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RESEARCH ARTICLE | Agricultural Science Digest

Growth, Phenophases, Growing Degree Days Requirement and Yield of Rice Cultivars under Semi-arid Tropics

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10.18805/ag.D-6072

ABSTRACT

Background: In India, several varieties are being developed by agricultural universities and research institutes which need to be tested for their suitability at a specific location. An experiment was conducted to identify rice cultivars suitable for Odisha and to know the effect of growing degree days at different phenophases on grain yield of rice under transplanted conditions

Methods: An experiment was conducted with fourteen cultivars during *kharif* season of 2023 having a duration of 120 to 150 days from sowing to harvest in randomized block design, replicated three times. The growing degree days (GDD) of rice calculated to understand the temperature requirement of the crop at different phenophases

Result: The cultivar CR Dhan 319 recorded significantly higher grain,straw and biological yield as compared to all other varieties. The GDD at vegetative stage ranged from 530 to 1204 Celsius, at reproductive stage 543 to 572Celsius and ripening stage 461 to 545 Celsius and the total GDD ranged between 1648 to2195Celsius. The GDD was higher at vegetative stage in long duration cultivars while it was higher at reproductive stage in short duration varieties. The cultivars 148 days duration recorded higher yield (4870 kg ha^{-1}) beyond which there was decrease in yield and the crop receiving total GDD of 2060 from transplanting to harvesting recoded maximum yield (4860 kg ha^{-1}). The optimum GDD at each phenophase found to be 120 at PI and young panicle stage, 245 at young panicle stage to reduction division, 178 at reduction division to anthesis, 113 at anthesis to ripening and 365 at ripening to maturity stages. This study is related SDG goals 1,2, 4 and 15 of United Nations.

Key words: Cultivars, Grain harvest index, Growing degree days, *Kharif* season, Rice.

INTRODUCTION

In India, rice occupies an area of 45.07 million ha with a production of 122.27 million tons and productivity of 2713 Kg/ha (Anonymous, 2023a). In Odisha, rice is cultivated in 4.03 million ha during *kharif* and *rabi* / summer seasons with a production of 8.73 million tons and productivity of 2173 kg ha^{-1} (Anonymous, 2023b). Cultivar productivity is greatly influenced by genotype-environment interactions, which plays a key role in yield performance. (Rasyad *et al.,* 2012; Jadhav *et al.,* 2019; Kesh Hari *et al.,* 2023). Selecting a variety not suited to the region's climate may result in reduced grain yield (Hussain *et al.,* 2020; Panja Suraj *et al.,* 2024). By understanding the specific environmental factors in southern Odisha and their interaction with different rice genotypes helps in identifying varieties that are most likely to give high and stable yields. Moreover, region-specific studies can help in selecting rice varieties that are resilient to biotic and abiotic stresses prevalent in the region. This adaptability is key for mitigating risks and ensuring reliable productivity. However, the information regarding the suitability of the released varieties for southern Odisha is not available, an explorative study was conducted with 14 rice varieties during kharif season to find out suitable cultivars for the region targeting SDG goals 1,2, 4 and 15 of United Nations.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* 2023 at Post Graduate Research Farm at M.S. Swaminathan School of Agriculture, Gajapati district, Odisha (18°48′16″ N latitude, 84°10′48″E longitude with an altitude of 64 m above the mean sea level) to study the performance of different rice cultivars during *Kharif* Season in Southern Odisha. The meteorological data was obtained from automated weather station at Parlakhemundi campus. The soil of the experimental site is sandy loam, slightly acidic in nature having low in nitrogen and phosphorus and medium in potassium.

The experiment was conducted with fourteen varieties (Table 1) in randomized block design with three replications. The nursery was sown on July 7, 2023 and it was transplanted on Aug 9, 2023 at a spacing of 20 cm x 15 cm. The crop was fertilized with 120:60:60 kg N, P_2O_5 and K_2Oha^{-1} as per the recommendation. Dry matter accumulation at 90 DAT, yield attributes and grain yield were recorded. GDD was estimated for different growth stages, focusing on reproductive and ripening phases. Data were analyzed using ANOVA at a 5% significance level

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How to cite this article: Vanitha, S., Sagar, L. and Reddy, M.D. (2025). Growth, Phenophases, Growing Degree Days Requirement and Yield of Rice Cultivars under Semi-arid Tropics. Agricultural Science Digest. 1-7. doi: 10.18805/ag.D-6072.

Submitted: 28-05-2024 **Accepted:** 18-12-2024 **Online:**28 -04-2025

(Panse and Sukhatme, 1967). Correlation and regression analyses were conducted between yield attributes, GDD and grain yield.

RESULTS AND DISCUSSION

The maximum temperature varied from 28.2°C to 35.06°C and the minimum temperature ranged from 18.57°C to 26.5°C. The sunshine hours ranged from 4.8 h/day to 11.0 h/day and relative humidity ranged from 83.57% to 89.71% and 59.29% to 80.42% in the 7:00 AM and 2:00PM, respectively. The total rainfall received during the crop growing period was 843 mm rainfall (Fig 1 and Fig 2).

Among the tested cultivars, CR Dhan 319 yielded comparable to MTU 1010 and was significantly superior to others (Table 1). It recorded a higher number of panicles/m² than several cultivars and was comparable to MTU 1075, MTU 1061, CR 315, MTU 1010, Mohini, Pooja and Sowbhagya (Table 2). CR Dhan 319 also had superior panicle length, spikelet number and yield attributes, positively correlating with grain yield (Table 3). Longer-duration varieties (154 days) have shown improved yields, aligning with reports that the best yields come from 130-140 day varieties (Vergara, 1970; Satapathy *et al.,* 2021), leading to their use for higher yields in some regions (Ishizuka *et al.,* 1973).

Grain production, the ultimate outcome of growth and development, hinges on dry matter production during the ripening phase (Tanaka *et al.* 1974; Sagar *et al.,* 2023). The higher dry matter production of the cultivar CR Dhan 319 (Table 1) helped to increase yield attributing characters; number of panicles per m^2 (Table 1), spike lets per panicle, panicle length as compared to other cultivars which could result in higher grain yield than other cultivars (Table 2). These yield attributes had positive correlation with grain yield (Table 3) indication of increase in these parameters improved the grain yield of rice.

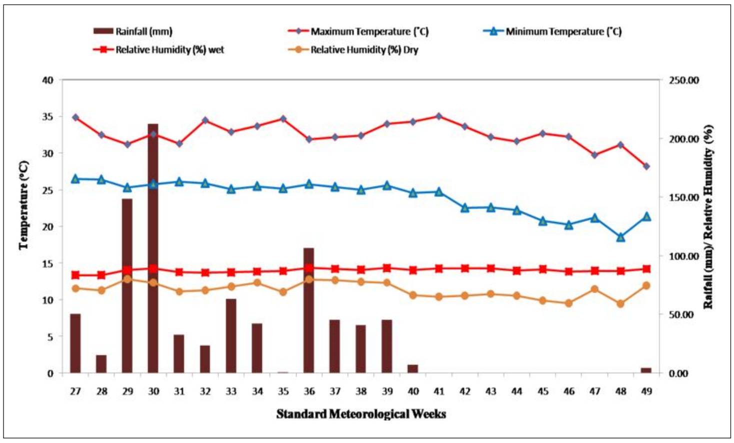

Fig 1: Maximum and Minimum temperature, Humidity, Rainfall during July to December, 2023 at CUTM Paralakhemundi.

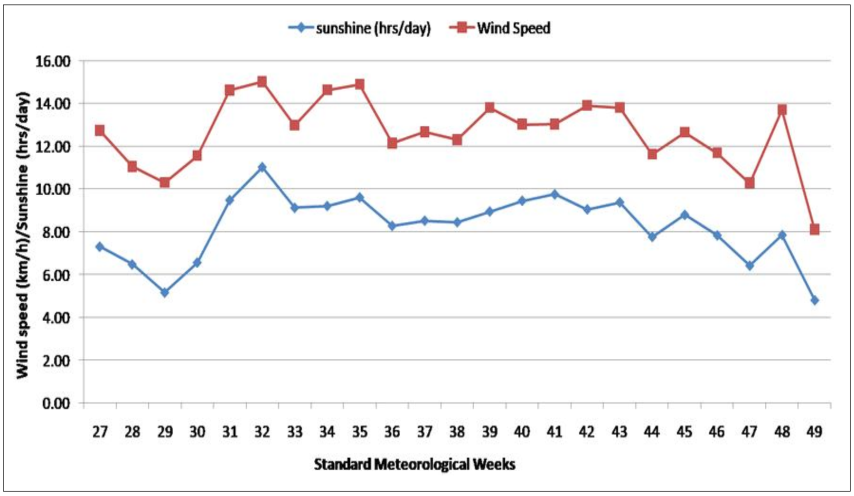

Fig 2: Wind speed and sunshine hours during July to December, 2023 at CUTM Paralakhemundi.

The different phenophases of the rice cultivars grown were identified in this experiment and days taken after transplanting was decided (Table 4). The GDD of different cultivars was estimated by taking in to consideration of standard procedure. The GDD at vegetative stage ranged from 530 to 1204, at reproductive stage 543 to 572 and ripening stage 461 to 545among different cultivars (Table 4). The GDD was higher at vegetative stage in long duration cultivars while it was higher at reproductive stage in short duration varieties. The total GDD from transplanting to harvesting was higher in case of long duration cultivars and less in short duration cultivars. Whenever the cumulative GDD were more, there was higher yield (Table 1) (Abhilash *et al.,* 2017, Brar *et al.,* 2011 and Sharma *et al.,* 2011). There was an increase in rice grain yield with improvement in total GDD (Fig 1). It has been found that maximum grain yield in *kharif* was obtained at 2060 GDD beyond which there was decrease in yield.

Table 1: Number of panicles, panicle length, number of spikelets per panicle, percentage of filled spikelets and 1000 seed weight of rice varieties grown during *kharif* season, 2023.

Treatments	No. of panicles/ m^2	Panicle length (cm)	No. of spikelets/ panicle	Percentage of filled spikelets (%)	1000 seed weight (g)	Dry matter, g m^2 90 Days after transplanting	Days from Sowing to 50% flowering
CR Dhan 319	227[a]	25.74[a]	176[a]	80.76[f]	21.56[cd]	1156[a]	127
MTU 1075	203[ab]	21.96[bcdefg]	141[cde]	85.02[bcde]	23.43[abc]	907[cd]	130
MTU 1061	211[ab]	23.12[abcde]	147[bcd]	83.83[cdef]	23.23[abc]	954[bc]	114
CR 316	195[bc]	21.15[cdefg]	131[efg]	85.68[abcd]	23.32[abc]	842[def]	130
MTU 1064	193[bc]	20.42[efg]	121[ghi]	87.05[abc]	24.46[ab]	897[cde]	126
CR 315	198[ab]	21.77[bcdefg]	135[defg]	85.11[bcde]	25.33[a]	814[fg]	118
MTU 1010	221[ab]	24.18[ab]	157[b]	81.15[ef]	23.64[abc]	993[b]	113
Mohini	212[ab]	23.67[abcd]	150[bc]	82.49[def]	23.32[abc]	976[bc]	116
CR Dhan 314	194[bc]	20.86[defg]	125[fgh]	86.20[abcd]	24.76[ab]	786[fg]	114
Pooja	219[ab]	23.81[abc]	152[bc]	82.13[def]	24.32[ab]	1007[b]	128
CR 313	191[bc]	20.01[fg]	116[hi]	87.24[abc]	23.55[abc]	802[fg]	127
Sowbhagya	205[ab]	22.80[bcdef]	146[bcd]	84.37[def]	22.67[bcd]	967[bc]	116
CR Dhan 308	154[d]	19.48[g]	111[i]	89.35[a]	23.03[abc]	754[g]	95
Marvel 1011	165[cd]	19.97[fg]	113[hi]	88.52[ab]	20.54[d]	818[efg]	98
S.Em.±	10.69	0.98	4.94	1.44	0.83	38	
CD (P=0.05)	31.07	2.84	14.36	4.20	2.40	112	
CV%	9.30	7.67	6.24	2.94	6.13	7.34	

Table 2: Grain, straw and biological yield and harvest index of rice cultivars grown during *kharif* 2023.

Treatments	Yield			
	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index, %
CR Dhan 319	5782[a]	7635[a]	13416[a]	43.11[a]
MTU 1075	4661[bcde]	6373[cde]	11034[def]	42.29[a]
MTU 1061	4915[bcd]	6328[cde]	11243[de]	43.49[a]
CR 316	4328[cde]	5864[de]	10191[fg]	42.53[a]
MTU 1064	4162[def]	6059[de]	10221[emg]	40.39[a]
CR 315	4346[cde]	5737[e]	10083[fg]	43.11[a]
MTU 1010	5426[ab]	6894[bc]	12319[bc]	43.99[a]
Mohini	4952[bc]	6528[bcd]	11479[bcd]	43.19[a]
CR Dhan 314	4231[cde]	5699[e]	9930[g]	42.58[a]
Pooja	5339[ab]	7163[ab]	12502[ab]	42.71[a]
CR 313	4135[ef]	5877[de]	10012[fg]	41.35[a]
Sowbhagya	4896[bcde]	6410[cde]	11305[cd]	43.47[a]
CR Dhan 308	3139[g]	4397[f]	7535[h]	41.75[a]
Marvel 1011	3404[fg]	4769[f]	8173[h]	41.52[a]
S.Em.±	263	248	361	1.7
CD (P=0.05)	765	722	1049	NS
CV%	10.02	7.02	5.86	6.23

Analysis of correlation between grain yield and GDD showed significant positive correlation between GDD at vegetative stage while there was no relation at reproductive stage and negative significant relation at ripening stages (Table 3) and in long duration cultivars the vegetative stage duration was more compared to medium and short duration varieties (Table 4). The significant positive correlation between yield and GDD at vegetative stage contributed to higher grain yield in long duration cultivars as these had long vegetative period and accumulated higher GDDs (Table 3). The cultivar Marvel and CR Dhan 308 have given lower grain yield due to less accumulation of GDD from transplanting to vegetative and these cultivars matured early hence recorded lower yield as compared to medium and long duration cultivars.

The reproductive and ripening stages were divided into five phenophases, with GDD varying across stages (Table 5). Short-duration cultivars (CR Dhan 308, Marvel 111) had higher GDD from reduction division to maturity, while CR Dhan 319, MTU 1075 and others recorded lower values. The optimum GDD for each stage was 120 (PI to young panicle), 245 (young panicle to reduction division), 178 (reduction division to anthesis), 113 (anthesis to ripening) and 365 (ripening to maturity). The correlation between GDD and grain yield at these stages was positive at reduction division to anthesis, anthesis to ripening and ripening to maturity stage indication of higher GDD at these stages increased the grain yield (Table 3).

Through regression analysis, best fit curves were fitted between grain yield and GDD. At all stages, the polynomial curve of order 2 better fitted except in case of reproductive stage where 4^{th} order polynomial was better fitted. The Regression analysis showed that the GDD at various phenophases and grain yield (Fig 3) had good agreement and indication that the variance in grain yield a dependent variable is explained by the GDD an independent variable to the extent of 52 % at vegetative and 51% ripening stages (Table 6).

The grain yield was higher with increase in duration of the crop (Fig 4). Vergara *et al.* (1966) indicated that in short-duration rice varieties, minimal carbohydrate accumulation, including starch and sugars, occurs during both the vegetative and reproductive stages.

At 90 DAT and harvest the dry matter production of CR Dhan 319 was comparable with MTU 1010 and significantly superior over all other cultivars (Table 1). There are reports

Table 3: Correlation between grain yield and yield attributesand grain yield and GDD at different stages of vegetative, reproductive, ripening and Panicle initiationto young panicle stage, young panicle stage to reduction division, reduction division to anthesis, anthesis to ripening and ripening to maturity stages.

Grain yield Vs yield attributes		Grain yield Vs GDD at phenophases	
Yield attributes	r value	GDD at phenophase	r value
Number of panicles	0.69**	Vegetative	0.56*
Panicle length(cm)	0.67**	Reproductive	-0.25
No. of spike lets per panicle	0.82**	Ripening	-0.60*
% of filled spikelet	-0.63**	Panicle initiation to young panicle stage	0.55*
1000 grain weight, g	0.08	Young panicle stage to reduction division	-0.01
		Reduction division to anthesis	-0.63*
		Anthesis to ripening	-0.68**
		Ripening to maturity stages	-0.54*

Table 4: GDD at vegetative, reproductive and ripening stages of rice.

Varieties	VegetativeDAT	GDD	Reproductive DAT	GDD	Ripening DAT	GDD	Total GDD
CR Dhan 319	1-59	1142	60-89	541	90-119	465	2148
MTU 1075	1-62	1204	63-92	530	93-122	461	2195
MTU 1061	1-46	887	47-76	572	77-106	497	1956
CR 316	1-62	1204	63-92	530	93-122	461	2195
MTU 1064	1-57	1104	58-87	545	88-117	472	2121
CR 315	1-49	946	50-79	566	80-109	490	2002
MTU 1010	1-45	868	46-75	574	76-105	500	1942
Mohini	1-43	926	44-78	569	79-108	492	1987
CR Dhan 314	1-46	887	47-76	572	77-106	497	1956
Pooja	1-60	1163	61-90	539	91-120	462	2164
CR 313	1-58	1123	59-88	543	89-118	468	2134
Sowbhagya	1-46	906	47-77	571	78-107	495	1972
CR Dhan 308	1-27	530	28-57	573	58-87	545	1648
Marvel 1011	1-30	584	31-60	578	61-90	539	1701

that differences have been observed in grain yield among genotypes having the same amount of dry matter due to differences in the utilization of photosynthates (Hayashi,1995). The biological yield of a cereal crop represents the total yield of plant tops and serves as a measure of the crop's photosynthetic capacity (Yoshida,

Table 5: GDD at panicle initiation to young panicle stage, young panicle stage to reduction division, reduction division to anthesis, anthesis to ripening and ripening to maturity stage of rice.

	Days after transplanting									
Varieties	Panicle initiation to young panicle stage	GDD	Young panicle stage to reduction division	GDD	Reduction division to anthesis	GDD	Anthesis to ripening	GDD	Ripening to maturity stage	GDD
CR Dhan 319	60-65	120	66-79	250	80-89	171	90-96	113	97-119	352
MTU 1075	63-68	115	69-82	245	83-92	170	93-99	111	100-122	350
MTU 1061	47-52	119	53-66	275	67-76	178	77-83	120	84-106	378
CR 316	63-68	115	69-82	245	83-92	170	93-99	111	100-122	350
MTU 1064	58-63	120	64-77	253	78-87	171	88-94	117	95-117	355
CR 315	50-55	118	56-69	272	70-79	176	80-86	118	87-109	372
MTU 1010	46-51	119	52-65	276	66-75	179	76-82	123	83-105	378
Mohini	49-54	118	55-68	275	69-78	177	79-85	118	86-108	374
CR Dhan 314	52-47	119	53-66	275	67-76	178	77-83	120	84-106	378
Pooja	66-61	119	67-80	249	81-90	171	91-97	111	98-120	352
CR 313	64-59	121	65-78	252	79-88	170	89-95	116	96-118	353
Sowbhagya	48-53	118	54-67	276	68-77	177	78-84	119	85-107	377
CR Dhan 308	28-33	115	34-47	261	48-57	197	58-64	140	65-87	405
Marvel 1011	31-36	113	50-37	269	51-60	196	61-64	138	68-90	401

Table 6: Regression analysis of grain yield of rice and GDD at different phenophases of rice cultivars during kharif season, 2023.

Phenphases	Yield	R^2
Vegetative stage	y = -0.007×2 + 14.56×- 2594.	0.516
Reproductive	y = 0.000×5 - 1.457×4 + 1639×3 - 92093×2 + 3E+08× - 3E+10	0.420
Ripening	y = -0.386×2+370.5× - 83909	0.506
Total	y = -0.010×2+43.03× - 39439	0.520
Panicle initiation to Young panicle stage	y = -37.13×2+8873.× - 52528	0.377
Young panicle stage to Reduction division	y = 5.529×2-2892× + 38206	0.339
Reduction to anthesis	y = -4.079×2+1444× - 12295	0.551
Anthesis to ripening	y = -2.138×2+480.0× - 22123	0.514
Ripening to maturity	y = -1.075×2+784.2× - 13803	0.514

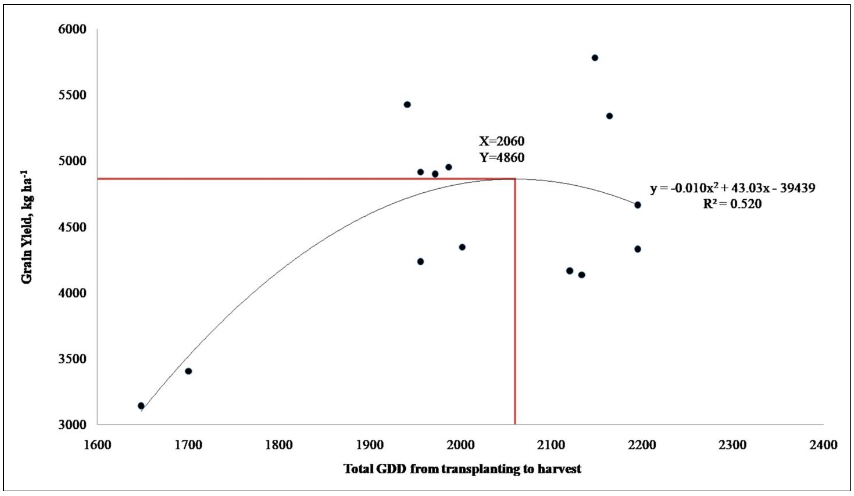

Fig 3: Relation between total GDD and grain yield.

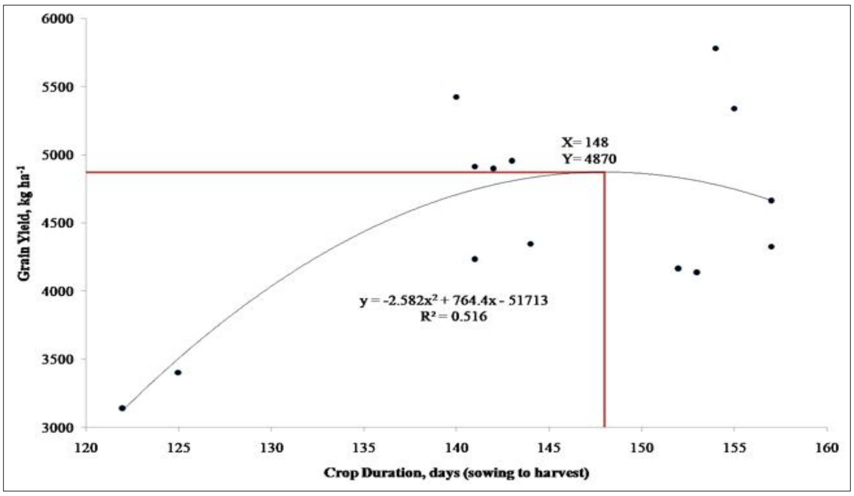

Fig 4: Grain yield of rice as influenced by the duration of crop during *kharif* season, 2023.

1981). It is determined by the crop's growth duration and the Crop Growth Rate (CGR) observed at various growth stages (Tanaka and Osaki, 1983).

The cultivars which had harvest index above 43% are MTU 1061, CR 315, MTU 1010, Mohini, Sowbhagya and CR Dhan 319 and other cultivars had HI less than 42%. There was higher HI in case of CR Dhan 315 and MTU 1010 besides other cultivars showed increasing yield trends and these increases were attributed to improvement in harvest index, which is associated with traits such as plant height, increase in biomass, or the combination of dry matter accumulation (Samonte *et al.,* 1998). Rice GHI values vary greatly among cultivars, locations, seasons and ecosystems thereby indicating the importance of this variable for yield simulation (Kiniry *et al.,*2001). As the CR Dhan 319 had higher GHI which ultimately recorded higher grain yield over other cultivars.

The variety MTU 1010 also recorded similar yield with that of CR Dhan 319 due to comparable yield attributes and dry matter production. The grain yield of MTU 1010 was significantly superior over CR 316, MTU 1064, CR315, CR Dhan 314, CR Dhan 308, Marvel 1011 and CR 313 cultivars due to increased growth and yield attributes as that of latter cultivars which ultimately resulted in higher yield. There was significant correlation between grain yield and yield attributes which indicates that the improved yield attributes in MTU 1010 resulted in higher yield. The yields of other cultivars are lower than above cultivar due to lower yield attributes there by lesser yield.

CONCLUSION

From these results it can be concluded that the cultivars CR Dhan 319 gives higher grain yield and net income among fourteen cultivars tested in southern Odisha. Further, for higher grain yield it is recommended to grow long duration cultivar having 145-150 days duration (sowing to harvest) with 2060 GDD Celsius (transplanting to maturity).

Conflict of interest

The authors declare that there is no conflict of interest related to this article.

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