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Agrometeorological Indices, Physiological Growth Parameters and Performance of Finger Millet as Influenced by Different Cultivars Under Hot and Sub-Humid Region of Odisha

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Abstract: Present-day agriculture is under tremendous pressure due to various factors such as climate change, degradation of soil and water quality, and yield plateauing of major food crops. Under these scenarios, there is an urgent need to choose a climate-resilient and ecologically hardy crop which can perform under adverse conditions with low input requirements. In this regard, millets can be suitable crops for agricultural sustainability. Among various millets, finger millet (*Eleusine coracana* L. Gaertn) is cultivated mainly in India and Africa. However, most farmers grow finger millet with local cultivars, which are low yielding and improved ones can be replaced by the adoption of recommended packages of practices to enhance productivity. The present investigation conducted at the Post Graduate Research Farm of Centurion University of Technology and Management, Odisha, focused on evaluating suitable improved cultivars of finger millet to boost its production in south Odisha conditions. The study revealed that cultivars significantly influenced finger millet growth, productivity, and economics. The physiological growth parameters, namely, crop growth rate, relative growth rate, net assimilation rate and leaf area duration, were significantly influenced by finger millet cultivars. The growing degree days (GDD), helio-thermal units (HTU) and photothermal units (PTU) of the finger millet showed a great variation among the cultivars. The Maximum total GDD (2169°C day), HTU (18141°C day hours) and PTU (24297°C day hours) were recorded in the cultivar Hima(w) VR 936. The cultivars Indravathi VR 1101, Sri Chaitanya VR 847 (1.73) and Hima (W) VR 936 (1.60) were superior to other cultivars in expression of the grain yield and economics of finger millet. The study concluded that the cultivation of Indravathi and Sri Chaitanya could be considered as short-duration cultivars; however, Hima can be chosen as long duration crop for successful finger millet cultivation with higher net returns and benefit-cost ratio under hot and sub-humid regions of Odisha.

Introduction

Rapid urbanization, shrinkage of land and degradation of natural resources created havoc problems in agriculture to produce the ever-increasing needs for fulfilling demands of growing population in the context of climate change (Das et al., 2021; Gaikwad et al., 2022; Sairam et al., 2023). The situation warrants adoption of climate-smart cropping system, improved agronomic management and ecologically hardy crops for agricultural sustainability (Hossain et al., 2021; Midya et al., 2021; Bhattacharya et al., 2023; Maitra et al., 2023a,b; Ray et al., 2024a; Sairam et al., 2024). In this regard, millets can be chosen for the future as climate-smart crops. Millets are robust and diverse crops having their place in the family Poaceae of monocotyledons clade (Maitra et al., 2000, 2022). There are several cultivated species of

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millets, namely, sorghum (*Sorghum bicolor* L.), pearl millet (*Pennisetum glaucum* L.), finger millet (*Eleusine coracana* L. Gaertn), barnyard millet (*Echinochloa frumentacea* L.), foxtail of Italian millet (*Setaria italica* L.), kodo millet (*Paspalum scrobiculatum* L.), proso millet (*Panicum miliaceum* L.) and brown-top millet (*Brachiaria ramosa* L. Stapf; *Panicum ramosum* L.) and so on. The first two are considered major millets, while the remaining are minor or small millets (Maitra et al., 2023a; Priya et al., 2023). India is one of the world's leading millet producers (Maitra et al., 2022b; 2023b). However, among these millets, finger millet is an important food grain crop grown in Africa and India. Being a C4 plant, the crop is adoptable for cultivation in semi-arid regions and the exceptional genetic makeup of the species provided the crop tolerant to high temperatures, moderate salinity and moisture stress (Anuradha et al., 2022). Along with its wider adoptability, the nutritional content of finger millet grains made the crop a unique coarse-cereal among the minor millets (Maitra et al., 2020).

Finger millet comprises carbohydrate (72 g), protein (7.3 g), fat (1.3 g), dietary fibre (11.8 g), mineral nutrients (2.7 g) and energy of 3.28 Kcal per 100 g of edible portion (Hiremath et al., 2018; Banerjee and Maitra, 2020). The dietary fibre in finger millet helps prevent hyperglycemia; phytates facilitate the prevention of stresses and phenolics and tannins function as cell reinforcements (Antony and Chandra, 1998). Finger millet alone produces approximately 85% of minor millet output in the country (Sakamma et al., 2018). In India, a 1.19 m ha area produces 1.98 million t of finger millet grain with an average productivity of 1661 kg ha^{-1} (Sakamma et al., 2018). Odisha cultivated 1.17 lakh hectares of finger millet, yielding 1.28 lakh tonnes of grains with a productivity of 1102 kg ha^{-1} (GoO, 2020). Finger millet productivity can be increased in the state by cultivating improved cultivars with better adaptability and high yield potential for enhancing profitability (Mukesh et al., 2024).

Most finger millet cultivation occurs in rainfed and dryland conditions with limited resources. Under this scenario, selecting cultivars best suitable for climatic conditions is essential for raising a successful crop (Pradhan et al., 2018). The cultivars have unique physiological and morphological characteristics as part of genetic inheritance (Ray et al., 2024b). Combined effects of genotypes and environments are also evident in farm outputs because the genetic variation across plant types, which results in differences in morphology and yield, is accentuated when they thrive under a vast array of climatic conditions (Sila et al., 2022; Sakamma et al., 2018). Among the agrometeorological indices influencing crop growth, the growing degree days (GDD) that predicts the development rates and timing of critical stages for plant growth estimation allows the study of each cultivar for selection of appropriate ones suitable to local environment and crop duration (Ray et al., 2024b). Such selection makes it easier to predict a certain degree of climate requirement and detect genotypes resistant under stress conditions, which can facilitate sustainability in finger millet cultivation (Ravathi et al., 2016).

Based on the above facts, the current research was carried out to evaluate the agrometeorological indices, physiological growth parameters and performance of finger millet cultivars under hot and subhumid regions of Odisha.

Materials and Methods

The present field experiment was conducted at the Post Graduate Research Farm (23°39' N latitude, 87°42' E longitude) of Centurion University of Technology and Management (CUTM), Odisha, India. During the study, the soil of the research plot was collected through random sampling, and the analysed physicochemical properties of the soil revealed that the experimental soil was sandy clay loam in texture with a soil pH of 6.62 and an organic carbon of 0.68%. The soil contained 263 kg ha^{-1}, 12.9 kg ha^{-1} and 122.4 kg ha^{-1} of nitrogen, phosphorous and potassium respectively. During the cropping season, the metrological data was collected from the Agro-metrological Observatory of CUTM (Figure 1). The mean maximum temperature during the crop period varied from 25.9°C to 34.9°C and the minimum temperature ranged between 20.2°C to 26.5°C. The mean maximum and minimum relative humidity ranged between 87 % to 65.2 % and 62.2 % to 80.4 %, respectively. The crop received a total rainfall of 847 mm and the average bright sunshine hour recorded was 8.16 hours day^{-1} (Figure 1). The experiment comprised eight finger millet cultivars for various durations (Figure 2). The study was laid out in a randomised complete block design with three replications for minimizing the error.

Finger millet seeds were sown at a seed rate of 10 kg ha^{-1} on well-prepared seedbeds. The main field was harrowed and ploughed twice with a cultivator and rotavator and levelled with the levellers. Then, the experimental layout was divided into plots. Further, each plot was manually levelled, and one pre-planting irrigation was provided for better soil conditions during the transplanting to establish finger millet seedlings. All plots received the recommended fertilizer dose of

40:20:20 kg ha^{-1} of nitrogen, phosphate and potash, respectively. During the experimental period, the plant height, dry matter accumulation, number of tillers and leaf area index were collected at 25-day intervals from 25 days after transplanting (DAT) to harvest. The following equations calculated the physiological growth indices, namely crop growth rate, net assimilation ratio and relative growth rate and leaf area duration.

$$CGR = \frac{W_2 - W_1}{d(t_2 - t_1)}$$

Where, W_1 and W_2 are plant dry weight at time $t_1 - t_2$ respectively, d is the ground area.

Relative growth rate (RGR) (mg g^{-1}day^{-1})

The term was coined by Williams (1946). Relative Growth Rate (RGR) defines the total plant dry weight increase in a time interval in relation to the initial weight.

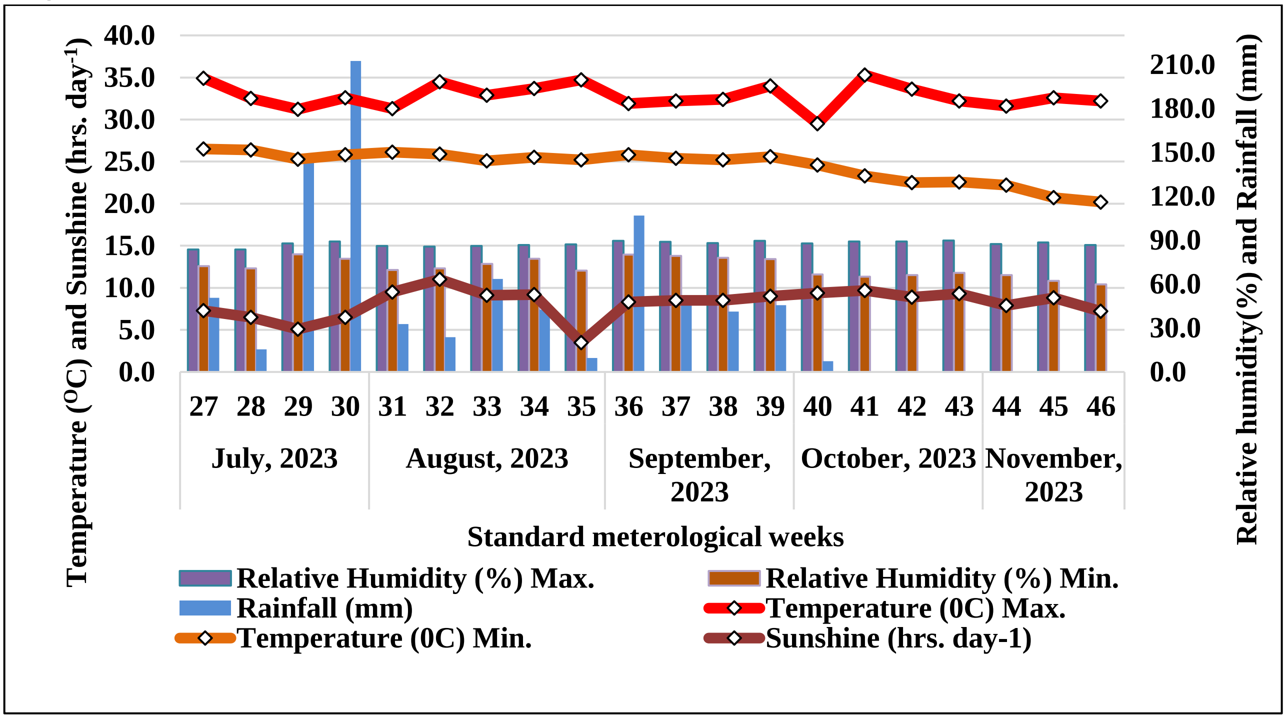

Figure 1. Meteorological data during the crop period (July to November, 2023).
Source: Agro-meteorological station, Centurion University, Paralakhemundi, Odisha, India.

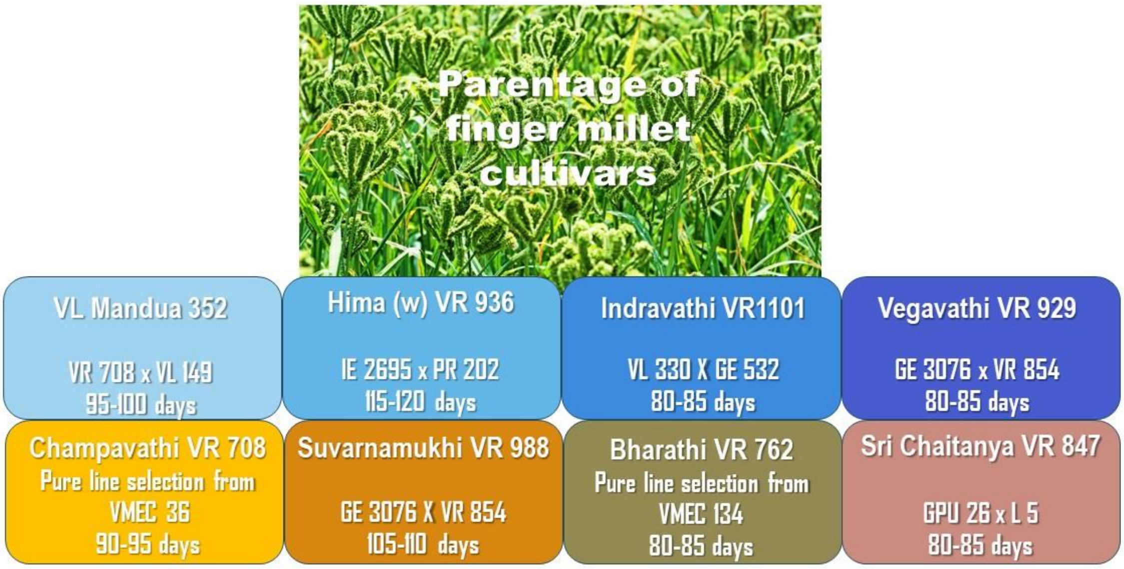

Figure 2. Details of the cultivars considered in the experiment.

Crop growth rate (CGR) (g m^{-2}day^{-1})

The method was demonstrated by Watson (1956). The CGR refers to the amount of dry matter accumulated per unit of land area per unit of time -

$$RGR = \frac{\log_e W_2 - \log_e W_1}{(t_2 - t_1)}$$

Where, W_1 and W_2 are plant dry weight at time $t_1 - t_2$ respectively.

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Net assimilation rate (NAR) (g m^{-2}day^{-1})

NAR is defined as dry matter increment per unit of leaf area per unit of time. The NAR is a measure of the average photosynthetic efficiency of leaves in a given time (Williams, 1946).

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} X \frac{\log_e L_2 - \log_e L_1}{L_2 - L_1}$$

Where, W_1 and W_2 are planted dry weight at time $t_1 - t_2$, respectively, L_1 and L_2 are leaf area at time t_1 and t_2, respectively.

Leaf area duration (LAD) (days)

Leaf area duration is derived by integrating leaf area with time. LAD takes into account of both the time and photosynthetically active green tissue of the crop canopy (Power et al., 1967) and the leaf area duration of different cultivars was calculated by the following formula.

$$\text{LAD} = \frac{(L_1 + L_2)}{2} \text{ x } (T_2 - T_1)$$

Helio-thermal unit (HTU) (°C day hour)

The helio-thermal units for a day were calculated as a product of GDD and bright sunshine hours (BSS) per day.

HTU = ∑{GDD x BSS)

Photo-thermal unit (HTU) (°C day hour)

The Photo-thermal units for a day were calculated as a product of GDD and day length hours (DLH) per day.

PTU = ∑{GDD x DLH)

Further, the calculated data was statistically analysed by using analysis of variance (ANOVA), standard error of means (S. Em. ±) and critical difference at 5% probability level of significance (Gomez and Gomez, 1984). The Excel software (Microsoft Office Home and Student version 2021-en-us, Microsoft Inc., Redmond, Washington, USA) was used for statistical analysis.

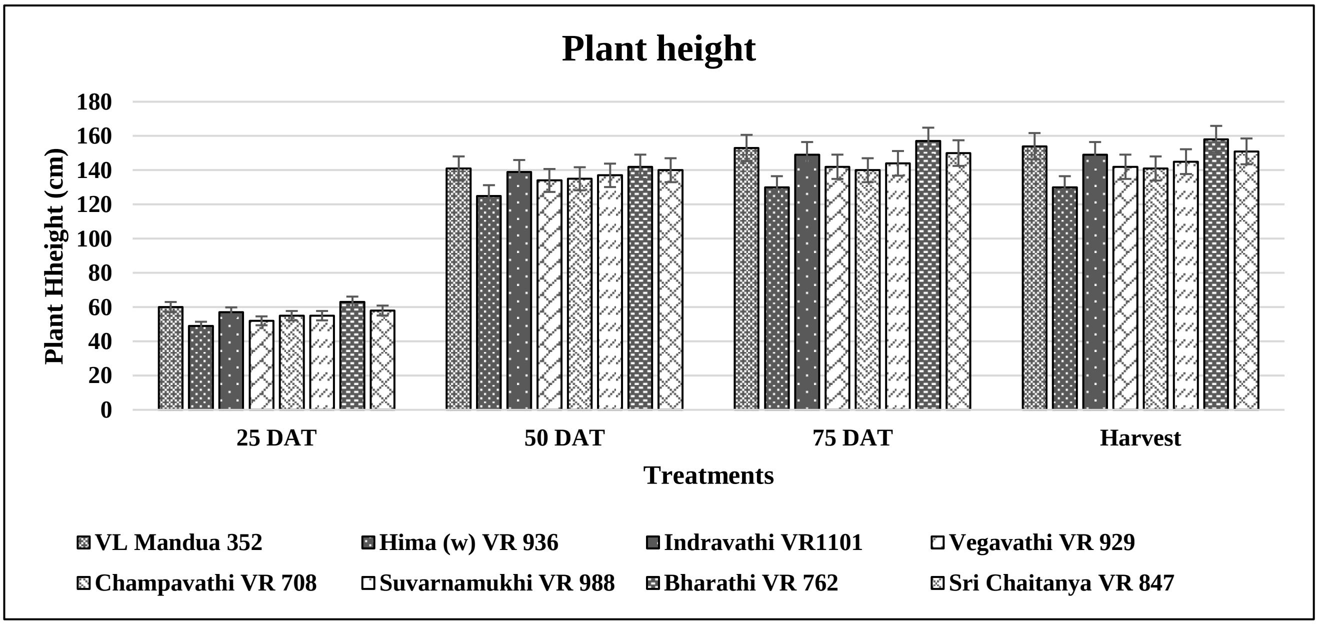

Figure 3. Plant height of finger millet as influenced by cultivars.

Moreover, the agrometeorological indices of finger millet cultivars, namely, growing degree days (GDD), photo-thermal units (PTU), and helio thermal units (HTU) were calculated by considering the following equations.

Growing degree days (GDD) (°C day)

The growing degree days of finger millet cultivars were computed by summing the daily mean temperature upon the base temperature. The base temperature for finger millet considered was 10°C (Nuttonson, 1995).

$$\text{GDD} = \frac{(T_{Max} + T_{Min})}{2} - T_{Base}$$

Where T_{Max} and T_{Min} are daily maximum and minimum temperatures (°C), T_{Base} is the base temperature.

Results and Discussion

Plant height

The plant height of finger millet was recorded at every 25 days interval from 25 DAT to harvest and results depicted that there was a significant difference among cultivars at different growth stages (Figure 3).

At 25 DAT and 50 DAT, the cultivar Bharathi VR 762 registered the highest plant height (63 cm) and it was statistically at par with VL Mandua 352(60 cm), Indravathi VR 1101(57 cm) and Sri Chaitanya VR 847(58 cm). Further, the cultivar Bharathi VR 762 remained significantly superior to Hima(w) VR 936, Vegavathi VR 929, Champavathi VR 708 and Suvarnamukhi VR 988. The cultivar Hima (w) VR 936 (49 cm) recorded the least plant height among the cultivars and remained statistically at par with Vegavathi VR 929 (52cm), Champavathi VR 708 (55 cm) and Suvarnamukhi VR 988 (55 cm). However, at 75 DAT and at harvest, the cultivar Bharathi VR 762 (157 cm) noted the highest plant height, which was statistically at par with VL Mandua 352 (153 cm), Indravathi VR 1101 (149cm), Sri Chaitanya VR 847(150 cm) and Suvarnamukhi VR 988 (144 cm). Moreover, the cultivar Hima (w) VR 936 (130 cm) noted the least plant height during the above-mentioned growth stages of finger millet. Such results were recorded probably due to the genetical characteristics of cultivars, which showed significant differences in plant height among cultivars. Along with genetical characteristics, the cultivars with early flowering (Bharathi, Sri Chaitanya and Indravathi) were related to higher plant height of finger millet, which (3.09) and Bharathi VR 762 (4.31) in the expression of LAI at the growth stage. At 75 DAT, the finger millet cultivar Hima (w) VR 936 (4.52) recorded the highest LAI which was significantly superior to VL Mandua 352 (3.21), Indravathi VR 1101 (3.79), Vagavathi VR 929 (3.02), Champavathi VR 708 (3.6), Suvarnamukhi VR 988 (3.19), Bharathi VR 762 (3.9) and Sri Chaitanya VR 847 (3.42). However, Vagavathi VR 929 (3.02) recorded the least leaf area index during this stage. At the stage of harvest, Indravathi VR 1101 (3.56) was statistically at par with Hima (w) VR 936 (2.9), Champavathi VR 708 (3.12), Bharathi VR 762 (2.97) and Sri Chaitanya VR 847 (3.36) recorded a higher LAI than other cultivars. The lowest LAI was noted in Suvarnamukhi VR 988 (2.42) at harvest. The cultivars with superior values of plant height

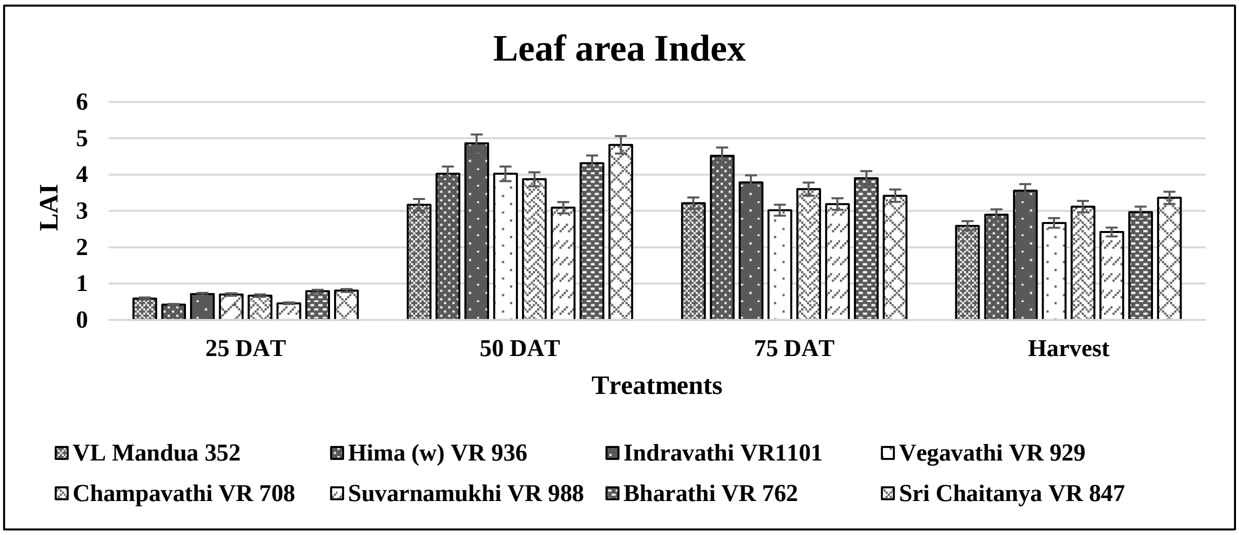

Figure 4. Leaf area index of finger millet as influenced by cultivars.

could be probably due to rapid growth of the plants during the initial and mid-growth stages. Similar findings of the significant influence of finger millet cultivars in terms of plant height and flowering were reported by Simion et al. (2020) and Pandey et al. (2023).

Leaf Area Index (LAI)

At 25 DAT, Sri Chaitanya VR 847 (0.81) recorded the highest LAI, which was statistically at par with Indravathi VR 1101 (0.71), Vagavathi VR 929 (0.73) and Bharathi VR 762 (0.79) (Figure 4). Further, Sri Chaitanya remained significantly superior to VL Mandua 352 (0.59), Hima (w) VR 936 (0.42), Champavathi VR 708 (0.67) and Suvarnamukhi VR 988 (0.46). At 50 DAT, Indravathi VR 1101 (4.86) showed the highest LAI, which remained statistically at par with Sri Chaitanya VR 847 (4.82). On the other hand, Indravathi VR 1101 showed significant superiority to VL Mandua 352 (3.17), Hima (w) VR 936 (4.02), Vagavathi VR 929 (4.02), Champavathi VR 708 (3.87), Suvarnamukhi VR 988 resulted in higher LAI of finger millet. Being a derived character, the LAI of finger millet cultivars was registered higher, with the genotype having more canopy with a greater leaf area of finger millet. The observed results are in conformity with the findings of Kumari (2018), Nanja Reddy et al. (2019) and Panda (2021).

Number of tillers per m^2

During all the growth stages, the cultivar Indravathi VR 1101 showed a significantly higher number of tillers with a value of 66 m^{-2}, 76 m^{-2} and 79 m^{-2} at 50 DAT, 75 DAT and at harvest, respectively (Figure 5). At 50 DAT, the cultivar Indravathi VR 1101 (66 m^{-2}) remained statistically at par with Sri Chaitanya VR 847 (61 m^2) and these two cultivars were significantly superior to others. Further, the cultivars Suvarnamukhi VR 988 (25 m^{-2}) and VL Mandua 352 (26 m^{-2}) recorded the least number of tillers at this growth stage. At 75 DAT, Indravathi VR 1101 (76 m^{-2}), being statistically at par with Hima (w) VR 936 (69 m^{-2}) and Sri Chaitanya VR 847 (75 m^{-2}), registered a significantly higher number of tillers than

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other cultivars. Conversely, VL Mandua 352 (43 m^{-2}) produced the lowest number of tillers. The superior values of the number of tillers per m^2 with the cultivar Indravati are probably because of the genetic characteristics. Similar results were observed by previous researchers like Sendhilvel and Veeramani, 2020; Panda et al., 2021; Teklu et al., 2023.

and a greater number of tillers, resulting in more biomass production. Further, the varietal characteristics, as well as the genetic makeup, might be responsible for the superior performance of the above-mentioned cultivars in in production of higher dry matter among the cultivars chosen for the study. The results are also supported by the previous findings of Radha et al. (2019), Nanja Reddy

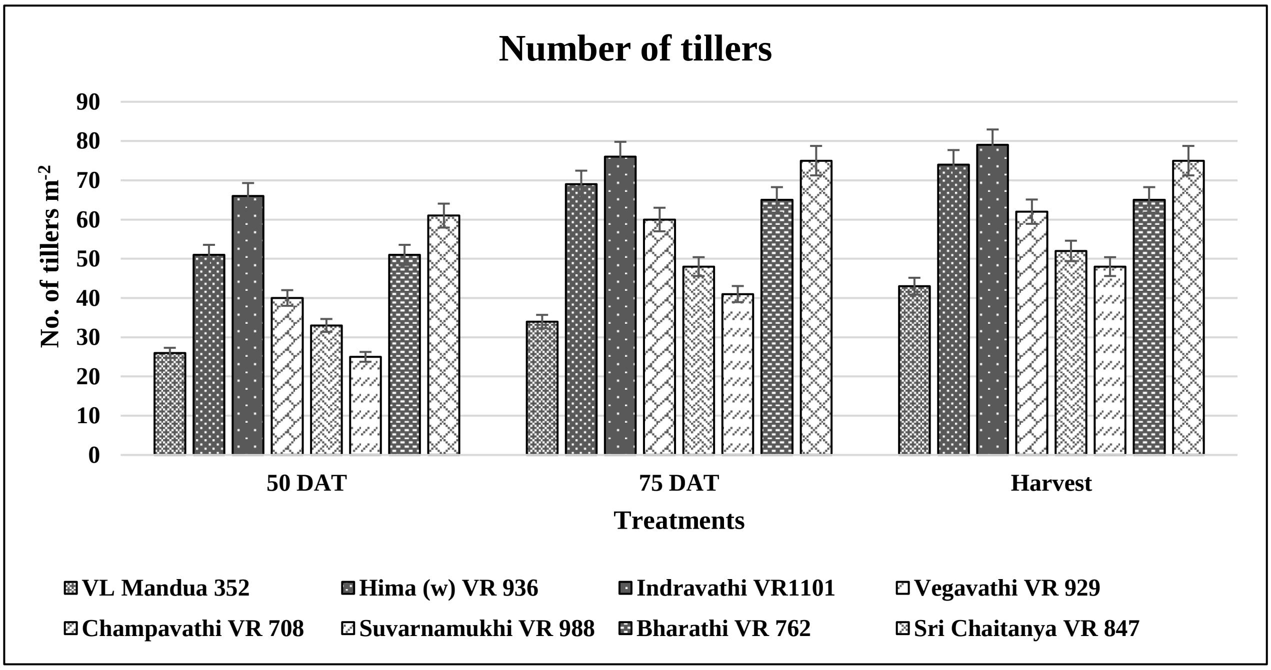

Figure 5. Number of tillers of finger millet as influenced by cultivars.

Dry matter accumulation

In the case of dry matter accumulation at all the growth stages, the cultivar Indravathi VR 1101 recorded the highest value (Figure 6). Further, at 25 DAT, the cultivar Indravathi VR 1101 (208 g m^{-2}) recorded the highest dry matter accumulation and it remained statistically at par with Hima (w) VR 936 (186 g m^{-2}) and Sri Chaitanya VR 847 (191 g m^{-2}). At 50 DAT, the same cultivar Indravathi VR 1101 (473 g m^{-2}) is statistically at par with Hima (w) VR 936 (447 g m^2), Vagavathi VR 929 (456 g m^{-2}), Champavathi VR 708 (462 g m^{-2}), Suvarnamukhi VR 988 (436 g m^{-2}), Bharathi VR 762 (442 g m^{-2}) and Sri Chaitanya VR 847 (451 g m^{-2}) recorded significantly higher dry matter accumulation. Whereas, the cultivar VL Mandua 352 (396 g m^{-2}) recorded the least dry matter accumulation during the particular growth stage. At 75 DAT and at harvest, there was a similar trend in dry matter accumulation of finger millet cultivars as recorded in the previous stage. During these growth stages, the cultivar Indravathi VR 929 recorded higher dry matter accumulation, which also remained statistically at par with Sri Chaitanya VR 847. The superior values of dry matter accumulation among cultivars Indravathi and Sri Chaitanya were probably due to their better performance in ensuring higher leaf area et al. (2019), Nanja Reddy et al. (2021) and Girisha et al. (2021).

Crop Growth Rate (g m^2 day^{-1})

During the period of 25-50 DAT, the cultivar Vegavathi VR 929 (11.4 g m^{-2} day^{-1}) showed a higher crop growth rate (CGR) and it remained statistically at par with all other cultivars of the experiment except VL Mandua 352 (Table 1). During 50-75 DAT, the cultivar Indravathi VR 1101 (11.5 g m^{-2} day^{-1}) recorded significantly higher CGR than other cultivars. During 75 DAT to harvest, the cultivar Sri Chaitanya VR 847 (3.18 g m^{-2} day^{-1}) recorded a higher CGR and it remained significantly superior to all other cultivars of the experiment. Further, the cultivar Bharathi VR 762 (0.28 g m^{-2} day^{-1}) recorded the lowest crop growth rate among the finger millet cultivars during this growth period. CGR, being a significant physiological parameter, had a strong influence on crop growth and it is related to leaf area and dry matter accumulation. Similar findings were also reported by Kumar et al. (2017), Ankit et al. (2022) and Pandey et al. (2023).

Net Assimilation Rate (g m^{-2} day^{-1})

During 25-50 DAT, the net assimilation rate (NAR) was recorded higher with the cultivar Suvarnamukhi VR 988 (7.8 g m^{-2} day^{-1}), and it remained significantly

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superior to other cultivars studied (Table 1). On the other hand, Sri Chaitanya VR 847 (4.6 g m^{-2} day^{-1}) registered the least NAR at the same growth period. During 50-75 DAT, Indravathi VR 1101 (2.7 g m^{-2} day^{-1}) resulted in a higher NAR, which remained statistically superior to other cultivars of the experiment. During 75- DAT to harvest, the cultivar Hima(w) VR 936 (0.7 g m^{-2} day^{-1}) recorded a higher net assimilation rate and remained significantly superior to all other cultivars. The variation in dry matter accumulation and change in crop growth period resulted in variation in NAR among finger millet cultivars. The findings are similar to the previous studies of Dongra et al. (2020), Kumar et al. (2020) and Zhu et al. (2020).

day^{-1}) registered a higher RGR which is statistically at par with Hima(w) VR 936 (34.99 mg g^{-1} day^{-1}), Champavathi VR 708 (37.91 mg g^{-1} day^{-1}), Suvarnamukhi VR 988 (38.07 mg g^{-1} day^{-1}) and Bharathi VR 762 (35.86 mg g^{-1} day^{-1}). Moreover, the cultivar Indravathi VR 1101 (32.82 mg g^{-1} day^{-1}) recorded the least RGR during the above-mentioned growth period. During 50-75 DAT, Indravathi VR 1101 (19.05 mg g^{-1} day^{-1}) noted a higher RGR and remained significantly superior to all other finger millet cultivars. During 75 DAT to harvest, Sri Chaitanya VR 847 (2.60 mg g^{-1} day^{-1}) registered the highest RGR and remained superior to all other cultivars of the study. Whereas Bharathi VR 762 (0.22 mg g^{-1} day^{-1}) recorded the lowest RGR of finger millet during the same growth period. The results are in pipeline with the previous findings of Dongra et al. (2020), Kumar et al. (2020) and Ankit et al. (2022).

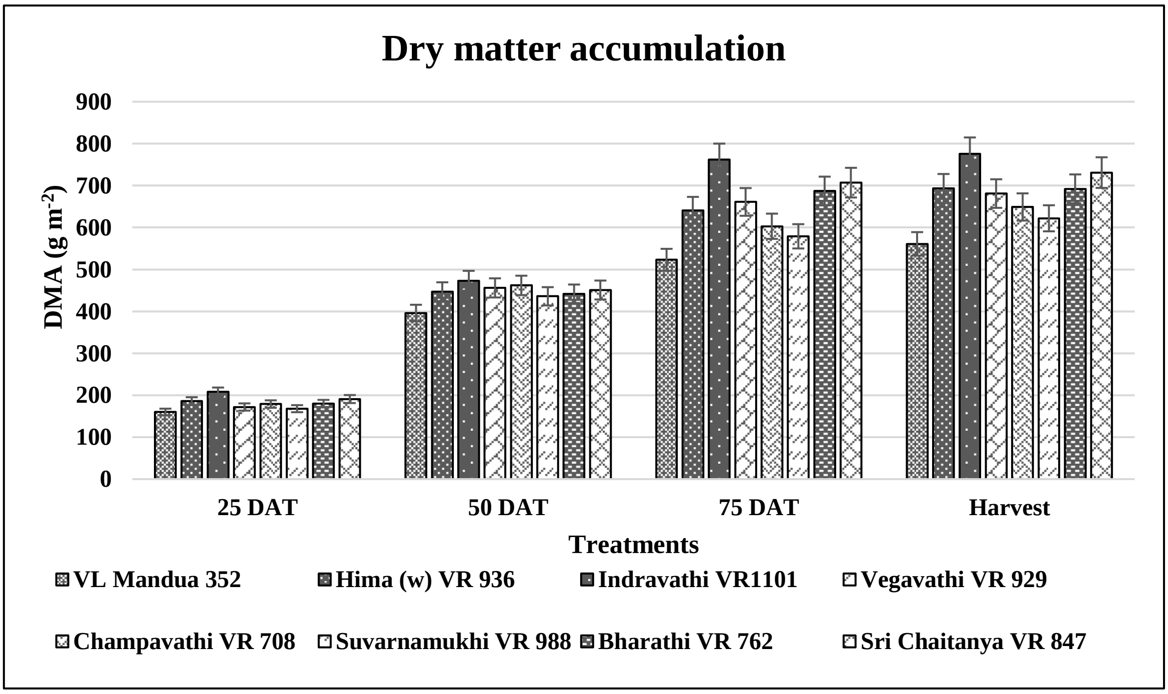

Figure 6. Dry matter accumulation of finger millet as influenced by cultivars.

Table 1. Crop growth rate (CGR) and net assimilation rate (NAR) of finger millet as influenced by cultivars.

Cultivars	CGR (g m^{-2} day^{-1})			NAR (g m^{-2} day^{-1})		
	25 - 50 DAT	50 - 75 DAT	75 DAT to harvest	25 - 50 DAT	50 – 75 DAT	75 DAT to harvest
VL Mandua 352	9.4	5.1	1.10	6.1	1.6	0.3
Hima (w) VR 936	10.4	7.7	0.92	6.5	1.8	0.7
Indravathi VR1101	10.6	11.5	0.72	4.9	2.7	0.1
Vegavathi VR 929	11.4	8.2	0.88	6.0	2.3	0.1
Champavathi VR 708	11.3	5.7	1.40	6.2	1.5	0.3
Suvarnamukhi VR 988	10.7	5.7	0.96	7.8	1.8	0.5
Bharathi VR 762	10.5	9.8	0.28	5.0	2.4	0.0
Sri Chaitanya VR 847	10.4	8.7	3.18	4.6	2.1	0.3
S.Em.±	0.3	0.2	0.03	0.2	0.1	0.03
C.D. (0.05)	1.0	0.7	0.1	0.6	0.3	0.1

Relative Growth Rate (mg g^{-1} day^{-1})

There was a significant influence on the relative growth rate (RGR) of finger millet cultivars (Table 2). During 25-50 DAT, Vegavathi VR 929 (38.95 mg g^{-1}

Leaf Area Duration (days)

During 25-50 DAT, the cultivar Indravathi VR 1101 (69 days) showed higher leaf area duration and it remained statistically at par with Bharathi VR 762 (64 days) and Sri Chaitanya VR 847 (71 days) (Table 2). Whereas, the cultivar Suvarnamukhi VR 988 (44 days) recorded the least leaf area duration during the same growth period. The cultivar Indravathi VR 1101 recorded the highest LAD during 50-75 DAT and it was statistically at par with Hima(w) VR 936 (107 days), Champavathi VR 708 (94 days), Bharathi VR 762 (104 days) and Sri Chaitanya VR 847 (104 days). However, Suvarnamukhi VR 988 (79 days) resulted in the least LAD among the cultivars during the above-mentioned growth period. During the later growth stage of 75 DAT to harvest, Hima(w) VR 936 (210 days) showed a higher LAD, which remained statistically at par with VL Mandua 352 (102 days), Champavathi VR 708 (112 days) and Suvarnamukhi VR 988 (127 days). Moreover, the cultivar Bharathi VR 762 (66 days) resulted in the least leaf area duration during 75DAT to harvest. The higher values of LAD during the early and mid-growth stage recorded with Indravathi could be due to the higher LAI and optimum tiller numbers which ultimately reflected in a higher LAD. Moreover, at the later stage, the Hima, being a long duration cultivar resulted in more LAD due to prolonged growth period. Similar findings were also reported by Babu et al. (2024) and Sunder et al. (2016).

Yield

The yield of finger millet collected at the time of harvesting revealed that the highest grain yield (2315 kg ha-1), stover yield (5372 kg ha-1), and biological yield (7687 kg ha^{-1}) were recorded with the cultivar Indravathi (Figure 7). Further, in case of grain yield, the cultivar Indravathi remained statistically at par with Hima and Sri Chaitanya. The lowest grain yield of 1527 kg ha^{-1} was observed in the variety VL Mandua 352 which was inferiorly followed by Suvarnamukhi (1743 kg ha^{-1}) and Champavathi (1802 kg ha^{-1}). A similar trend was observed with respect to stover yield and biological yield of finger millet cultivars. Among the cultivars, Indravathi

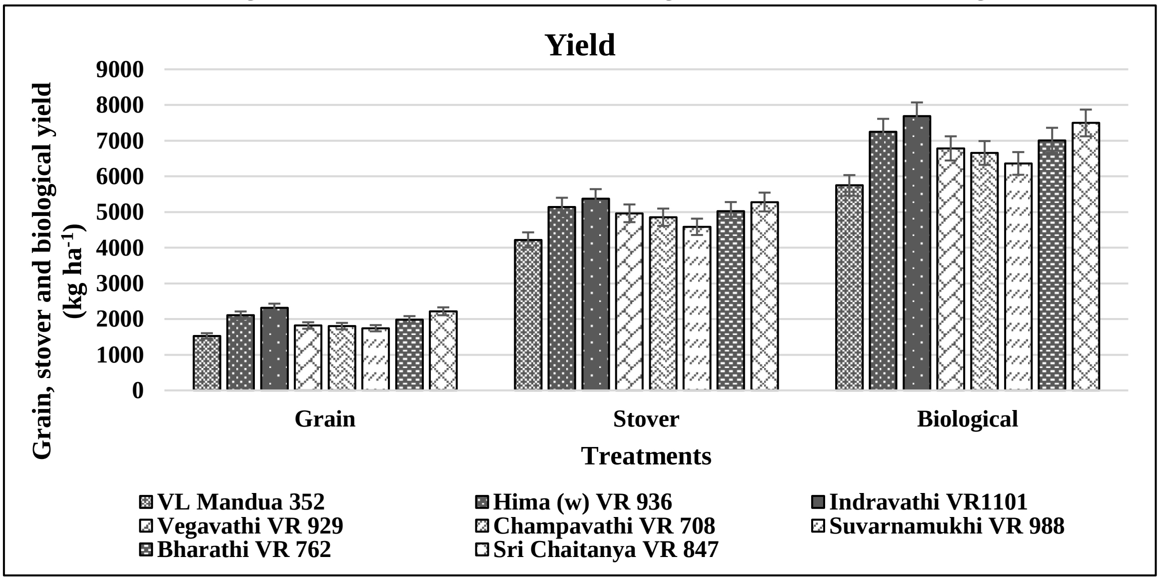

Figure 7. Yield of finger millet as influenced by cultivars.

Table 2. Relative growth rate and leaf area duration of finger millet as influenced by cultivars.

Cultivars	RGR (mg g^{-1} day^{-1})			LAD (days)		
	25 - 50 DAT	50 – 75 DAT	75 DAT to harvest	25 - 50 DAT	50 – 75 DAT	75 DAT to harvest
VL Mandua 352	36.23	36.23	36.23	47	80	102
Hima (w) VR 936	34.99	34.99	34.99	56	107	210
Indravathi VR1101	32.82	32.82	32.82	69	108	73
Vegavathi VR 929	38.95	38.95	38.95	59	88	66
Champavathi VR 708	37.91	37.91	37.91	56	94	112
Suvarnamukhi VR 988	38.07	38.07	38.07	44	79	127
Bharathi VR 762	35.86	35.86	35.86	64	104	66
Sri Chaitanya VR 847	34.32	34.32	34.32	71	104	68
S.Em.±	1.5	1.5	1.5	2.1	5.0	4.6
C.D. (0.05)	4.5	4.5	4.5	6.5	15.2	14.1

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remained statistically at par with Sri Chaitanya, Hima, Bharathi and Champavathi. Moreover, the cultivar VL Mandua registered the lowest stover yield (4584 kg ha^{-1}) and biological yield (6327 kg ha^{-1}) of finger millet. The superior performance of Indravathi could be due to its higher yield potential related to the genetic makeup as well as a better performance of growth and yield attributes contributing to higher grain and stover yield production of the cultivar (Anuradha and Patro, 2019; Das et al., 2022; Prabhakar et al., 2023).

Table 3. Phenological growth stages of finger millet cultivars.

Phenological stages of finger millet cultivars										
Cultivars	Date of transplanting	Active tillering		50 % flowering		Grain formation		Maturity		
VL Mandua 352	30-07-2023	30-08-2023	32 DAT	28-09-2023	61 DAT	17-10-2023	80 DAT	31-10-2023	94 DAT
Hima (W) VR 936	30-07-2023	13-09-2023	46 DAT	15-10-2023	78 DAT	04-11-2023	98 DAT	22-11-2023	116 DAT
Indravathi VR1101	30-07-2023	26-08-2023	28 DAT	22-09-2023	55 DAT	09-10-2023	72 DAT	17-10-2023	80 DAT
Vegavathi VR 929	30-07-2023	27-08-2023	29 DAT	24-09-2023	57 DAT	08-10-2023	71 DAT	17-10-2023	80 DAT
Champavathi VR 708	30-07-2023	01-09-2023	34 DAT	30-09-2023	63 DAT	15-10-2023	78 DAT	29-10-2023	92 DAT
Suvarnamukhi VR 988	30-07-2023	09-09-2023	42 DAT	09-10-2023	72 DAT	28-10-2023	91 DAT	12-11-2023	106 DAT
Bharathi VR 762	30-07-2023	26-08-2023	28 DAT	20-09-2023	53 DAT	06-10-2023	69 DAT	15-10-2023	78 DAT
Sri Chaitanya VR 847	30-07-2023	26-08-2023	28 DAT	22-09-2023	55 DAT	06-10-2023	69 DAT	16-10-2023	79 DAT

Phenological growth stages of finger millet cultivars

The phenological growth stages of finger millet cultivars recorded revealed that Hima(w) VR 936 reported the maximum days for active tillering (46 DAT) and it was closely followed by the cultivar Suvarnamukhi VR 988 (42 DAT) (Table 3). Further, Bharathi VR 762, Sri Chaitanya VR 847 and Indravathi VR1101 registered lesser days (28 DAT) for active tillering. In the case of 50% flowering, the cultivar Hima(w) VR 936 took the maximum number of days (78 DAT) and it was closely followed by Suvarnamukhi VR 988 (72 DAT). Moreover, Bharathi VR 762 and Indravathi VR1101 took the least days (53 DAT AND 55 DAT, respectively) for 50% flowering. The number of days for grain filling showed a similar trend as observed for 50% flowering, with the maximum days for grain filling (98 DAT) reported with Hima(w) VR 936. Similarly, the least number of days for grain filling was registered with Bharathi VR 762, Indravathi VR1101 and Sri Chaitanya VR 847. In the case of crop maturity, Hima(w) VR 936 (116 DAT) took the maximum number of days after transplanting and it was closely followed by Suvarnamukhi VR988 (106 DAT). However, the cultivars Bharathi VR 762 and Sri Chaitanya VR 847 showed early maturity with 78 DAT and 79 DAT, respectively. The variation in the crop duration could be the genetic makeup of cultivars and the climatic requirements of the specific genotype to fulfill the GDD for undergoing the phenophases of the finger millet (Prabhakar et al., 2023).

Growing degree days, helio-thermal unit and photo-thermal unit of finger millet cultivars

During transplanting to active tillering period, the cultivar Hima (w) VR 936 recorded higher growing degree days (GDD), helio-thermal unit (HTU), and photo thermal unit (PTU) of 891°C day, 7456°C day hours and 9836°C day hours, respectively which was closely followed by Suvarnamukhi VR 988, Champavathi VR 708 (Table 4). However, Indravathi VR1101 recorded the lowest GDD, HTU and PTU (544°C day, 4668°C day hours and 6020 °C day hours respectively) and it was followed by Bharathi VR 762 and Sri Chaitanya VR 847 during above-mentioned growth period. During the period of active tillers to 50% flowering, the cultivar Hima (w) VR 936 recorded higher GDD (638°C day), HTU (5283°C day hours) and PTU (7015°C day hours) and it was closely followed by VL Mandua 352 and Suvarnamukhi VR 988. However, Bharathi VR 762 noted the lowest GDD, HTU, PTU of 477°C day, 3982°C day hours and 5453°C day hours, respectively among the cultivars studied. Interestingly, during 50% flowering to grain formation, the cultivar VL Mandua 352 registered a higher GDD, HTU and PTU of 370°C day, 1669°C day hours and 2141°C day hours, respectively and it was

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closely followed by Hima (w) VR 936 and Suvarnamukhi VR 988. On the other hand, Sri Chaitanya VR 847 recorded the least GDD, HTU and PTU of 275°C day, 2463°C day hours, 3234°C day hours respectively during the growth period. During the later growth stage of grain formation to maturity, the cultivar Hima (w) VR 936 noticed the highest GDD (293°C day), HTU (2462°C day hours) and PTU (3422°C day hours), respectively which was closely followed by Suvarnamukhi VR 988 and Champavathi VR 708. However, Bharathi VR 762 recorded the lowest GDD, HTU, PTU of 178°C day, 1681°C day hours and 2168°C day hours, receptively. Moreover, GDD, HTU, PTU during the above-mentioned growth period. Moreover, the Maximum total GDD (2169°C day), HTU (18141°C day hours) and PTU (24297°C day hours) were recorded in the cultivar Hima(w) VR 936. GDD is directly related to the duration of the crop, and the cultivars with prolonged growth periods resulted in higher GDD. This can be a reason due to which the cultivar Hima (w) VR 936, with a longer crop duration (116 days), registered the highest growing degree days among the finger millet cultivars. The HTU

indicated the interaction between GDD and sunshine hours which is important to cultivars to attain various physiological stages, where Hima (w) VR 936 and Suvarnamukhi VR 988 performed for utilizing climatic resources well because of their genetic makeup. Similarly, the PTU recorded in the study narrated the relationship between GDD and day length, where the above-mentioned cultivars registered superior performance. Similar results were recorded by Ray et al. (2024b) and Kulkarni et al. (2022) in finger millet and Nandini and Sridhara (2019) in foxtail millet.

Table 4. Growing degree days (°C day), helio-thermal unit (°C day hours) and photo-thermal unit (°C day hours) of finger millet as influenced by cultivars.

Cultivars	Transplanting to active tillers			Active tillers to 50 % flowering			50% flowering to grain farming			Grain formation to maturity			Total		
	GDD	HTU	PTU	GDD	HTU	PTU	GDD	HTU	PTU	GDD	HTU	PTU	GDD	HTU	PTU
VL Mandua 352	623	4593	6323	594	4593	6323	370	1669	2141	242	2058	2854	1829	12913	17641
Hima (w) VR 936	891	7456	9836	638	5283	7015	347	2940	4024	293	2462	3422	2169	18141	24297
Indravathi VR1101	544	4668	6020	515	4286	5871	336	2969	3901	154	1487	1918	1549	13410	17710
Vegavathi VR 929	563	4845	6236	535	4453	6103	276	2477	3247	174	1662	2141	1548	13437	17727
Champavathi VR 708	663	5702	7337	554	4590	6320	294	2665	3454	245	2145	2908	1756	15102	20019
Suvarnamukhi VR 988	816	6933	9016	579	4861	6589	346	3112	4032	269	2102	2958	2010	17008	22595
Bharathi VR 762	543	4668	6020	477	3982	5453	313	2746	3617	178	1681	2168	1511	13077	17258
Sri Chaitanya VR 847	544	4668	6020	515	4286	5871	275	2463	3234	196	1847	2372	1530	13264	17497

GDD= growing degree days; HTU= helio-thermal unit; PTU= photo thermal unit

Economics

The economics of finger millet revealed that the cost of cultivation (Rs 26249 ha^{-1}) among the cultivars remained the same as a similar package of practices was followed for all the cultivars (Table 5). However, Indravathi VR 1101 recorded moderately higher gross return (Rs 74822 ha^{-1}) and the cultivar was closely followed by Sri Chaitanya VR 847 (Rs 71788 ha^{-1}) and Hima (W) VR 936 (Rs 68352 ha^{-1}). Moreover, the least gross return was computed with VL Mandua 352 (Rs 50027 ha^{-1}). In case of net returns, Indravathi VR 1101 (Rs 48573 ha^{-1}) recorded moderately higher net return, which was followed by Sri Chaitanya VR 847 (Rs 45539 ha^{-1}) and Hima (W) VR 936 (Rs 42103 ha^{-1}), however, the least net return among the finger millet cultivars was observed in VL Mandua (Rs 23778 ha^{-1}). Moreover, the cultivar Indravathi VR 1101 recorded a higher B:C ratio (1.85) which was followed by Sri Chaitanya VR 847 (1.73) and Hima (W) VR 936 (1.60). The cultivars with higher grain and stover yield resulted in more net returns and B:C ratio (Panda, 2021; Das et al., 2021; Girisha et al., 2021).

Conclusion

The study showed that cultivars of finger millet significantly growth factors such as plant height, leaf area index, leaf area duration, dry matter accumulation, crop growth rate, relative growth rate and net assimilation rate, which were ultimately reflected in yields and economics. The GDD, HTU and PTU of finger millet cultivars showed a great variation among themselves. The Maximum total GDD (2169°C day), HTU (18141°C day hours) and PTU (24297°C day hours) were recorded in the cultivar Hima(w) VR 936. The cultivars Indravathi

Table 5. Economics of finger millet as influenced by cultivars.

Cultivars	Economics (Rs ha^{-1})			B:C ratio
	Total cost	Gross return	Net return	
VL Mandua 352	26249	50027	23778	0.91
Hima (w) VR 936	26249	68352	42103	1.60
Indravathi VR1101	26249	74822	48573	1.85
Vegavathi VR 929	26249	59534	33285	1.27
Champavathi VR 708	26249	58913	32664	1.24
Suvarnamukhi VR 988	26249	56874	30625	1.17
Bharathi VR 762	26249	64487	38238	1.46
Sri Chaitanya VR 847	26249	71788	45539	1.73

VR 1101, Sri Chaitanya VR 847 (1.73) and Hima (W) VR 936 (1.60) were superior to other cultivars in expression of the grain yield and economics of finger millet. The study concluded that the cultivation of Indravathi and Sri Chaitanya could be either opted as short-duration cultivars or Hima could be chosen as long long-duration crop for successful finger millet cultivation with economic viability under hot and sub-humid regions of Odisha.

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Conflict of interest

All authors declare that there is no conflict of interest.

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