW version 1.01.16 (make Thermofisher) at 450 nm and presented in the Table 6. SkanIt Software 4.1 for Microplate Readers RE, ver. 4.1.0.43 was used to calculate cut off value for the presence of *cry*1Ac and *cry*2Ab. The cutoff value was calculated by adding the negative control value with 0.2. Always the negative control values would be less than 0.1 and blank values were to be 0.05. The samples exhibiting the absorbance values of less than 0.3 were considered as negative for the presence of both *cry*1Ac and *cry*2Ab proteins, whereas the samples exhibited absorbance vales of e” ‘+0.3 were considered to be as positive for the traits. The mean absorbance values of the BGII samples evidently displayed the occurrence of proteins in the samples while some samples showed negative mean absorbence values as they did not have the genes (non bt cotton lines). The samples which exhibited both trait positive was subjected to one more time confirmation and those samples were tested with PCR for homozygosity using zygosity primers for stabilization of the lines under *cry*1Ac and *cry*2Ab background as shown in Figure 2. The samples which possessed homozygous for both the traits were selfed and advanced to BC_3F_4 /F_3 to F_4 generation/maintaince of bulks. Similar reports were reported by Alka and Tank, 2014, Ramanjali *et al*., 2015, Shahid *et al*., 2015, Cheema *et al*., 2016, Likhitha *et al*., 2023. Out of 9125 samples from yield trials, 8760 (96%) samples exhibited positiveness for both the traits while from the segregating generations out of 1663 test samples 1297 (78%) only showed positiveness for *cry*1Ac and *cry*2Ab proteins.

CONCLUSIONS

From the above study, it was evident that ELISA technique was a handy technique for identification of c*ry*1Ac and c*ry*2Ab proteins in the cotton leaf samples for the advancement of trait specific positive selections in cotton crop improvement programme and easily adoptable. Few limitations observed from the assay were high light sensitivity, required more time for assay coupled with high costs for purchase of precoated plates. In cotton aged plants (more than 120 days) showed less protein expression for c*ry*1Ac and c*ry*2Ab hence using ELISA technique at this stage did not provide accurate results. The early detection of positive samples for c*ry*1Ac and c*ry*2Ab in the segregating generations with ELISA technique saved many resources in the breeding programme. The ELISA technique followed by detection of events with PCR for homozygosity practiced for efficient conversion of cotton elite lines under c*ry*1Ac and c*ry*2Ab background. This procedure may also be applied in identification of the purity issues for varietal samples.

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CULTURAL AND MORPHOLOGICAL CHARACTERIZATION OF *ALTERNARIA BRASSICAE* OF MUSTARD IN ALLAHABAD UTTAR PRADESH

***SHAILENDRA KUMAR, S. M. PRASAD and H. K. KEHRI**

*Department of Botany, Kutir P.G. College, Chakkey, Jaunpur -222146

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ABSTRACT

Alternaria brassicae isolates were collected from the black leaf spot of mustard during the winter season (2019-2021) in the various regions of the Allahabad district. *In vitro*, results show significant variability in growth pattern, sporulation, conidial length, width, and septa number in different culture media, temperature, pH, and relative humidity. The conidial length of the isolates II-2C20, III-5C20, V-2A20, V-7A20, and I-6A1y21 was the shortest, measuring 14 ìm. The isolate I-4B21 and II-7C21 had the longest conidial length, ranging from 72 ìm to 72.8 ìm, respectively. The average conidial length ranged from 30.1 ìm to 50.9 ìm, with mustard isolate I-6A1y21 having the lowest value and I-4B21 having the highest. The highest average width was 15.86 ìm. The best mediums for 31 isolates were Potato Dextrose Agar, Meal Agar, Corn Meal Agar, Czapex dox agar, Carrot meal agar, and V-8 juice Agar. The highest radial growth was shown in the OMA medium by I-6A1y21 isolates, while the lowest growth was shown in the CA medium by II-7C21 and II-8B21 isolates. Out of all of them, the isolate I-6B121 sporulated the most ($41.75x10^5$/ml) whereas the isolate I-4A21 sporulated the least ($0.5x10^5$/ml) in OMA and CA medium. The radial growth and sporulation are optimal at 24°C, moderate at 18°C and 30°C, and lowest at 6°C and 36°C. Isolate III-3B20 and II-5C20 showed the least average radial growth and sporulation at all pH levels, while isolate I-6A1y21 showed maximum growth. The pH 7 is more favourable for radial growth and sporulation. The study found that radial growth and sporulation increased in relative humidity between 80-100%, while decreased in 20-40%, with isolate I-6A1y21 showing the highest growth while II-UN120 and III-5C21 exhibited the least. Among the 31 isolates, 9 isolates II-UN120, IV-5C20 I-4A21, I-6B21, I-6A1y21, II-8B21, III-6C21, IV-4B21, and IV- 6AY21 were found to be high degree of infection as the spot produced by them were more than 10 mm in diameter. Statistical analyses were conducted using Microsoft 365 Excel and SPSS 28.0 version on Windows 10, using ANOVA and Duncan's multiple range test of homogeneity at a P=0.05 level.

Keywords: *Alternaria brassicae*, cultural growth, leaf spot diseases, morphological variations, mustard crop, Allahabad mustard crop.

*Corresponding Author E-mail i.d: chaudharishailendra.1@gmail.com; Part of Ph.D. thesis submitted to Kutir P.G. College, Chakkey, Jaunpur

INTRODUCTION

Mustard is an economically important genus of the family Brassicaceae and this family includes oil seed crops like mustard (*Brassica juncea*) *and* rape (*Brassica campestris*). These crops are grown all over the world under a wide range of agro-climatic conditions including India. These crops are commercially significant in both national and international trade because they provide edible oil, which is the primary cooking medium in Northern India. Global estimates for the area, production, and yield of rape seed-mustard in 2018–2019 and 2019–2020 were 34.86 million hectares (mha), 69.07 million tonnes (mt), and 1980 kg/ha and 35.95 million hectares, 71.49 million tonnes, and 1990 kg/ha, respectively (DRMR, 2020-21). While in respect to India, estimates for the area, production, and yield of rape seed-mustard in 2018–2019 and 2019–2020 were 6.12 mha, 9.26 mt, and 1511 kg/ha and 6.86 mha, 9.12 mt, and 1331 kg/ha, respectively (DRMR, 2020-21). The fungal diseases, including white rust, downy mildew, powdery mildew, stem rot, clubroot, damping-off, and Alternaria blight, are recognized as major causes of the losses in mustard production. Among several diseases, Alternaria blight, also referred to as Alternaria dark spot or Alternaria leaf spot, is the most devastating disease, which is caused by the *Alternaria brassicae*. The symptom of Alternaria blight which appear as brown to black circular spots on upper and lower parts of mustard leaf. *Alternaria brassicae* caused losses of up to 47% and 20.28% in Indian mustard (*Brassica juncea*) (Chattopadhyay, 2008; Singh *et al*., 2021). Alternaria blight is a global headache and could reduce yield up to 70% in rapeseed mustard (Pandey *et al*., 2023). Alternaria leaf blight (black spot) on various crucifers, such as oil rapeseed, cabbage, cauliflower and mustard has been documented in different countries including United States, United Kingdom, several other European countries (Blagojevic *et al*., 2020) and India.

This pathogen has the potential to survive in the infected seed, in plant-diseased debris, in soil and on weed hosts for several months at different temperatures and Relative humidity (Punia *et al*., 2021). The main taxonomic criteria for defining fungal species are the morphological properties of conidia and conidiophores, as well as occasionally host plant relationships (Fatima *et al*., 2019). Brassica are affected by Alternaria blight depending on the season, the location, and even the specific crop within a region. There have been reports of variations in the morphological traits of *A. brassicae* isolates from various parts of India (Goyal *et al.,* 2011). In view of the above facts, a present study has been undertaken to investigate the *Alternaria brassicae* and serverity of *Alternaria brassicae* disease in mustard in Allahabad districts.

MATERIAL AND METHODS

31 infected leaf samples were collected from various regions of Allahabad (25.4683° N, 81.8546° E), and the total geographical area is approximately 5,482 km². Infected leaves were collected, sterilized (4% NaOCl), washed, and placed on Potato Dextrose Agar (PDA) medium. After 4-5 days of incubation at +24°C, fungal colony growth was observed in PDA plates, which were isolated and preserved at 4°C. Streptomycin antibiotics were used to prevent bacteria growth in *Alternaria brassicae* culture medium, identified by single spore technique and calibrated using an ocular micrometre (Patel *et al*., 2023).

Thirty-one single-spore cultures of *A. brassicae* were examined for their cultural diversity at Six different culture media, seven distinct pH values (5, 6, 7, 8, 9 and 10), four different RH conditions (20-40%, 40-60%, 60-

80% and 80-100%), and six different temperatures (6^0C, 12^0C, 18^0C, 24^0C, 30^0C, and 36^0C).

A. brassicae colonies were cultured in PDA medium with pH 7.0 for 10 days, examining humidity's impact on mycelial growth and sporulation. Six different culture media (PDA, CMA, CZA, V-8J, OMA, and CA) were developed, and colony growth and sporulation were observed at different conditions.

The haemocytometer, a counting-chamber device, was utilized to measure the conidial concentration of each culture after 10 days of inoculation for sporulation observations.

The observations were made regarding the symptomatology, disease incidence, and disease severity. Seventy randomly selected plants were used to record disease incidence data per 100 m^2 area of every survey area. To determine the frequency and severity of the disease the five lowest (oldest) leaves on each plant were selected. The following formula were used to determine the disease severity and incidence using the systematic sampling method.

$$\text{Disease incidence (\%)} = \frac{\text{Total number of infected plants}}{\text{Total number of plant in sample unit}} \times 100$$

$$\text{Disease severity (\%)} = \frac{\text{Total infected leaf area per plant}}{\text{Total leaf area of infected plant}} \times 100$$

This formula was used to determine the percent disease index (PDI)

$$\text{PDI} = \frac{\text{Sum of all numerical rating}}{\text{Total number of leaves examined x maximum disease rating}} \times 100$$

A pathogenicity test was conducted on mustard plants using conidial suspension and mustard seeds were sown in the botanical garden of the University of Allahabad, from October 2019 to 2021. After seven weeks, plants should emerge from dense plants, creating a 25-30 cm distance between them, and the leaf area should be sprayed with an optimal inoculum concentration (1.0 x10^5 conidia /ml).

Microsoft 365 Excel and SPSS version 28.0 on Windows 10 were used for conducting the statistical analyses. The data in the table were analysed by single-way analysis of variance (ANOVA). Means were separated by Duncan's multiple range test of homogeneity at the P=0.05 level.

RESULTS AND DISCUSSION

The morphological and cultural features of various isolates

A survey was carried out from February of 2019 to 2021 to document the incidence and severity of Alternaria leaf blight in mustard and rapeseed, as well as to gather disease samples from various mustard and rapeseed-growing in Allahabad regions (Figure 2). According to data at different locations, the disease severity and incidence on different cultivars varied from 5 to 50% and 15 to 85% respectively**.** Barwa II and Morahu had the highest disease incidence (85%), with a 45% to 50% disease severity on cultivar Coral PAC-432 (Hybrid) and Pusa mustard 26 (NPJ 113), respectively. The isolate II-UN120 from the Phulpur region exhibited the lowest disease incidence (15%) and severity (5%) on the Pusa mustard 26 (NPJ 113) variety of mustard. It was followed by 25% disease incidence on Pusa mustard 27 (EJ 17) collected from Kotawa with 5% disease severity (Figure1) (Table 2 &3).

The color of conidia on PDA remained consistent, with colonies ranging from light brown to dark brown, and mycelia ranging between grey and brown. Significant morphological variability ($P < 0.05$) was observed in 31 isolates of *A.brassicae* single-spore cultures with respect to conidia length, conidia breadth, beak length, and septum number. The isolates II-2C20, III-5C20, V-2A20, V-7A20, and I-6A1y21 had the lowest conidial length, measuring 14 ìm, while the isolates I-4B21 and II-7C21 had the longest conidial length, between 72 ìm and 72.8 ìm, respectively. The average conidial length varied between 30.1 ìm and 50.9 ìm; the values were lowest in the isolate I-6A1y21 and greatest in the isolate I-4B21 at 50.9 ìm. The average conidial width varied between 8.4 ìm and 15.86 ìm, with the isolate I-4B21 having the highest average width at 15.86 ìm and the isolate IV-6Ay21 having the lowest average width at 8.4 ìm. The number of transverse septa varied from 3.0 to 7.0, with the isolate II-7C21 having the highest number at 7.0 and the isolate V-1B20 having the lowest number at 3.0. The number of vertical septa ranged from 1.0 to 4.0, with the isolate II-7C21 having the highest number at 4.0 and the isolate II-2C20 having the lowest number at 1.0 (Table 1 & 4).

(Saha *et al*., 2016) who requested that substantial variability was observed among the *A. brassicae* isolated from several locations.

Radial growth on different culture media

The radial growth of *A. brassicae* in various cultural media ranged from 11.46 mm to 71.20 mm. The radial growth ranges of various *A. brassicae* isolates on different culture media are as follows: 28.28 mm to 52.35 mm on PDA, 12.56 mm to 42.16 mm on CMA, 37.4 mm to 71.20 mm on OMA, 23.33 mm to 62.66 mm on CZA, 11.46 mm to 32.30 mm on CA, and 27.26 mm to 49.73 mm on V-8J media are, respectively (Table 5). The highest radial growth (71.20 mm) was shown in the OMA medium by I-6A1y21 isolates, while the lowest radial growth (11.46 mm and 11.56 mm) is shown in the CA medium by I-6A1y21 isolates, while the lowest radial growth (11.46 mm and 11.56 mm) is shown in the CA medium by the II-7C21 and II-8B21 isolates.The OMA medium showed maximum radial growth for *A. brassicae* isolates, while CA medium showed the least growth (Figure 3 & 4).

Sporulation on different culture media: The average sporulation range in PDA medium was 16.50 x 10^5 to 29.50 x 10^5/ml, among them the maximum sporulation (29.50 x 105 /ml) was shown by the isolate I-6A1y21, while the isolate II-5C20 and IV-5C20 had the least sporulation (16.25 x 10^5/ml) in PDA medium. The sporulation range in CMA medium was 5.25 x 10^5/ml - 14.50 x 10^5/ml

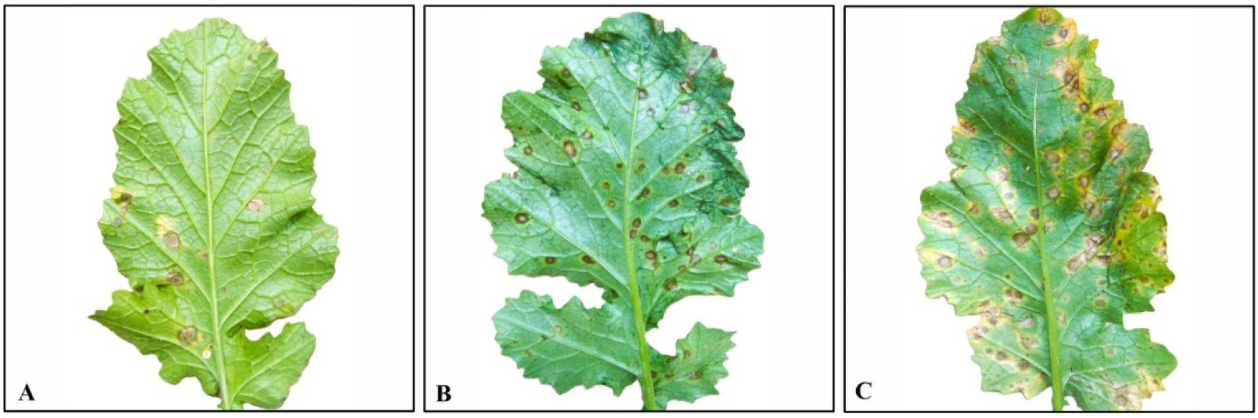

Fig. 1. Disease severity on mustard leaf per plant : **A**) A leaf with minimum grade of infection (10-25%) **B**) A leaf with moderate grade of infection (50-70%) **C**) A leaf with maximum grade of infection (70-100%)

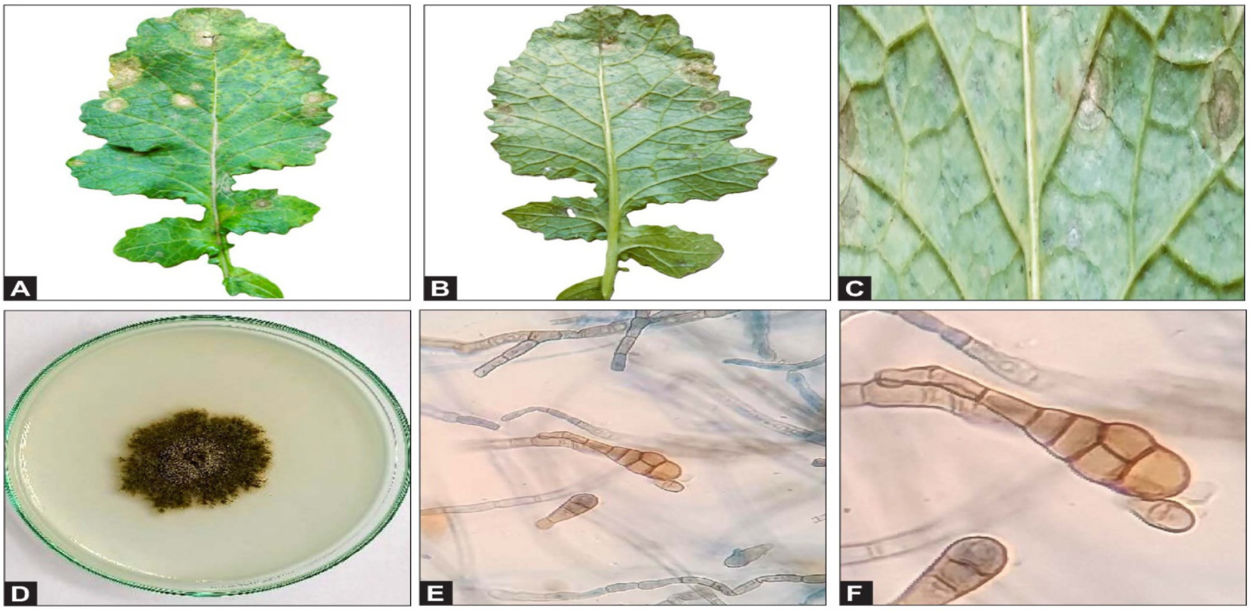

Fig. 2 Survey of field, morphological and cultural characteristic of *A.brassicae* isolate I-4B121.**A** Dorsal view of an infected leaf with pathogen, **B** ventral view of infected leaf, **C** Leaf with concentric ring, **D** Growth on culture medium, **E** Fungal hyphae with spore, **F** A single spore of *Alternaria brassicae* isolate I-4B121.

among them, with the isolate I-6A1y21 was most sporulated (14.50 x 10^5/ml), while the isolates I-7B21 and II-3B21 was sporulated least (5.25 x 10^5/ml) in CMA medium. The magnitude of sporulation in OMA medium is 16.25 x 10^5/ml - 30.25 x 10^5/ml, in which maximum sporulation (30.25 x 10^5/ml) was observed in isolate I-6A1y21 while the least sporulation (16.25 x 10^5/ml) was reported in the II-3B21 isolate of *Alternaria brassicae*. The sporulation range in CZA medium was 10.50 x 10^5/ml–23.50 x 10^5/ml, in which the maximum sporulation (23.50 x 10^5/ml) was found in isolate I-6A1y21 while the least sporulation (10.50 x 10^5/ml) was observed in the isolate IV-5C20. In CA medium, the range of sporulation was 3.95 x 105/ml–8.2 x 10^5/ml. The maximum sporulation (8.25 x 10^5/ml) was shown by the isolate I-6A1y21, while the least sporulation (3.95 x 10^5/ml) was shown by isolate IV-4B21 in CA medium (Table 6).

The previous investigation confirmed the finding of current study which showed that high sporulation and radial growth of *A. brassicae* on PDA medium across a variety of tested conditions (Prasad *et al*., 2019). It has also been reported that culture medium affect the morphology and development of conidia (Kumar and Sharma, 2017).

Radial growth at different temperatures

The radial growth range of different *A.brassicae* isolates at different temperatures was as follows: 1.75 mm to 9.18 mm at 6°C, 11.40 mm to 23.73 mm at 12°C, 15.20 mm to 33.36 mm at 18°C, 28.28 mm to 52.35 mm at 24°C, 27.28 mm to 38.11 mm at 30°C, and 4.64 mm to 13.65 mm at 36°C temperature, respectively.

Among 31 isolates, four isolates, such as I-6A1y21, III-7B21, I-4B21 and IV-4B21, showed the highest radial growth at 6°C temperatures, (9.18 mm), (8.7 mm), (8.46 mm), and (8.23 mm), respectively. While four isolates, III-1B20, II-6C21, II-5C20 and III-

5C20, showed the least radial growth, (1.75 mm), (2.6 mm), (2.76 mm) and (2.78 mm), respectively, at 6°C temperatures. The maximum (23.73 mm and 33.36 mm) and minimum radial (11.40 mm and 15.20 mm) growth was shown by the isolate I-6A1y21 and the isolate I-7B21 at 12°C and 18°C, respectively. The isolate I-6A1y21 showed the maximum radial growth (52.35 mm, 38.11 mm, and 13.65 mm), while the least radial growth (28.28 mm, 27.28 mm, and 4.64 mm) was shown by the isolates I-11A21, III-3B20, and II-6C21 at 24°C, 30°C, and 36°C temperatures, respectively. Results show that radial growth of 31 *A. brassicae* isolates is influenced by very high and very low temperatures, with optimal growth at 24°C.

Sporulation at different temperatures

The cultures were cultivated at six distinct temperatures to determine the conidial concentration of each isolate. Each isolate of *Alternaria brassicae* showed different sporulation at different temperatures on 10 days after incubation. Sporulation on 10 days of 15 isolates I-6B21, I-6A1y21, II-4II20, UN120, III-3B20, II-6C21, II-7C21, II-8B21, III-6C21, IV-4B21, V-7A20, I-4A21, I-4B21, I-7B21 and III-7B21 was higher at 24^{o}C (range: 20.41 x 10^5/ml–29.50 x 10^5/ml), and among them, the isolate I-6A1y21 showed the highest sporulation (29.50 x 10^5/ml), while the isolate II-4II20 showed the lowest sporulation (20.41 x 10^5/ml). At 24°C, the overall sporulation range of all 31 isolates was 16.50 x 10^5/ml - 29.50 x 10^5/ml. Out of these, isolate I-6A1y21 showed the highest sporulation (29.50 x 10^5/ml), while the isolates IV-5C20 and II-5C20 showed the least sporulation (16.50 x 10^5/ml). The range of sporulation of 31 isolates at 18 °C was 5.5 x 10^5/ml - 12.25 x 10^5/ml; among them, isolate I-6A1y21 showed the highest sporulation (12.25 x 10^5/ml), while the isolates III-1B20 and IV-5C20 showed the least sporulation (5.5 x 10^5/ml). At 30^{o}C the sporulation range of 31 isolates was 11.50 x 10^5/ml - 19.75 x 10^5/ml; among them, the higher sporulation (19.75 x 10^5/ml) was observed in the isolate I-6A1y21 while the least sporulation (11.50 x 10^5/ml) was found in the isolate III-1B20.

The range of sporulation of 31 isolates at 12 °C temperatures was 2.15 x 10^5/ml - 9.25 x 10^5/ml; among these, the isolate I-6A1y21 showed maximum sporulation (9.25 x 10^5/ml), while the isolate IV-6Ay21 showed the least sporulation (2.15 x 10^5/ml). The sporulation range of all 31 isolates at 6 ^{o}C was 1.08 x 10^5/ml - 3.25 x 10^5/ml; among these, isolate I-6A1y21 showed maximum sporulation (3.25 x 105/ml), while the isolate II-4II20 showed the least sporulation (1.08 x 10^5/ml).The range of sporulation of 31 isolates at 36 °C was 1.15 x 10^5/ml–3.95 x 10^5/ml; among these, isolate II-4II20 showed the least sporulation (1.15 x 10^5/ml), while the isolate I-6A1y21 showed maximum sporulation (3.95 x 10^5/ml). The study found that sporulation of all isolates was influenced by very high and very low temperatures, with the highest sporulation at 24°C, moderate at 18°C and 30°C, and least at 6°C, 12°C, and 36°C.

Similar findings were observed by Singh *et al*. (2021), who reported that maximum mycelial growth and sporulation were recorded at 25°C, 30°C, 20°, and 35°C, and a minimum at 40°C temperatures. The present study proved that different temperatures were favorable for the mycelial growth and sporulation of various *A. brassicae* isolates, indicating cultural variation among them.

Radial growth at different pH level

The various isolates of *A. brassicae* showed different rates of radial growth at various pH level**.** Radial growth on 10-days-old cultures of all 31 isolates was higher (range: 37.06 mm - 49.77 mm) at pH 7.0. Among them, isolate I-6A1y21 showed the highest radial

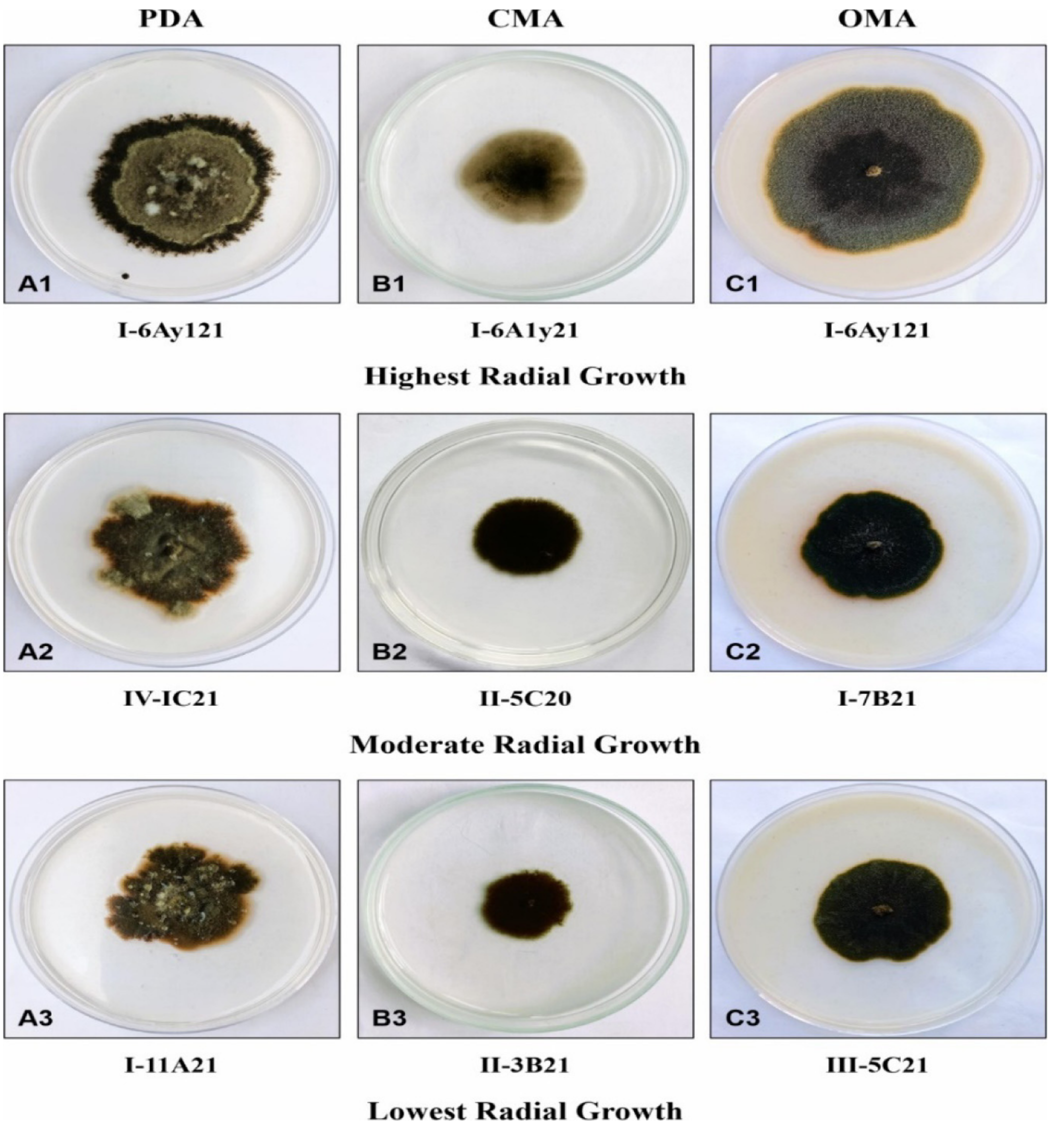

Fig. 3. The effect of culture media on 31 isolates of *Alternaria brassicae*. Of these, A (1) The isolate I-6Ay121 showed the highest radial growth, while C (3) Isolate III-5C21 showed the least radial growth on OMA medium

growth (49.77 mm), whereas the isolate III-3B20 showed the least radial growth (37.06 mm) and at pH 8.0 was from 18.22 mm to 22.76 mm, and among them, isolate I-6A1y21 showed the highest radial growth (22.76 mm), while the isolate I-4B21 showed the least radial growth (18.22 mm). The radial growth range of all isolates at pH 5.0 was from 11.75 mm to 17.26 mm, and among them, the isolate I-6A1y2 showed the highest radial growth (17.26 mm), while the isolate III-6C20 showed the least radial growth (11.75 mm). At pH 6.0 the range of radial growth was from 21.33 mm to 38.34 mm; among 31 isolates, the isolate II-UN120 showed the least radial growth (21.33 mm), while the isolate I-6A1y21 showed the highest radial growth (38.34 mm). All isolates showed radial growth ranging from 16.43 mm to 21.24 mm at pH 9.

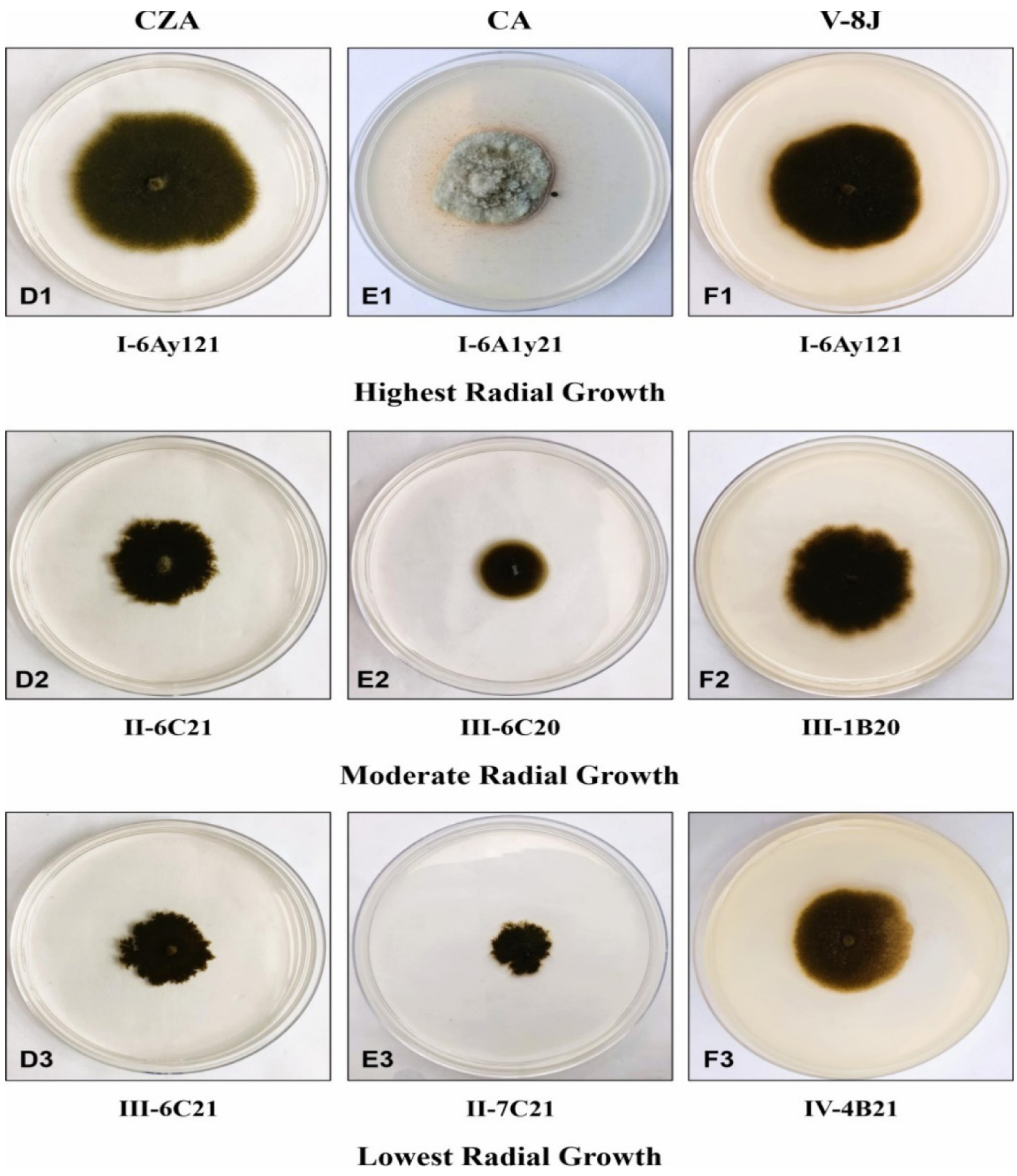

Fig. 4. The effect of culture media was observed on 31 isolates of *Alternaria brassicae*. Of these, — D (1) The isolate I-6Ay121 showed the highest radial growth, while F (3) Isolate IV-4B21 showed the least radial growth on V-8J medium.

Among all of these, only the isolate I-6A1y21 shows more radial growth (22.26 mm), while the isolate IV-IC21 shows the least radial growth (16.43 mm) at pH 9. The radial growth range of all isolates at pH 10 was 8.53 mm to 10.06 mm; the isolate I-6A1y21 exhibits greater radial growth (10.06 mm) among 31 isolates, whereas the isolates I-6B21 and II-2C20 exhibit the least radial growth (8.53 mm). The isolate III-3B20 showed the least average radial growth in all six different pH levels, while the isolate I-6A1y21 showed the maximum average radial growth in all six different pH levels. The pH 7 is more favorable for radial growth of all isolates, while pH 6, 8, and 9 are moderately suitable for radial growth. Above and below a pH of 7, radial growth appears to decrease.

Sporulation at different pH level

The various isolates of *A.brassicae* showed different rates of sporulation at various pH level. Sporulation of all 31 isolates on 10-days-old culture was higher (range:16.66 x10^5/ml -35.50 x10^5/ml) at pH 7.0. Among them, the isolate I-6A1y21 showed the highest sporulation (35.50 x10^5/ml) whereas the isolate III-5C21 showed the least sporulation (16.66 x10^5/ml).The sporulation range of all 31 isolates at pH 8.0 was 10.25 x10^5/ml to 18.15 x10^5/ml and among them, the isolate I-6A1y21 showed the highest sporulation (18.15 x10^5/ml), while the isolate I-1B20 showed the least sporulation (10.25 x10^5/ml). The sporulation range of all 31 isolates at pH 5.0 from 9.58 x10^5/ml – 17 x10^5/ml and among them, the isolate I-6A1y21 showed the highest sporulation (17 x10^5/ml) while the isolate I-1B20 showed the least sporulation (9.58 x10^5/ml). Sporulation of 31 isolates at pH 6.0, the range was from 13.66 x10^5/ml to 27.50 x10^5/ml out of these, isolate I-11A21 showed the least sporulation (13.66 x10^5/ml) while the isolate I-6A1y21 showed the highest sporulation (27.50 x10^5/ml). Among all of these, only isolate I-6A1y21 shows more sporulation (10.08 x10^5/ml and 7.25 x10^5/ml) while the isolates II-5C20 and II-2C20 shows the least sporulation (5.58 x10^5/ml and 1.66 x10^5/ml) at pH 9 and 10, respectively. The isolate II-5C20 showed the least average sporulation in all six different pH levels, while the isolate I-6A1y21 showed the maximum average sporulation in all six different pH levels. The study found that pH 7 is the most suitable for sporulation of all 31 *Alternaria brassicae*, followed by pH 6, with moderate sporulation at pH 5 and 8.

Radial growth on different Relative humidity

The various isolates of *Alternaria brassicae* at different relative humidity showed different rates of radial growth**.** The maximum radial growth occurred at 80-100% relative humidity in all 10-days-old cultures (range: 33.15 mm-46.12 mm), and among them, isolate I-6A1y21 showed the highest radial growth (46.12 mm), while the isolate V-7A20 showed the least radial growth (33.15 mm). At RH 60-80%, the range of radial growth was from 18.30 mm to 24.12 mm. Isolate I-4A21 showed the least radial growth (18.30 mm), while the isolate I-6A1y21 showed the highest radial growth (37.24 mm). All isolates showed radial growth ranging from 11.78 mm to 16.24 mm at RH 40-60%. Among all of these, isolate I-6A1y21 isolate shows more radial growth (16.24 mm), while the isolate I-11A21 shows the least radial growth (11.78 mm). The radial growth range of all 31 isolates at 20-40% was 4.17 mm to 10.25 mm; among all of these, the isolate I-6A1y21 exhibited greater radial growth (10.25 mm) whereas the isolate II-UN120 and the isolate II-4II20 exhibited the least radial growth (4.17 mm). The observation found that the radial growth was more in relative humidity between 80-100%, while the least radial growth was observed in relative humidity between 20-40%.

Sporulation on Relative humidity

The various isolates at different relative humidity showed different rates of sporulation, and the maximum sporulation occurred at 80-100% relative humidity in all 10-days-old cultures (range: 11.58 x 10^5/ml - 34.50 x 10^5/ml). Among these, isolate I-6A1y21 showed the highest sporulation (34.50 x 10^5/ml), while the isolate II-6C21 showed the least sporulation (11.58 x 10^5/ml). At RH 60-80%, the range of sporulation was from 10.50 x 10^5/ml to 23.5 x 10^5/ml; out of these, isolates IV-5C20 and II-

Table 1. Morphological and cultural features of *Alternaria brassicae* isolates (31) collected from different regions of Allahabad Uttar Pradesh

Isolate code	Plant parts	Survey site	Geographical data	Appearance of culture on PDA plates	Hyphae	Conidia			
						Colour	Surface	Shape	Beak
I.1B20	Leaf	Mubarakpurkotwa, PRG	25.4356° N 81.7555° E	Brownish black	Septate and brownish	Dark brown	Rough	Long pear shaped	Long
II.2C20	leaf	Kahimapur,Jhusi PRG	25.4453° N 81.9562° E	Grey compact and light white at the upper surface	Septate and light grey	Light grey	Rough	Long obpyriform	Long
II.UN$_1$20	leaf	Phoolpur,PRG	25.5510° N 82.0884° E	Dark brown and leathery growth	Brown withseptations	Brown	Rough	Elongated pyriform	Long and septate
II-4II20	leaf	Sahso, PRG	25.4848° N 81.9805° E	A light brown, concentric ring at centre with a mild whitish upper surface	septation with brownish	Dark Brown	Mild rough	Long obpyriform	Long and septate
II-5C20	leaf	Babuganj,PRG	25.5214° N 82.0428° E	Brown with fuzzy-type growth	Septate and brown	Brown	Rough	Elongated with pyriform	Long and septate
III-1B20	leaf	Govindpur Naini, PRG	25.3830° N 81.8446° E	Dark brown compact with leathery at the centre	Septate and dark brown	Brown	Rough	obpyriform	Long and septate
III-3B20	leaf	Sarangapur,PRG	25.3494° N 81.8429° E	Brown and sooty growth	Septate and brown	Brown	Rough	Elongated pear-shaped	Long and septate
III-5C20	leaf	Shimra,Ghoorpur, PRG	25.3096° N 81.8156° E	Brown, sooty growth and concentric ring-like structure in culture	Brown and septate	Brown	Rough	obpyriform	Long
III-6C20	leaf	SHUATS,Naini, PRG	25.4120° N 81.8476° E	Brown woolly colony	Brown and septate	Brown	Rough	Obclavate and septate	Long
IV-5C20	leaf	Malakharhar,Soraon, PRG	25.5380° N 81.8261° E	Dark brown colony	Brown and septate	Brown	Rough	obpyriform	Long
V-1B20	leaf	Narayan Daspura, Jhusi,PRG	25.4627°N 81.9475°E	Light brown at the periphery	Brown and septate	Brown	Rough	spatulate	Long
V-2A20	leaf	Chamnpur,Jhusi, PRG	25.4279677°N 81.8980579°E	Brown and fuzzy growth	Brown and septate	Brown	Rough	Club shaped	Long
V-7A20	leaf	Sundripurkla, PRG	25.4142° N 82.0261° E	Grey whitish compact colony growth	Grey and septate	Grey	Rough	Obovate	Long
I-4A21	leaf	Shekhsarwa, PRG	25.25'559°N 81.42'295° E	Brown and Woolly colony	Brown and septate	Brown	Rough	Obovoid	Long
I-4B121	leaf	Sekhsarwa, PRG	25.25'55.9 °N 81.42'29.5 °E	Dark brown with scattered and compact growth	Brown and septate	Brown	Rough	obpyriform	Long

Isolate code	Plant parts	Survey site	Geographical data	Appearance of culture on PDA plates	Hyphae	Conidia			
						Colour	Surface	Shape	Beak
I-6B121	leaf	Barwa, PRG	25.25'55.9^{o}N 81.42'29.5^{o}E	Dark green with a concentric ring	Brown and septate	Green	Rough	Pyriform	Long
I-6A$_1$Y21	leaf	Barwa, PRG	25.25'55.9^{o}N 81.42'29.5^{o}E	Dark brown with scattered and compact growth	Brown and septate	Brown	Rough	Ovate	Long
I-7B21	leaf	Bhagwatpur, PRG	25.4322° N 81.7083° E	Brown with woolly growth and pearl-like structure at centre	Brown and septate	Brown	Rough	obpyriform	Long
I-11A21	leaf	Peepalgaon,PRG	25.4224° N 81.7709° E	Light brown with scrubby dusted colony	Brown and septate	Brown	Rough	obpyriform	Long
II-1B21	leaf	Andhawa, jhusi, PRG	25.4238° N 81.9169° E	Light brown with whitish at the whole periphery	Brown septate	Brown	Rough	Pyriform	Long
II-3B21	leaf	Sherdeeh, jhusi, PRG	25.4549149^{o}N 81.9180762^{o} E	Whitish cottony and compact colony	Light grey septate	Light grey	Rough	Pyriform	Long
II-6C21	leaf	Kaserua,Jhusi, PRG	25.4786699^{o}N 81.9353613^{o} E	Dark brown at the centre with whitish at corner	Brown and septate	Brown	Rough	obpyriform	Long
II-7C21	leaf	Thanpur, sahso, PRG	25.495969^{o} N 82.0101305^{o} E	Greyish compact colony	Grey and septate	Brown	Rough	Club-shaped	Long
II-8B21	leaf	Devnahri,Phoolpur, PRG	25.5068047^{o}N 82.0113325^{o} E	Greyish compact whitish at the centre	Grey and septate	Grey	Rough	Elongated	Long and septate
III-4C21	leaf	MamabhanjaTalab, Naini PRG	25.3706773^{o}N 81.8386209^{o} E	Brown compact and wheel-shaped growth from centre to periphery	Brown and septate	Brown	Rough	Club-shaped	Long
III-5C21	leaf	Bhandra,Naini, PRG	25.356599^{o} N 81.8461002^{o} E	Light grey whitish at the periphery	Grey and septate	Grey	Rough	Club shaped	Long
III-6C21	leaf	Sarangapur,PRG	25.356599^{o} N 81.8461002^{o} E	Brownish and circled growth	Brown and septate	Brown	Rough	obpyriform	Long
III-7B21	leaf	Bigahiya, Ghoorpur, PRG	25.3275513^{o}N 81.8208703^{o} E	Greyish, concentric in centre	Grey and septate	Grey	Rough	obpyriform	Long
IV-IC21	leaf	Teliyarganj, Barud khana,PRG	25.4990823^{o}N 81.8548549^{o} E	Dark brown and compact colony	Brown and septate	Brown	Rough	Club-shaped	Long
IV-4B21	leaf	Phaphamau, Belakachhar,PRG	25.5201477^{o}N 81.8280953^{o} E	Whitish with scrubby dusted colony	Light brown and septate	Light brown	Rough	obpyriform	Long
IV-6AY21	leaf	Morahu, patelbasti, PRG	26.7734286^{o}N 82.6452016^{o} E	Brown compact and smoothy	Brown and septate	Brown	Rough	Club - shaped	Long

The severity of the disease was measured on 0-5 scale as follows:

Table 2. The grade and degree (severity) of infection

S.No.	Grade	The degree of infection
1.	0	Healthy leaves
2.	1	Between 1 to 10% of the leaf surface is infected
3.	2	Between 11 to 25% of the leaf surface is infected
4.	3	Between 26 to 50% of the leaf surface is infected
5.	4	Between 51 to 75% of the leaf surface is infected
6.	5	Mare than 75% of the leaf surface is infected

8B21 showed the least sporulation (10.50 x 10^5/ml), while the isolate I-6A1y21 showed the highest sporulation (23.50 x 10^5/ml). All 31 isolates showed sporulation ranges from 7.33 x 10^5/ml to 16.25 x 10^5/ml at RH 40-60%. Among all of these, only isolate I-6A1y21 showed the highest sporulation (16.25 x 10^5/ml), while the isolate III-5C21 showed the least sporulation (7.33 x 10^5/ml). The sporulation range of all isolates at 20-40% was 1.96 x 10^5/ml to 4.15 x 10^5/ml; among all of them, isolate I-6A1y21 exhibits the highest sporulation (4.15 x 10^5/ml) among all of these, whereas the isolates III-5C21 exhibit the least sporulation (1.96 x 10^5/ml). The RH (80-100%) is the standard scale for sporulation; below this scale, the sporulation gradually decreases. The pathogen produces fewer conidia in lower humidity conditions. The sporulation significantly decreased when RH dropped below 70%, and no sporulation was observed at RH levels below 50 (Thakur, 2024). The previous study supports the present study that *Alternaria brassicae* showed high radial growth and sporulation in relative humidity more than 50% and significantly showed reduction below 50% relative humidity.

Pathogenicity test

It was found that all 31 of the *A.brassicae* isolates showed pathogenic behaviour. Among the 31 isolates, 9 isolates II-UN120, IV-5C20, I-4A21, I-6B21, I-6A1y21, II-8B21, III-6C21, IV-4B21 and IV-6AY21 were found to be high degree of infection as the spot produced by them were more than 10 mm (>10 mm) in diameter. Five isolates I-1B2, I-4B21, II-3B21, II-7C21 and III-7B21 showed least degree of infection as the spot produced by them were 1mm -5 mm in diameter. Seventeen isolates II-2C2, II-4II20, II-5C20, III-1B20, III-3B20, III-5C20, III-6C20, V-1B20, V-2A20, V-7A20, I-7B21, I-11A21, II-1B21, II-6C21, III-4C21, III-5C21 and IV-IC21 were found to be moderately degree of infection as the spot produced by them from 6 mm to 10 mm in diameter.

Table 7 showing pathogenicity test on mustard leaves, a black leaf spot with a yellow halo was evaluated as plus (+), and no symptoms were recorded as minus (-). The three categories for the symptom's appearance were: black spots measuring between 0.2 and 0.5 cm were ranked as single plus (+), 0.6 to 1.0 cm were scored as double plus (++), and spots measuring more than 1 cm were ranked as triple plus signs (+++).

The previous investigation confirmed the finding of current study which showed that the fungal pathogen pathogenicity, hosts, and modes of dissemination is essential for maintaining global biosecurity (Fontaine *et al.*, 2021).

Table 3. Occurance of Alternaria black spot disease on mustard in Allahabad district (from 2019 to 2021)

S.No.	Isolate	Location	variety	Incidence (%)	Severity (%)
1	I-1B20	Mubarapur - Kotwa	Pusa mustard 27 (EJ 17)	25	5
2	II-2C20	Kahimapur - Jhusi	K-88	45	15
3	II-UN$_1$20	Phoolpur	Pusa mustard 26 (NPJ 113)	15	5
4	II-4II20	Sahso	Pusa Double zero -33(PDZ-33)	35	10
5	II-5C20	Babuganj	Narendra Swarna -08	55	20
6	III-1B20	Govindpuram - Naini	Vardhan (RK1481)	70	25
7	III-3B20	Sarangapur	Coral PAC- 432 (Hybrid)	55	35
8	III-5C20	Shimra - Ghoorpur	Coral PAC- 432 (Hybrid)	55	20
9	III-6C20	SHUATS - Naini	Coral PAC- 432 (Hybrid)	45	15
10	IV-5C20	Malak harhar - Soraon	Coral PAC- 432 (Hybrid)	35	10
11	V-1B20	Narayan Daspura-Jhusi	Narendra Swarna -08	45	25
12	V-2A20	Chamnpur - Jhusi	Narendra Swarna -08	60	25
13	V-7A20	Sundripur kla - Hanumanganj	(NRCHB-506)	50	20
14	I-4A$_2$21	Shekhsarwa I	Pusa Double zero -33 (PDZ-33)	45	15
15	I-4B121	Sekhsarwa II	Pusa Double zero -33 (PDZ-33)	70	35
16	I-6B121	Barwa I	Narendra Swarna -08	55	30
17	I-6A1y21	Barwa II	Coral PAC- 432 (Hybrid)	85	50
18	I-7B121	Bhagwatpur	Pusa mustard 25 (NPJ 112)	50	35
19	I-11A21	Peepalgaon	Vardhan (RK1481)	40	25
20	II-1b21	Andhawa - Jhusi	Pusa mustard 25 (NPJ 112)	35	15
21	II-3B21	Sherdeeh - Jhusi	K-88	60	35
22	II-6C21	Kaserua - Jhusi	Pusa mustard 25 (NPJ 112)	55	20
23	II-7C21	Thanpur - Sahso	(NRCHB-506)	65	25
24	II-8b21	Devnahri - Phoolpur	Coral PAC- 432 (Hybrid)	45	30
25	III-4C21	Mamabhanja Talab - Naini	Laha-101 (Type 101)	45	20
26	III-5C21	Bhandra - Naini	Laha-101 (Type 101)	35	25
27	III-6C21	Sarangapur	Laha-101 (Type 101)	55	30
28	III-7b21	Bigahiya - Ghoorpur	K-88	65	25
29	IV-IC21	Teliyarganj - Barud khana	Pusa mustard 26 (NPJ 113)	75	30
30	IV-4B21	Phaphamau - Belakachhar	Pusa Double zero -33(PDZ-33)	70	35
31	IV-6AY21	Morahu	Pusa mustard 26 (NPJ 113)	80	45

Table 4. Comparison of conidial size and septation of *Alternaria brassicae* isolates collected from the different geographical regions of Allahabad district

Isolate code	Conidial Length in µm				Conidial breadth in µm				No. of Transverse septa	No. of vertical septa
	Least length	Median length	Maximum length	Average length	Least breadth	Median breadth	Maximum breadth	Average		
I-1B20	16.8	32.33	39.2	30.6	5.6	8.4	11.2	8.4	3.0	2.0
II-2C20	14.0	34.6	39.2	31.44	5.6	11.2	14	10.5	3.0	1.0
II-UN120	15.5	39.13	44.8	35.2	5.8	10.64	11.2	9.21	3.0	3.0
II-4II20	16.5	42	50.4	38.58	5.8	9.8	11.2	8.9	4.0	2.0
II-5C20	16.8	43.4	50.4	39.48	8.4	10.2	11.2	9.93	4.0	2.0
III-1B20	14.0	39.2	47.6	35.7	5.6	11.2	11.2	9.31	3.0	2.0
III-3B20	22.4	33.6	44.8	34.3	5.6	11.2	14	11.05	6.0	3.0
III-5C20	14.0	33.6	54.6	36.75	5.6	8.4	14	9.33	4.0	2.0
III-6C20	22.4	46.2	53.2	43.05	11.2	14	19.6	14	6.0	2.0
IV-5C20	16.8	39.2	47.6	36.3	8.4	11.2	14	11.2	5.0	1.0
V-1B20	16.8	30.8	39.2	30.4	8.4	9.8	9.8	9.3	3.0	2.0
V-2A20	14.0	44.8	50.4	39.2	2.8	14	14	10.26	4.0	2.0
V-7A20	14.0	37.8	56.6	36.9	6.25	11.2	11.2	9.55	4.0	3.0
I-4A21	20.44	39.2	56	39.41	8.4	11.2	18.2	12.6	4.0	2.0
I-4B21	28	42	72	50.9	8.4	11.2	14	12.6	6.0	2.0
I-6B21	22.4	39.2	67.2	42.7	8.4	16.8	22.4	15.86	6.0	2.0
I-6A1 y21	14	30.8	42	30.1	8.4	11.2	13.72	11.06	3.0	2.0
I-7B21	23.8	44.8	67.2	46.55	8.4	11.2	14	11.2	4.0	3.0
I-11A21	23.8	33.6	44.8	34.65	8.4	14	15.4	12.66	4.0	2.0
II-1B21	26.6	32.2	36.4	32.2	8.4	14	16.8	13.06	3.0	2.0
II-3B21	26.6	42	63	46.9	9.8	10.64	11.2	10.54	5.0	3.0
II-6C21	26.6	28	40	34.65	11.2	12.6	14	12.6	4.0	2.0
II-7C21	21	44.8	72.8	49.35	8.4	11.2	14	11.2	7.0	4.0
II-8B21	25.2	39.2	47.6	38.5	8.4	11.2	16.8	12.13	4.0	2.0
III-4C21	22.4	43.4	53.2	41.05	9.8	11.2	14	11.2	5.0	2.0
III-5C21	16.8	32.2	39.2	31.15	8.4	11.2	12.08	10.56	3.0	2.0
III-6C21	21	25.2	58.8	35	8.4	11.2	14	11.2	5.0	3.0
III-7B21	26.6	44.8	58.8	45.15	8.4	11.2	14	11.2	4.0	2.0
IV-IC21	14	33.6	53.2	34.4	8.4	11.2	12.6	10.73	5.0	2.0
IV-4B21	25.2	33.6	50.4	36.5	5.6	8.4	11.2	8.4	4.0	1.0
IV-6AY21	14	42	44.8	36.05	8.4	11.2	14.0	11.2	4.0	2.0

Table 5. Measurement of radial growth (mm) of *Alternaria brassicae* in different culture media

Isolates	PDA	CMA	OMA	CZA	CA	V-8J
I-1B20	48.35	24.35	47.7	40.8	18.25	39.4
II-2C20	34.51	34.38	41.36	33.25	26.25	36.6
II-UN120	33.31	30.43	69.26	37.63	23.63	48.26
II-4II20	37.35	31.35	56.23	31.25	25.41	37.26
II-5C20	45.35	27.45	38.38	27.23	15.23	39.56
III-1B20	39.31	28.25	53.25	29.43	19.56	38.23
III-3B20	32.28	29.31	39.4	32.56	19.7	41.13
III-5C20	31.35	40.25	53.6	57.56	18.2	41.7
III-6C20	37.31	26.25	63.25	34.25	20.56	47.26
IV-5C20	36.35	26.45	48.45	27.53	31.13	30.63
V-1B20	37.25	25.36	39.25	31.25	15.1	37.76
V-2A20	44.13	24.45	42.13	44.41	22.2	38.56
V-7A20	45.25	17.38	42.46	35.25	14.26	37.56
I-4A21	37.25	23.25	40.53	36.26	20.23	28.43
I-4B21	34.36	17.26	39.63	27.56	16.2	30.56
I-6B21	41.33	22.45	46.46	33.63	14.76	36.26
I-6A1y21	52.35	42.16	71.20	62.66	32.30	49.73
I-7B21	33.23	14.25	40.25	60.33	16.33	37.65
I-11A21	28.28	25.25	46.23	35.56	19.76	36.66
II-1B21	50.25	18.73	46.25	46.6	17.33	38.56
II-3B21	38.25	12.56	44.28	31.2	12.76	28.56
II-6C21	35.31	23.25	54.4	41.2	16.36	37.56
II-7C21	29.35	13.5	46.36	24.56	11.46	29.38
II-8B21	30.25	14.3	41.23	29.26	11.56	36.56
III-4C21	41.35	22.31	43.25	37.43	18.53	39.25
III-5C21	37.61	21.25	37.4	35.63	19.66	41.58
III-6C21	31.58	28.25	45.38	23.33	22.4	45.08
III-7B21	38.35	22.8	42.2	39.56	15.36	40.63
IV-IC21	41.31	23.4	41.2	36.3	19.75	36.36
IV-4B21	37.25	13.26	37.66	24.2	12.26	27.26
IV-6AY21	29.43	25.45	40.7	28.63	15.76	41.4

Table 6. Effect of different culture media in fungal sporulation.

Isolates	Spore concentration (10^5/ml)					
	PDA	CMA	OMA	CZA	CA	V-8J
I-1B20	17.24	8.25	18.25	15.5	5.5	12.5
II-2C20	17.5	7.41	20.5	12.5	6.45	13.25
II-UN120	20.5	8.5	21.25	17.25	5.76	12.4
II-4II20	20.41	6.33	19.5	14.5	4.35	10.58
II-5C20	16.5	7.5	22.5	13.25	4.75	9.25
III-1B20	18.5	7.25	24.5	15.65	6.25	11.85
III-3B20	20.5	8.25	23.5	17.5	4.58	9.95
III-5C20	19.5	7.5	21.41	16.41	6.5	10.65
III-6C20	17.25	9.25	18.5	12.5	7.85	12.63
IV-5C20	16.5	10.5	18.25	10.5	7.15	8.95
V-1B20	16.66	10.33	19.5	13.5	5.25	10.85
V-2A20	19.25	8.5	18.5	13.75	4.15	12.85
V-7A20	23.5	9.25	20.25	18.5	5.65	11.65
I-4A21	22.5	6.5	26.5	16.25	7.35	8.45
I-4B21	28.5	5.5	27.5	20.5	4	11.25
I-6B21	21.5	8.5	26.15	15.5	5.15	14.45
I-6A1y21	29.5	14.5	30.25	23.5	8.25	16.66
I-7B21	24.5	5.25	23.25	14.33	6.55	13.56
I-11A21	18.5	7.25	16.5	13.25	4.5	9.55
II-1B21	18.5	6.55	19.5	12.25	4.45	10.56
II-3B21	17.5	5.25	16.25	14.41	4.5	9.35
II-6C21	21.5	9.75	22.5	16.33	5.55	11.95
II-7C21	22.5	8.25	25.5	17.58	7	7.95
II-8B21	22.5	6.25	25.5	18.5	6	9.95
III-4C21	18.33	9.25	28.25	14.41	5.25	7.33
III-5C21	19.5	9.75	23.5	12.5	6.45	10.61
III-6C21	20.58	8.25	26.5	16.41	5.65	7.75
III-7B21	21.5	8.75	25.5	13.33	6.25	14.55
IV-IC21	19.33	7.45	21.5	14.25	4.35	15.45
IV-4B21	22.5	7.25	23.5	14.33	3.95	8.35
IV-6AY21	18.5	8.5	22.25	11.41	5.65	12.35

Table 7 Pathogenicity test of isolates of *Alternaria brassicae* on mustard

Isolates	Degree of infection	Isolates	Degree of infection
I-1B20	+	I-6A1y21	+++
II-2C20	++	I-7B21	++
II-UN120	+++	I-11A21	++
II-4II20	++	II-1B21	++
II-5C20	++	II-3B21	+
III-1B20	++	II-6C21	++
III-3B20	++	II-7C21	+
III-5C20	++	II-8B21	+++
III-6C20	++	III-4C21	++
IV-5C20	+++	III-5C21	++
V-1B20	++	III-6C21	+++
V-2A20	++	III-7B21	+
V-7A20	++	IV-IC21	++
I-4A21	+++	IV-4B21	+++
I-4B21	+	IV- 6AY21	+++
I-6B21	+++		

CONCLUSIONS

The survey in Allahabad revealed Alternaria leaf blight incidence and severity varying with cultivars, geographical locations, and micro-environmental conditions, ranging from 5 to 50% and 15 to 85%, respectively. The cultural characteristics of 31 *A. brassicae* isolates reveal high variability in conidial length, width, beak length, and septa number *in vitro*. Among the selected culture media, oatmeal agar was found to be the most favourable medium for *A. brassicae* isolates, exhibiting maximum radial growth and spore production. The optimal temperature for *A. brassicae* isolates' growth and spore production is +24°C, with temperature variation significantly affecting growth and sporulation, with significant reductions observed at lower and higher temperatures. The study found that pH variations significantly impacted radial growth and sporulation, with growth increasing at pH 6 and 7 and decreasing at pH 5, 8, 9, and 10. Significant reduction in growth and sporulation was recorded at 20-40% relative humidity. While 40-60%, 60-80% and 80-100%, relative humidity caused increase in growth and sporulation, however the magnitude of sporulation increase varies isolate to isolate.

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PERFORMANCE OF RICE (*Oryza sativa* L.) CULTIVARS AT VARIOUS SPACINGS DURING *KHARIF* SEASON UNDER SOUTHERN ODISHA CONDITION

SUBIR RANA, TRIPTESH MONDAL, TANMOY SHANKAR and TUFLEUDDIN BISWAS

Department of Agronomy and Agroforestry, M. S. Swaminathan School of Agriculture,
Centurion University of Technology and Management,
Paralakhemundi, Gajapati -761 211 (Odisha), India

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ABSTRACT

A field experiment was conducted during *Kharif*, 2023 in split plot design with three replications. Results inferred that out of rice cultivars, V1-Naveen recorded highest plant height (113.3 cm), no. of tillers m^{-2} (292.1) and dry matter accumulation at harvest (1229.4 g m^{-2}). No. of panicles m^{-2} (207.7), length of panicle (25.7 cm), total no. of spikelets $panicle^{-1}$ (146.0), no. of filled grains $panicle^{-1}$ (125.6) and 1000-grain weight (21.4 g) than other two cultivars. Naveen recorded significantly higher grain yield (5.2 t ha^{-1}) than other cultivars due to the achievement of best results of all the yield attributing characters. The spacing of 15 cm × 15 cm recorded the highest plant height at harvest (106.9 cm). Similarly, the significantly higher no. of tillers m^{-2} at 60 DAT (266.4) than other spacings due to lesser competition in utilization of available nutrients as compared to closer spacings and maximum dry matter accumulation at harvest (1094.2 g m^{-2}) were obtained with 15 cm × 15 cm spacing. The maximum panicle length (23.1 cm), total no. of spikelets $panicle^{-1}$ (135.8), no. of filled grains $panicle^{-1}$ (120.7) and grain yield (4.7 t ha^{-1}) were recorded with 15 cm × 15 cm spacing which were significantly higher than other spacing options. Highest panicle length (26.1 cm), number of filled grains $panicle^{-1}$ (128.7) and grain yield (5.5 t ha^{-1}) were recorded when Naveen cultivar was transplanted at 15 cm × 15 cm spacing which was significantly higher than all other combinations.

Keywords: Cultivar, Spacing, Rice, Yield

INTRODUCTION

Rice (*Oryza sativa* L.) is the most widely consumed staple food for more than 60 per cent of the world's human population. Around 90 per cent of the world's rice production is being produced and eaten in Asia (Shankar *et al.,* 2021). India is the 2nd largest rice producing country in the world where rice occupies 45.77 million hectares with a production of 124.37 million tonnes and productivity of 2.72 t ha^{-1} (Economics & statistics Division, DA&FW, GoI., 2021-22). Odisha is one of the leading rice-growing states in India and with an area of 3.84 million hectares, production of 9.52 million tonnes and productivity of 2.48 t ha^{-1} (Economics &

Corresponding Author E-mail i.d: mtriptesh@gmail.com; Part of the M.Sc. thesis submitted to Centurion University of Technology and Management, Paralakhemundi, Gajapati – 761 211 statistics Division, DA & FW, GoI., 2021-22). Rice is a high-calorie food, consisting of approximately 78.2% carbohydrates, 6.8% protein, 0.5% fat, and 0.6% minerals. Over the centuries, rice cultivation has spread across various regions of India, adapting to different climatic and geographical conditions. However, the full yield potential of rice cultivars is often limited by nutrient deficiencies and inadequate nutrient management practices. The selection of the appropriate cultivar, suited to the specific ecological conditions of a region, can be highly beneficial for farmers. Most of today's high-yielding rice cultivars are thermosensitive, meaning their growth periods and phenological phases are significantly influenced by the microenvironment.

Plant spacing determines the plant population in unit area thereby affecting the use efficiency of inputs and grain yield. Plant density is a major input which has a significant role in measuring growth and yield of the crop. Spacing of a crop influences the interception of solar radiation, plant canopy area, dry matter production and growth rate of a crop (Anwar *et al.,* 2011). The closer spacing results in competition among plants for light, water and nutrients which ultimately slows down the growth as well as the grain yield. Optimum plant spacing ensures proper growth of above-ground and underground portions by efficient utilization of solar radiation, nutrients and water resources. Similarly, the tillering habit and formation of spikelets panicle^{-1} also affected by the spacing (Bithy *et al.*, 2020), which is responsible for the production of rice per unit area. So, the spacing should be optimized by keeping in mind the various aspects of crop management. Odisha is a predominantly agrarian state where rice is the staple crop, and introducing high-yielding, disease-resistant, and climate-resilient varieties has helped boost productivity and farmer livelihoods. Varieties such as Naveen, RNR 15048, and Satabdi taken in the study are few among the major varieties growing in Odisha have been significant in terms of yield improvement, economic benefit, adaptability to local conditions, and sustainability. As spacing per unit area is an important management tool with reducing production cost and to get optimal grain yield from suitable rice cultivars, the present study has taken to understand how different spacings affect the growth, yield, and overall performance of major rice cultivars in Odisha.

MATERIAL AND METHODS

An experiment was carried out during *Kharif*, 2023 at M. S. Swaminathan School of Agriculture in Paralakhemundi, Gajapati district, Odisha. During the crop growing season, the weekly mean maximum and minimum temperatures ranged between 31.2° and 35.0°C and between 22.5° and 26.5°C, respectively. The crop received a total rainfall of 884.4 mm. The relative humidity varied from 83.6 to 89.7%. The bright sunshine hours ranged between 5.17 and 11.0 hours. The experimental soil was sandy loam in texture with a pH 6.2 and organic carbon content of 0.3%. Initial available nitrogen, phosphorus, potassium in the soil were 230 kg ha^{-1}, 12.7 kg ha^{-1}, 141.2 kg ha^{-1}, respectively. The experiment was laid out in a split plot design (SPD) with twelve treatment combinations. Main plot treatments were three different cultivars *viz.*, V_1- Naveen, V_2- RNR 15048, V_3- Satabdi and sub plot treatments were four different spacings *viz.*, S_1- 10 cm × 15 cm, S_2- 15 cm × 15 cm, S_3- 20 cm × 15 cm, S_4- 25 cm × 15 cm). Thirty-day old rice seedlings of all three cultivars were transplanted on 4th August, 2023. Two seedlings were transplanted in each hill of all the plots. According to the plan and arrangement, the field was divided into 36 plots, each of 4.8 m × 3 m *i.e.*, 14.4 m^2 area. Recommended dose of NPK @ 80 kg N, 40 kg

P_2O_5 and 40 kg K_2O ha^{-1} were applied. The sources of fertilisers were urea, single superphosphate and muriate of potash. In all the treatments, entire recommended rates of phosphorus and potassium were applied as basal. N was applied in split doses. Half of N was applied at the time of sowing, and the remaining half of N was applied in two equal splits at tillering and panicle initiation.

Crop growth rate (CGR) was calculated at 30-60 DAT in the experiment. CGR is the gain in dry matter production by unit area of rice per unit time expressed as g m^{-2} day^{-1}.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \quad \text{g m}^{-2}\ \text{day}^{-1}$$

Where, W_1 = Dry weight of the above-ground plant parts per unit area at time t_1; W_2 = Dry weight of the above-ground plant parts per unit area at time t_2; t_1 = Time of 1st sampling and t_2 = Time of 2nd sampling

Relative growth rate (RGR) was also calculated at 30-60 DAT in the experiment. RGR represents as g of dry matter produced by g of existing dry matter per unit time and expressed as g g^{-1} day^{-1}.

Where, W_1 = Dry weight of the above-ground plant parts per unit area at time t_1; W_2 = Dry weight of the above-ground plant parts per unit area at time t_2; t_1 = Time of 1st sampling and t_2 = Time of 2nd sampling

$$\frac{\log_e W_2 - \log_e W_1}{t_2 - t_1} \quad \text{g g}^{-1}\ \text{day}^{-1}$$

Growing degree days (GDD) was calculated by using the following formula:

GDD (! day hrs.) = Σ kj $(T_{max.} + T_{min.})/2] - T_{base}$

Where, T_{max} = Daily maximum temperature (°C); T_{min} = Daily minimum temperature (°C); T_{base} = Base temperature of rice which was taken as 10°C; j is initial date of phenological phase of interest; k is last date of phenological phase of interest and Σ is accumulated of starting to ending date of phenological phases.

Heliothermal units (HTU) was measured by using the following formula:

HTU (^{0}C day hrs.) = GDD × Bright sunshine hours

Photothermal units (PTU) was calculated by using the following formula:

PTU (^{0}C day hrs.) = GDD × Day length

Heat use efficiency (HUE) of rice was measured following Shamim *et al.* (2013), for which grain yield of the crop and the GDD from transplanting to physiological maturity were used.

HUE (kg ha^{-1} ^{0}C day $hrs.^{-1}$) = Grain yield/GDD

Heliothermal unit use efficiency (HTUE) of rice was measured by following the formula as per Sreenivas *et al.* (2010), for which grain yield of the crop and the HTU from transplanting to physiological maturity were used.

HTUE ” eld/ HTU

$$CV = \left(\frac{S.Em.}{\text{Mean}}\right) \times 100$$

To calculate the Coefficient of Variation (CV) for the yield attributes

Where:

S.Em. is the Standard Error of the Mean.

Mean is the average value for each yield attribute across the cultivars.

RESULTS AND DISSCUSSION

Growth parameters

The findings (Table 1) showed that the rice cultivar, Naveen expressed significant superiority in the growth parameters *viz.*, plant height at harvest (113.3 cm) (Figure 1A), number of tillers m^{-2} at 60 DAT (292.1), dry matter accumulation (DMA) at harvest (1229.4 g m^{-2}) and crop growth rate (CGR) at 30-60 DAT (11.8 g m^{-2} day^{-1}) in comparison to the other cultivars. The lowest plant height at harvest (98.1 cm), number of tillers m^{-2} at 60 DAT (238.3) and DMA at harvest (961.8 g m^{-2}) were obtained with the cultivar, Satabdi which was significantly lower than other two cultivars. The minimum CGR was recorded with RNR 15048 (9.4 g m^{-2} day^{-1}) which was significantly lower than Naveen and Satabdi. The leaf area index (LAI) at 60 DAT was significantly higher in RNR 15048 (2.5) cultivar than others (Figure 2A) and it was significantly lower in Naveen (2.3) cultivar than others. But the cultivar, Satabdi showed significant superiority in RGR at 30-60 DAT (0.0186 g g^{-1} day^{-1}). RGR at 30-60 DAT was found same in the cultivar, Naveen (0.0149 g g^{-1} day^{-1}) and RNR 15048 (0.0149 g g^{-1} day^{-1}). The maximum DMA under the cultivar, Naveen was probably due to better nutrient utilization efficiency of this cultivar than two other cultivars used in the experiment.

Among the different spacings (Table 1), 15 cm × 15 cm showed significantly higher results of growth parameters *i.e.*, plant height at harvest (106.9 cm) (Figure 1B), number of tillers m^{-2} at 60 DAT (266.4) and LAI at 60 DAT

Table 1: Growth parameters of rice as influenced by the cultivars under different spacings

Treatments	Growth parameters					
	Plant height (cm) at harvest	No. of tillers m^{-2} at 60 DAT	DMA (g m^{-2}) at harvest	LAI at 60 DAT	CGR at 30-60 DAT (g m^{-2} day^{-1})	RGR at 30-60 DAT (g g^{-1} day^{-1})
Mainplot treatments: Cultivars						
V_1 : Naveen	113.3	292.1	1229.4	2.3	11.8	0.0149
V_2 : RNR 15048	104.0	255.9	1011.2	2.5	9.4	0.0149
V_3 : Satabdi	98.1	238.3	961.8	2.5	10.6	0.0186
S. Em. (±)	0.71	1.26	13.08	0.010	0.13	0.0004
C.D. (P=0.05)	2.13	3.79	45.80	0.034	0.45	0.0015
CV (%)	2.34	1.67	4.25	1.45	4.35	8.16
Subplot treatments: Spacings						
S_1 : 10 cm × 15 cm	103.6	257.4	1044.1	2.4	10.3	0.0163
S_2 : 15 cm × 15 cm	106.9	266.4	1094.2	2.5	10.6	0.0157
S_3 : 20 cm × 15 cm	105.7	264.0	1073.2	2.4	10.7	0.0161
S_4 : 25 cm × 15 cm	104.2	260.4	1058.3	2.4	10.7	0.0165
S.Em. (±)	0.38	0.73	9.87	0.004	0.06	0.0001
C.D. (P=0.05)	1.14	2.18	29.65	0.014	0.18	0.0003
CV (%)	1.08	0.84	2.77	0.47	1.69	1.36
Cultivar × Spacing						
S.Em. (±)	0.65	1.27	17.09	0.007	0.10	0.0001
C.D. (P=0.05)	1.95	NS	NS	0.024	0.31	0.0004

Table 1A. Interaction effect between cultivars and spacings on plant height (cm) at harvest

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V_1 : Naveen	V_2: RNR 15048	V_3: Satabdi	Mean
S_1 : 10 cm × 15 cm	112.3	101.7	96.9	103.6
S_2 : 15 cm × 15 cm	114.2	108.0	98.5	106.9
S_3 : 20 cm × 15 cm	113.8	104.5	98.9	105.7
S_4 : 25 cm × 15 cm	112.8	101.9	97.9	104.2
Mean	113.3	104.0	98.1	
S.Em. (±)		0.65		
C.D. (P=0.05)		1.95		

(2.5) in comparison to the other plant spacing treatments though this spacing showed significantly lower RGR at 30-60 DAT (0.0157 g g^{-1} day^{-1}) than all other options. The spacing of 15 cm × 15 cm (1094.2 g m^{-2}) recorded highest DMA at harvest which was statistically *at par* with the spacing of 20 cm × 15 cm (1073.2 g m^{-2}). In case of CGR at 30-60 DAT, 15 cm × 15 cm spacing (10.6 g m^{-2} day^{-1}) recorded statistically *at par* result with 25 cm × 15 cm spacing (10.7 g m^{-2} day^{-1}) and 20 cm × 15 cm spacing (10.7 g m^{-2} day^{-1}) but significantly higher result than 10 cm × 15 cm spacing (10.3 g m^{-2} day^{-1}). The shortest plants at harvest (103.6 cm), number of tillers m^{-2} at 60 DAT (257.4) and LAI at 60 DAT (2.4) (Figure 2B) were obtained with planting distance of 10 cm × 15 cm.

The number of tillers m^{-2} was decreased with the closer spacing because of competition in utilization of available nutrients as compared to wider spacing where more interception of solar radiation and lesser inter-plant competition prevailed as reported by Mohammad *et al.* (2004). LAI was found lower in closer spacing due to limitation of sunlight due to mutual shading effect among the leaves in densely populated plants (Mondal and Puteh, 2013).

Table 1B: Interaction effect between cultivars and spacings on LAI at 60 DAT

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V_1 : Naveen	V_2: RNR 15048	V_3: Satabdi	Mean
S_1 : 10 cm × 15 cm	2.3	2.5	2.4	2.4
S_2 : 15 cm × 15 cm	2.4	2.6	2.5	2.5
S_3 : 20 cm × 15 cm	2.3	2.5	2.5	2.4
S_4 : 25 cm × 15 cm	2.3	2.5	2.5	2.4
Mean	2.3	2.5	2.5	
S.Em. (±)		0.007		
C.D. (P=0.05)		0.02		

Table 1C. Interaction effect between cultivars and spacings on CGR at 30-60 DAT ($g\ m^{-2}\ d^{-1}$)

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V_1 : Naveen	V_2: RNR 15048	V_3: Satabdi	Mean
S_1 : 10 cm × 15 cm	11.0	9.9	10.1	10.3
S_2 : 15 cm × 15 cm	12.3	9.0	10.5	10.6
S_3 : 20 cm × 15 cm	12.1	9.3	10.7	10.7
S_4 : 25 cm × 15 cm	11.8	9.4	11.0	10.7
Mean	11.8	9.4	10.6	
S.Em. (±)		0.10		
C.D. (P=0.05)		0.31		

In case of interaction (Table 1A and Table 1C), highest plant height at harvest (114.2 cm) and CGR at 30-60 DAT (12.3 g m^{-2} day^{-1}) were obtained under the combination of the cultivar, Naveen and planting distance of 15 cm × 15 cm which were statistically *at par* with the treatment combination of the cultivar, Naveen and planting distance of 20 cm × 15 cm where 113.8 cm and 12.1 g m^{-2} day^{-1} were plant height at harvest and CGR at 30-60 DAT, respectively. But LAI at 60 DAT was found highest under the combination of the cultivar, RNR 15048 and planting distance of 15 cm × 15 cm (2.6) which was significantly higher than all other treatment combinations (Table 1B). Maximum RGR at 30-60 DAT was obtained (Table 1D) under the combination of the cultivar, Satabdi and plant spacing of 25 cm × 15 cm (0.0187 g g^{-1} day^{-1}) which was significantly higher than all other treatment combinations.

Phenological dates

The cultivar, RNR 15048 took significantly more no. of days to attain 50% flowering (60.3 DAT) and physiological maturity (82.0 DAT)

Table 1D. Interaction effect between cultivars and spacings on RGR at 30-60 DAT ($g\ g^{-1}\ d^{-1}$)

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V_1 : Naveen	V_2: RNR 15048	V_3: Satabdi	Mean
S_1 : 10 cm × 15 cm	0.0148	0.0149	0.0193	0.0163
S_2 : 15 cm × 15 cm	0.0152	0.0140	0.0180	0.0157
S_3 : 20 cm × 15 cm	0.0151	0.0146	0.0187	0.0161
S_4 : 25 cm × 15 cm	0.0146	0.0161	0.0187	0.0165
Mean	0.0149	0.0149	0.0186	
S.Em. (±)		0.0001		
C.D. (P=0.05)		0.0004		

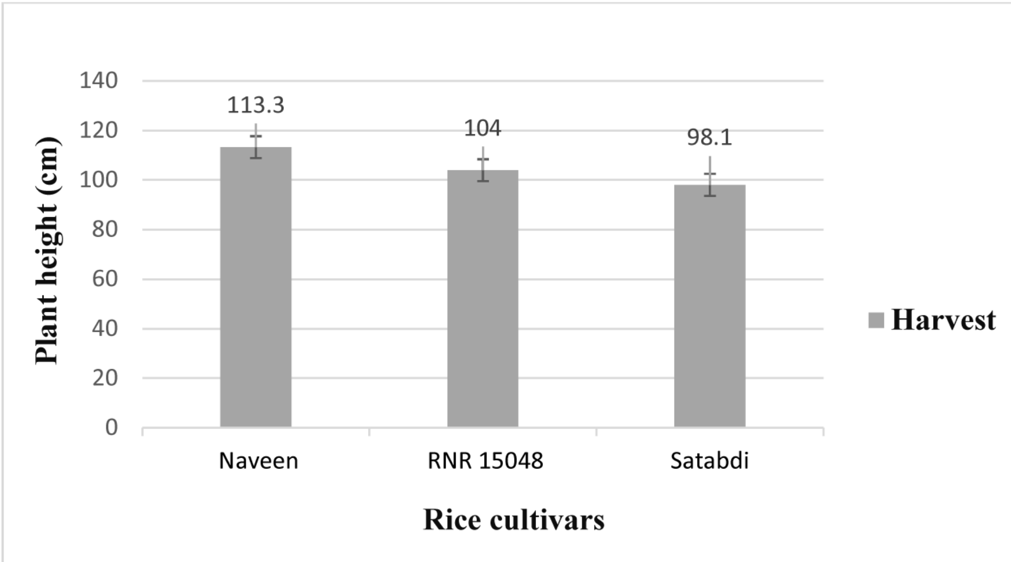

Figure 1A. Plant height at harvest (cm) as influenced by the cultivars

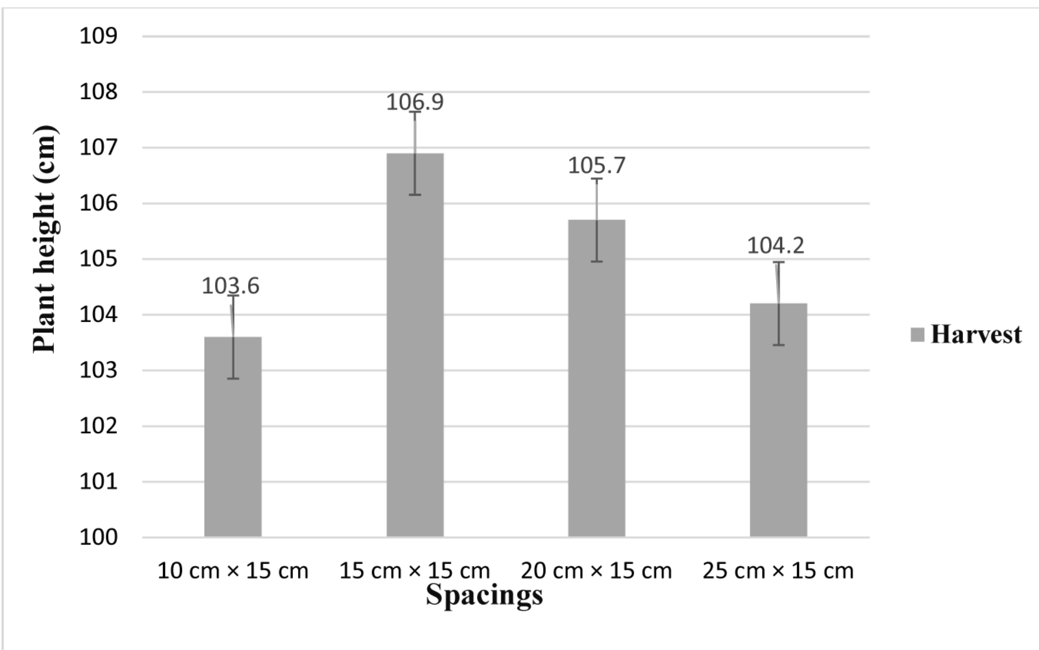

Figure 1B. Plant height at harvest (cm) as influenced by the different spacings

than other two rice cultivars due to its longer growing period *i.e.*, 120-125 days (Figure 3A and Figure 3B). For attaining 50% flowering and physiological maturity, the cultivar, Naveen (56.6 and 78.9 DAT, respectively) which was a cultivar of 115-120 days duration (Patnaik *et al.*, 2008) took statistically similar time period with the cultivar, Satabdi (55.6 and 78.3 DAT, respectively) which was also a cultivar of 120 days duration (ICAR-NRRI, 2000).

Days to 50% flowering was significantly influenced by the different planting spaces and 25 cm × 15 cm of spacing *i.e.*, 26 hills m^{-2} took highest no. of days to attain 50% flowering (58.1 DAT). The no. of days required to attain 50% flowering with the spacing of 15 cm × 15

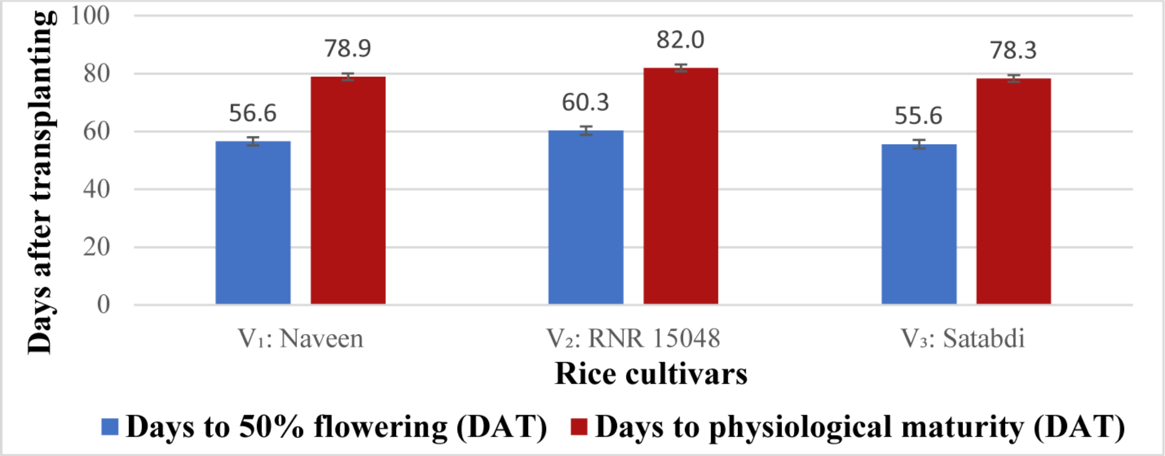

Figure 3A. Days to 50% flowering and days to physiological maturity as influenced by the cultivars

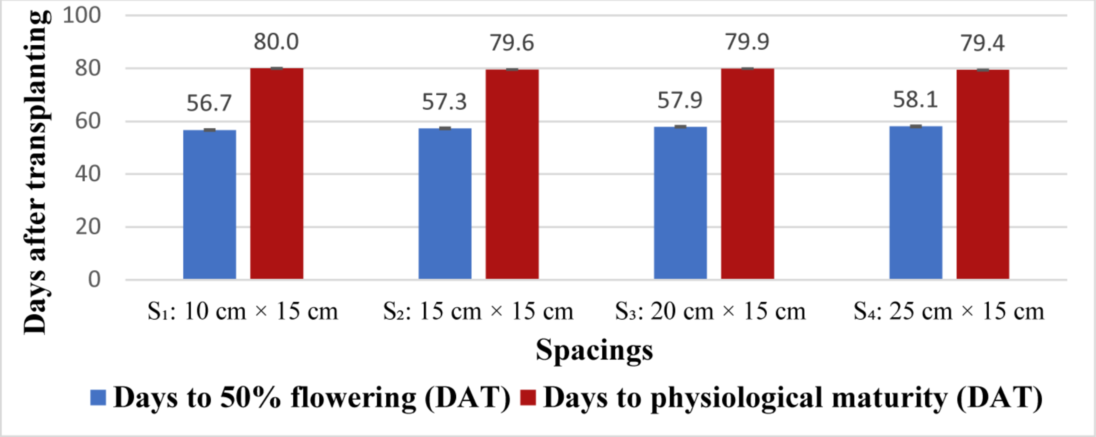

Figure 3B. Days to 50% flowering and days to physiological maturity as influenced by the different spacings

cm *i.e.*, 44 hills m^{-2} (57.3 DAT) and 10 cm × 15 cm *i.e.*, 66 hills m^{-2} (56.6 DAT) were significantly lesser than the earlier one due to less water stress per plant resulted in less elongation of stems and leaves (Nishiuchi *et al.*, 2012) which leads to shorter vegetative phase of rice plants under these two plant spacings than the previously mentioned plant spacing. The spacing of 20 cm × 15 cm *i.e.*, 33 hills m^{-2} (57.9 DAT) taken statistically similar time duration with the spacing of 25 cm × 15 cm for attaining 50% flowering. This result indicated that the similar CGR at 30-60 DAT under these two spacings leads to attain 50% flowering in statistically similar time. The different spacings had no significant impact in the attainment of physiological maturity of rice plants.

Yield attributes

Different rice cultivars had a substantial impact on yield attributes such as the no. of panicles m^{-2}, length of panicle, total no. of spikelets panicle^{-1}, no. of filled grains panicle^{-1} and 1000-grain weight (Table 2). It was observed that the cultivar, Naveen had significantly higher results of all the yield attributing characters (207.7, 25.5 cm, 146.0, 125.6 and 21.4 g were number of panicles m^{-2}, length of panicle, total number of spikelets panicle^{-1}, number of filled grains panicle^{-1} and 1000-grain weight, respectively) than all other cultivars. Significantly higher no. of panicles m^{-2}, panicle length and 1000-grain weight were previously found under the rice cultivar, Naveen than other cultivars (Satapathy *et al.*, 2016). This was mainly due to significantly higher CGR at 30-60 DAT of the rice cultivar, Naveen than others. The minimum panicle length (20.6 cm), total no. of spikelets panicle^{-1} (120.6), no. of filled grains panicle^{-1} (110.5) and 1000-grain weight (18.1 g) were found with the cultivar, Satabdi. But the cultivar, RNR 15048 recorded significantly lower no. of panicles m^{-2} (179.0) than Naveen and Satabdi. Number of panicles m^{-2} were higher in the cultivar, Naveen and Satabdi was mainly due to more CGR at 30-60 DAT than RNR 15048. The higher no. of panicles^{-2} in the rice cultivar, Satabdi than RNR 15048 was also due to more RGR at 30-60 DAT which was in agreement with the previous report of Gill *et al.* (2006).

It was also observed that the yield attributing characters were significantly increased under 15 cm × 15 cm of spacing (23.1 cm, 135.8, 120.7 and 21.4 g were length of panicle, total no. of spikelets panicle^{-1} and no. of filled grains panicle^{-1}, respectively) than all other spacings except number of panicles m^{-2} (197.3) and 1000-grain weight (20.0 g) which were statistically *at par* with the spacing of 20 cm × 15 cm (194.1 and 20.0 g were number of panicles m^{-2} and 1000-grain weight, respectively) (Table 2). But it was not happened under the spacing of 20 cm × 15 cm which indicated the optimum availability of all resources under 15 cm × 15 cm spacing resulted in maximum no. of panicles m^{-2}. 1000-grain weight being a genetic character was not significantly varied by minor variation in row to row spacing. Similarly, spacing of 10 cm × 15 cm (188.1) provided significantly lower no. of panicles m^{-2} than all other spacings. The closer spacing reduced the no. of effective tillers m^{-2} and increased tiller mortality due to scarcity of light, water and nutrient. Hence, lower no. of panicles m^{-2} was obtained (Patra and Nayak, 2001). The minimum panicle length (21.4 cm) and total no. of spikelets panicle^{-1} (130.9) were recorded with the spacing of 10 cm × 15 cm. Poor utilization of growth resources, more intra species competition coupled with lower availability of nutrients among the narrowly spaced crop plants may be ascribed the reason for inferiority in panicle length and total number of spikelets panicle^{-1} of rice (Rasool *et al.*, 2012). The minimum no. of filled grains panicle^{-1} was obtained with the spacing, 10 cm × 15 cm (115.3) which was statistically *at par* with the spacing, 25 cm × 15 cm (116.0). This was due to the fact that no. of filled grain panicle^{-1} is determined by the rate of spikelet differentiation (Li *et al.*, 2021) which was ultimately depended on RGR at 30-60 DAT.

Interaction between cultivar and spacing showed significant response towards number of panicles m^{-2} (Table 2A), panicle length (Table 2B) and number of filled grains panicle^{-1} (Table 2C). Longest panicle (26.1 cm) and maximum no. of filled grains panicle^{-1} (128.7) were obtained with the combination of the cultivar, Naveen and spacing of 15 cm × 15 cm which was significantly higher than all other treatments combinations. But the number of panicles m^{-2} under the cultivar, Naveen at spacing of 15 cm × 15 cm (213.0) was statistically *at par* with the cultivar, Naveen with the spacing of 20 cm × 15 cm (210.7).

Yield and harvest index

Grain yield of rice was significantly higher in the cultivar, Naveen (5.2 t ha^{-1}) than other two cultivars (Table 3). This was due to the achievement of best results of all the yield attributing characters in Naveen. The minimum grain yield was achieved in the cultivar, Satabdi (3.8 t ha^{-1}) which showed the least results of all the yield attributes except no. of panicles m^{-2}. Straw yield was also recorded significantly higher in the cultivar, Naveen (9.2 t ha^{-1}) than

Table 2. Yield attributes of rice as influenced by the cultivars combined with different spacings

Treatments	Yield attributes				
	No. of panicles m^{-2}	Panicle length (cm)	Total No.of spikelets $panicle^{-1}$	No.of filled grains $panicle^{-1}$	1000 -grain weight (g)
Mainplot treatments: Cultivars					
V_1 : Naveen	207.7	25.5	146.0	125.6	21.4
V_2 : RNR 15048	179.0	21.5	133.7	116.1	20.3
V_3 : Satabdi	189.8	20.3	120.6	110.5	18.1
S.Em. (±)	2.08	0.09	0.81	1.30	0.02
C.D. (P=0.05)	7.28	0.32	2.83	4.55	0.07
CV (%)	3.75	1.42	2.09	3.84	0.37
Subplot treatments: Spacings					
S_1 : 10 cm × 15 cm	188.1	21.4	130.9	115.3	19.9
S_2 : 15 cm × 15 cm	197.3	23.1	135.8	120.7	20.0
S_3 : 20 cm × 15 cm	194.1	22.8	134.4	117.6	20.0
S_4 : 25 cm × 15 cm	189.1	22.4	132.6	116.0	19.9
S.Em. (±)	0.98	0.03	0.20	0.27	0.01
C.D. (P=0.05)	3.43	0.10	0.59	0.80	0.03
CV (%)	1.53	0.42	0.44	0.69	0.16
Cultivar × Spacing					
S.Em. (±)	1.70	0.05	0.34	0.46	0.02
C.D. (P=0.05)	5.05	0.16	NS	1.38	NS

Table 2A: Interaction effect between cultivars and spacings on number of panicles m^{-2}

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V_1: Naveen	V_2: RNR 15048	V_3: Satabdi	Mean
S_1 : 10 cm × 15 cm	200.0	178.3	186.0	188.1
S_2 : 15 cm × 15 cm	213.0	184.3	194.7	197.3
S_3 : 20 cm × 15 cm	210.7	181.0	190.7	194.1
S_4: 25 cm × 15 cm	207.0	172.3	188.0	189.1
Mean	207.7	179.0	189.8	
S.Em. (±)	1.70			
C.D. (P=0.05)	5.05			

Table 2B: Interaction effect between cultivars and spacings on panicle length (cm)

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V_2 : Naveen	V_2: RNR 15048	V_3: Satabdi	Mean
S_1 : 10 cm × 15 cm	24.6	20.3	19.4	21.4
S_2 : 15 cm × 15 cm	26.1	22.1	21.0	23.1
S_3 : 20 cm × 15 cm	25.8	21.8	20.7	22.8
S_4 : 25 cm × 15 cm	25.3	21.3	20.4	22.4
Mean	25.5	21.5	20.3	
S.Em. (±)		0.05		
C.D. (P=0.05)		0.16		

Table 2C. Interaction effect between cultivars and spacings on number of filled grains panicle^{-1}

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V_1 : Naveen	V_2: RNR 15048	V_3: Satabdi	Mean
S_1 : 10 cm × 15 cm	122.7	115.3	108.0	115.3
S_2 : 15 cm × 15 cm	128.7	119.3	114.0	120.7
S_3 : 20 cm × 15 cm	126.3	117.0	109.3	117.6
S_4 : 25 cm × 15 cm	124.7	112.7	110.7	116.0
Mean	125.6	116.1	110.5	
S.Em. (±)		0.46		
C.D. (P=0.05)		1.38		

all others. The minimum straw yield was obtained in the cultivar, RNR 15048 (7.4 t ha^{-1}) which was statistically *at par* with the cultivar, Satabdi (7.7 t ha^{-1}) (Table 3). Harvest index of rice was varied significantly due to the various cultivars used in this experiment (Table 3). The cultivar, RNR 15048 recorded highest harvest index (36.4%) which was statistically *at par* with the cultivar, Naveen (35.9%). The cultivar, Satabdi recorded significantly lower harvest index (33.1%) than other two cultivars. This might be due to lower translocation of photosynthates from vegetative part to sink in case of the cultivar, Satabdi.

Spacing, 15 cm × 15 cm provided significantly higher grain yield (4.7 t ha^{-1}) than all other spacings. The higher grain yield with closer spacing was owing to significantly higher no. of panicles m^{-2} (Patra and Nayak, 2001), longer panicle length, more no. of spikelets panicle^{-1}, more no. of filled grains panicle^{-1} and higher 1000-grain weight. Bashir *et al.* (2010) and also reported significant positive correlation between grain yield and panicle

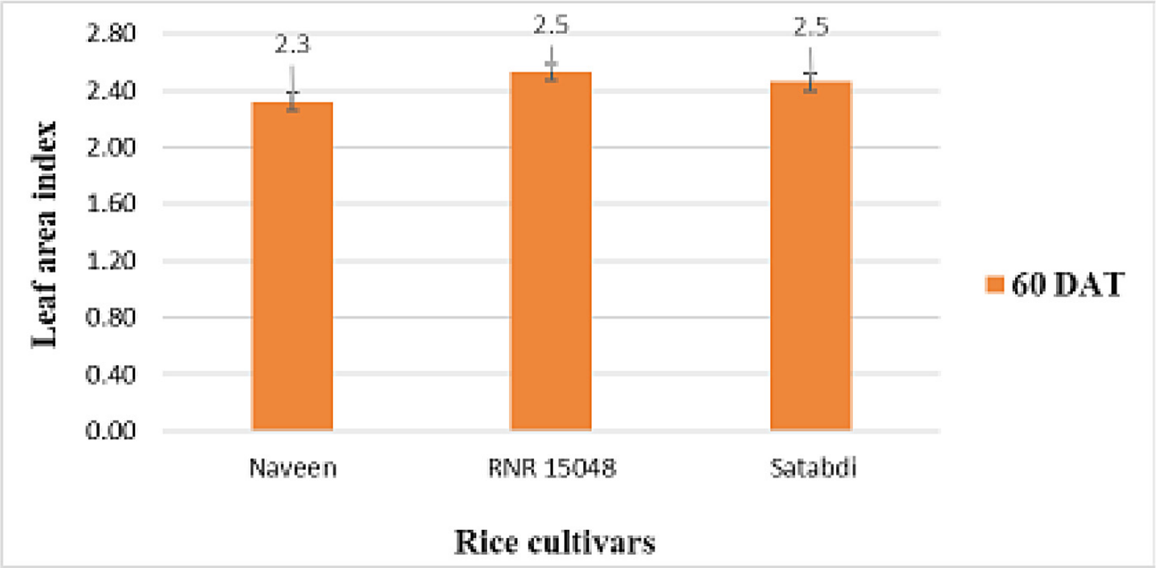

Figure 2A. Leaf area index (LAI) at 60 DAS as influenced by the cultivars

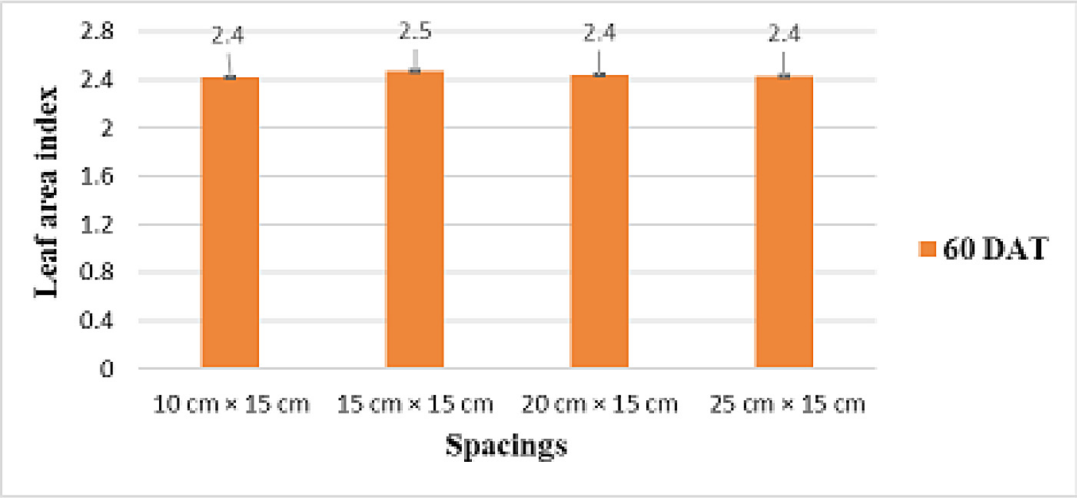

Figure 2B. Leaf area index (LAI) at 60 DAS as influenced by the different spacings

length; grain yield and number of panicles m^{-2}, respectively. The minimum grain yield was found with the plant spacing, 25 cm × 15 cm (4.3 t ha^{-1}) which was statistically *at par* with the plant spacing of 10 cm × 15 cm (4.2 t ha^{-1}). In case of plant spacing, 15 cm × 15 cm recorded significantly higher straw yield (8.4 t ha^{-1}) than 10 cm × 15 cm (7.9 t ha^{-1}) and 25 cm × 15 cm (8.0 t ha^{-1}) but it was statistically *at par* with 20 cm × 15 cm (8.2 t ha^{-1}). The plant spacing of 10 cm × 15 cm and 25 cm × 15 cm recorded statistically *at par* result in respect to straw yield. The harvest index was recorded maximum with the spacing of 15 cm × 15 cm (36.0%) which was statistically *at par* with the spacing of 20 cm × 15 cm (35.3%). The lowest harvest index was recorded with the spacing, 10 cm × 15 cm (34.1%) which was statistically *at par* with the spacing of 25 cm × 15 cm (34.6%). These results were related to achievement of similar straw yield under both the spacing options.

Table 3. Yield and harvest index of rice as influenced by the cultivars combined with different spacings

Treatments	Yield		
	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Harvest index (%)
Mainplot treatments: Cultivars			
V_1 : Naveen	5.2	9.2	35.9
V_2 : RNR 15048	4.2	7.4	36.4
V_3 : Satabdi	3.8	7.7	33.1
S.Em. (±)	0.04	0.11	0.38
C.D. (P=0.05)	0.13	0.35	1.19
Subplot treatments: Spacings			
S_1 : 10 cm × 15 cm	4.2	7.9	34.1
S_2 : 15 cm × 15 cm	4.7	8.4	36.0
S_3 : 20 cm × 15 cm	4.5	8.2	35.3
S_4 : 25 cm × 15 cm	4.3	8.0	34.6
S.Em. (±)	0.01	0.09	0.26
C.D. (P=0.05)	0.03	0.28	0.78
Cultivar × Spacing			
S.Em. (±)	0.02	0.16	0.45
C.D. (P=0.05)	0.06	NS	NS

Table 3A: Interaction effect between cultivars and spacings on grain yield ($t\ ha^{-1}$)

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V_1 : Naveen	V_2: RNR 15048	V_3: Satabdi	Mean
S_1 : 10 cm × 15 cm	4.8	4.1	3.6	4.2
S_2 : 15 cm × 15 cm	5.5	4.5	4.1	4.7
S_3 : 20 cm × 15 cm	5.3	4.3	3.9	4.5
S_4 : 25 cm × 15 cm	5.0	4.0	3.8	4.3
Mean	5.2	4.2	3.8	
S.Em. (±)	0.02			
C.D. (P=0.05)	0.06			

Grain yield was significantly varied due to the interaction between the cultivars and spacings where Naveen combined with 15 cm × 15 cm of spacing showed significantly higher grain yield than all other treatment combinations (5.5 t ha^{-1}) (Table 3A).

Agrometeorological indices, heat use efficiency (HUE) and heliothermal unit use efficiency (HTUE)

The Maximum GDD, HTU and PTU were accumulated (1140.3, 10560.6, 14148.3^0 C day hours were GDD, HTU and PTU, respectively) in the phenophase, transplanting to 50% flowering when the cultivar, RNR 15048 was transplanted with the spacing of 20 cm × 15 cm and 25 cm × 15 cm (Table 4). This finding was obtained because of more thermal energy accumulation as a result of longer vegetative period of RNR 15048 and longer period of this phenophase under wider row spacing. The highest GDD, HTU and PTU accumulated by the cultivar, Satabdi and the plant spacing of 10 cm × 15 cm (435.6, 4062.2, 5080.0 ! day hours were GDD, HTU and PTU, respectively) in the phenological phase, 50% flowering to physiological maturity. This finding supported the fact that Satabdi accumulated maximum thermal energy when transplanted in closer spacing during 50% flowering to physiological maturity as a result of delay in attainment of physiological maturity with closer plant spacing. Senescence of leaves and slower nutrient acquisition rate of plant roots in the post anthesis period resulted in more leaching and volatilization loss as well as lower uptake major nutrients in widely spaced crop which led to earlier attainment of physiological maturity than densely planted crop. On the other hand, Satabdi had slightly longer duration of the phenophase, 50% flowering to physiological maturity than two other cultivars.

The Maximum heat use efficiency (HUE) and heliothermal unit use efficiency (HTUE) were recorded by the cultivar, Naveen under the spacing of 15 cm × 15 cm (0.00377 and 0.00040 kg ha^{-1} ^{0}C day $hrs.^{-1}$ were HUE and HTUE, respectively) (Table 4). This was due to achievement of maximum grain yield of the cultivar, Naveen when transplanted at 15 cm × 15 cm spacing. The efficiencies were recorded minimum for the cultivar, Satabdi under the spacing of 10 cm × 15 cm (0.00247 and 0.00026 kg ha^{-1} ^{0}C day $hrs.^{-1}$ were HUE and HTUE, respectively). This was due to the minimum grain yield of Satabdi when transplanted at 10 cm × 15 cm spacing.

Economics

The cultivation cost of the cultivar, Satabdi was minimum (¹ 45086 ha^{-1}) due to lower market price of seeds than other two cultivars. The planting distance of 25 cm × 15 cm showed minimum cost of cultivation (42776 ha^{-1}) due to requirement of lesser no. of seedlings per unit area than all other planting distances. Cost of cultivation was also minimum when the cultivar, Satabdi was transplanted at 25 cm × 15 cm spacing *i.e.*, V_3S_4 (42745 ha^{-1}) (Table 5). Gross return (114253 ha^{-1}) and net return (68848 ha^{-1}) were found highest when Naveen was cultivated. The probable reason behind this result was Naveen provided higher grain yield than others. Similarly, the plant spacing of 15 cm × 15 cm achieved maximum gross return and net return due to maximum grain yield under this plant spacing option. In case of interaction effect, the cultivar, Naveen when transplanted at the spacing of 15 cm × 15 cm *i.e.*, V_1 S_1 maximum gross and net profit was observed due to achievement of maximum grain yield. In case of benefit-cost (B:C) ratio, the cultivar, Naveen showed best result due maximum proportionate increase in net return with respect to cost of cultivation. The spacing of 15 cm × 15 cm noted highest B:C ratio. Higher proportionate increase in net return with respect to cost of

Table 4. GDD, HTU and PTU at transplanting–50% flowering and 50% flowering-physiological maturity accumulated by the cultivars under different spacings and HUE and HTUE of the cultivars under different spacings

	Transplanting–50% flowering			50% flowering–physiological maturity			HUE (kg ha^{-1} °C day hrs.$^{-1}$)	HTUE (kg ha^{-1} °C day hrs.$^{-1}$)
	GDD (°C day hours)	HTU (°C day hours)	PTU (°C day hours)	GDD (°C day hours)	HTU (°C day hours)	PTU (°C day hours)		
Cultivar- Naveen								
10 cm × 15 cm	1041.8	9723.0	12983.9	433.8	4038.6	5049.2	0.00325	0.00035
15 cm × 15 cm	1041.8	9723.0	12983.9	415.7	3867.2	4843.3	0.00377	0.00040
20 cm × 15 cm	1062.2	9891.9	13225.5	432.1	4015.2	5020.0	0.00355	0.00038
25 cm × 15 cm	1062.2	9891.9	13225.5	395.4	3698.3	4601.7	0.00343	0.00037
Cultivar- RNR 15048								
10 cm × 15 cm	1102.6	10215.2	13703.7	426.6	4019.6	4938.6	0.00268	0.00029
15 cm × 15 cm	1122.0	10400.0	13933.3	407.2	3834.8	4709.0	0.00294	0.00032
20 cm × 15 cm	1140.3	10560.6	14148.3	388.9	3674.2	4494.0	0.00281	0.00030
25 cm × 15 cm	1140.3	10560.6	14148.3	388.9	3674.2	4494.0	0.00262	0.00028
Cultivar- Satabdi								
10 cm × 15 cm	1021.9	9528.0	12747.2	435.6	4062.2	5080.0	0.00247	0.00026
15 cm × 15 cm	1041.8	9723.0	12983.9	415.7	3867.2	4843.3	0.00281	0.00030
20 cm × 15 cm	1041.8	9723.0	12983.9	415.7	3867.2	4843.3	0.00268	0.00029
25 cm × 15 cm	1062.2	9891.9	13225.5	395.4	3698.3	4601.7	0.00261	0.00028

*GDD: Growing degree days; PTU: Photothermal units; HTU: Heliothermal units; HUE: heat use efficiency; HTUE: heliothermal unit use efficiency

Table 5. Economics of rice as influenced by the cultivars planted in different spacings

Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
Mainplot treatments: Cultivars				
V_1 : Naveen	45160	112798	67638	1.5
V_2 : RNR 15048	45159	97485	52327	1.2
V_3 : Satabdi	45086	80369	35284	0.8
Subplot treatments: Spacings				
S_1 : 10 cm × 15 cm	48633	91846	43214	0.9
S_2 : 15 cm × 15 cm	45379	103344	57965	1.3
S_3 : 20 cm × 15 cm	43752	98464	54712	1.3
S_4 : 25 cm × 15 cm	42776	93883	51107	1.2
Cultivar × Spacing				
$V_1 S_1$	48672	105923	57252	1.2
$V_1 S_2$	45405	120253	74848	1.7
$V_1 S_3$	43772	115390	71618	1.6
$V_1 S_4$	42792	109627	66835	1.6
$V_2 S_1$	48670	94733	46063	1.0
$V_2 S_2$	45404	103698	58295	1.3
$V_2 S_3$	43771	98779	55008	1.3
$V_2 S_4$	42791	92731	49940	1.2
$V_3 S_1$	48556	74883	26328	0.5
$V_3 S_2$	45328	86080	40752	0.9
$V_3 S_3$	43714	81223	37510	0.9
$V_3 S_4$	42745	79290	36545	0.9

cultivation under spacing of 15 cm × 15 cm than all others was responsible for this result. The cultivar, Naveen when transplanted in the spacing of 15 cm × 15 cm *i.e.*, $V_1 S_2$ (1.52) and showed highest B:C ratio.

CONCLUSIONS

In this investigation, the combination of cultivar, Naveen with 15 cm × 15 cm spacing and cultivar, Naveen with 20 cm × 15 cm spacing provided statistically *at par* results of plant height at harvest, CGR at 30-60 DAT, no. of panicles m^{-2}. Transplanting of Naveen cultivar at 15 cm × 15 cm spacing also provided significantly superior results of panicle length (26.1 cm), no. of filled grains $panicle^{-1}$ (128.7) and grain yield (5.5 t ha^{-1}). The interaction of Naveen with 15 cm × 15 cm spacing showed highest HUE (0.00377 kg ha^{-1} ^{0}C day $hrs.^{-1}$), HTUE (0.00040 kg ha^{-1} ^{0}C day $hrs.^{-1}$), gross return (□ 120253 ha^{-1}), net return (□ 74848 ha^{-1}) and B:C ratio (1.7). It can be concluded that transplanting of the rice cultivar, Naveen at 15 cm × 15 cm spacing is a better option for transplanted *Kharif* rice cultivation in southern Odisha to achieve higher yield and profit. Further research is required to find out the impact of transplanting of Naveen at 15 cm × 15 cm spacing with three or more seedlings hill^{-1}.

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PROXIMATE AND CELLWALL COMPOSITION OF SUPER NAPIER GRASS (*PENNISETUM PURPUREUM*) HARVESTED AT DIFFERENT GROWTH STAGES

A. KAVYA and G. NAGI REDDY

Department of Animal Nutrition, C. V. Sc,
Sri Venkateswara Veterinary University, Tirupati, A.P-517502.

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ABSTRACT

The investigation was conducted to find out and compare the proximate composition of Super Napier grass harvested at different growth stages which were 45 days, 60 days and 75 days during the months of January and February, 2022. The plant samples were collected at fodder unit of LFC, CVSc, Tirupati. Then, the samples were dried and ground before being analyzed for proximate composition (Moisture, Ash, Crude protein, Crude fiber, Ether extract and Nitrogen free extract) and fibre fractions (Neutral detergent fibre, Acid detergent fibre, Hemicellulose, Cellulose and Acid detergent lignin). Results of the present study indicated that, increasing the cutting interval (*i.e.,* advancing age of maturity) increased drymatter and nutrient yields significantly ($P < 0.05$). In terms of nutrient content, it also increased the per cent of crude fiber (23.5, 27.1 and 30.2), acid detergent fiber (39.22, 40.08 and 41.32), neutral detergent fiber (67.12, 71.01 and 73.84), Hemicellulose (27.9, 30.93 and 32.52), Cellulose (33.52, 35.7 and 37.11) and acid detergent lignin (5.12, 5.94 and 6.62) in the plant. However, per cent of crude protein (9.78, 8.32 and 7.05) and ash (11.92, 9.56 and 7.99) was markedly decreased as the cutting interval increased. Therefore, the Super Napier at 45 days age growth is the best for harvesting which provides high nutritive value of the animal feed.

keywords: Cell – wall fractions, Growth stages, Proximate composition,Super Napier grass

INTRODUCTION

India has the highest number of livestock (536.76 million) in the world and the population of buffalo, cattle, sheep, and goat is 109.85, 193.46, 74.26 and 148.88 millions, respectively (20^{th} Livestock census, 2019). Fodder is an essential component for livestock production, its demand increases with increasing population of livestock. For ages usually constitute the major portion of the ruminant feeds and high quality nutritious green fodder is required to realize the productive potential of ruminants in our country. The critical constraint in profitable animal production in developing countries is the inadequacy of quality forage. Currently, India is facing a net deficit of green fodder by 35.6%, dry fodder (straw) by 10.95% and concentrates by 44% (Kushwaha *et al*., 2018).

CorrespondingauthorEmail : arekatlakavya@gmail.com

Deficiency of quality fodder and feed for livestock leads to decrease in production level, and has impact on their health, which ultimately influences return from livestock sector. There are many alternatives to overcome the shortage of quality forage and one among them is the introduction of high yielding forage varieties. Napier grass (*Pennisetum purpureum*) is currently the most popular fodder grass in dairy and feedlot production systems due to high productivity and good nutritive value. The Napier grass also known as Elephant grass is a species of perennial grass which is native to sub-tropical Africa. The Napier grass provides a high phytomass in most tropical and sub-tropical climates and well-known grassas a livestock fodder (Kebede *et al.,* 2016).

Hence, the Department of Livestock Development in Thailand has come out with a new hybrid Napier called Super Napier developed by Dr. Krailas Kiyothong, an animal nutritionist and plant breeder, by crossing *Pennisetum purpureum* (the ordinary Napier grass) and *Pennisetum glaucum* (better known as Pearl Millet). Super Napier grass is an improved fodder grass, that is highly nutritious, easy to grow, more adaptable and productive which is suitable for Indian conditions. It is smooth, juicy and very consumable grass, high in moisture content, making this grass as one of the preferred ingredients for animal food producers (Lounglawan *et al*., 2014). It has large, thick leaves that are dark green and the blades of the leaves were serrated, and the leaf margins are slightly hairy. This is the fast-growing perennial grass that can group up to 6-8 feet height, which typically takes about 60 days to reach the full height. Super Napier can be harvested multiple times throughout the growing season.

Selecting the right fodder grass species is most important for cultivation and must take into consideration the yield, digestibility and chemical composition of the grass. Proximate analysis provides meaningful information and also helpful in assessing the samples quality. It was reported that the Napier grass has a good nutritive value as well as the chemical compositions (Lounglawan *et al.,* 2014). However, chemical composition of forages is highly variable and affected by type of species, variety, soil composition, climate, and season, stage of growth and application of manure. According to Lounglawan *et al*., (2014), a young plant is characterized by their high protein content, ether extract, and ash, while the maturing plant have high of crude fiber content.

The main objective of the study is to analyze and compare the proximate composition and cell-wall fractions of super Napiergreen fodder harvested at different growth stages which were 30 days, 45 days and 60 days.

MATERIAL AND METHODS

Location of Study

Study was conducted at College of Veterinary Science, Tirupati.Tirupati has a tropical wet and dry climate and the temperature during the experiment period ranged from 28! to 32! and relative humidity ranged from 66 to 74%. Rainy season usually starts in July and ends in September, while the summer season begins in March and ends in June, whereas winter occupy from October to February. The geographical location of experimental site was 79.42°E longitude and 13.65 N latitude.

Procurement of Green Fodder

The green fodder (Super Napier) was procured from the fodder unit of Livestock Farm Complex (LFC), College of Veterinary Science, Tirupati during January and February of year 2022. First cut was done on 90th day of plantation. Subsequently, the fodder was

Figure 1

Figure 2

Figure 3

harvested on 45th, 60th and 75th day (Figure 1, 2 and 3, respectively) and evaluated for proximate analysis and fiber fractions. Fodder was harvested on 45th, 60th and 75th day by cutting the stubble 5 cm above the ground level using knife, and fresh stems and leaves were then put in zipper plastic bags and transferred for further analysis.

Sample Preparation

The fodder samples were detached from plastic bags and washed with deionized water to remove soil and dust particles. Then, the sample was chopped into small pieces and was dried in an oven at 60°C for 48 hours. The dried samples were ground in a hammer mill (2 mm screen) and were kept in the zip lock plastic bag and stored under cool and dry conditions at room temperature. Thereafter, the samples were analyzed for proximate composition and fibre fractions.

ANALYTICAL TECHNIQUES

Proximate Analysis

The method was used for the analysis of crude protein (CP), crude fibre (CF), moisture content, ether extract (EE), total ash and NFE content. Proximate components were determined based on themethod of AOAC (2012).

Determining the Moisture Content

For determining the moisture, 200 g of Super Napier grass sample was taken and chopped into short length (2-5 cm). The samples were then placed in an oven at 60-80 °C for 24-48 h (AOAC, 2012). The loss in weight after drying is the moisture content

Determining the Drymatter Content

The amount of dry matter was calculated by using the formula given below. % Drymatter = 100 – Moisture Content.

Determining the Crude Protein Content

Crude protein was assessed by weighing 0.5g sample in the Kjeldahl flask and digested it with sulphuric acid with added digestion mixture and the total organic nitrogen is converted to ammonium sulfate. Ammonia is formed and distilled into boric acid solution under alkaline conditions. The solution was thentitrated with 0.1 N sulphuric acid until light pink color appeared. The amount of protein is measured by the amount of acid used and obtained nitrogen content was multiplied with a factor of 6.25 to obtain crude protein content.

Determining the Crude Fibre Content

It was determined by boiling the sample with 1.25% of diluted sulfuric acid followed by

1.25% of sodium hydroxide. Taken 2g sample in a beaker and added 125 ml of 1.25% sulfuric acid. The sample was boiled for 45 mins, cooled and filtered by using muslin cloth. The material was washed 3 times by using distilled water and then transferred in to the beaker and again 125 ml of 1.25% sodium hydroxide was added, boiled for 45 minutes, cooled and then filtered to obtain residues of the sample. The material was then again washed three by distilled water and dried by putting it in to the oven, cooled and record the weight. The difference between the weights of the sample was the crude fiber content.

Determining the Crude Fat or Ether Extract Content

About 2 g of dried sample was extracted with petroleum ether (80^0 C) in Soxhlet apparatus to remove the ether soluble components present in it. The material was then dried to a constant weight in an oven at 105^0C and record the weight to determine the fat content.

Determining the Total Ash Content

The ash component was determined by igniting 5-10 g of grass sample in a muffle furnace at 500 °C for 3 h to burn all the organic content. The residue after burning in the furnace is the ash which contain in organic matter. Ash content was determined by using formulae given below.

Ash % = (weight of ash × 100) / weight of sample

Determining the NFE Content

Nitrogen Free Extract (NFE) is actually not a determined value, but a calculated value. NFE was calculated by the formula given below.

NFE (%) = 100 - (% Crude protein + % Total ash + % Ether extract + % Crude fiber)

Van Soest Analysis

The fibre fractions (NDF, ADF, Hemi cellulose, Cellulose and ADL) were determined according to the procedures given by Van Soest *et al.* (1991).

Statistical Analysis

One-way Variance (ANOVA) was used to analyze the data in order to determine significant differences in proximate composition and fibre fractions harvested at different growth stages (45^{th} day, 60^{th} day and 75^{th} day) of Super Napier by using version 23.0; SPSS (2015) statistical software. The value of $p < 0.05$ was considered a significant difference.

RESULTS AND DISCUSSION

Proximate Composition

Proximate composition of Super Napier grass at different growth stages has a considerable effect on the percentage content of all components measured as shown in Table 1. The crude fiber percentage increased linearly ($P < 0.05$) with increase in age of the fodder grassfrom 45 days to 75 days. While the percentage of moisture, ash, crude protein and crude fat decreases ($P < 0.05$) with increase in age of fodder.The dry matter content depicts the actual amount of nutrients present in the fodder. Results in the present study revealed that the DM of forage harvested at 45, 60 and 75 days of growth was 20.03, 22.19 and 24.85%, respectively. The DM content of fodder increased linearly ($P < 0.05$) with delay in day of harvest. This agrees with the results of Lounglawan *et al*. (2014), who reported a progressive increase in DM content with the advancement of maturity of fodder (13.37% at 30 days to 18.39% at 60 days) in Napier grass.

The CP content of fodder harvested at 45, 60 and 75 days of growth was 9.78, 8.32

Table 1. Proximate composition of Super Napier harvested at different growth stages

Nutrient	Days of harvest		
	45	60	75
Dry matter (%)	20.03±0.99[c]	22.19±0.81[b]	24.85±0.92[a]
Organic matter (%)	88.08±1.01[c]	90.44±1.11[b]	92.01±1.23[a]
Crude protein (%)	9.78±0.52[a]	8.32±0.33[b]	7.05±0.42[c]
Crude fibre (%)	23.5±0.33[c]	27.1±0.23[b]	30.2±0.20[a]
Ether extract (%)	2.52±0.11[a]	2.27±0.10[b]	1.97±0.22[c]
Nitrogen free extract (%)	52.1±0.63[c]	52.78±0.52[b]	52.99±0.61[a]
Total ash (%)	11.92±0.32[a]	9.56±0.41[b]	7.99±0.27[c]

Figures in a column followed by the same letters are not significant at P=0.05 level of significance.

Table 2. Cell-wall fractions of Super Napier harvested at different growth stages

Nutrient	Days of harvest		
	45	60	75
Neutral detergent fibre (%)	67.12±1.20[c]	71.01±1.23[b]	73.84±0.52[a]
Acid detergent fibre (%)	39.22±0.60[c]	40.08±0.66[b]	41.32±0.75[a]
Hemicellulose (%)	27.9±0.20[c]	30.93±0.27[b]	32.52±0.25[a]
Cellulose (%)	33.52±0.05[c]	35.7±0.03[b]	37.11±0.02[a]
Acid detergent lignin (%)	5.12±0.04[c]	5.94±0.06[b]	6.62±0.03[a]

Figures in a column followed by the same letters are not significant at P=0.05 level of significance.

and 7.05%, respectively. The decrease in CP content with growth advancement of the fodder in the study is in comparison with observations made by Lounglawan *et al.* (2014) and Jagadeesh *et al.* (2017) in Napier grass varieties. As one would expect, the crude fat of Super Napier grass decreased with increase in maturity of fodder. Similar observations of progressive decrease in EE content with advancement of maturity of fodder were made by Lounglawan *et al.* (2014) and Jagadeesh *et al.* (2017).

The crude fibre content of forage increased ($P < 0.05$) as the age of fodder get advanced. Lounglawan *et al.* (2014) and Jagadeesh *et al.* (2017) also reported similar progressive increase in CF content with advancement of maturity of fodder in Napier grass varieties.

The ash content of the grass showed a significant differenced ($P < 0.05$) pattern, as the age advances. The mean value of ash at 45 days of age was higher (11.92%) compared to cutting interval of 60 days (9.56%) and 75 days (7.99%). Lounglawan *et al.* (2014) who reported similar findings that ash content gets decreased as the cutting interval increased. In general, higher ash content is indicative of higher minerals in the plants. In the present study, as the ash content was significantly higher ($P < 0.05$) during 45 days of harvest, proportionately the mineral content was also expected to be higher in early cut than in the late cuts.

Cell-wall Fractions

The cell wall compositions of fodders (per cent on DMB) are summarized in Table2. The NDF and ADF are most common measure of fibre used for animal feed analysis; it measures the structural components viz., hemicellulose, cellulose, lignin and pectin in plant cells.

In the study, the per cent NDF, ADF, Hemicellulose, Cellulose and Lignin contents of fodder increased progressively ($P < 0.05$) as the age of the supernapier fodder grass advances. These results were in agreement with the results of Lounglawan *et al.* (2014) and Jagadeesh *et al.* (2017) in Napier grass varieties, who reported that the cell wall constituents increases with advancement in age. As the fodder matures, forage quality declines because of translocation of soluble carbohydrates from the stem and leaves to the inflorescence, leading to increase in the relative proportion of lignified cell-walls in the leaves and stems.

CONCLUSIONS

The cutting interval had a marked effect on the chemical composition. Super Napier grass harvested at 45 days age has better nutrient content in terms of more crude protein content and less cell-wall fractions. This finding is useful as baseline data that provides information on Super Napier's nutritional composition grown at a particular cropping site.

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PROCESS OPTIMISATION AND QUALITY EVALUATION OF INSTANT CUSTARD POWDER INCORPORATED WITH RESISTANT STARCH FROM GRAND NAINE BANANA

SRUTHY. P. M, SHARON. C. L, SEEJA THOMACHAN, A. N. JYOTHI, ANEENA E. R, AND LAKSHMY P. S.

*Department of Community Science, College of Agriculture, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala-680 656

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ABSTRACT

The research aimed (2023-2024) to create an instant custard powder utilizing resistant starch derived from the Grand Naine banana.The process involved peeling, slicing, drying, and powdering mature banana at 50!, followed by isolating starch from banana flour using a modified water-alkaline extraction method. Isolated starch was modified by autoclaving at 121! for 30 minutes with a moisture content of 10 per cent. Custard powder was prepared by incorporating resistant starch at different levels with corn flour and other suitable ingredients (T_0- T_6). Custard were formulated using these treatments and subjected to organoleptic evaluation. The most effective 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 custard (T_4), which were prepared by blending resistant starch (20 %), corn flour (15 %) and other ingredients (65 %). The nutritional composition of the selected custard powder included moisture (6.25 %) carbohydrate (63.64 g $100g^{-1}$), starch (54.95 %), resistant starch (14.64 %) and *in vitro* digestibility of starch (45.2 %). The formulated custard powder containing banana resistant starch resulted in slowly digestible starch characteristics, accomplishing this without significantly affecting the sensory qualities.

Keywords: Banana starch, Custard powder, Grand Naine banana, Organoleptic and nutritional qualities, Resistant starch

INTRODUCTION

Banana is considered to be amongst the most significant fruit crops cultivated in India. Termed as Kalpatharu, signifying a plant with diverse uses, it holds the distinction of being the earliest fruit referred to as the 'Apple of Paradise'. The Grand Naine banana stands out as a renowned Cavendish banana cultivar, well-recognized for its productivity. This particular cultivar is well-known for its abundant yield and is widely favoured in India. It makes a substantial impact on India's position as the leading banana producer globally, with an annual output of around 33 million tons. Its moderate stature and generous fruit production make it highly suitable for commercial agricultural purposes (NRCB, 2023).

Corresponding Author E-mail i.d: Sruthy-2020-24-006@student.kau.in; Part of the Ph.D thesis submitted to Kerala Agricultural University, Thrissur-680586

Banana starch, derived from green banana, is a type of resistant starch that resists digestion in the small intestine and reaches the large intestine intact. The resistant starch content of green banana makes it a valuable prebiotic food. This resistant starch is not digested in the small intestine but is fermented in the large intestine. The consistent consumption of unripe banana flour, which boasts a high starch content, can offer diverse health advantages to individuals. Consequently, unripe banana flour has been employed as a functional component in food products (Zhang *et al.,* 2005).

Starchbased custard flour is commonly used to make a smooth and creamy gruel or paste by dissolving it in water and boiling it. The gelling capability and consistency of custard are attributed to corn starch, traditionally used as the main ingredient. However, corn starch is a high-energy food with a high glycemic index, making it less suitable for health-conscious individuals (O-Salami *et al.,* 2019). Consequently, there is a need to enhance the nutritional profile of custard to better cater to these individuals. One promising strategy is to partially substitute corn starch with health-promoting ingredients, such as green banana resistant starch, in the development of custard.

MATERIAL AND METHODS

The research was carried out between 2023 - 2024 at the Department of Community Science, College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur. For this study, a fully mature Cavendish variety (AAA) (Grand Naine) was procured from the Banana Research Station, Kannara, of Kerala Agricultural University. All other ingredients required for the study were purchased from the local market.

Preparation of banana flour

The fresh banana variety were washed and peeled. It was sliced to an average thickness of 1 cm. The slices were dried at 50°C for 8 hrs in a hot air oven. The dried chips were ground and sieved to obtain a uniform flour.

Isolation of starch from banana flour

Starch was isolated from the banana flour by a modified water-alkaline extraction process suggested by Vasanthan (2001). The powdered banana is then blended with water to form a paste. Additional water, in a ratio of 1:10, was added to the paste after grinding. A small amount of sodium metabisulphite, precisely 0.01%, is incorporated into the mixture. This mixture was then allowed to settle for 5-8 hours.

Table 1. Treatments for the formulation of custard powder

Sl.No	Treatments	Combinations
1	T_0	35 % CF + 65 % OI
2	T_1	35 % BRS +65 % OI
3	T_2	30 % BRS + 5 % CF + 65 % OI
4	T_3	25 % BRS + 10 % CF + 65 % OI
5	T_4	20 % BRS + 15 % CF + 65 % OI
6	T_5	15 % BRS + 20% CF + 65 % OI
7	T_6	10% BRS + 25 % CF + 65 % OI

BRS – Banana resistant starch, CF-Corn flour, OI-Other ingredients

Table 2. Mean score for organoleptic evaluation of Grand Naine banana RS incorporated custard

Sl.No	Parameters	T_0	T_1	T_2	T_3	T_4	T_5	T_6	Kendall's W
1	Appearance	8.73 (6.55)	7.77 (2.50)	7.78 (2.55)	8.05 (3.23)	8.28 (4.63)	8.20 (4.33)	8.18 (4.23)	0.474**
2	Colour	8.78 (6.50)	7.42 (2.00)	7.70 (2.95)	7.72 (3.00)	8.18 (4.73)	8.00 (4.50)	7.98 (4.33)	0.533**
3	Flavour	8.63 (6.25)	7.51 (2.30)	7.77 (3.48)	7.81 (3.30)	8.10 (4.40)	8.07 (4.38)	7.95 (3.90)	0.368**
4	Texture	8.68 (6.45)	7.45 (1.88)	7.75 (2.93)	7.80 (2.85)	8.47 (5.80)	8.12 (4.23)	8.00 (3.88)	0.623**
5	Taste	8.68 (6.38)	7.87 (2.88)	7.88 (2.88)	7.91 (3.08)	8.25 (4.83)	8.12 (4.00)	8.10 (3.98)	0.381**
6	Overall acceptability	8.63 (6.60)	7.52 (2.23)	7.62 (2.60)	7.65 (2.78)	8.22 (5.33)	8.02 (4.50)	7.90 (3.98)	0.608**
	Total mean rank score	8.68	7.59	7.74	7.82	8.25	8.08	8.01	

The figures in parenthesis indicate the mean rank scores based on Kendall's coefficient of concordance (W), (** significant at 1 % level)

Following the settling period, the mixture was filtered through a double layer of cheese cloth. The filtered mixture was subsequently washed multiple times with water. Finally, the resulting slurry was dried using hot air oven at 60^{0}C for 12 hours.

Processing of isolated starch

The isolated starch was modified by autoclaving at 121! for 30 minutes with a moisture content of 10 per cent. The mixture was cooled to room temperature and stored at 4! for 24 h. After three cycles of autoclaving and cooling, the sample was dried and ground into fine particles.

Standardisation of custard powder

Instant custard mix powder was standardised by incorporating corn flour, milk powder, modified banana resistant starch (BRS) and other suitable ingredients such as milk powder (15 %), sugar (40 %), cashew nuts (4 %), salt (1%), desiccated coconut (4%) and vanilla essence and permitted yellow orange food colour (1%).The treatments adopted for standardisation are given below.

Organoleptic evaluation

The sensory evaluation of the prepared banana RS custard was conducted using a nine-point hedonic scale. A panel of 20 judges assessed six sensory parameters, including appearance, colour, flavour, texture, taste, and overall acceptability. The best treatment was determined based on organoleptic mean scores and selected for further studies alongside the control.

Nutritional properties of custard mix

The nutritional properties, such as moisture, carbohydrate, starch, resistant starch and *in vitro* digestibility of starch of best selected banana resistant starch custard powder were evaluated along with those of the control.

Statistical analysis

The data were analysed during the year 2023-2024 using appropriate statistical methods such as the best treatments were selected. The mean scores and mean rank scores were statistically analysed by applying

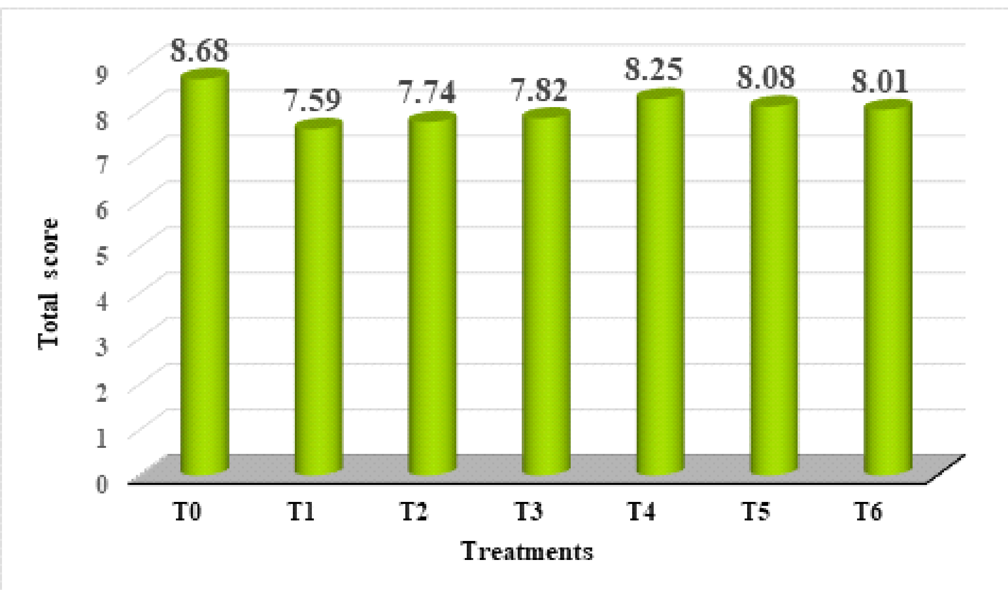

Fig 1. Total score of the organoleptic evaluation of Chengalikodan banana RS incorporated custard powder

Kendall's coefficient of concordance (W), and the nutritional parameters were subjected to an independent sample t-test using IBM SPSS Statistics software version 22.

RESULTS AND DISCUSSION

Organoleptic evaluation of custard

The custard was prepared using banana RS custard powder following the standard procedure of Shabina (2011). Sensory evaluation was conducted by a panel of 20 judges, and the organoleptic scores are presented in Table 2.

An evaluation of various treatments of banana resistant starch custard showed that treatment T_4, containing 20 per cent banana resistant starch, received the highest scores in all categories including appearance, colour, flavour, texture, taste, and overall acceptability (refer to Plate 1 and 2). The quality of the custard influenced by the physical properties of the starch used, with texture being the most crucial aspect, followed by taste and flavour. Treatment T_4 had the highest average score of 8.25, followed by T_5 (8.08) and T_6 (8.01) (Fig 1).The judges also showed significant agreement in their evaluation of the different quality attributes of banana RS custard based on Kendall's value (W). As per the organoleptic evaluation, treatment T_4 was selected for nutritional evaluation.

Simi *et al.,* (2016) standardised ready-made custard powders using canna starch and cornstarch in different combinations. The overall acceptability of custard prepared completely with rhizome starch (35%) was 8.69, which was selected as the best combination. Elias (2018) reported that custard powder prepared from 60 per cent cornstarch and 40 per cent Tannia starch powder had the highest average score of 8.5.

Nutritional composition of BRS custard powder

The best banana RS custard powder(T_4) was selected for the organoleptic evaluation and was subjected to nutritional analysis along with control (Table 3). The moisture content of the selected banana RS custard powder was measured at 6.25 per cent, slightly higher than the control's 5.6 per cent. The carbohydrate content of the selected custard was 63.64 g $100g^{-1}$, which was slightly lower than that of the control (68.57 g $100g^{-1}$). Ezegbe *et al.* (2021) standardised a custard powder with soya bean, sweet potato and corn starch. The custard

Plate 1. Banana RS Custard powder

Plate 2. Custard

Table 3. Nutritional composition of banana RS custard powder

Sl.No	Parameters	Control	T_4	t value
1	Moisture (%)	5.6	6.25	5.58*
2	Carbohydrate (g $100g^{-1}$)	68.57	63.64	2.77*
6	Starch (%)	62.91	54.95	3.70*
7	Resistant starch (%)	10.21	14.64	2.30*
8	*In vitro* digestibility of starch (%)	52.70	45.20	2.70*

*Significant at 5% per cent level, (T_4 – 20 % banana resistant starch, 15 % corn flour, 65 % other ingredients)

powder samples had a carbohydrate content ranging from 68.87 to 76.90 g per 100g. The protein content of the control was 3.56 g per 100g, while the banana starch custard powder had 3.47 g per 100g. According to t test there was a significant difference between the treatments in all the parameters.

In this study, the starch content of the control custard powder was 62.91 %, and that of the developed banana starch custard powder contains 54.95 per cent starch. The developed banana starch custard had a resistant starch content of 14.64%, slightly greater than that of the control (10.21%). Alimi *et al.* (2017) conducted a study on standardized corn banana custard. They found that custard paste prepared with modified starch contained the highest resistant starch level, around 14%, compared to 11% in custard paste made with native banana starch and the control sample. The increased resistant starch content in the custard paste containing modified starch is due to its higher amylose content, which limits the amylase enzyme's access to amylose and reduces amylolytic hydrolysis.The formation of type 3 resistant starch, formed through hydrothermal modification of starch could improve its health benefits

The *in vitro* digestibility of starch of the selected custard powder was found to be 45.20 %, slightly lower than that of the control (52.70%). Alimi *et al*. (2017) reported that custard paste containing native banana starch (BS) had slightly higher rapidly digestible starch (RDS) content compared to those made with modified banana starch. This suggests that banana starch modification may lead to the formation of an indigestible starch fraction.The interaction between banana-resistant starch (RS) and corn flour in custard powder enhances its nutritional properties by lowering the glycaemic index and promoting gut health through prebiotic effects. This combination also improves texture, reduces caloric density, and enriches the micronutrient profile, making the custard healthier and more appealing to health-conscious consumers.

CONCLUSIONS

The study concluded that custard powder was formulated with varying levels of banana resistant starch, corn flour and other ingredients (T_0-T_6) and evaluated for sensory properties. The selected (T_4) formulation, containing 20% resistant starch, 15% corn flour, and 65% other ingredients, achieved the highest sensory scores (8.25). The nutritional composition of the selected treatments was found to be moisture (6.25%), carbohydrates (63.64 g/100g), resistant starch (14.64%) and *In vitro* digestibility of starch (45.20%). The incorporation of banana starch, whether in its natural form or hydrothermally treated, enhances the consistency of custard powder. It also increases the proportion of slowly digested starch, making it potentially beneficial for the dietary management of various diseases. The improved functional characteristics of custard powder samples could lead to their production on a commercial scale.

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A STUDY ON QUALITY TEACHING-LEARNING ENVIRONMENT ON SOCIAL AND EMOTIONAL DEVELOPMENT OF PRESCHOOLERS

SOUMYA HIRELINGANNAVAR and MANJULA PATIL

Department of Human Development and Family Studies College of Community Science

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ABSTRACT

A research study examining the quality of teaching and learning environments and their effects on the social and emotional growth of preschool children was carried out in Dharwad taluk, Karnataka, from 2018 to 2020. The research included a sample of 208 children, aged between 3 and 6 years, who were enrolled in various Early Childhood Care and Education (ECCE) centers located in both rural and urban regions of Dharwad taluk. The results conferred that children in centers characterized by medium-quality teaching-learning environments achieved significantly higher scores, averaging 36.13 ± 4.14, in social and emotional development compared to their peers in low-quality centers, regardless of whether they were in rural or urban areas. Notable differences were observed in specific areas, including emotional expression (5.23 ± 0.87), emotional adaptability (5.19 ± 0.97), emotion regulation arousal states (5.15 ± 0.99), behavioral regulation (5.19 ± 0.86), sense of self (4.90 ± 0.77), emotional themes in play (5.00 ± 0.65), and social interaction (5.46 ± 0.93), all of which were influenced by the quality of the teaching-learning environment in both settings.

INTRODUCTION

Quality in Early Childhood Care and Education (ECCE) pertains to various environmental aspects that are linked to beneficial outcomes for children in academic and social areas. The assessment of ECCE quality typically revolves around two primary dimensions: the program's infrastructure features and the direct classroom experiences of children. The call for quality in Early Childhood Education is widely recognized, asserting that every child is entitled to a 'Quality start,' which is a duty shared by both parents and educators. In defining 'quality' in the context of Early Childhood Education, it is important to include all elements that contribute to enriching experiences for young children. (The Early Childhood Education Handbook. Linda Dunlap, 2020).

The effectiveness of early childhood care and education settings is crucial for young children, who have unique needs for physical and emotional nurturing, as well as careful guidance. They require adequate time and space for social play, exploration, and learning. This principle is applicable in both home environments and early childhood education services. The United Nations Convention on the Rights of the Child emphasizes that every child has the right to an education that establishes a foundational basis for their future, enhances their capabilities, and acknowledges

Corresponding Author E-mail: soumyafh8585@gmail.com

their family, cultural, and linguistic identities. (Quality in Early Childhood Education. Nancy Freeman, 2019).

In the context of quality assurance, it is vital to acknowledge the various stakeholders engaged in different services and sectors within Early Childhood Education (ECE). In an ECE setting, both educators and children originate from diverse backgrounds, fields, and experiences. Teachers hold the important responsibility of providing care and education to these young individuals. While a high-quality ECE program should be adaptable, it is imperative for teachers to conduct comprehensive planning to ensure that the program is balanced, appropriate, and responsive to the needs, interests, and abilities of the children.

The United Nations Convention recognizes the right of children, including very young ones, to voice their perspectives on issues that affect their lives. This right is applicable in both family settings and other early years contexts.

The Early Childhood Care and Education Programme (ECCE) in the Republic of Ireland provides children with access to free early childhood care and education, commonly referred to as 'free preschool,' prior to their entry into primary school. The quality of ECCE environments, where young children spend considerable time both at home and in external settings, plays a crucial role in their overall wellbeing, learning, and development.(Early Childhood Education: An International Perspective.

In light of this background, there arose a necessity to examine the effects of the teaching-learning environment's quality on the social and emotional growth of preschool children within the local community.

MATERIAL AND METHODS

Between 2018 and 2020, a qualitative approach was adopted to investigate the social and emotional development of children attending various Early Childhood Care and Education (ECCE) centers in both rural and urban regions of Dharwad taluk. The study utilized naturalistic observation to systematically document, analyze, and evaluate the effects of play-based activities on children's social and emotional development. Observations were made during children's free play sessions, employing video recordings, participant observation, and thorough field notes for comprehensive analysis.

Selection of ECCE centers:

The process of selecting ECCE centers included sampling from eight anganwadis and two preschools in the rural areas of Dharwad taluk, in addition to six anganwadis and six preschools in urban settings. These centers were visited to evaluate the social and emotional activities conducted within the ECCE framework. Subsequently, a self-developed checklist was created to assess and identify ECCE centers that employed analogous play-based activities. Figure 1 provides a visual representation of the social and emotional development activities.

Tool Description

The Transdisciplinary Play-Based Assessment-2 (TPBA-2), created by Linder in 2012, evaluates the social and emotional development of children aged 0 to 6 years across various domains. These domains include emotional expression, emotional style and adaptability, approach versus withdrawal behaviors, regulation of emotions and arousal states, behavioral regulation, self-perception, emotional themes in play, and social interactions.

The scoring system analyzes the play activities conducted among children, assessing their abilities on a scale from 1 to 9 in terms of social and emotional skills. Based on the scores obtained, children are classified into categories such as above average, typical, watch, and concern.

Score	Category
7-20	Concern
21-34	Watch
35-48	Typical
49-63	Above average

Early Childhood Environment Rating Scale-III (ECERS-III) developed by Harms and Clifford in 2014, serves as a tool for assessing the structural quality of preschool classrooms and the educational environment for young learners. The scale includes 35 items that delineate different quality levels in common early childhood education contexts.

The evaluation employs a 7-point Likert scale for scoring each item, with values ranging from 1 (representing inadequate quality) to 7 (representing excellent quality). The cumulative scores facilitate the classification of the educational environment in school.

RESULTS AND DISCUSSION

Percentage distribution of children attending different ECCE center of rural and urban areas

Table 1 presents the distribution of children attending different Early Childhood Care and Education (ECCE) centers, categorized by various child characteristics, including age, gender, socio-economic status, and the quality of the home environment. In rural anganwadi centers, the predominant age group is 36-48 months, accounting for 38.46% of the children, followed by 32.69% in the 49–60-month group and 28.85% in the 61–72-month group. For preschool centers, the age distribution mirrors this, with 34.62% of children in the 36–48-month category, 32.69% in the 49–60-month category, and another 32.69% in the 61–72-month category. In urban anganwadi centers, 34.62% of children fall within the 36-48 month and 49–60-month age groups, while 30.76% are in the 61–72-month group. In urban preschools, the age distribution is 40.38% for 36-48 months, 32.69% for 49-60 months, and 26.93% for 61-72 months.

In rural anganwadis, the gender distribution of children revealed that 53.84 percent were girls, while 46.16 percent were boys. Conversely, in rural preschools, the situation was reversed, with 55.76 percent of children being boys and 44.24 percent being girls. In urban areas, a significant majority of children in anganwadis were girls, accounting for 59.62 percent, compared to 40.38 percent who were boys. In urban preschools, the gender ratio was more balanced, with 51.92 percent of children being boys and 48.08 percent being girls.

In terms of socio-economic status, a significant portion (53.84%) of children attending rural anganwadis are classified as belonging to a poor socio-economic background, while 46.16% fall into the lower middle category. Conversely, in preschools, 61.54% of children are categorized as upper

Categories	Score
Low teaching learning environment (LTLE)	35-105
Medium teaching learning environment (MTLE)	106-176
High teaching learning environment (HTLE)	177-245

middle class, with 38.46% identified as lower middle class. In urban areas, a majority (67.30%) of children in anganwadis are from the lower middle socio-economic group, whereas 32.70% are classified as poor. In preschools, 69.23% of children belong to the upper middle category, while 30.77% are in the lower middle category.

Influence of quality of ECCE environment on social and emotional development of children

According to the data in Table 2, thesignificant relationship between the quality of the teaching-learning environment and the social and emotional development of children in rural areas ($\div^2 = 60.48$) at the 1 percent significance threshold.

The analysis revealed that among children in these rural environments, a substantial proportion (65.38%) who experienced a low-quality teaching-learning environment were categorized as "watch" in terms of their social and emotional development. Additionally, 34.62 percent were identified as being at a "concern" level, with no children from the low-quality environment classified as having a "typical" level of social and emotional development.

Within the cohort of children in a medium teaching and learning environment, most (69.23%) demonstrated typical social and emotional development, whereas 30.76% were identified as having watch levels of social and emotional development.

The quality of the teaching-learning environment in urban areas is significantly associated with the social and emotional development of children, as evidenced by a chi-square value of 32.39 at the 1 percent significance level. It was noted that among urban children, a large percentage from low-quality teaching-learning environments were categorized as "watch" (59.62%) regarding their social and emotional development, with 26.92% falling into the "concern" category and 13.46% classified as typical.

Conversely, for children in a medium-quality teaching-learning environment, a majority (61.53%) were found to be at a typical level of social and emotional development, while 38.47% were categorized as "watch."

A notable association was identified between the quality of Early Childhood Care and Education (ECCE) and the social and emotional development of preschoolers in both rural and urban settings. It was observed that all anganwadis operated within a low-quality teaching and learning environment, while preschools were categorized as having a medium-quality environment. Children in the low-quality settings were classified as being under "watch" and "concern," with no children falling into the typical development category, indicating a significant association. The most critical factor influencing this outcome was the appropriate teacher-child ratio of 1:15, along with sufficient space for both indoor and outdoor activities that facilitate play-based group interactions.

A significant change was noticed in the social and emotional development of children attending anganwadis compared to those in preschools. Anganwadis were found to have inferior furnishings, restricted space for activities, and a lack of adequate equipment and play materials as compared to preschools.

According to Gialamas *et al.,* (2014), there wa a correlation between higher quality relationships and a decrease in both internalizing and externalizing behavioral problems. The nature of child care activities and the attributes of care providers or programs were found to influence children's social and emotional growth.

Similarly, Peisner-Feinberg (2001) demonstrated that child-care quality has a modest but lasting effect on children's cognitive, social, and emotional development, at least through the kindergarten years. The practices observed in classrooms were linked to children's language and academic performance, while the quality of the teacher-child relationship was related with cognitive and social skills, particularly the latter. Additionally, the study noted that family characteristics could moderate some outcomes, stating that the benefits of high-quality child care are more pronounced for certain children.

According to the findings in Table 3, children in medium teaching-learning environment centers demonstrated significantly higher scores in social and emotional development, averaging 36.13, in contrast to those from low teaching-learning environments, who scored 22.04 in rural areas and 26.38 in urban areas.

Preschools offered a safe and clean environment, along with a physically stimulating and cognitively enriching atmosphere. They maintained smaller group sizes and focused on sensitive, child-directed activities. Teachers in preschools cultivated positive relationships, engaged in responsive conversations, and encouraged group play. The use of corner play, dollhouses, and various themes facilitated children's learning of social skills through sharing and cooperation.

The results in table 4 illustrates that there are significant differences in the social and emotional development of children, influenced by the quality of the Early Childhood Care and Education (ECCE) environment in both rural and urban contexts. The analysis highlights key areas of difference, including emotional expression, emotional adaptability, emotion regulation, arousal states, behavioral regulation, self-identity, emotional themes in play, and social interaction. Notably, children in medium-quality teaching and learning environments scored higher mean values than their peers in low-quality settings, with scores of 5.23 for emotional expression, 5.19 for

Table 1 Demographic characteristics of anganwadi and preschool children in rural and urban areas

Child characteristics	Categories	Rural (n=104)		Urban (n=104)	
		Anganwadi	Preschool	Anganwadi	Preschool
Age (months)	36-48	20 (38.46)	18 (34.62)	18 (34.62)	21 (40.38)
	49-60	17 (32.69)	17 (32.69)	18 (34.62)	17 (32.69)
	61-72	15 (28.85)	17 (32.69)	16 (30.76)	14 (26.93)
	Total	52 (100)	52 (100)	52 (100)	52 (100)
Gender	Boys	24 (46.16)	29 (55.76)	21 (40.38)	27 (51.92)
	Girls	28 (53.84)	23 (44.24)	31 (59.62)	25 (48.08)
	Total	52 (100)	52 (100)	52 (100)	52 (100)
SES	Upper high	-	-	-	-
	High	-	-	-	-
	Upper middle	-	32 (61.54)		36 (69.23)
	Lower middle	24 (46.16)	20 (38.46)	35 (67.30)	16 (30.77)
	Poor	28 (53.84)	-	17 (32.70)	-
	Very poor	-	-	-	-
	Total	52 (100)	52 (100)	52 (100)	52 (100)

Fig 1Activities for social and emotional development

Activities	Rural								Urban							
	School 1		School 2		School 3		School 4		School 5		School 6		School 7		School 8	
	Daily	Weekly	Daily	Weekly	Daily	Weekly	Daily	Weekly	Daily	Weekly	Daily	Weekly	Daily	Weekly	Daily	Weekly
Rhymes	YES		YES		YES		YES		YES		YES		YES		YES	
Informal talk	YES		YES		YES		YES		YES		YES		YES		YES	
Dance		YES		YES		YES		YES		YES		YES		YES		YES
Story telling		YES		YES		YES		YES		YES		YES		YES		YES
Story book readi				YES				YES				YES				YES
Drawing				YES				YES				YES				YES
Painting				YES				YES				YES				YES
Arts and crafts				YES				YES				YES				YES
Passing the ball			YES				YES				YES				YES	
Circle time		Yes		YES		Yes		YES		Yes		YES		Yes		YES
Dramatic play	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Play dough	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sharing the news	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Science activities	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Theme based pla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	05		10		05		10		05		10		05		10	

Table 2 Association of between social and emotional development of children by quality of ECCE centers N=208

Categories of social and emotional development	Rural (104)			Urban (104)		
	Low teaching learning environment	Medium teaching learning environment	Modified χ^2	w teaching learning environmer	Medium teaching learningenvironment	Modified χ^2
Typical (Average)	-	36 (69.23)	60.48**		32 (61.53)	32.39**
Watch (Below Average)	34 (65.38)	16 (30.76)		38 (73.08)	20 (38.47)	
Concern (Poor)	18 (34.62)	-		14 (26.92)	-	
Total	52 (100)	52 (100)		52 (100)	52 (100)	

Figure in parentheses indicates percentage

**Significant at 0.01 level

Table 3 Comparison of mean scores of social and emotional development of children by quality of ECCE environment in rural and urban areas

Locality	Type of ECCE centre	Mean ± S.D	t-Value
Rural	Low teaching learning environment	22.04 ± 3.44	18.844**
	Medium teaching learning environment	36.13 ± 4.14	
Urban	Low teaching learning environment	26.38 ± 6.42	9.194**
	Medium teaching learning environment	36.13 ± 4.14	

**Significant at 0.01 level

emotional adaptability, 5.15 for regulation of emotions and arousal states, 5.19 for behavioral regulation, 4.90 for sense of self, 5.00 for emotional themes in play, and 5.46 for social interaction.

The analysis conducted in urban environment demonstrated that children attending medium-quality teaching and learning centers had significantly higher mean scores compared to those in low-quality centers in several areas of social and emotional development. The specific mean scores recorded were: emotional expression (5.28), emotional adaptability (5.29), regulation of emotions and arousal states (5.25), behavioral regulation (5.31), sense of self (4.89), emotional themes in play (5.05), and social interaction (5.65).

The findings align with the research conducted by Broekhuizen *et al.,* (2016), which revealed that children in pre-kindergarten and kindergarten who experienced elevated levels of emotional and organizational quality in the classroom exhibited enhanced social skills and fewer behavioral problems in both kindergarten and first grade compared to their peers who did not experience such high-quality classroom environments.

The results of a different study resonate with those of Diazgranados *et al.,* (2016), which revealed that children in high-quality preschools experienced greater benefits in social and emotional skills compared to their non-preschool counterparts, with significant growth observed over time.

Similarly, Brinkman *et al.,* (2016) found a strong connection between the ECCE environment and the domain of social competence, noting that a favorable student-to-staff ratio had a significant impact on social and emotional development.

Table 3 Comparison of mean scores of domains of social and emotional development of children by quality of ECCE environment in rural and urban areas N=208

Domains of social and emotional development	Rural			Urban		
	Low teaching learning environment Mean ± S. D	Medium teaching learning environment Mean ± S. D	t-value	Lowteaching learning environment Mean ± S. D	Mediumteaching learning environment Mean ± S. D	t-value
Emotional expression	3.09 ± 0.77	5.23 ± 0.87	**13.16****	3.76 ± 0.94	5.28 ± 0.87	**8.19****
Emotional style/ adaptability	2.92 ± 0.62	5.19 ± 0.97	**14.19****	3.61 ± 1.08	5.29 ± 0.97	**7.80****
Regulations of emotions and arousal states	3.11 ± 0.61	5.15 ± 0.99	**12.54****	3.75 ± 0.83	5.25 ± 0.99	**7.77****
Behavioral Regulation	3.19 ± 0.56	5.19 ± 0.86	**13.99****	3.80 ± 0.92	5.31 ± 0.86	**7.86****
Sense of Self	3.00 ± 0.65	4.90 ± 0.77	**13.52****	3.73 ± 1.01	4.89 ± 0.77	**6.64****
Emotional Themes in Play	3.00 ± 0.56	5.00 ± 0.65	**16.70****	3.55 ± 1.16	5.05 ± 0.65	**7.79****
Social interaction	3.71 ± 1.03	5.46 ± 0.93	**9.03****	4.15 ± 1.25	5.65 ± 0.93	**6.00****

***Significant at 0.01 level**

CONCLUSIONS

The research established a significant relationship between the quality of the ECCE environment and the social and emotional development of children across both rural and urban areas, with a significance level of 0.01. A clear difference was noted between medium and low teaching-learning environments. All anganwadis were found to fall under the low teaching-learning category, while preschools were classified as medium. In the low teaching-learning environment, 65.38 percent of children were categorized as “watch,” and 34.62 percent as “concern,” with no children identified as typical, demonstrating a significant association.

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PREVALENCE OF SCHOLASTIC BACKWARDNESS AMONG LOWER PRIMARY SCHOOL STUDENTS IN ERNAKULAM DISTRICT, KERALA

SAJITHA SUSEELAN S and SHEMI GEORGE

P.G. and Research Department of Home Science, Morning Star Home Science College, Angamaly, Ernakulam– 683573, Affiliated to Mahatma Gandhi University, Kottayam, Kerala

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ABSTRACT

The study carried out in the year 2023 aimed to assess the extent of academic under achievement among lower primary school students. A cross-sectional study has been undertaken in both government and aided lower primary schools in the district, Ernakulam in Kerala.The students who exhibited poor scholastic performance were identified with the assistance of teachers and by reviewing annual school reports. IQ level of the identified scholastically backward students was measured using the Seguin Form Board Test, a standardized intelligence test. Results showed that out of 1084 lower primary students studied,166 (15.31%) students were scholastically backward, with 82 (16.84%) from the government schools and 84 (14.07%) from the aided schools. Most of the students had an IQ in the borderline range (70 – 79).The majority of scholastically backward students were boys and the highest number was in the age group 9-10, followed by the 8-9 and 7-8 years groups. Classes III and IV had the highest number of backward students.A significant majority 78 (46.99%) were from rural areas. There is a significant association between the area of residence and the type of school attended by scholastically backward students.

Keywords: Intelligence Quotient (IQ), Lower Primary School Students, Scholastic Backwardness

INTRODUCTION

In modern society, children are highly competitive in their scholastic as well as non-scholastic activities. Scholastic skills determine the ability of school children to read, write, spell, and perform arithmetic computations. Scholastic backwardness occurs when a child's school performance falls below expected standards. A child with scholastic backwardness may face the challenges such as; failure in one or more subjects, failure in one or more classes, will be in lower 10th percentile marks in his/her class or identified by parent or teacher to be difficult to teach. A child with general scholastic backwardness struggles with all subjects in the school curriculum. In contrast, a child with specific scholastic backwardness lags behind in only one or two subjects, while their performance in other subjects may be satisfactory or even exceptional (Mangal, 2015).

Corresponding Author E-mail i.d: sajitha.suseelan@gmail.com; Part of the Ph.D. thesis to be submitted to Mahatma Gandhi University, Kottayam, Kerala.

Scholastic backwardness is often associated with cognitive inferiority, faulty academic behaviour, poor attention, lack of interest in studies, exam failure, emotional imbalance, aggression, and physical and psychological complaints andmay have lasting effects on a child's life. Slow learners have below-average cognitive abilities with IQ ranging from 70 to 89. They struggle to cope with the traditional academic demands of a regular classroom. Around 8percent to 9 per cent of primary school children score below average on standard IQ tests (Pal and Kumar, 2022).

Various studies estimated that 20 per cent to 50 per cent of school-going children experience scholastic backwardness. A study conducted in Alappuzha District, Kerala showed that 23.7 per cent of upper primary studentshad scholastic backwardness (Jayaprakash and Rajamohanan, 2022). A cross-sectional study conducted in Kerala discovered that children aged 13 to 16 years were the majority (61.4%) who had scholastic backwardness (Ramadas and Vijayan, 2019).The overall prevalence rate of academically backward children among 7th, 8th, and 9th grade students in rural schools was found as 49 per cent. However, this rate varied widely, ranging from 31percent in one school to 75 per cent in another (Thakur and Agrawal, 2016). A study on 'scholastic backwardness in children attending normal schools' found that intelligence is not the sole determinant of academic performance. Various cognitive and non-cognitive factors, both within the child and in their environment-such as family, school, and society-are responsible for shaping the students' scholastic performance (Santhosh, 2014).

The study focused on determining the rate of academic under achievement among students in lower primary classes in Ernakulam District of Kerala State. The study area, Ernakulam District in Kerala, represents a diverse demographic and educational landscape, with both urban and rural regions and a mix of government and aided schools. Kerala is recognized for its remarkable literacy levels and emphasis on educational development, yet disparities in academic performance remain, particularly among students in lower primary classes. The study aimed to determine the overall percentage of scholastically backward students in lower primary government and aided schools, to categorize the scholastically backward students based on their IQ levels, to identify any disparities in the gender and geographic distribution of scholastically backward students and to analyse the distribution of scholastically backward students across different age groups and school grades.

MATERIAL AND METHODS

The study was conducted in the year 2023 among the students from the selected 10 lower primary government and aided schools, in Ernakulam, Kerala. The total students population comprised of 1084, with 487 from government schools and 597 from aided schools. Among these students, 612 were boys and 472 were girls. Students from Class I to Class IV were included in the study. Purposive sampling technique was employed. Scholastic backwardness was identified if a child consistently performed poorly and regularly failed in all subjects or one or more subjects. Teachers and annual school reports served as sources of information. Based on these criteria, scholastically backward students were identified as sample for the study, from government and aided schools. Children with any physical disability or psychological disorder were excluded from the study. Consent was sought and received from the General Education Department, the heads of the institutions, the teachers, and the parents.

The IQ level of the sample was assessed using the Seguin Form Board Test (1856), a standardized intelligence test under the guidance of a clinical psychologist. The Seguin Form Board Test (1856) is a performance-based intelligence assessment that evaluates shape recognition, visual perception, eye-hand coordination, and cognitive skills using nonverbal methods. It also measures visuomotor coordination, spatial organization, motor dexterity, and the speed and precision of their performance. (Venkatesan, 2014). Three consecutive trials were administered to each sample. The mental age was determined using a standard chart by identifying the fastest time among the three trials, which was then used to calculate the intelligence quotient (IQ). The classification of IQ levels in this study was based on the Wechsler Intelligence Scale for Children–Fourth Edition (WISC-IV). The gathered data was subjected to statistical analysis and interpreted using percentage analysis and the Chi-square test.

RESULTS AND DISCUSSION

Results from Table 1 revealed that 16.84 per cent of the students were scholastically backward in government schools followed by aided schools (14.07 %). With respective to IQ level, 56.10 per cent were in the 'borderline' category followed by 'low average' category (29.27%) and 'extremely low' category (14.63%) in government schools. In aided schools, 64.29 per cent were in the 'borderline' category followed by 'low average' category (26.19%), and 'extremely low' category (9.52%).

The results were in line with the study by Beniwal *et al.* (2018) who stated that 11.46 per cent of children within the 5–15 years age rangewere having Scholastic Backwardness and Sharma *et al.* (2018) reported that 11.33 per cent of scholastic backwardness was found out among urban lower middle-class school children. According to Ramadas and Vijayan (2019) varying degrees of intellectual impairment was the main cause of scholastic

Table 1. Distribution of Scholastic Backward Students by School Types (n=1084) and IQ values (n=166)

Sl.No.	Particulars	Government n = 487	Aided n = 597	Total n = 1084
1	Scholastically backward students	82 (16.84)	84 (14.07)	166 (15.31)
2	***IQ Level**	**Government n = 82**	**Aided n = 84**	**Total n = 166**
	Low average (80 – 89)	24 (29.27)	22 (26.19)	46 (27.71)
	Borderline (70 – 79)	46 (56.10)	54 (64.29)	100 (60.24)
	Extremely low (69 and below)	12 (14.63)	8 (9.52)	20 (12.05)

*Value in parentheses are percentages

Source: *IQ classification based on Wechsler Intelligence Scale for Children (WISC-IV) backwardness. Haneesh *et al.* (2013) reported that 36 per cent of scholastically backward students had borderline intelligence in their study conducted among children in the 6-12 year age group attending regular schools.

The findings from the study indicate a notable disparity in scholastic performance between government and aided schools, with varying levels of intellectual impairment significantly contributing to scholastic backwardness, particularly among students in the 'borderline' IQ category who face greater challenges in meeting academic demands.

Table 2 revealed that 69.28 per cent of the scholastically backward students were boys followed by girls (30.72%) per cent. Among boys 70.73 per cent were in government schools and followed by in aided schools (67.86%). 29.27 per cent of the girls were in government schools followed by aided schools (67.86%). This indicates a relatively consistent gender distribution of scholastically backward students across government and aided schools, with boys being more prominently represented in both.

The findings were consistent with a similar study conducted among 12-16 year-old children by Nayak *et al.* (2017), that a significant portion of academic underachievers were boys, comprising 36.63 per cent. Another research study undertaken by Gohiya and Shrivastav (2015), revealed thatamong 57 academic backward school children, 77.19 per cent were male 23.36 per cent were female. Raghavendra and Reddy (2020) found that there was a marked majority of males (76.9%) compared to females (23.1%) in a study conducted on 'Etiology and risk factors for scholastic backwardness in children. Jayaprakash and Rajamohanan (2022) stated that there was a male domination (66.67%) in scholastic backwardness in their study.The predominance of boys among scholastically backward students observed in this study could be explained by their higher representation within the overall study population. This demographic imbalance suggests that the greater number of boys enrolled in the schools studied may have influenced the gender

Table 2. Distribution of Scholastic Backward Studentsby Gender, Age and School Grades(n=166)

Sl.No.	Variable	Category	Government n = 82	Aided n = 84	Total n = 166
1	**Gender**	Boys	58 (70.73)	57 (67.86)	115 (69.28)
		Girls	24 (29.27)	27 (32.14)	51 (30.72)
2	**Age(years)**	6 – 7	18 (21.95)	11 (13.10)	29 (17.47)
		7 – 8	20 (24.39)	22 (26.19)	42 (25.30)
		8 – 9	20 (24.39)	24 (28.57)	44 (26.51)
		9 – 10	24 (29.27)	27 (32.14)	51 (30.72)
3	**School grades**	Class I	19 (23.17)	12 (14.29)	31 (18.67)
		Class II	19 (23.17)	22 (26.19)	41 (24.70)
		Class III	24 (29.27)	25 (29.76)	49 (29.52)
		Class IV	20 (24.39)	25 (29.76)	45 (27.11)

*Value in parentheses are percentages

distribution of scholastically backward students.

With respective to the age distribution, 30.72 per centof the scholastic backward students were in the age group of 9-10 yearssucceeded by those in 8-9 years age group (26.51%), 7-8 years a (25.30%) and 6-7 years (17.47%). In government schools, 29.27 per cent of the scholastic backward students were in the age group of 9-10 years by those in 8-9 years age group (24.39%), 7-8 years (24.39%) and 6-7 years (21.95%). In aided schools, 32.14 per cent of the scholastic backward students were in the age group of 9-10 years succeeded by those in 8-9 years age group(28.57%), 7-8 years (26.19%) and 6-7 years (13.10%). The age distribution reveals that the percentage of scholastically backward students remains relatively steady as children get older, though there is a slight increase in the older age groups. This indicates that as students advance in their education, they encounter increasingly complex academic challenges.These challenges can make it more difficult for students with learning difficulties to keep pace, thereby making their scholastic backwardness more apparent. As the curriculum becomes more advanced and demanding, students facing academic difficulties are more likely to fall behind, highlighting their difficulties in a more noticeable way. Consequently, the educational gap between these students and their peers becomes more noticeable with age.

With respective to school grades. 29.52 per cent of the scholastic backward students are in Class III followed by Class IV (27.11%), Class II (24.70%) and Class I (18.67%). In government schools, 29.27 per cent of the scholastic backward students belonged to Class III followed by Class IV (24.39%), Class II (23.17%) and Class I (23.17%). In aided schools, 29.76 per cent of the scholastic backward students belonged to Class III and Class IV each, followed by Class II (26.19%) and Class I (14.29%). The results indicatea higher concentration of scholastic backward students in Class III and Class IV, with a relatively balanced distribution between government and aided schools.The higher concentration of scholastically backward students in Class III and Class IV can be attributed to several factors related to the increasing academic demands and cumulative learning gaps as students progress through these grades. In early primary grades, students typically focus on foundational skills like basic reading, writing, and arithmetic. However, as they enter Class III and Class IV, the curriculum shifts towards more complex concepts, including problem-solving, critical thinking, and the application of foundational skills in more advanced subjects.

Table 3. Distribution of Scholastic Backward Students by Area of Residence

Sl.No.	Area	Government n = 82	Aided n = 84	Total n = 166	Chi-square value	p-value
1	Urban	16 (19.51)	31 (36.91)	47 (28.31)	9.5281	0.008531*
2	Semi Urban	18 (21.95)	23 (27.38)	41 (24.70)		
3	Rural	48 (58.54)	30 (35.71)	78 (46.99)		

*Value in parentheses are percentages

**The result is significant at p < .05.*

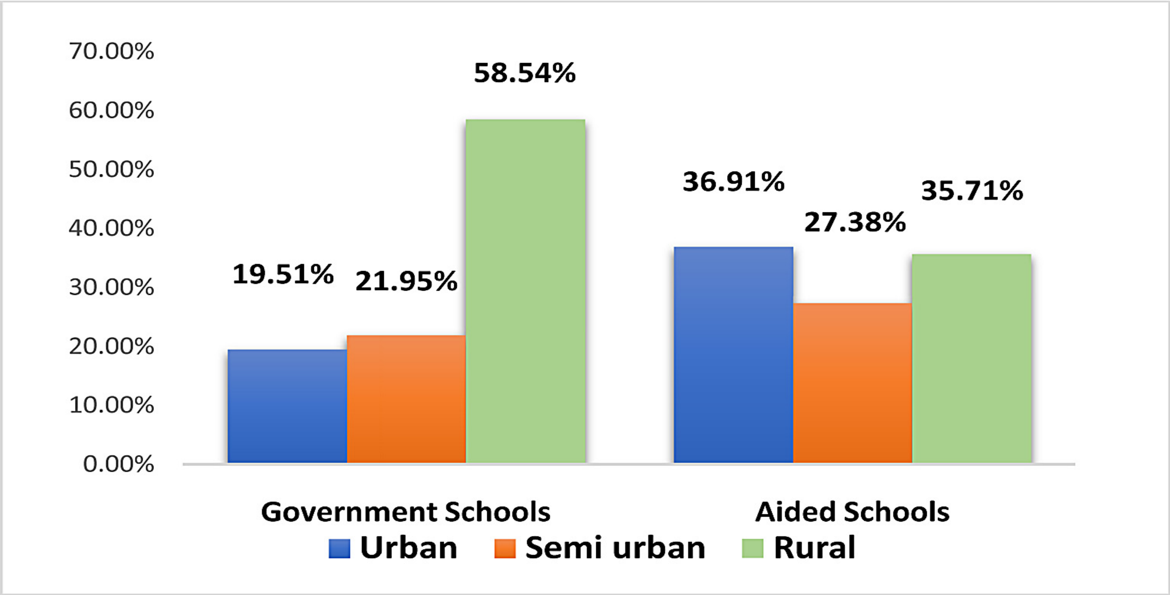

Fig. 1. Distribution of Scholastic Backward Students by Area of Residence

Results from Table 3 and Figure 1 revealed that 46.99 per cent of the scholastic backward students were from rural areas followed by students from urban areas (28.31%) and semi-urban areas (24.70%). In government schools, 58.54 per cent of the scholastic backward students were from rural areas followed by students from semi-urban areas (21.95%) and urban areas (19.51%). In aided schools, 36.91 per cent of the scholastic backward students were from rural areas followed by students from urban areas (36.91%) and semi-urban areas (27.38%).

It is evident from the data that rural areas had the highest proportion of scholastic backward students, with a notable predominance in government schools, whereas urban and semi-urban areas had a more balanced distribution between government and aided schools.The results align with Ramadas and Vijayan's (2019) study, which found that most of the scholastically backward children in their sample were from rural background (81.6%).

The chi-square results indicated that there is a statistically significant difference in the distribution of scholastically backward students by area of residence between government and aided schools. The area of residence is significantly associated with the type of school attended by scholastically backward students. In rural areas, government schools often serve as the primary educational institutions, particularly in areas with lower socioeconomic status. These schools may face challenges such as limited resources, inadequate infrastructure, and fewer trained teachers, which can hinder the academic progress of students. Additionally, there may be less access to supplementary educational support like private tutoring, study materials, and extra curricular activities in rural areas. As a result, students in rural government schools tend to exhibit higher levels of scholastic backwardness.

CONCLUSIONS

The study reveals that 15.31% of students are scholastically backward, with higher proportions in government schools. Most (60.24%) belong to the borderline IQ category, indicating learning challenges. Boys constituted a significant majority (69.28%), highlighting gender disparity. The 9-10 age group has the highest concentration (30.72%), with Classes III and IV showing the largest grade-wise distribution. Rural areas showed the highest proportion of scholastic backward students (46.99%), with a notable predominance in government schools, highlighting a significant urban-rural divide. These findings highlight the necessity for targeted interventions, including teacher training, resource access, early identification, and parental involvement, to enhance learning outcomes for scholastically backward students.

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VALORISATION OF PLANT BIOMASS FOR KALAMKARI OF ANDHRA PRADESH: WASTE DISPOSAL ISSUES

SRIVANI THADEPALLI and SUNDERVEL AMSAMANI

Department of Fashion Technology, National Institute of Fashion Technology, Hyderabad, 50008, Telangana, India

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ABSTRACT

Indian crafts utilize indigenous materials known for their sustainability and biodegradability. A craft diagnostic survey conducted in 2023 at the Machilipatnam Kalamkari cluster in Andhra Pradesh revealed improper disposal of organic waste from production processes, posing environmental and health risks. Analysis of gross calorific value (GCV), ash content, moisture content, fixed carbon, and volatile matter showed that the GCV of bio-waste samples ranged from 3848 to 4143 Kcal/kg, surpassing that of cow dung and matching or exceeding Indian coal (4050 K. Cal/Kg) and lignite (3200 K. Cal/Kg). *T. chebula* had moisture content (8.95%), lower than Indian coal (16.5%).A strong correlation (0.8226) between GCV values of bio-waste and fossil fuels was observed, highlighting the dual opportunity to address waste disposal issues and mitigate energy crises. Implementing these solutions can tackle environmental concerns while promoting sustainable development, creating value-added opportunities for traditional craft industries.

Keywords: Biofuels, Bio-waste, Kalamkari, Recycling, Sustainability, Valorisation.

INTRODUCTION

The Machilipatnam Kalamkari craft cluster in Andhra Pradesh is renowned for natural dyeing and hand block printing using eco-friendly materials (Edwards, 2016). However, a survey revealed improper disposal of production waste, including plant-based mordants and dyes, into garbage bins or local canals. This practice poses environmental and health risks, such as pest infestations and water pollution, particularly during the rainy season. Solid waste mismanagement contributes to issues like eutrophication, impacting water quality and ecosystems (Handayani *et al.,* 2018).

Despite their biodegradability, the environmental impact of natural dyes remains underexplored. Moist or biodegradable waste decomposes over time, and recycling plays a crucial role in conserving resources, reducing pollution, and generating employment (Handayani *et al.,* 2018). The recycling process involves collection, sorting, and manufacturing, fostering environmental sustainability and community engagement.

Organic waste has diverse applications, including handmade paper production, composting, biogas and biofuel generation, and wastewater treatment (Waghmode, 2016). Biomass from red rose dye extraction, for

*Corresponding Author E-mail i.d: thadepalli.srivani@nift.ac.in; Part of Ph.D. thesis going to be submitted to Avinashilingam University, Coimbatore, Tamilnadu

instance, can absorb chromium (VI) from water. Agricultural and food processing wastes are valuable resources, aiding in bioethanol and biomethane production (Rehman, 2015), enzyme synthesis (Nitin, 2017), and textile effluent treatment (Basu, 2016).

Biofuels, derived from biomass, offer renewable energy solutions. Traditional biofuels like wood provide heat and electricity, while ethanol, initially from plant starches, now includes non-edible fibrous materials (Selin, 2021). Biofuels also support transportation, with ethanol blends like E10 widely used (BETO, 2024).

The Gross Calorific Value (GCV) of various agricultural, forest, and animal residues in kilocalories per kilogram (K. Cal/Kg) represents the energy content of different biomass residues, which are potential sources for biofuel production. Coconut waste has the highest Gross Calorific Value (GCV) at 5200 K. Cal/Kg, making it highly energy-dense. Moderate GCV materials include Paper (4801), Babool stalk (4707), Groundnut shells (4661), and Sawdust (4654). Lower GCV biomass includes Bagasse (4300), Cotton stalks (4252), and Sugarcane (3966), while Bark (2675) has the lowest energy content, making it less efficient for biofuel production (Eco Stan, 2023). GCV, measured by a bomb calorimeter, determines the heat released during combustion, aiding in selecting biomass for energy applications and waste valorization. This data is crucial for selecting appropriate biomass materials for biofuel production and waste valorization. Higher GCV materials are more suitable for energy applications, while lower GCV materials may be better suited for composting or other uses.

Field surveys identified a research gap in vegetable dye waste valorization in Kalamkari production. This study explores waste generation, utilization, feasible technologies, and barriers to adoption. With limited literature on bio-waste management from dyeing plants, recycling into incense sticks presents a sustainable solution, addressing energy concerns and supporting handmade production.

MATERIAL AND METHODS

The first phase of the study involved qualitative research through a field survey of fifteen skilled master craftsmen in the Machilipatnam Kalamkari craft cluster in Andhra Pradesh. Primary data was collected via an interview schedule, focusing on open-ended responses to capture insights from personal discussions. The sample included ten master block printers, two block makers, and three younger craftsmen from five villages: *Pedana, Machilipatnam, Polavaram, Kappa-ldoddi, and Guduru*. Anonymized responses highlighted diverse perspectives on waste generation, pollution, and disposal issues, forming the basis for experimental research. The second phase adopted a quantitative approach, incorporating secondary data for comparative analysis with the experimental findings.

Insights from Field Research - Materials disposed of during and after the craft activity: Materials discarded during and after the crafting activity include more predominantly the wet waste/pulp generated from the use of natural plant sources like *T. chebula*, *L. microcarpa, R. cardifolia, P. granatum, B. monosperma*etc., in Kalamkari production. The organic waste collected from the mentioned five plant sources as shown in Figure 1 are used in the present study to explore their potential for reuse/ recycling.

Materials:

The organic biomass disposed of after the extraction and boiling (dyeing) in the Kalamkari craft cluster used for the study is given in Table 1.

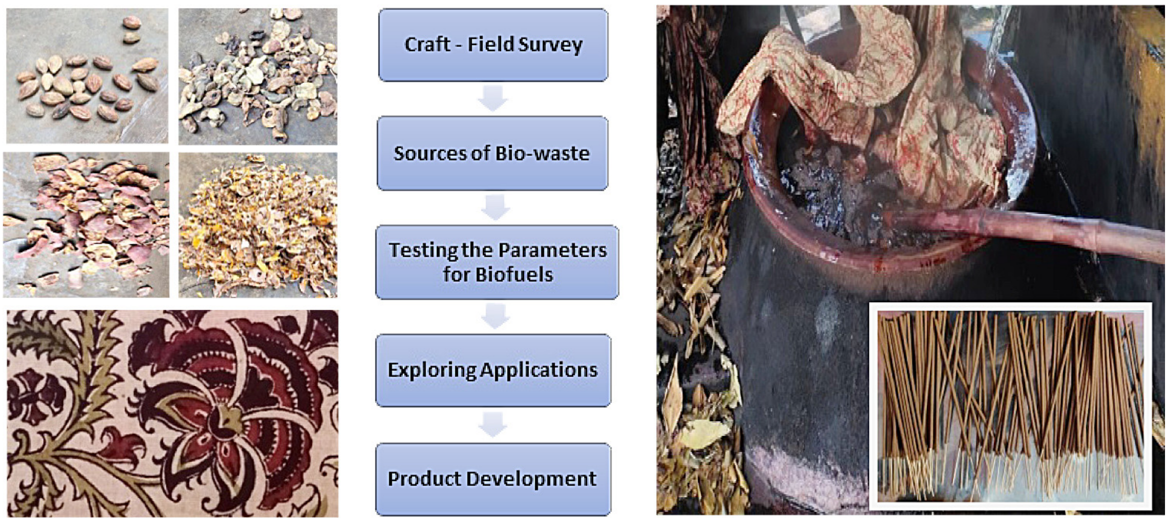

Fig. 1. The flowchart of processes for conversion of biomass into incense sticks

Preparation of Bio-waste for Testing

Solid organic waste is collected from job workers involved in boiling processes across the cluster. The wet waste is washed with distilled water, air-dried for 72 hours, and powdered to a uniform size as shown in Figure 2. For experimenting with the burning propagation of the dried solid waste (which is a residual waste after natural dyeing) the bio-waste is then tested for its biofuel efficiency. The coarse powders are further ball-milled for one hour using a Milling Machine (RSBM-1/060-718) to produce fine powders with an 80 mesh size, suitable for making various types

Table 1. Selected plant sources used in Kalamkari production

S. No.	Plant source	Purpose	Local name Telugu/Hindi/ English name	Scientific Name	Sample Code	Consumption per day at the cluster (Kg.)
1	Roots	Dye	***Manjistha***	***Rubia Cardifolia***	MJ	100 (approx.)
2	Flowers	Dye	*ModugaPuvvu /Palash*	*Butea monosperma*	MP	100 (approx.)
3	Fruit peel/ Rind	Dye	*Danimmaberadu/* Pomegranate rind/*Anar ka chilka*	*Punicagra-natum*	PP	100 (approx.)
4	Dried unripe fruit	Mordant	*Karakkaya/* Myrobalam/ *Haritaki/ harad*	*Terminalia Chebula*	KR	300 (approx.)
5	Leaves	Dying auxiliary	*Chennangiaaku/ Kasaundhi/Jajaku*	*Lagerstroemia microcarpa*	JJ	600 (approx.)

a) b) c)

Fig. 2. a). Coarsely ground powders b). Ball mill c). Ball-milled powders.

a) b) c) d)

Fig. 3. a). Bomb Calorimeter b). Combustion bomb c). Oven d). Muffle furnace

of incense sticks both by hand and machine processes in a systematic procedure using the recipes given in table 2.

Methods

Tests for Biofuel Applications: The Gross Calorific Value (GCV -ASTM 5865 – 10a) of the dried and powdered samples of plant waste is tested using a Bomb calorimeter as shown in Figure 3.

The Ash Content (ASTM D 3174 – 04), Moisture content (ASTM 3302M-17), Fixed Carbon (ASTM D 3172-13) and Volatile Matter (ASTM D 3175-17) are determined with respect to ASTM standards and formulas.

Description of Ingredients and Procedure Followed for Making Incense Sticks:

The incense stick formula comprises 30-40 parts bamboo core, 30-40 parts herbal powder, 15-40 parts sticky powder, and 1-5 parts potassium nitrate by weight. In this study, the traditional carbon/charcoal or mango wood sawdust was replaced with bio-waste powder. *Raal* powder, derived from the Sal tree (*Shorearobusta*), and *jigat/makko* powder, made from the bark of *Litseaglutinosa*, served as natural binders. Potassium nitrate (KNO_3), a naturally occurring mineral, enhances combustion performance and reduces carbon monoxide emissions, while also producing smoke and maintaining stable conditions.

The base mixture for unscented incense sticks was prepared by combining these ingredients with water to achieve the desired dough consistency. Bamboo sticks were coated under compression using an incense stick-making machine, then dried for 24-48 hours. Finally, the sticks were dipped in essential oils for 30 minutes, dried, and stored in the form of

Table 2. Composition of ingredients used in making incense sticks

Ingredients	T. c	P. g	B. m	L. m	R. c	Function	Price in Rs. /Kg.
Powder (gr.) (Bio-waste)	100	100	40	32	50	Bio-fuel used for generation of heat	Grinding Charges
Raal (gr.)	50	20	30	30	20	Generates smoke	55
Binder (gr.)	50	40	30	15	15	A medium to bind all the ingredients used	55
Potassium Nitrate/PN (gr.) (Saltpetre)	15	15	15	15	15	Accelerates burning of combustible materials	128
Water (ml.) / Rose water	100	100	25	13	40	For making dough in the required consistency	-
Essential oils (Cintronella)	For dipping of non-incensed sticks in oil-based fragrance					For fragrance in general or special purpose	Rs.1500/- -5000/ lt.
Bamboo skewers or sticksmade of sandal are used as core that gets burned along with the incense1.3mm						For rolling of incense and handling for use	9 inches 80-100

Note: *T. c (Terminalia chebula), P.g (Punicagranatum), B. m (Butea monosperma), L. m (Lagerstroemia microcarpa)* and *R. c (Rubiacardifolia).*

bundles in airtight containers to prevent bending and to retain incense property to enhance scent. Notably, it was observed that *Terminalia chebula* fruit powder has oil holding capacity of 4.93±0.01 mL/g and a water holding capacity of 6.28±0.06 mL/g (Amina, 2023) which might have contributed to the successful performance of incense sticks made from *T.chebula*, that received high ratings from a prominent *agarbatti* manufacturer involved in the exploration of new materials.

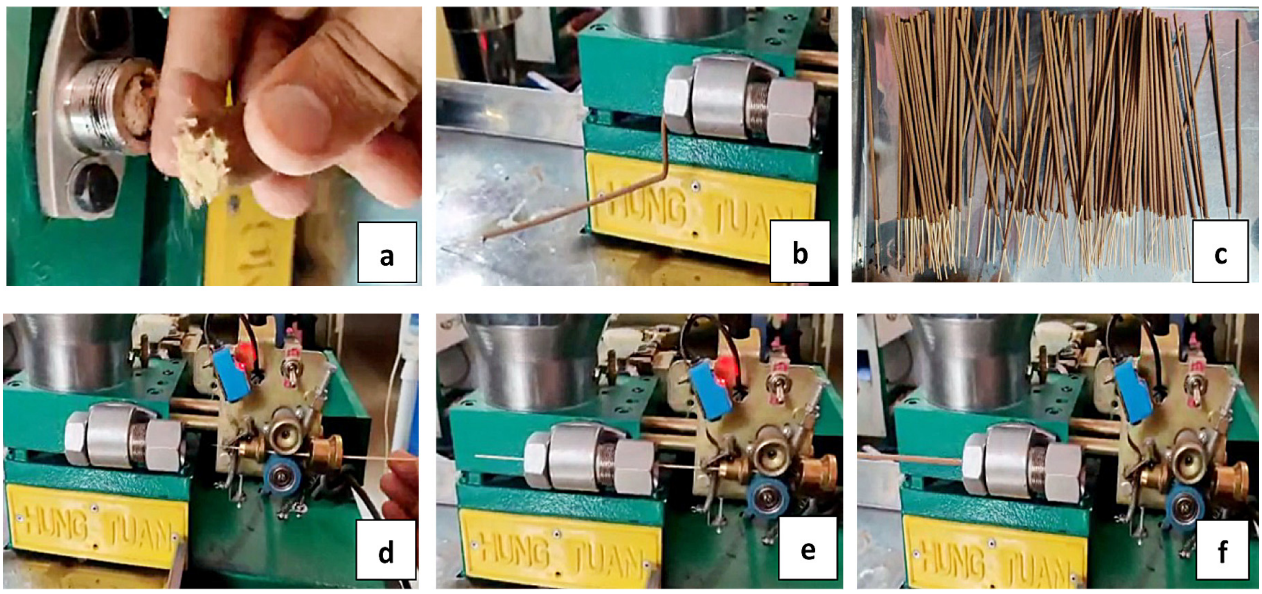

Figure 4. a) - b). Hard and sticky mass resulting in broken incense sticks; c). Incense sticks produced out of *T. chebula*waste; d) - f). Making of incense sticks

As the hand-made sticks are thick and uneven, taking more time to dry, further production was carried out only by machine as shown in Figure 4.

The hand-made incense sticks failed to burn continuously till the end. It was observed that the burning propagation of machine-made sticks was continuous, which is supported by the inherent calorific value of ***T. chebula*** (4007 K. Cal/Kg) and *L. microcarpa* (4143K. Cal/Kg). Hence the incense sticks are entirely made by machine. *T. chebula* showed excellent performance when ignited, similar to carbon powder. It proved easy to handle, taking a drying time of 2.5 hours. *P. granatum* was found to produce dough that gets hard and sticky causing machine jam. With *B. m, L. m* and *R. c.*, as bio-waste powder, moderate performance of ignition and non-uniform liberation of smoke was observed. The material might be suitable for use as *dhoop* cups and coils.

RESULTS AND DISCUSSION

Assessment of parameters for biofuel applications:

The gross calorific values (GCVs) of agricultural, forest, and animal residues typically range from 2675 to 5200 Kcal/Kg. Bio-waste collected from the Kalamkari cluster was tested and showed GCVs ranging from 3848 to 4143 Kcal/Kg. These results indicate that the GCVs of the bio-waste tested are higher compared to several other bio-wastes such as paddy straw, cow dung, rice husk, wood waste, tobacco waste and barks. They are also comparable to biofuels derived from maize stalks and sugarcane. Furthermore, other parameters like ash content, moisture content, volatile matter, and fixed carbon of the bio-wastes from the cluster were tested and compared with those of fossil fuels, as detailed in Table 3.

Table 3. GCV and other parameters of some Bio-fuels

Bio-fuels	GCV (K.Cal/Kg)	AC (%)	MC(%)	VM (%)	FC (%)
***Animal residues**					
Cow dung	3240	20.35	7.34	35.25	12.66
***Fossil fuels**					
Indian coal	4050	21.00	16.50	41.50	30.00
S. African coal	6018	16.72	8.06	31.53	48.94
Indonesian coal	5611	3.86	33.72	41.48	41.00
Lignite	3200	20.35	7.34	35.25	15.25
****Bio-waste from Kalamkari production**					
R. cardifolia	3848	6.20	12.56	34.20	16.14
B. monosperma	3924	7.84	12.56	35.15	17.64
T. chebula	4007	8.20	8.95	32.10	24.94
L. microcarpa	4143	4.75	9.22	30.37	15.45
P. granatum	3916	6.32	20.40	40.12	20.00

Source*: www.ces.iisc.ernet.in; note**: Test results of the study

Gross Calorific Value (GCV): The GCV is a key for assessing biofuels. All tested materials exceeded cow dung's GCV (3240 K. Cal/Kg), with *L. microcarpa*(4143K.Cal/Kg) surpassing both Indian coal (4050 K. Cal/Kg) and lignite (3200 K. Cal/Kg). However, traditional fossil fuels like South African coal (6018 K. Cal/Kg) and Indonesian coal (5611 K. Cal/Kg) had higher values.

Ash Content (AC): Ash content indicates combustion residue. All samples had lower AC than cow dung (20.35%), Indian coal (21%), and lignite (20.35%), with *T. chebula* showing an AC of 8.20%. Indonesian coal had a notably low AC of 3.86%.

Moisture Content (MC): Low moisture is crucial for biofuel efficiency. All bio-wastes had higher MC than cow dung (7.34%) and lignite (7.34%) but were lower than Indonesian coal (33.72%). *T. chebula* had a MC of 8.95%, which is lower than Indian coal (16.5%).

Volatile Matter (VM): Generally, a lower volatile matter content is preferable for biofuels because a high volatile matter can lead to inefficient combustion. *T. chebula* (32.1%), *B. monosperma* (35.15%), and *L. microcarpa* (30.37%) had VM values lower than cow dung (35.25%).*P. granatum* (40.12%) was comparable to Indian and Indonesian coals.

Fixed Carbon (FC): Higher fixed carbon is desirable. All bio-wastes surpassed cow dung (12.66%) and lignite (15.25%) but were below fossil fuels. *T. chebula* had the highest FC at 24.94%, suggesting strong potential for biofuel use.

Limitations of the study: This study focuses on biomass collected from copper dyeing vessels, where fabrics dyed with *T. chebula* and fermented iron acetate mordants are treated with vegetable dyes. Comparing these results to existing literature is challenging due to variations in factors such as growth and storage conditions, environmental variables like temperature and humidity and different auxiliaries used in the dye bath.

Burning Performance of Incense Sticks: *T. chebula* showed excellent performance when ignited, similar to carbon powder. It proved easy to handle, taking a drying time of 2.5 hours. *P. granatum* was found to produce dough that gets hard and sticky causing machine jam. With *B. m, L. m* and *R.c.,*as bio-waste powder, moderate performance of ignition and non-uniform liberation of smoke were observed. The material might be suitable for use as *dhoop/* smoke cups and coils.

Analysis of Emission of Incense:

The study explored three methods of applying essential oils to incense sticks, using five plant-based essential oils that are rarely used in incense: Camphor, Camel grass, Benjoin resin, Marjoram, and Fragrant screw pine. The process followed small-scale agarbatti manufacturing practices, where *T. chebula* based blank incense sticks were soaked in essential oil for 30 minutes or rolled in an aluminum tin with a 1:2 fragrance-to-stick ratio, followed by a 24-hour drying period. Commercial manufacturers typically soak sticks for 24 hours to three days for better absorption, while aroma therapists apply twelve drops of essential oil per stick for more controlled aroma release. Among the oils tested, marjoram and camphor were most perceptible in terms of consistent aroma emission during the first minute of ignition, based on a qualitative analysis by a panel of five female evaluators.

Statistical Analysis: The statistical analysis was performed using IBM SPSS software version 22 for assessing all the values done in triplicate. GCV values of bio-wastes and fossil fuels are highly correlated (0.8226) and other parameters showed reasonable correlation (0.6234). The calculated chi-square value(7.30) is less than the tabulated chi-square value (24.996) at the significance level (á=0.05), with the associated p-value (0.948). Hence, there is no significant association between the variables of fossil fuels and bio-wastes.

CONCLUSIONS

Results from the study indicated that the Kalamkari residual wastes possess significant energy potential, with GCV values (3848 to 4143 Kcal/kg) surpassing several agricultural, forest and animal residues such as bark, tobacco waste, rice husk, cow dung, paddy straw (2675 to 3800 Kcal/Kg), and also lignite, the fossil fuel(3200 Kcal/Kg). All samples exhibited lower ash content (4.75% to 8.2%) than animal residue cow dung (20.35%) and fossil fuels such as Indian coal and lignite (20.35% to 21%). The moisture content of all bio-waste samples was lower than that of Indonesian coal (33.72%), with *T. chebula* having moisture levels (8.95%) comparable to S. African coal (8.06%). The volatile matter of *B. monosperma* (35.15%) was similar to that of cow dung (35.25%) and lignite (35.25%) whereas *P. granatum* showed VM values (40.12%) akin to Indian and Indonesian coal (41.48% and 41.5% respectively). Notably, *T. chebula* had the highest fixed carbon content (24.94%) among the tested bio-wastes, highlighting its suitability for use in incense sticks and other biofuel applications. Among the selected essential oils tested in combination with the blank sticks of *T. chebula*, marjoram and camphor were most perceptible in terms of consistent aroma emission during the first minute of ignition.

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FORMULATION AND DEVELOPMENT OF STRESS-RELIEVING HERBAL TEA

MANJULA KOLA, KALYANI BANDI and PARAVASTHU LEELAPRIYANKA

Professor, Food Science and Nutrition, Department of Home Science, Sri Venkateswara University, Tirupati, Andhra Pradesh, India

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ABSTRACT

The aim of the recent study was conducted in the year 2022 to formulate and develop stress relieving herbal tea with a combination of various herbs and spices. Formulated herbal tea was evaluated by organoleptic evaluation protocols. The sensory evaluation was done on 5-point scale of 'like very much' to 'dislike very much' by the untrained and semi trained panel members to know the acceptability of herbal mix by all groups. A randomized method was employed inthe distribution of samples. Formulation of herbal tea with various compositions considered for further analysis.The sensory scores obtained for the herbal tea mix (code-199) were 4.23 for flavor, 4.06 for aroma, 3.96 for color, 4.43 for aftertaste, 3.86 for astringency and 4.33 for overall acceptability. The sample code 199 was found most acceptable among other samples. whereas with respect tocode [316], scores were obtained against the flavour it was 2.86 followed by aroma (2.73) colour (3.66), aftertaste (2.80), astringency (2.33) and overall acceptability (3.00). The sample code 316 was found least acceptable.

Keywords: Evaluation, Herbs, Standardization, Stress and Tea

INTRODUCTION

Tea is ancient old traditional brewing drink; tea in India dates back to the scripts of Ramayana which states that the leaves of a certain plant in the Himalayas were used for healing which believe is the tea plant. Tea, the most popular beverage consumed by two-thirds of the world's population is made from the processed leaf of *Camellia sinensis*. Tea types, based on processing or harvested leaf development are black/fermented, green/non-fermented and oolong/semi-fermented tea. In recent year's different type of herbal teas was developed to overcome and manage the day-to-day stress among all professionals (Pargman, 2006). Tea consequently belongs to a quickly intensifying marketplace of 'health beverages. India is one of the world's largest purchasers and producers of tea. By characterization, tea is an brew of the leaves or other parts of the timeless tea plant (Camellia sp). Tea is a beverage that can be enjoyed hot, warm, or iced. In certain instances, milk and/or sweeteners like honey or sucrose may be added prior to consumption (Kraujalyte *et al.*, 2016). Herbs refer to the leafy components of plants utilized in culinary practices, and they can be used either fresh or

Corresponding Author E-mail id: drmanjukola.svu@gmail.com; part of Ph.D. thesis Sri Venkateswara University, Tirupati, Andhra Pradesh, India

dried. In contrast, other parts of the plant, which are typically dried, are classified as spices. These comprise, for sample, bark (cinnamon), berries (peppercorns), seeds (cumin), roots (turmeric), flower (chamomile), buds (cloves) and the stigma of a flower (saffron). Distinct out moded teas, herb teas are formulated from plants besides Camellia. Whether it's true tea extracted from the plant leaves of the *Camellia Sinensis* or an herbal infusion, tea has a wealth of benefits that can help fight the symptoms of anxiety and stress and promote peace of mind and relaxation (McKay and Blumberg, 2002). While the polyphenols or flavonoids are likely a key component contained in tea and herbs have been shown to have a positive effect in treating mental health issues, the ritual surrounding tea can be just as significant in terms of improving symptoms of stress and anxiety (Aoshim Hirata and Ayabe, 2007). As tea is an crucial drink, the tea stood formulated with numerous herbs which are having potential benefits and it can used as a stress reliever.

MATERIAL AND METHODS

Due to the increasing demands of health conscious among consumers, a herbal tea with various ingredients with stress relieving components was formulated, tested and developed. The formulation, standardization and evaluation work were done in the Food Science and Technology laboratory.

Materials: Procurement of Ingredients: The following herbs were carefully chosen such that they can provide taste along with numerous well-being aids mainly reducing stress. Each and every ingredient has unique functional components which is beneficial to health. Fresh spinach leaves and mint leaves are collected from the vegetable market in Gandhi Road, Tirupati. Dried lemon grass, thyme, rosemary, basil, cinnamon, ashwagandha, turmeric, cumin, ginger, and nutmeg are collected from Nilgiris supermarket in Air Bypass Road, Tirupati.

Pre-Processing of Ingredients: Fresh mint and spinach leaves were washed, leaves are separated from the stalks. Leaves were layered delicately on paper and dehydrated in a solar drying for 3 days. Dried Lemon grass leaves and basil were collected free from foreign particles and ground in the motor pistol. The other herbs and spices ginger, turmeric, ashwagandha, cumin, cinnamon, thyme, rosemary, and nutmeg were cleaned and ensured that is free from foreign particles. The ingredients were crushed/ground in the cleaned motor pistol. The crushed samples were kept in glass bottles with close-fitting lids and labeled.

Product Formulation: The dried and crushed ingredients are taken and prepared the composition for different formulations. Prepared formulations were bagged in infusion tea bags. A piece of tea bag contained approximately 1.5 to 2.0g of produce. The tea bags were stored in glass containers with secure lids and clearly labelled for sensory evaluation. The milled and dehydrated herbs were mixed together in diverse amounts to obtain four different formulations. 2.0 gram each formulation was placed in infusion tea bags for sampling. The bagged samples were stored in glass jars, maintained at temperatures between 28°C and 34°C, and protected from direct sunlight. They were labelled for sensory evaluation. The herbal tea formulations were tabulated in table1.

Sensory evaluation

The testing was done on 5-point scale of 'like very much' to 'dislike very much' by the untrained and semi trained panel members to know the acceptability of herbal mix by all groups. A randomized method was utilized in the design inserving the samples to avoid any

Table.1. Formulation of Herbal Tea with Different Compositions

S.No.	Ingredients (g)	Sample 1 [199]	Sample 2 [316]	Sample 3 [629]	Sample 2 [997]
1	Lemongrass	0.150	0.200	0.200	0.150
2	Ginger	0.220	0.150	0.200	0.180
3	Cumin	0.110	0.070	0.160	0.170
4	Turmeric	0.150	0.200	0.160	0.100
5	Aswagandha	0.330	0.200	0.160	0.400
6	Mint	0.300	0.200	0.160	0.300
7	Spinach	0.100	0.200	0.160	0.300
8	Cinnamon	0.200	0.100	0.160	0.150
9	Basil	0.200	0.200	0.160	0.090
10	Thyme	0.085	0.080	0.160	0.070
11	Rosemary	0.095	0.200	0.160	0.050
12	Nutmeg	0.060	0.200	0.160	0.040
	Total (g)	2.00	2.00	2.00	2.00

Figure 1. Sample Codings

predetermining effect.The scores were presented for further examination.

Packaging: The perfect blend of freshly dried leaves infused with herbs was packed for a well-balanced cup of herbal tea. Packaging provides outstanding protection from environmental and storage conditions which cannot compromise the quality of the product.

RESULTS AND DISCUSSION

Four different combinations of herbal tea mixes were formulated, coding was specified to the samples (figure 1) for sensory analysis to assess the flavour, aroma, colour, aftertaste, astringency, taste and overall acceptability was assessed using a 5-point hedonic scale. The sensory scores attained for the herbal tea mix (code-199) were 4.23 for flavor, 4.06 for aroma, 3.96 for color, 4.43 for aftertaste, 3.86 for astringency and 4.33 for overall acceptability, these sensory scores of herbal tea mix combination was found most acceptable.

The second combination of stress relieving herbal tea mix the sample code [316] scores were the flavour 2.86, aroma 2.73, colour 3.66, aftertaste 2.80, astringency 2.33 and overall acceptability 3.00, sample code 316 was found least acceptable. For the third combination of stress relieving herbal tea mix, the sample code [629] scores were the flavour is 2.93, aroma 2.80, colour 3.23, aftertaste 3.26, astringency 2.70 and overall acceptability 3.06, scores of stress relieving herbal tea mix combination were found normal acceptable. For the fourth combination of stress relieving herbal tea mix the sample code [997] scores were the flavour 3.13, aroma is 2.93, colour 3.76, aftertaste 3.13, astringency 2.73 and overall acceptability 3.50. These sensory scores of stress relieving herbal tea mix combination were found average acceptable. The four formulations of stress reliving herbal tea mix were analyzed, based on the acceptable levels sample code 199 was more acceptable because of the pleasant blend of all the ingredients. The outcomes of each sensory parameter of all the formulations were discussed below.

Sensory Evaluation

A. Flavour: The sample products which are brewed teas with the most favored flavors for different samples were 199(127.00%) followed by 997(94.00%), 629(88.00%), and 316(86.00%) showed in Figure 2. Infusions from Bachieved the least score in flavor (Mishra

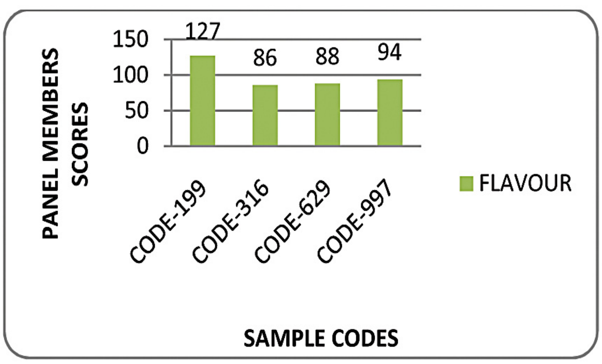

Figure 2.Flavor Acceptance Scores by Panelists

et al., 2000). Whereas the product that had a higher concentration of nutmeg was not preferred as the other formulations.

Conversely, products with medium proportions of all herbs some high amounts of ginger, and cinnamon based on other compositions required a more pleasing flavor. The volatile components found in different types of teas comprise over 50 aroma-active compounds, which can produce a range of characteristics such as nutty, popcorn-like, metallic, floral, meaty, fruity, potato, green, cucumber-like, and hay-like characteristics (Lee and Chambers, 2007) found that epigallocatechingallate and epigallocatechin appeared to significantly influence the sensory attributes of a processed green tea beverage. The impact of age and fermentation level on volatile flavor compounds is substantial. Teas produced from the youngest leaves usually exhibit higherconcentrations of catechins and amino acids, potentially resulting in off-flavors.

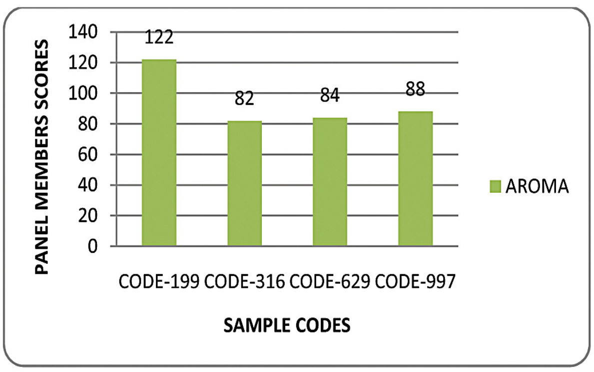

Figure 3. Aroma Acceptance Scores by Panelists

B. Aroma: Panelists showed that the greatest preference for the aroma of the product was 199 (122.00%) followed by 997(88.00%), 629(82.00%), and 316(82.00%) in the order (figure 3). where the least preferable aroma in 316(82.00%) due to significance presence of turmeric, rosemary, basil, and nutmeg, it was expected that sample with a higher proportion of 316 (82.00%) would be less preferable than other samples in the aroma.

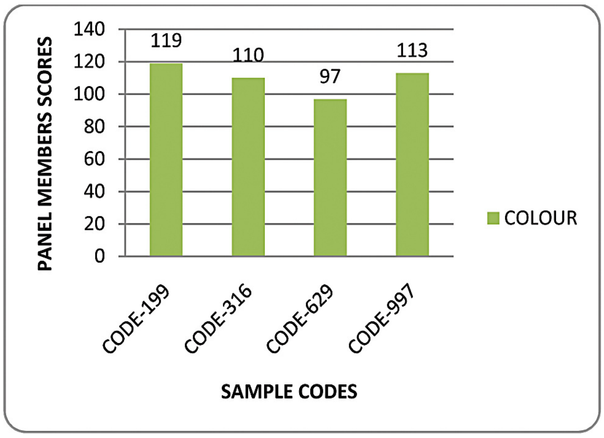

Figure 4. Color Acceptance Scores by Panelists

C. Colour: The color of food can either enhance or reduce consumer interest, as it often serves as a cue for the food's flavor (Ingrid *et al.,* 2010). The two utmost liked products are 199(119.00%) and 997(113.00%). Conversely the least preferred products 629(97.00%) and 316(110.00%) (Figure-4). 629(97.00%) contained an equal amount of all ingredients that may look dark in color due to the pigments that are present in the herbs and 316(110.00%) they contain high proportions of turmeric and nutmeg related to the other samples they may appear dark in color owed to the pigments that are present in these herbs.

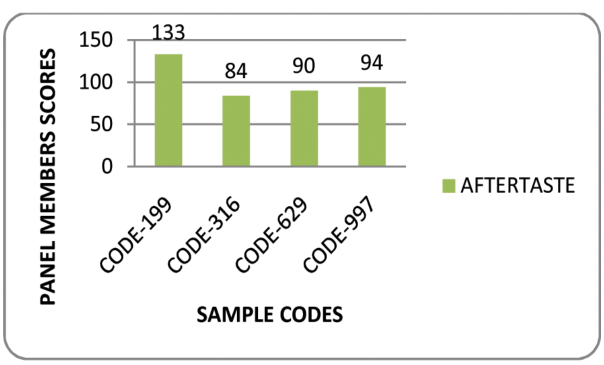

Figure 5. Aftertaste Acceptance Scores by Panelists

D. Aftertaste: It was depicted from the figure 5 that product 199 (133.00%) was however the most preferred product followed by 997 (94.00%), 629 (90.00%) and 316 (84.00%). The slightestchosen sample contains a high proportion of turmeric that gives bitterness to the sample.

E. Astringency: Similarly, product 199(116.00%) was the maximum chosen in astringency followed by 997(82.00%), 629 (74.00%) and 316(70.00%) as in figure-6. From the products with high rosemary, nutmeg proportions were least preferable in astringency. Xu *et al. (*2006) stated that astringency was generally recognized as a feeling of dryness or puckering that was not confined to a particular region of the mouth or

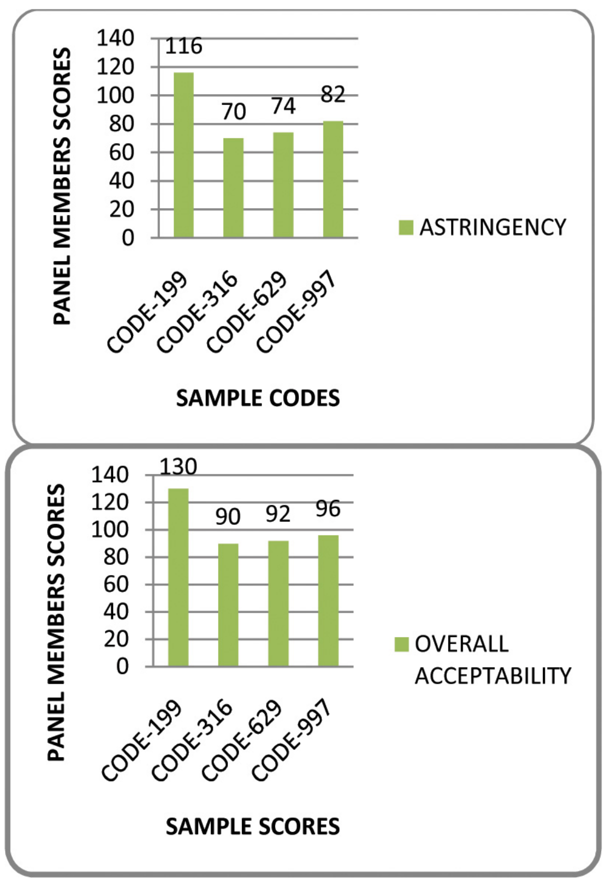

Figure -6. Astringency and Overall acceptability Acceptance Scores by Panelist

tongue but is experienced invariably as a diffuse stimulus.

F. Overall Acceptability: Product 199(130.00%) had the most preferable sample in overall acceptability. And the slight preferred formulation 316(90.00%) in flavor, aroma, aftertaste, and astringency. The overall acceptability of the products that are utmost chosen 199 (130.00%) followed by 997 (96.00%), 629 (92.00%) and 316 (90.00%) in order figure-6. Roychoudhury *et al*. (2017), utilized descriptive analysis to assess 10 different canned tea products by examining 17 various attributes, which included floral characteristics, lemon, roasted tea, roasted rice tea (artificial), sweet odor, green tea, oolong tea, black tea, boiled milk, arrowroot/rooty, sour taste, sweet taste, chestnut shell, oily, burnt leaf, bitter taste, and astringency. All studies utilized a limited selection of samples, which might not represent the wide array of available teas (Mishra *et al*., 2000). Based on the sensory evaluation the panel members preferred the sample code no 199. In this sample the ingredients used are lemongrass (0.100g), ginger (0.200g), cumin (0.110g), turmeric (0.150g), aswagandha (0.311g), mint (0.200g), spinach (0.100g), cinnamon (0.200g), basil (0.100g), thyme (0.085g), rosemery (0.080g), nutmeg (0.060g). In this product the flavor and aroma are pleasant and the color is acceptable and the aftertaste and astringency are also good compared to other samples.

CONCLUSIONS

The formulated stress reliving herbal tea was subjected to sensory evaluation to study the acceptability. Based on the results, it was inferred that owed to strong concentration of turmeric, rosemary, basil, and nutmeg 316(82.00%) was least acceptable than other samples in aroma, color and astringency. Product 199(116.00%) was the highly accepted in astringency. Product 199(130.00%) had the upper mostliked sample in overall acceptability. This was expected as it was the most preferred in flavor, aroma, color, aftertaste, astringency, and overall acceptability. And the least preferred product was 316(90.00%) in flavor, aroma, aftertaste, and astringency. The results indicated that the well-blended combination of all the potential ingredients was more accepted. Hence the formulation code-199 was standardized and subjected to further studies. Sensory attributes of herbal teas have accredited comparatively modest explore attention inspite of the rising acceptance of herbal teas globally.

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COMPARATIVE STUDY ON CHALKBOARD AND POWERPOINT TEACHING METHODS FOR EFFECTIVE LEARNING

SADDIKUTI PRASHANTHI and T. LAKSHMI

Department of Agricultural Extension Education,
S.V. Agricultural College, Tirupati.

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ABSTRACT

This comparative study investigates the effectiveness of traditional chalkboard and modern Power Point teaching methods in contemporary education. The study was conducted among third-year B.Sc. (Hons.) Agriculture students at Sri Venkateswara Agricultural College, Tirupati. A descriptive survey method was employed, utilizing questionnaires distributed via Google Forms, with 120 randomly selected responses analyzed using statistical tools. Results indicated that while PowerPoint presentations are perceived to offer better organization, clarity and visual aids, chalkboards are valued for their ability to stimulate interest, facilitate note-taking, and enhance student-teacher interaction. Specifically, 63.33 per cent of students found Power Point presentations well-organized and 86.67 per cent appreciated the visibility of lecture content. Conversely, 81.67 per cent of students reported better understanding through chalkboard teaching and 85.00 per cent valued the interaction it fosters. The study highlights that each method has distinct advantages: PowerPoint's multimedia capabilities and ease of updating content versus the chalkboard's simplicity and reliability. The findings suggest that an optimal teaching approach might integrate both methods to leverage their respective strengths, thereby enhancing educational quality and learning outcomes.

Keywords: Chalkboard Teaching; Power Point Presentations; Student Perceptions; Teaching Methods

INTRODUCTION

In the realm of education, the methods employed by educators to impart knowledge have evolved significantly over the years. Among the myriad of teaching techniques, the use of traditional chalkboards and modern Power Point presentations stand out as two prominent methods. This comparative study aims to explore the efficacy of these teaching tools in the context of contemporary education.

The chalkboard, also known as a blackboard, has been a staple in classrooms for centuries. Its simplicity, cost-effectiveness, and ease of use have made it a reliable tool for teachers globally. Chalkboards allow for spontaneous illustrations and a tactile learning experience, fostering direct interaction between the teacher and students. However, they also come with limitations, such as dust from chalk and the potential for reduced visibility in large classrooms.

Corresponding author E-mail: prashanthisaddikuti@gmail.com

Conversely, the advent of digital technology has introduced Power Point presentations as a popular alternative. PowerPoint, developed by Microsoft, offers a multimedia approach to teaching, incorporating text, images, videos, and animations. This method caters to diverse learning styles and can enhance engagement through visually appealing slides and interactive elements. Nevertheless, the effectiveness of Power Point is contingent on the teacher's proficiency with the software and the quality of the presentation design.

According to a study by Szabo and Hastings (2000), Power Point can enhance student attention and retention when used effectively. However, Bartsch and Cobern (2003) found that overly complex slides might detract from learning. On the other hand, research by Mayer (2009) highlights the benefits of multimedia learning, suggesting that well-designed Power Point presentations can support cognitive processes involved in learning.

In contrast, studies on traditional teaching methods underscore the importance of direct interaction and the tactile benefits of using chalkboards (Brophy, 1986). Additionally, Cline and ishi, (2006) argue that the simplicity and reliability of chalkboards can be advantageous, particularly in resource-limited settings. Chalkboard teaching emphasizes teaching methods as systematic procedures adopted by educators, while Power Point presentations can be classified under audiovisual (AV) aids, tools used to enhance the delivery of content.

Teaching method is a broad, structured plan or approach used by teachers to deliver lessons and achieve learning objectives.It's general and overarching and guides how a subject is taught.Teaching Technique as specific, concrete strategy or tactic used within a method to accomplish a particular goal. It is Narrow and focused. It's the "how-to" of implementing a method. A method is the overall approach (like using a discussion format), while a technique is a tool or action within that method (like using brainstorming exercises during the discussion).

Teaching Aids are any material or tool used to support and enhance teaching, making lessons more effective and engaging. It is a broad category which includes both traditional and modern tools. AV Aids are a subset of teaching aids that specifically use sight and/or sound to facilitate learning. It is focused on multimedia tools that appeal to the visual and auditory senses. All AV aids are teaching aids, but not all teaching aids are AV aids. For example, a chalkboard is a teaching aid but not an AV aid, whereas a video is both a teaching aid and an AV aid.

Furthermore, Power Point can increase students' engagement and bridge the gap between abstract and concrete concepts. Also, it was revealed that Power Point has no relationship with students' genders (Igwe, 2022). The comparative analysis of chalkboard and Power Point teaching methods seeks to provide a comprehensive understanding of their respective advantages and drawbacks. By evaluating their impact on various educational parameters, the study aims to inform best practices in teaching and contribute to the enhancement of educational quality.

MATERIAL AND METHODS

The study adopted a comparative and descriptive survey in which the questionnaire was sent to the students using Google forms. The B.Sc. (Hons.) Agriculture students of Sri Venkateswara Agricultural College, Tirupati were selected for the study. The components of the study were collected by thorough review of literature. The Google questionnaire was circulated in the WhatsApp group of the

Table 1. Perception of learners towards power point presentations in the class (n=120)

S.No.	Category	Frequency	Percentage
1.	Least effective	24	20.00
2.	Moderately effective	68	56.67
3.	Most effective	28	23.33

students. Out of the responses received, 120 were selected randomly for analysis. Statistical tools like mean, standard deviation, frequency and percentage were used for analysis of the collected data.

RESULTS AND DISCUSSION

The results of the study are discussed below

Perception of learners towards power point presentations in the class

Perception is the act of being able to observe and evaluate emotions based on the past experiences. the way in which the students perceive the classes though power point might significantly impact their learning. The data on perception of the students about power point presentations in the class was collected using a schedule with a five continuum of agreement. The results were analysed using mean and standard deviation and categorized into three groups which were presented in the Table 1.

It could be inferred from the above table that more than half (56.67 %) of the students find the power point as a moderately effective method of teaching followed by most effective (23.33 %) and least effective (20.00).

The moderately to most effective nature of the power point presentations as perceived by the students might be justified by the reason that the retaining capacity of students has been more with power point mode

Table 2. Students' responses to chalkboard and power point (n=120)

S.No.	Statements	Chalkboard		Power point	
		Frequency	Percentage	Frequency	Percentage
1.	Lectures were well organized and structured	44	36.67	76	63.33
2.	Clarity of the contents/diagram	32	26.67	88	73.33
3.	Visibility of lecture contents	16	13.33	104	86.67
4.	Reproducibility of text and diagram	36	30.00	84	70.00
5.	Stimulates interest in subject	88	73.33	32	26.67
6.	Integration of text with figures	44	36.67	76	63.33
7.	Able to take notes and copy diagrams	64	53.33	56	46.67
8.	Better understanding of topic	98	81.67	22	18.33
9.	Overall satisfaction and effectiveness	80	66.67	40	33.33
10.	Demonstration of practical aspects	36	30.00	84	70.00
11.	Student - teacher interaction	102	85.00	18	15.00

of teaching. The results seek support from the findings of Ghimire and Joshi (2023) who stated that students memory was improved which in turn enhanced their overall perception on Power Point use. The findings of Ghimire and Joshi (2023) also revealed that notable percentage (37.8%) of students strongly agreed and 58.30 per cent of students agreed that the lesson more interesting with Power Point.

Comparison of students' responses to chalkboard and power point

The students' responses on different components were collected, analysed and presented in the Table 2.

The results from Table 2 can be interpreted as nearly two-thirds (63.33 %) of the students responded that lectures were well organized and structured in power point presentation. Nearly one-fourth (73.33 %) of the students felt that the clarity of contents/ diagram was more in power point. Majority (86.67 %) of the respondents felt that visibility of lecture contents was more in power point and 70.00 per cent responded that reproducibility of text and diagrams was more using power point. On contrary to the above findings, 73.33 per cent of students felt that lessons through chalkboard method of teaching stimulates interest in the subject. The integration of text with images is possible through power point according to 63.33 per cent of students and more than half (53.33 %) revealed that chalkboard provides ability to take notes and copy diagrams.Chalkboard provides better understanding of the topic as responded by majority (81.67 %) and also the overall satisfaction and effectiveness (66.67 %)was more in chalkboard teaching. Demonstration of practical aspects was more effective in power point as opined by 70.00 per cent and student-teacher interaction was more in chalkboard according to 85.00 per cent of the students.

Advantages of Chalk and board method of teaching

The response of the students regarding advantages of chalk and board method of teaching are collected on a three-point continuum. The results are analysed and organized in the Table 3.

Table 3. Students' responses on advantages of chalk and board method of teaching

(n=120)

S.No.	Statements	Agree		Undecided		Disagree	
		No.	%	No.	%	No.	%
1.	No need of technical support	90	75.00	4	3.33	26	21.67
2.	Taking notes is possible	112	93.34	4	3.33	4	3.33
3.	Students are visible and thus their responses can be judged	92	76.67	20	16.67	8	6.67
4.	Presentation remains on board	86	71.67	20	16.67	14	11.67
5.	Facial expressions of teacher can be seen	96	80.00	18	15.00	6	5.00
6.	Step by step teaching	114	95.00	6	5.00	0	0.00
7.	More involvement of teacher	102	85.00	16	13.33	2	1.67

The finding from table 3 reveal that step by step teaching is the major advantage of chalk and boardmethod of teaching as opined by majority (95.00 %) of the respondents followed by taking notes is possible (93.34 %), more involvement of teacher (85.00 %) and facial expressions of teacher can be seen (80.00 %).

Research underscores the effectiveness of the chalk-and-board teaching method in fostering structured learning and active student engagement. Sequential presentation on the board aids cognitive processing and retention (Nouri and Shah, 2020), while handwritten note-taking, as highlighted by Mueller and Oppenheimer (2014), enhances understanding through active summarization. The teacher's physical presence at the board promotes interaction and motivation, positively impacting learning outcomes (Grossman *et al*., 2017). Additionally, non-verbal cues like gestures and facial expressions strengthen comprehension and emotional connection with the material (Argyle, 2017). These factors collectively affirm the enduring value of the chalk-and-board method in education, even amidst technological advancements.

Disadvantages of Chalk and board method of teaching

The response of the students regarding disadvantages of chalk and board teaching are collected on a three-point continuum. The results are analysed and organized in the Table 4.

The major disadvantage of chalkboard method of teaching as listed by majority (83.33 %) of the student respondents was less no. of diagrams, flow charts and animation followed by difficulty in understanding the handwriting (78.33%), non-availability of contents for further reference(76.67 %) and distraction of students after teacher faces board (75.00 %).

While the chalkboard method has its strengths, research highlights several limitations in addressing modern educational

Table 4. Students' responses on disadvantages of chalk and board method of teaching

(n=120)

S.No.	Statements	Agree		Undecided		Disagree	
		No.	%	No.	No.	%	No.
1.	Difficulty in understanding the handwriting	94	78.33	14	11.67	12	10.00
2.	Distraction of students after teacher faces board	90	75.00	16	13.33	14	11.67
3.	Non-availability of contents for further reference	92	76.67	20	16.67	8	6.67
4.	Writing and cleaning on board takes time	84	70.00	12	10.00	24	20.00
5.	Usage of short forms is more	73	63.33	20	16.67	24	20.00
6.	Less no. of diagrams, flow charts and animation	100	83.33	6	5.00	14	11.67
7.	Limited content of lecture	88	73.33	14	11.67	18	15.00

needs. Mayer (2009) emphasizes the importance of visual aids, such as diagrams and animations, for visual learners and illustrating complex concepts - features that chalkboards often lack. Handwriting on chalkboards can also be hard to read, particularly for those with visual impairments, impacting engagement and comprehension (Lee *et al*., 2011). Additionally, the temporary nature of chalkboard content restricts students' ability to review material outside the classroom, a critical factor for deeper learning and retention, as noted by Penuel *et al*. (2007). Facing the chalkboard during lectures can further reduce teacher-student interaction and engagement, as Evertson and Weinstein (2006) highlight the importance of eye contact and connection in maintaining focus. These limitations suggest that while the chalkboard method has traditional merits, it may fall short in meeting the diverse and evolving needs of contemporary education.

Advantages of power point method of teaching

The response of the students regarding advantages of power point teaching are collected on a three-point continuum. The results are analysed and organized in the Table 5.

From the Table 5, it could be inferred that pictures, videos, animations etc., can be added was the major advantage responded by 96.67 per cent of students followed by multimedia can be used (93.33 %), the presentation can be updated (85.00 %) and no hand writing issues (81.67 %).

Research highlights the growing preference for multimedia presentations in education due to their ability to improve learning outcomes through visual stimulation, engagement and clarity. Studies by Mayer (2009) and Clark and Mayer (2016) demonstrate that incorporating visuals such as pictures, videos, and animations improves comprehension and retention by aiding information processing. Multimedia also fosters higher student engagement and motivation through interactive learning experiences

Table 5. Students' responses on advantages of power point method of teaching

(n=120)

S.No.	Statements	Agree		Undecided		Disagree	
		No.	%	No.	%	No.	%
1.	Pictures, videos, animations etc., can be added	116	96.67	0	0.00	4	3.33
2.	Multimedia can be used	112	93.33	4	3.33	4	3.33
3.	No handwriting issues	98	81.67	10	8.33	12	10.00
4.	Humour, stories and quotes can be added	84	70.00	8	6.67	28	23.33
5.	Numerous illustrations are possible	90	75.00	18	15.00	12	10.00
6.	It is possible to update the presentation.	102	85.00	4	3.33	12	10.00
7.	Good retention of knowledge	92	76.67	24	20.00	4	3.33

(Tindall-Ford *et al*., 2016). Unlike static traditional methods, multimedia offers flexibility for updates, corrections, and adaptation to diverse learning needs, as emphasized by Li and Kirkup (2007). Additionally, multimedia eliminates issues of handwriting legibility, presenting information clearly and reducing cognitive load (Merrill, 2002). These advantages position

multimedia as an effective and versatile tool for modern education.

Disadvantages of power point method of teaching

The response of the students regarding advantages of power point teaching are collected on a three-point continuum. The results are analysed and organized in the Table 6.

The results from Table 6 conclude that 95.00 per cent of students responded that the main disadvantage of power point teaching was many times, it appears that the faculty is merely reading the content followed by teacher will be in a hurry to read and finish the slide (93.33 %), the quick pace and darkness make it impossible to take notes (88.33 %) and frequent electricity or technical errors (83.33 %).

While Power Point presentations offer numerous benefits, research highlights several potential drawbacks if not used judiciously. Gurung (2005) notes that merely reading slides can reduce interaction and lead to passive learning, which diminishes retention and understanding. Additionally, rushing through slides to fit within time constraints can result in information overload, hindering comprehension (Hohenstein *et al*., 2018). Dimmed lighting,

Table 6. Students' responses on disadvantages of power point method of teaching

(n=120)

S. No.	Statements	Agree		Undecided		Disagree	
		No.	%	No.	%	No.	%
1.	Many times, it appears that the faculty is merely reading the content.	114	95.00	2	1.67	4	3.33
2.	Teacher will be in a hurry to read and finish the slide	112	93.33	6	5.00	2	1.67
3.	More information on single slide often confuses the students	96	80.00	20	16.67	4	3.33
4.	The quick pace and darkness make it impossible to take notes.	106	88.33	12	10.00	2	1.67
5.	Faculty will be unable to continue the lecture after ppt failure	94	78.33	14	11.67	12	10.00
6.	The PowerPoints are poorly constructed and unreadable.	78	65.00	30	25.00	12	10.00
7.	Less attention due to darkness	94	78.33	18	15.00	8	6.67
8.	Frequent electricity or technical errors	100	83.33	20	16.67	0	0.00

often required for slide visibility, can impede effective note-taking—a critical aspect of learning, as emphasized by Peverly (2006). Furthermore, reliance on technology introduces risks of technical issues, which can disrupt lessons and reduce instructional time (Clark and Mayer, 2016). These challenges underscore the importance of integrating Power Point presentations thoughtfully, prioritizing active engagement, appropriate pacing, conducive environments for note-taking, and robust technical support to maximize their effectiveness in education.

CONCLUSION

In contemporary education, balancing traditional methods like chalkboard teaching with modern approaches such as multimedia presentations is crucial for optimizing learning outcomes. Chalkboard teaching fosters structured communication and direct interaction, though it is limited by challenges such as handwriting legibility (78.33%), difficulties in illustrating complex concepts (83.33%), and the transient nature of content (76.67%). Multimedia presentations, including Power Point, enhance engagement through dynamic visuals (96.67%) and flexibility (85.00%) but risk promoting passive learning when slides are over-relied upon (78.33%), rushed (93.33%), or presented in note-taking-unfriendly conditions (88.33%).

A balanced approach integrates multimedia's interactive and visual strengths with the clarity and personal engagement of traditional methods. Educators should focus on active learning strategies, professional development for effective multimedia use, and addressing accessibility and technological challenges. Institutions must prioritize robust technological infrastructure to ensure seamless delivery and minimize disruptions.

Future research should explore the effectiveness of varied teaching methods across contexts, with student feedback guiding instructional practices. By combining innovation with foundational teaching principles, educational institutions can foster inclusive, engaging environments that equip students for future challenges.

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RICE PRODUCTION IN UTTAR PRADESH: GROWTH, INSTABILITY AND DECOMPOSITION ANALYSIS

PARVAT SINGH

Department of Economics, University of Lucknow, Lucknow, Uttar Pradesh - 226007

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ABSTRACT

The present study investigated the association between growth rate and instability regarding to the production, area and yield of rice in Uttar Pradesh. The data was extracted from the (Directorate of Economics and Statistics, DES), Department of Agriculture and Farmers Welfare, (MoA, GoI), spanning from 1990-91 to 2021-22. The data has been segmented into four periods for analysis. The compound annual growth rate, Coppock's and Cuddy-Della Valle Instability Index have been estimated for the four periods.The growth rate analysis showed the rice crops for the area (0.56%), production (1.30%) and productivity (1.4%) overall, respectively. The highlights of the overall instability measures result of the CDVI Index in rice were observed to be low under area (4.09%) and low (9.59%) instability in production, respectively. In terms of Coppock's performed measure of instability was registered to be low (38.42%) under area cultivation and medium (42.93%) in the production, respectively. The results from the decomposition analysis revealed that the yieldeffect contributed the highest in production observed during period II (155.56%), which shows that there is a negative in-area effect (-65.56%), and an interaction effect was observed (7.78%). The study suggests that production should be prioritized and improving productivity to reach the future demand for rice; it also indicates that there is further potential for the enhancing production of rice in Uttar Pradesh by the adoption of advanced inputs technology.

Keywords: Decomposition,Growth Rate, Instability Analysis, Rice, Uttar Pradesh

INTRODUCTION

The rice crop is the only staple food crop for consumption by nearly half of the world's population. Therefore, rice production should be increased to connect the future demands of the growing global population. Uttar Pradesh accounted for around 12 per cent of the nation-leveltotal rice production and contributed significantly to the area cultivation during 2021-22 (MoA and FW, GoI, 2021-22). The consumption of rice is increasing daily intake due to the increase in population, which can be achieved only through the increase in yield. It has been achieved by introducing new high-yielding varieties and crop management techniques (Jambhulkar *et al.,* 2023).

Global rice production was projected to increase from 501.2 million tonnes to 510.6 million tonnes between 2017 and 2019, respectively. The variation in production from

Corresponding Author E-mail i.d: singhparvat20@gmail.com

2018-19 over 2017-18 was only 1.3 percent in the world market (Food and Agriculture Organization, 2018). India has witnessed a tremendous rise in rice food production from 20.58 millionin 1950-51 to 129.47 mt in 2021-22 (Department of Agriculture, Cooperation and Farmers Welfare, 2022-23, Government of India). the rice growth was made possible by adapting high-yielding varieties due to expansion in irrigation, using modern inputs, and developing infrastructure and institutions, credit markets, and minimum support price policy. Agricultural credit in itself is not an input, but it helps create an environment for adopting modern production technology (Sidhu and Gill, 2006). India is the second largest producer globally, with 23.5 per cent of global rice production, next to China nation. The producers and consumers India is the world's second-largest country. Rice registered (41%) of total food grain production, occupies 35 per cent of the food gains area of the nation and persistently plays an essential importance in livelihood and food security (Nirmala *et al.,* 2019). Rice is an important staple food throughout the national crops. Among the major rice-producing states, West Bengal (13.79%), Uttar Pradesh (13.34%), and Andhra Pradesh, including Telangana (12.84%), are the top three in terms of their contribution to rice production in India (Singh *et al.,* 2021). The forecasted consumption demand for rice by 2025 in Asian countries means that rice consumption will increase more than the population. In India, rice consumption will rise by more than 47 per cent and 51 per cent in Asia (Papademetriou, 2000). The primary reason for the variability in wheat and rice is that the expansion of irrigation in rice was less than in wheat. Rice area under irrigation increased from 37 per cent to 43 per cent between 1965 and 1988. Additionally, food and agriculture production instability play a pivotal role in effective food management (Chand and Raju, 2009). Rice holds importance in Uttar Pradesh, with an area of cultivation of 5.90 million hectares, observed for 13.5 per cent of the total production in India (Ansari *et al.,* 2022). Agriculture was the most essential sector of the economy. However, the population growth in the past few decades has outpaced agricultural production, thereby creating a disparity in the availability and demand of the rice crop. Therefore, the present study considers rice a major staple in the world, particularly in India, whereit contributes overhalf of the worldwide calorie intake of all human beings. However, there is a demand to significantly enhance the average yields of rice; against this background, the study investigates the growth and trends in production, area,and productivity of rice along with instability in rice crops.

MATERIAL AND METHODS

The study was conducted on rice crops from 1990-91 to 2021-22 in Uttar Pradesh. The study used secondary data for 32 years of year-to-year data regarding the productivity, production and area of ricein Uttar Pradesh obtained from the (DES, MoA&FW), Government of India, Agricultural Statistics at a Glance. The thirty-two-year data used for the analysis from 1990-91 to 2021-22 on the productivity, production and area, of rice crops in Uttar Pradesh. Analysing the growth rates using CAGR and estimating the impact of yield, the area, and their interaction on total rice production was achieved using log-linear growth models and a decomposition approach. Additionally, (CV), Coppock's Instability Index and (CDVI), were calculated as the variability in production, productivity and area.

The study was spanning into three periods (1990-91 to 1999-2000)-Period I, (2000-01 to 2009-10)-II, (2010-11 to 2021-22)-III, and (1990-91 to 2021-22)- Overall of rice crops in Uttar Pradesh.

Analysis of Data

The annual growth rate analysis was forecasted for the production and productivity and area of the rice crop as follows:

$$Y = ab^t$$

The equation takes the linear form by taking the logarithm of both sides.

$$\log Y = \log a + t\log b$$

Y= a + bt

Where;

y = Dependent variable (Area, production and productivity)

t = time/year (independent variable)

a = constant/intercept

b = (regression coefficient)

CAGR = {Antilog (In b) -1} *100

The significance of the estimated compound annual growth rate was tested with a student's t-test.

Instability Analysis in Rice

The extent and type of instability within the rice production, yield and area in Uttar Pradesh were estimated using the coefficient of variation (CV). However, the basic CV does not adequately capture the underlying trend in the year-by-year data. To address this issue, the degree of variability in production, yield and area was computed to estimate the variability using the instability index originally given by Cuddy and Valle (1978). A low value of this index shows low instability in production. The CV is measured by the formula with equation (1) to estimate the instability index of rice crops in Uttar Pradesh concerning production, area, and yield.

(CV%) $= \frac{\sigma}{\mu} * 100$

CDVI in Rice

$$CDVI = CV \times \sqrt{(1-\bar{R})^2}$$

CDVI = (Cuddy Della Valle Index, %), CV = (Coefficient of Variation), $\overline{R^2}$=Adjusted Coefficient of Determination, CDVI = Cuddy Dell Valle Index, very low = 0 to 5, Low instability = between 5 to 15, Medium instability = 15<CDVI<30, High instability = 30<CDVI>50, Very high = greater than 50.

Coppock's Instability Index (CII)

The study measured variation using the (CV), which calculate the level of instability in continuous data characterised by long-term trends. The Coppock's Instability Index (CII) approximates the average year-to-year % variation adjusted for the trend to overcome this issue. The equation's algebraic form.

Coppock's Instability Index = $\left(\sqrt{logV} - 1\right)*100$

$$Log\ V = \frac{\left[\left(log\frac{X_{t+1}}{X_t}\right)m\right]^2}{N-1}$$

X_t = area/production/productivity in the year 't'

N = number of years;m = (mean of the difference between logs) of X_{t+1}, X_t

Log V = Logarithmic variance of the series.

Decomposition Analysis

Minha and Vaidyanathan (1965) introduced the initial structure method for breaking down the growth trend. Several scholars have adopted and modified this decomposition technique model to estimate the comparative contribution of yield of area and their interaction with rice (Devegowda, 2024), presenting it in the following format.

$P_o = A_o * Y_o$

$P_n = Y_o * Y_n$

$\Delta P = P_n - P_o$ (Production Change)

A_o = Area (Base Year)

A_n = Area (Current Year)

Y_o = Yield (Base year)

ΔA = Change in Area (An- Ao)

ΔY = Change in Yield (Yn – Yo)

$$P = \frac{A_0\,\Delta Y\,\times\,100}{\Delta P} + \frac{Y_0\,\Delta A\,\times\,100}{\Delta P} + \frac{\Delta Y\Delta A\,\times 100}{\Delta P}$$

P (Production change) = Area effect + Yield effect + Interaction effect.

RESULTS AND DISCUSSION

Uttar Pradesh, often referred to as the “Rice Bowl of Central India has witnessed a remarkable contribution in cultivation in Uttar Pradesh since post-reforms in India. In terms of area under rice in Uttar Pradesh, it has consistently increased from 5.6 million hectares to 5.7 million hectares from (1990-2000). This growth has been accompanied by increased rice production with (10.3 MT in 1990-91 to 15.5MT) in 2021-22. Similarly, the productivity (yield) of rice in Uttar Pradesh has also experienced growth from1.8 t/ha in 1990-91 to 2.7 t/ha in 2021-22.These statistics are presented in Table 1, which outlines the production, productivity and area of rice in Uttar Pradesh during the period (1990-91 to 2019-20). This tremendous rise in production can be attributed to favourable climate conditions in different regions of the state. In addition, great production also supports significant scientific research in the rice crop.

Growth Performance for Area, Production and Yield of Rice Crops

In Uttar Pradesh, the compound annual growth rates analysis of production, area and rice productivity for three periods and the entire study period have been estimated and presented in Table 2. Analysis results revealed that the compound annual growth rates of production, productivity and yield fluctuated throughout each period.The finding of the growth analysis showed that the compound annual growth rates of production, area and yield varied throughout the three periods.

The growth rate analysis showed that the highest growth rates were recorded in production (3.18), which was significant during period I. However, positive growth rates were registered for the area, production and productivity during period I. During period II, the compound annual area growth rate was (-0.44) negative and non-significant, while production and yield growth rates were observed positive but non-significant.This may be due to diversifying rice cultivation areas to non-agricultural and commercial crops and purposes during the period.

During Period III, the growth rate in terms of area was observed to be negative (-0.24) and positive and significant growth rates registered in production(1.67) at a 10 per cent level, while productivity (0.34) was significant at a 1% significance level.

Examining Uttar Pradesh as a whole, the period I growth rates in production, area and productivity of rice were 3.18,0.94 and 2.21 per cent, respectively. In terms of area, production and yield in all components were observed statistically non-significant in UP during period II. In periods II and III, the growth rates of area, production, and productivity of Uttar Pradesh were less than in Period I. In the entire period, compound growth rates for the area (0.56), production (1.30***), and productivity (1.14***) of Uttar Pradesh registered positive in all three components and statistically significant at 1 per cent level, except in the area. The growth rate analysis observed a decline in the area in periods II and III could be characteristics of drought, dry spells, low farm-level technical efficiency, and low profitability. In the state, the requisiteis to expand research to increase rice productivity and ensure a sustainable solution for food security and rice production growth.

Table 1. Production, area and productivity (yield) of rice crop in Uttar Pradesh (1990-91 to 2019-20).

Year	Area (Mha)	Production (Mt)	Yield (t/ha)
1990-91	5.6	10.3	1.8
1991-92	5.4	9.4	1.7
1992-93	5.5	9.7	1.8
1993-94	5.4	10.2	1.9
1994-95	5.6	10.4	1.9
1995-96	5.6	10.4	1.9
1996-97	5.5	11.8	2.1
1997-98	5.7	12.2	2.1
1998-99	5.9	11.4	1.9
1999-00	6.1	13.2	2.2
2000-01	5.9	11.7	2.0
2001-02	6.1	12.9	2.1
2002-03	5.2	9.6	1.8
2003-04	6.0	13.0	2.2
2004-05	5.3	9.6	1.8
2005-06	5.6	11.1	2.0
2006-07	5.9	11.1	1.9
2007-08	5.7	11.8	2.1
2008-09	6.0	13.1	2.2
2009-10	5.2	10.8	2.1
2010-11	5.7	12.0	2.1
2011-12	5.9	14.0	2.4
2012-13	5.9	14.4	2.5
2013-14	6.0	14.6	2.4
2014-15	5.9	12.2	2.1
2015-16	5.9	12.5	2.1
2016-17	6.0	13.8	2.3
2017-18	5.8	13.3	2.3
2018-19	5.7	15.5	2.7
2019-20	5.7	15.5	2.7
2020-21	5.7	15.5	2.7
2021-22	5.7	15.3	2.7

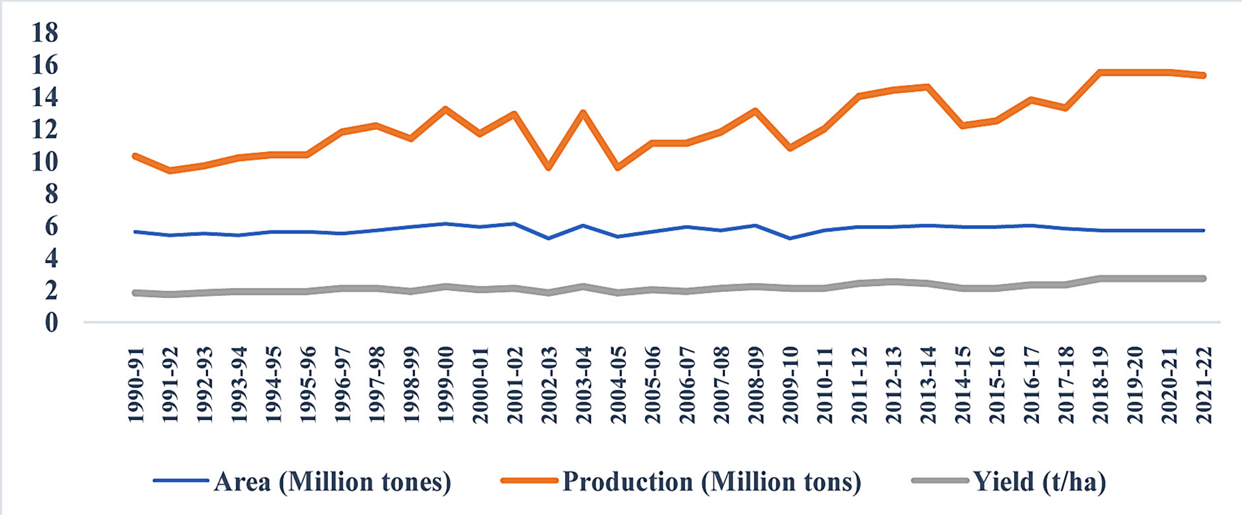

Fig. 1. Area (Mha), production (Mt) and yield (t/ha) of rice in Uttar Pradesh (1990-91 to 2019-20).

Table 2. Growth rates Analysis of production, areaand yield of rice crop in Uttar Pradesh(1990-91 to 2021-22)

Period	(CAGR%)		
	Area	Production	Yield
I	0.94**	3.18***	2.21***
II	-0.44	0.08	0.52
III	-0.24	1.67**	0.34***
Overall	0.56	1.30***	1.14***

*** and ** indicatesignificant at 1% and 10% significance level.
Note: A- area, P- production, Y-yield

Instability Analysis in Rice

Instability indices measuring in regarding of production and area rice productivity from 1990-91 to 2021-22 were computed using the CV, Coppock’s Instability Index (CII), and Cuddy-Della Vale index methods. The results of the analysis are presented in Table 3. The instability measure determines whether the growth progress of the variable under study was unstable or stable entire period.

Coppock’s Instability Index

Table 3 shows that CII is another measure of instability that approximates the average year-to-year per cent variation. The estimation of variation in rice crops shows that more variation was observed in production than in productivity and area. Table 3 describes the results of the Coppock’s instability analysis revealing the rice's production, productivity and area. The discussion was period-wise, including the overall period. The instability analysis revealed that periods I, II, and II observed low instability for the area, production, and productivity in Uttar Pradesh. The entire period also showed low variability for the three components: production, productivity, and area. The analysis of the

Table3. Instability analysis ofproduction, area and yield of rice in Uttar Pradesh

Period	Area			Production			Yield		
	CV%	CDVI	CII	CV%	CDVI	CII	CV%	CDVI	CII
Period I	3.84	2.65	38.21	11.10	5.72	40.99	8.22	3.2	39.89
Period II	6.0	2.6	39.1	11.25	12	41.25	6.89	7.11	39.45
Period III	2.01	1.9	37.54	9.45	7.72	40.41	10.14	7.75	40.74
Overall	4.27	4.09	38.42	15.45	9.59	42.93	13.44	7.94	41.91

CV, CDVI and CII: (Coefficient of variation), (Cuddy Della Vally Index) and (Coppock's Instability Index)

instability index for the state of Uttar Pradesh revealed that all components were unstable for all periods of the study.

Cuddy Della Valle Index in rice

Table 3 indicates that the results of the period (I), the instability for production, area and yield was found to be very low (2.65), low (5.72), and very low (3.2), respectively. The instability measures vary from very low to low, and the area is less stable. During the period (II), low variability for production and productivity was recorded (12.0 and 7.11), respectively. The instability measures vary from 7.11 to 12 per cent for production and productivity. In period (III), the low instability index for production and productivity was registered (7.72 and 7.75), respectively. Overall, Uttar Pradesh had low production (9.59) and productivity (7.94).

Decomposition Analysis in Rice

The decomposition analysis of the rice crops' area yield and interaction. However, this analysis did not measure the exact contribution of area and productivity towards rice production growth. Decomposition analysis measured the contribution of area and yield and their interaction effects on production variability. The contribution of area and yield, as well as the impact of their relationship, on production variability, is examined using decomposition analysis. Three effects—area, yield, and interaction effects—were identified as the basis of production growth. In period III, the area effect was the most critical driver of change in rice production in Uttar Pradesh (Table 4). In the rice production in the state during periods (I and II), the yield effect was responsible for the most significant change in rice production. The highest yield effect was observed during II (155.56 per cent), with an area and interaction effect of -65.56 and 7.78 per cent. In the (I and III)- the yield effects were 31.03% and 6.36%, respectively, with area effects (77.24 and 103.64 per cent, respectively) and interaction effects (6.90 and 1.80 per cent). In the overall period, area, yield, and interaction effects were 100.8, 3.60 and 1.80 per cent, respectively.

CONCLUSIONS

Rice is the staple food crop of Uttar Pradesh. It provides more than 50% of the daily energy requirement and plays a significant role in the solution of food and nutritional security of the state. The results revealed a 5.6 million ha area and 10.3 million tonnes of total rice production during 1991-92, which was increased to 0.1 million ha and 4 million tonnes during 2021-22. The highest growth rates in area, production, and yield were registered during period I, where as the lowest was during period II. The lowest variability was observed

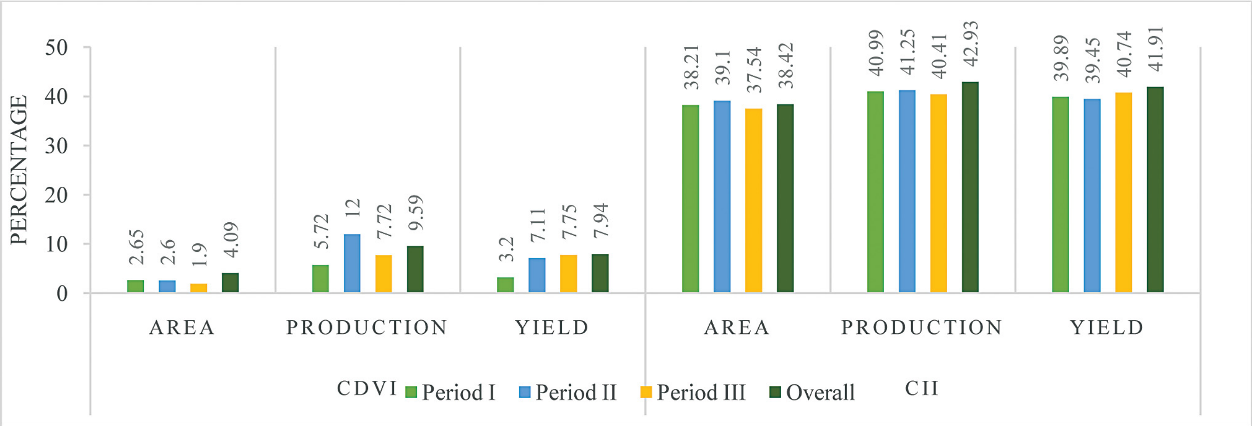

Fig.2. Instability for the production, areaand yield of rice during three periods in Uttar Pradesh, I (1990-91 to 1990-2000); II- (2000-01-2009-10); III-(2010-11 to 2021-22) and overall (1990-91 to 2021-22).

Table 4. Decomposition analysis in production, area and yield of rice in Uttar Pradesh (1990-91 to 2021-22)

Period	Decomposition Analysis (%)		
	Area Effect	Yield Effect	Interaction Effect
I	77.24	31.03	6.90
II	-65.56	155.56	7.78
III	103.64	6.36	1.82
Overall	100.8	3.60	1.80

in all the periods I to III for production, area and yield results from Coppock's indices. The decomposition analysis confirmed that the yield effect is higher in the rice for period II compared to the negative in-area effect and the interaction effect of rice was lowest. improving productivity to meet future demand for rice in Uttar Pradesh. There is assistance for policy emphasis on enhancing rice production through appropriate modern technology, enabling consistent production growth. Also, fluctuations in area and production under rice crops should be addressed, and diversified cultivation patterns should be adopted.

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IMPACT OF TELEVISION ADVERTISEMENTS ON HIGH FAT, SALT, AND SUGAR (HFSS) FOOD CONSUMPTION IN SCHOOL CHILDREN

SHONIMA VENUGOPAL, VAIBHAVI SHINDE and UMA IYER

Department of Foods and Nutrition, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat, India-390002.

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India is predicted to have more than 27 million obese children, representing one in 10 children globally, and over half of the obese children in the South East Asian region by 2030 (World Obesity Federation, 2022). A diet high in fat, salt, and sugar (HFSS) is an important modifiable risk factor for childhood obesity and other diet-related non-communicable diseases (Brown *et al.*, 2018).

In a study that evaluated the frequency and typology of food advertisements on popular television channels watched by young school going adolescents in Delhi, it was found that 69.3 per cent of the food item advertisements were of candies, chocolates, or confectionaries and 14.8 per cent were of salty snacks; 85 per cent of the beverage advertisements were of sugar sweetened beverages and 95 per cent of the advertised food outlets were fast food joints (Gupta *et al.*, 2017).The present study was planned with an objective to explore whether television advertisements influence HFSS food consumption in school children.

This cross-sectional study was carried out in a purposively selected English medium private school from urban Vadodara, Gujarat, India. All the children studying from 6^{th} to 12^{th} standard for whom parent's informed consent and child's assent were obtained were enrolled in the study (n=378). An online self-administered pre-tested questionnaire was circulated among the children. Data on background information, self-reported anthropometric measurements, HFSS food consumption (previous 24-hour consumption, sources of information, reasons for consumption), spending of pocket money and television advertisement properties was collected.

Nutritional status assessment of children using anthropometric measurements was done with the help of WHO AnthroPlus software based on WHO reference 2007 for children aged 5-19 years. Age (months), height (cm) and weight (Kg) values were entered and Z-scores for the Body Mass Index (BMI)-for-age indicator were derived with the help of the software. Nutritional status was classified as severe thinness (<-3SD), thinness (≥-3SD to <-2SD), normal (≥-2SD to ≤+1SD), overweight (>+1SD to ≤ +2SD) and obesity (>+2SD) for BMI-for-age. Results are expressed as Mean ± S.D and percentages. The study was approved by the Institutional Ethics Committee for Human Research (No. IECHR/FCSc/2020/50).

A total of 378 children (208 girls and 170 boys) submitted their responses. The mean age of the children was 14.4 ± 2.04 years (Age range: 10-19 years). Anthropometric

Corresponding author email id: shonima.venugopal-fn@msubaroda.ac.in; Part of M.Sc. thesis submitted to The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat.

measurements were obtained for 319 children. Based on their nutritional status, around 5.3 per cent children were in the thin category, 61.1 per cent in the normal category, 26 per cent in the overweight category and 7.5 per cent in the obese category. The prevalence of overweight (28.8% vs. 23.6%) and obesity (11.6% vs. 4%) was higher among boys as compared to girls.

Around 70.6 per cent, 81.7 per cent, 73.2 per cent and 83.3 per cent of thin, normal, overweight, and obese children reported HFSS food consumption in the previous 24 hours respectively. Around 44.9 per cent, 23.5 per cent, and 31.6 per cent children reported consumption of one, two, and three or more HFSS food products in the previous 24 hours respectively. In Rohtak, Haryana, around 84.5 per cent school children reported consumption of junk food in the last 24 hours with two or more junk food items being consumed by 54.5 per cent of the children (Agrawal *et al.*, 2019). Around 58.1 per cent, 47.8 per cent, 21.3 per cent, and 20.6 per cent children reported consumption of food items high in salt and fat, high in fat, high in sugar and fat, and high in sugar respectively (Table 1).

Majority of the children (67.5%) reported getting information about HFSS food items from television advertisements (Table 2). Friends, internet, and the social media were information sources for 45.1 per cent, 44.3 per cent and 37.0 per cent of the children respectively. Adolescents from across six countries have reported exposure to unhealthy food advertisements in the past 30 days to be highest on television and digital media (Demers-Potvin *et al.*, 2022).

When asked whether they like to try out the new food products shown in television advertisements, 59.1 per cent of the children replied in the affirmative. Around 52.1 per cent children reported that they try out the new food products shown in television advertisements within a month. In the China health and nutrition survey, children's request and purchase of television advertised foods were positively associated with children's overweight/obesity and dietary intake of energy, protein, fat and carbohydrate (Xian *et al.*, 2021).

Taste (94.9%), easy accessibility (14.9%) and time saving (as they are easy to eat) (9.1%) were the predominant reasons reported by the children for consumption of HFSS foods. In Puducherry, a school-based study found that the leading self-perceived reasons for unhealthy eating habits among adolescents were taste of junk/fast foods, increased online food delivery, attractive advertisements, negative peer influences and, easy readymade food preparations (Nancy *et al.*, 2022).

Table 1. Consumption of HFSS food items according to HFSS category in the last 24 hours

(n=272)

S.No.	Category	Yes		No	
		Frequency	Percentage	Frequency	Percentage
1	Food high in fat	130	47.8	142	52.2
2	Food high in sugar and fat	58	21.3	214	78.7
3	Food high in sugar	56	20.6	216	79.4
4	Food high in salt and fat	158	58.1	114	41.9
5	Food high in salt	27	9.9	245	90.1

Table 2. Sources of information about HFSS food (n=357)

S.No.	Sources of information about HFSS food	Frequency	Percentage
1	Television advertisements	241	67.5
2	Parents/Siblings/Relatives	72	20.2
3	Friends	161	45.1
4	Social Media	132	37.0
5	Flyers/newspaper	65	18.2
6	Internet	158	44.3
7	Others	4	1.1

Around 33.1 per cent children reported receiving pocket money. Majority of the children (49.6%) spent their pocket money on buying food items followed by books/ magazines (39.1%) (Table 3). A cross-sectional study on Thai adolescents found that among underweight adolescents, higher snack consumption was associated with receiving a higher daily allowance and among overweight and obese adolescents, higher daily pocket money was associated with increased consumption of processed foods (Kunset *et al.*, 2023).

Table 4 shows data on various television advertisement properties that attract children's attention. Most of the children reported that they were attracted by the humour element (41.9%) in the advertisements, followed by animation (41.3%), visual and special effects (38.3%), and music/advertisement jingles (31.3%).

To conclude, around 31.6 per cent children in the present study reportedly consumed three or more HFSS food products in the previous 24 hours. Television advertisements were the major source of information about HFSS food items for 67.5 per cent of the children. New food products shown in television advertisements were tried out within a month by 52.1 per cent of the children. HFSS food attributes like taste (94.9%) and easy accessibility (14.9%) were driving factors for HFSS food intake among these children. Pocket money received was spent by most of the children (49.6%) on buying food items. Television advertisement properties like humour (41.9%), animation (41.3%), visual and special effects (38.3%), and music/ advertisement jingles (31.3%) were found to

Table 3.Information onspending of pocket money by the children (n=115)

S.No.	Spending ofpocket money	Frequency	Percentage
1	Food	57	49.6
2	Video games	9	7.8
3	Music/Movies (CD/DVD)	6	5.2
4	Movies at a theatre	13	11.3
5	Books/Magazine	45	39.1
6	Saving money or buying other items	44	38.3

Table 4.Television advertisement properties attracting children's attention (n=332)

S.No.	Properties	Frequency	Percentage
1	Humor	139	41.9
2	Animation	137	41.3
3	Endorsement by celebrities or sports persons	46	13.9
4	Premium offers like free gifts, discounts etc.	64	19.3
5	Visuals and special effects	127	38.3
6	Music / Advertisement jingles	104	31.3
7	Others	2	0.6

attract children's attention. The results indicate regular consumption of HFSS foods by the children which may lead to poor growth outcomes. Hence, children need to be sensitized about the possible health consequences of consuming HFSS food and should be encouraged to make healthy lifestyle choices. It is necessary to implement and enforce existing laws to regulate the advertising of HFSS foods. Additionally, healthy food advertising needs to be promoted. Promoting healthy food consumption behaviours along with regular physical activity through the medium of television could help in addressing the rapidly growing childhood obesity problem and its associated health risks.

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CONSUMER SATISFACTION ON THE CURRENT USE OF FURNITURE IN COMPACT DWELLINGS

KARTHIGA T. and D.SUMATHI

[1]Ph.D Research Scholar, [2]Assistant Professor (SS),
Department of Resource Management, Avinasilingam Institute
for Home science and Higher Education for Women, Coimbatore.

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Most people in India live in small flats mostly due to their cost and a shortage of available living space, so space management is an important aspect to be perceived. Space management, according to Archibus (1987), is the process of efficiently managing space in order to reduce the expense of unused space and maximize its utilization.

Space management in houses refers to the efficient utilization of available space in a way that maximizes functionality and comfort. In India, due to the growing population and urbanization, there is a shortage of housing in urban areas. Historical research provides insights into the minimum space requirements for humans in residential settings; in many cultures, habitable rooms smaller than 100 square feet per person are associated with psychological suffering (Hall, 1966). This has led to the development of smaller living spaces, thereby increasing the focus on space management. The apartments, also known as flats, are small parts of a housing unit, which is typically viewed as a collection of amenities used only by a household, a distinct social group. Sankha (2021) stated that human requirements are either the same or more than they were previously, despite the fact the places have become more confined. This has led to the space being used for multiple purposes. Houses generally consist of four areas: communal areas; functional areas (kitchen, utilities, office); personal areas (bedrooms, bathrooms); and storage areas (cabinets, closets, and cabinets). In most cases, there are functional ties between the zones. For example, the kitchen and dining area are usually located near each other, and the bedrooms are usually clustered around a common bathroom. There may be overlaps in other zones. The “great room,” often known as the kitchen-dining area, is a common element of contemporary homes.

A well-designed space should allow activities to flow easily and efficiently from one zoned area to another. The space-planning process identifies which areas and functions are to be associated. To make the most of the available space, architects and interior designers use various techniques such as using multifunctional furniture, creating storage spaces in unused areas and utilizing natural light. With the increasing popularity of minimalism, Additionally, individuals are growing more aware of the possessions owned and the space needs of the respondents.

Creating the illusion of spaciousness may be desired because modern homes

Corresponding author email id: [1]karthigaidd@gmail.com, [2]sumathi_rm@avinuty.ac.in; part of Ph.D. thesis submitted toAcharya N.G. Ranga Agricultural University, Guntur, Andhra Pradesh

frequently contain less space. “Stretching space” is a space-saving method that creates the illusion of larger areas while also serving as an economic tool. Overall, space management in houses is a significant component of modern living in India. It not only helps to create functional and comfortable living spaces, but also contributes to sustainable living by reducing the need for larger homes and minimizing waste. Switching to multipurpose furniture allows the consumers to make the most of the condensed areas without sacrificing comfort, utility, or organization. According to Xie(2016),furniture makes up almost 50% of the floor area of an apartment, making it an essential component. The most prevalent pieces of furniture in apartments are beds, couches, chairs, tables, wardrobes, and commodes. Apartments are too small to fit all thefurniture pieces at once, thus there is an increasing need for multipurpose, space-saving furniture.

The adaptable furniture pieces help harmonize areas while maintaining the aesthetic appeal. The purpose of the investigation is to map out any parallels and contrasts between the furniture arrangements configurations of various families.

Tamil Nadu, in India, has Chennai, commonly referred to as Madras, as its capital. Situated on the Bay of Bengal on the Coromandel Coast, It acts as an important base for commerce, culture, education, and the economy in South India. It is also known as the “Cultural South India’s capital” According to the 2011 Census’ provisional results, the city has 4.68 million inhabitants, ranking sixth in India; the urban agglomeration, which consists of the city and its suburbs, has roughly 8.9 million inhabitants, ranking fourth in the country’s metropolitan area and the 31st largest metropolitan area in terms of population.

The four main regions of Chennai are the North, Central, South, and West.

The majority of North Chennai is an industrial sector. Once primarily residential areas, South and West Chennai are quickly transitioning to business areas, a growing quantity of contact centers, financial institutions, and information technology corporations. The metro area is rapidly growing westward towards Ambattur, Koyambedu, and Sriperumbudur, and southward along the Grand Southern Trunk Road (GST Road) and the Old Mahabalipuram Road. The Chennai district has 11 lakh dwellings, of which 51% are renters, as per the Census (2011). Pallikaranai, South portion of the Chennai was the area of location the study was conducted.

To carry out the study, an exploratory research approach was used on satisfaction level of consumers on furniture selection in the households. The study was conducted by direct interview method in which a structured interview schedule was designed and validated. The study involved 100 household owners belonging to single apartment only. Each household (dwelling) was 800 sq.ft in size. The selection of sample was random sampling method, and the data was gathered by direct interview method. The location of the study was specifically conducted in apartments, and was purposively chosen by the researcher to analyse the mindset of people dwelling in apartments with similar space area. The research was conducted in 2024. The general details of households, family type, income status, number of members residing in the houses, the types of furniture in different rooms, the satisfaction level of respondents on the use of furniture in the households were studied.

Table 1 represents the general details such as family type, size, housing type and monthly income of the respondents. It was observed from the table that households selected for the study were all nuclear family category in which 63 percent of the families were having four members in each household and 37 percent of the families were three member families. All the houses selected for the study were own houses of the respondents. The family monthly income represented that 10 percent of the families had a monthly income of Rs.45,000-65,000; 25 percent had a monthly income of Rs.65,001- 85,000. Nearly half of the families (45%) had a monthly income of Rs.85,001-1,00,000. Twenty percent had a monthly income of more than Rs.1,00,000. The study showed that all the families representing the study belong to both middle income and high-income groups.

Figure 1 depicts the major influencers in selection of interiors. Ninety percent of the house owners had represented that the family members were the major influencers in choice of furniture. 20 percent of the participants had been influenced by internet. Influence by relatives/friends and architects were 10 percent each. 8 percent had been influenced by the selection of furniture by interior designers and 5 percent through advertisements. Since the selecting process was impacted by more than one category, the graph represents a multi choice response by the house owners.

Figure 2 infers attributes that influence selection of furniture in which 90 percent of the respondents have reported that the size of the furniture is an important factor in selection. 70 percent have mentioned the utility of the furniture plays the major role in selection. 60 percent of the respondents have given importance to flexibility in the use of the furniture as reported in the study. 38 percent mentioned the cost matters in selection of furniture. 30 percent of them mentioned that the life durability of the furniture was an important factor. As mentioned by OztopHulya *et al.,*(2008) the selection of furniture for households reflects the use of space and the lifestyle of the inmates in the house and the attributes like comfort, durability and utility provide peace and tranquility for the people using the furniture at households. 22 and 20 percent have reported that style and beauty as an influencing attribute in furniture selection respectively. 10 percent had mentioned the least modern and trend being the influencing factors in selection of furniture. The attributes in selection of furniture were a multi choice response from the house owners, and thus the

Table 1. General details of the household

N=100

S.no	**Variables**	**Categories**	**Percentage (%)**
1	Family type	Joint family	0
		Nuclear family	100
2	Family Size	Three members	37
		Four members	63
3	Types of Housing	Rent	0
		Own	100
4	Monthly Income (Rs)	45,000-65,000	10
		65,001-85,000	25
		85,001-1,00,000	45
		1,00,001 and above	20

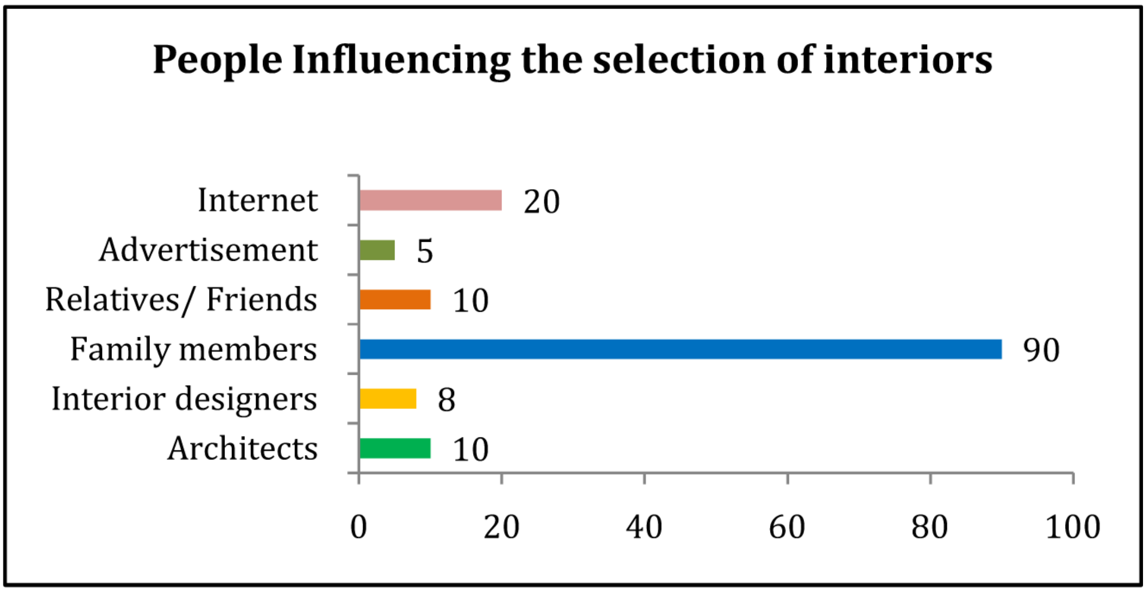

Fig. 1: People influencing the selection of interiors

major influencing factors identified from the study in selection of furniture were size, utility and flexibility.

The purchase place of furniture by the consumers in the study is given in table 2. Forty per cent of the respondents, opted to purchase furniture from local furniture shops, which can be ascribed to the preference for supporting local businesses or the desire to see and test the furniture in person before making a purchase. A majority, standing at 50 per cent, prefer to purchase the furniture traditionally from one shop, indicating a strong inclination towards shopping at a single shop perhaps trusted, retailer for the furniture needs. This could occur because of loyalty, convenience, or the availability of a wide selection of products in one place. A smaller percentage, 20 per cent, chooses furniture designed by a carpenter, suggesting a

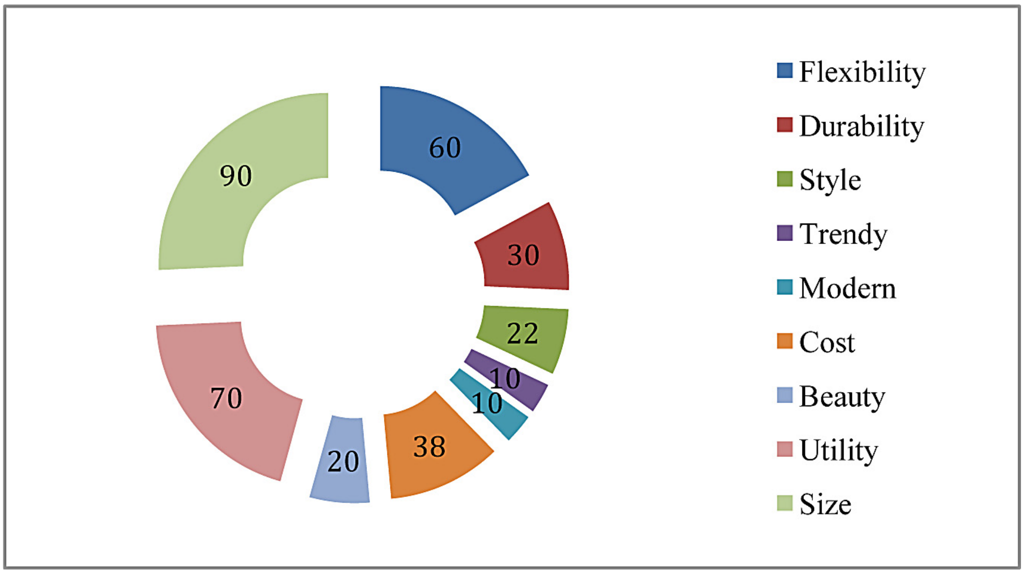

Fig. 2 : Attributes that influence selection of furniture

Table 2. Purchase of furniture

	N=100
Categories	**Percentage (%)**
Purchased from local furniture shop	40
Purchased traditionally from one shop	50
Furniture designed by carpenter	20
Purchased from online	30

preference for custom-made or personalized pieces that cater to specific tastes or requirements. The results coincide with the study done by Niswarushen and Ponnumani, (2021) which was found that 54.8 percent of the respondents buy furniture from showrooms followed by 23.7 percent from small workshops and 14.1 percent from roadside shops. Lastly, 30per cent of the individuals purchase furniture online, reflecting a growing trend towards e-commerce and the convenience of shopping from home. Online shopping trends were influenced by the wider selection and competitive pricing often found on the internet.

According to figure 3 on information about the expenditure sent on furniture as bulk purchase in selected households, half of the individuals surveyed indicate that they had spent between one lakh to two lakhs of rupees on furniture for the irrespective homes. 30 per cent reported spending an amount ranging from two lakhs to three lakhs on their furniture purchases. 10 per cent of the respondents had invested more than three lakhs, while the remaining 10 per cent had spent less than one lakh rupee on furniture. The data clearly shows that a substantial 90 per cent of the total respondents had allocated a significant budget of over one lakh rupees for their home furniture. The consumers also prefer brands, comfort and style of furniture nowadays making the furniture market more demanding on costs and therefore the spending on furniture mostly depends on the user comfort and quality leading to higher cost on furniture purchase Niswarushen and Ponnumani, (2021) has also indicated in their study that consumer prefer brands and comfort as major attribute in purchase of furniture for home. It indicated that furniture purchase constitutes a major expense for households and is often considered a lifetime investment. Consequently, the choice of furniture has a significant influence on the overall aesthetics, functionality, durability, and comfort of the living space.

Figure 4 above illustrates the satisfaction levels of respondents regarding their furniture selection at home. A small percentage, i.e12 per cent, reported satisfaction, with only 4 per cent indicating a high level of satisfaction. A quarter of the respondents, 24 per cent, were neutral, expressing a moderate level of contentment with the furniture choices. However, the majority, 60 per cent, were not satisfied with their current furniture. Within this group, 48 per cent were dissatisfied, and 12 per cent were highly dissatisfied with their furniture selection. It indicated that a significant number of respondents were unhappy with their current furniture; with the lack of space being a commonly cited issue that affects the usage and satisfaction of furniture in their homes. As mentioned by Nagasudha *et al.,* (2022), small apartments often become crowded and cluttered, contributing to feelings of stress, entrapment, and claustrophobia among

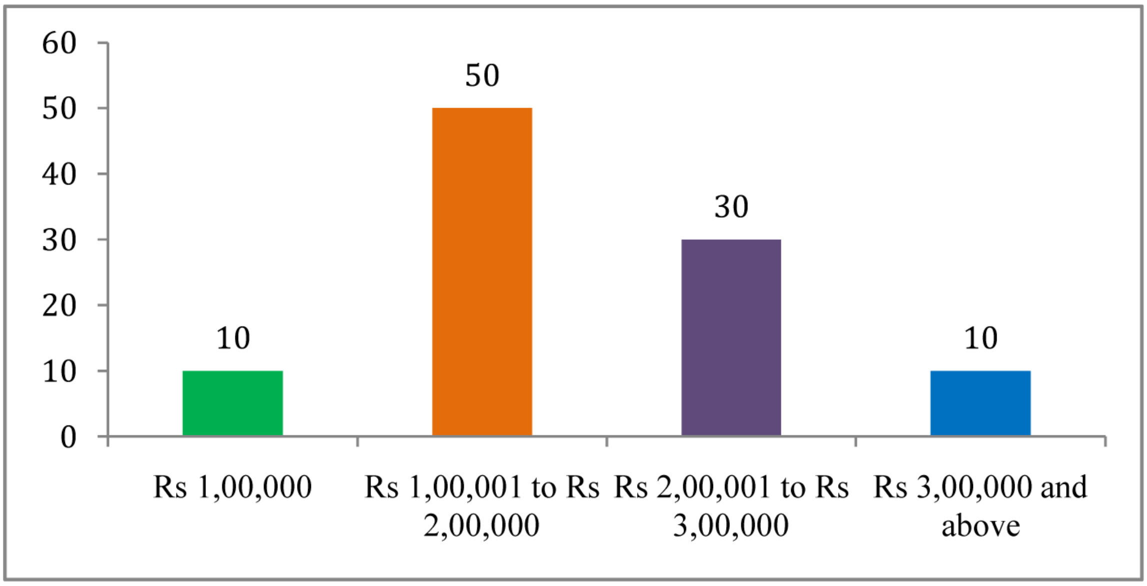

Fig. 3: Amount spent on furniture in the selected households

residents. This is due not only to the limited floor space but also to the presence of physical items such as furniture and personal belongings. Consequently, space-saving furniture can significantly enhance the satisfaction of apartment dwellers.

Table 3 gives the association between levels of satisfaction on furniture at household with independent variables. Gender of the person determines many decision changes in day-to-day life. Deciding on the selection of furniture for households has become a common factor that influences both men and women in current trending lifestyles. Thus, there is no significant association (P>0.05) between the gender and the level of satisfaction on household furniture.

The monthly income of a family influences the purchase of the furniture in the households. As the income increased there is a significant increase (P<0.05) in the level of satisfaction of furniture design. This showed that affordability of furniture enhances the satisfaction level of the customers. The more

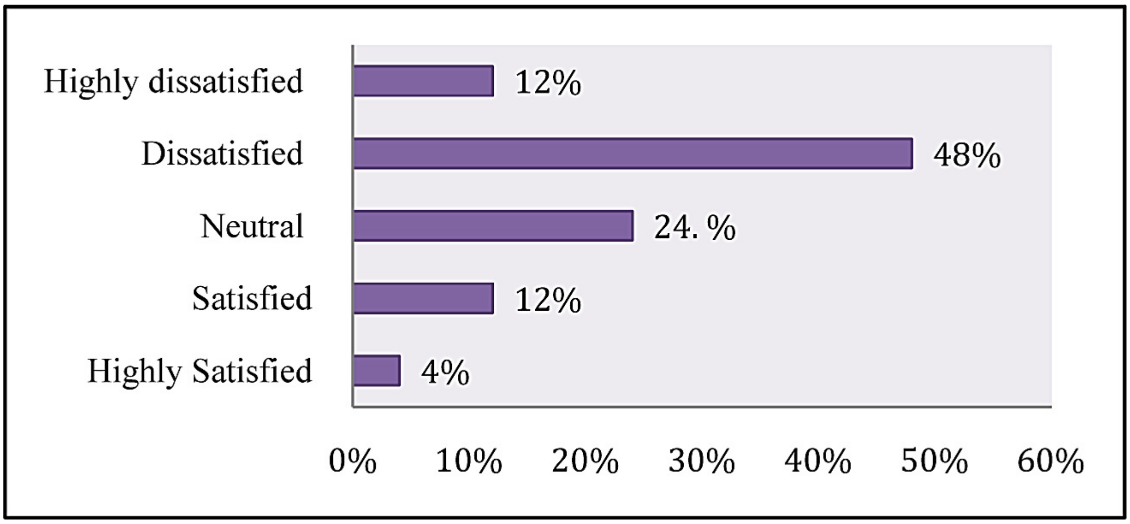

Fig. 4: Satisfaction level in selection and current usage of furniture in households

the income of the family the higher is the satisfaction level on household furniture.

There is highly significant association (P<0.01) found between the plan to redesign space management interiors in households and the satisfaction level on current usage of furniture. The study defines that as the satisfaction level decreases there is an increase in the plan for redesigning interiors in the households.

The study examined consumer satisfaction regarding furniture selection in apartment households in Pallikaranai, Chennai. The findings indicate that all surveyed households belonged to nuclear families, with the majority (63%) consisting of four members. All participants were home owners, with income levels ranging from middle to high income. The primary influencers in furniture selection were family members (90%), followed by online sources (20%), relatives and architects (10% each), interior designers (8%),and advertisements (5%).

The attributes influencing furniture selection were predominantly size (90%), utility (70%), and flexibility (60%), with cost (38%) and durability (30%) also playing a role. Purchasing patterns revealed that 50% of the respondents preferred buying from a single trusted shop, while 40% opted for local furniture stores, 30% bought furniture online, and 20% preferred custom-made designs from carpenters.

Regarding expenditure, 90% of the households allocated over ¹ 1,00,000 for furniture, reflecting a significant financial commitment towards interior furnishing. However, satisfaction levels were notably low, with only 12% expressing contentment and 60% reporting dissatisfaction, citing lack of space as a major concern.

Statistical analysis showed no significant association between gender and satisfaction levels (P > 0.05). However, a significant positive correlation (P < 0.05) was observed between income and satisfaction, indicating that higher-income groups reported greater satisfaction with their furniture choices. Additionally, a highly significant negative correlation (P < 0.01) was found between satisfaction levels and the intention to redesign interiors, suggesting that dissatisfaction often leads to considerations for interior modifications.

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These findings highlight the challenges of furniture selection in compact dwellings, highlighting the necessity of flexible and space-efficient designs in order to better meet the needs and expectations of customers.

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Table 3. Association between levels of satisfaction on furniture at household with independent variables

Independent variables	Chi square value	Correlation
Gender	2.511^{NS}	0.108
Income	22.666*	0.060
Planning to redesign	41.94**	-0.474

*P<= 0.05, **P<0.01 and NS- non significant

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