**Original Research Article**

**Vigor-Based Classification of Traditional Pigmented Rice Cultivars in Relation to Yield Traits**

**ABSTRACT**

**Aims:** To classify the coloured rice cultivars into different vigour groups using total vigour response indices.

**Study Design:** Randomized Block Design.

**Place and Duration of Study:** University Research Farm, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar 736165, West Bengal, India. The geographical coordinates of the site are 26°19′86′′ N latitude and 89°23′53′′ E longitude, with an elevation of 43 meters above sea level. Experiments were conducted during *Kharif 2022* and *Kharif* 2023.

**Methodology:** Thirty nine coloured rice cultivars were cultivated during *Kharif* 2022 and *Kharif* 2023. The 30-days old seedlings were transplanted in randomized block design with two replications. Row to row spacing was 30 cm and plant to plant spacing was 20 cm. Standard agronomic practices compatible to the humid tropic of Terai Zone were practiced. Ten random plants from each plot were selected for recording data. Observations were recorded on yield and yield attributing parameters.

**Results:** The statistical analysis of variance showed high significant variations among the coloured rice cultivars. Individual vigour indices, cumulative vigour response indices and then total vigour response indices were calculated and total vigour response indices were used for classification of rice cultivars in different vigour groups. Cultivars were classified into five groups- ‘very low ’, ‘low ’, ‘moderate ’, ‘high’ and ‘very high’. Three cultivars were found to have very low vigour, five were fallen under low vigour group, 10 were under moderate vigourgroup, 17 were under high vigour group and four were under very high vigour group.

*Keywords: Coloured rice, individual vigour indices, cumulative vigour response indices and then total vigour response indices.*

**1. INTRODUCTION**

Rice (*Oryza sativa* L.) is in cultivation in South-east Asia since 10000 years and it is cultivated in over 100 countries worldwide as staple food for one half of the world population [1]. Rice ranked second only to wheat as a key food crop. As a crucial agricultural commodity, it plays a key role in ongoing efforts to improve both its quality and total production. Rice provides 27% of dietary energy needs for human beings, 20% of nutritional proteins and 3% of dietary fiber [2]. The USDA predicts that worldwide rice production will reach 513.5 million tonnes in 2023-2024, still the greatest amount ever. India has 44.6 million hectares of land planted to rice, the most of any country.

With the growing global population and rising living standards, the demand for high-quality rice products continues to increase. In addition to high production, key factors considered in rice are its quality and health benefits. Colored rice, particularly those with high anthocyanin content, is known for its antioxidant properties, which help counteract free radicals and are beneficial in the treatment of chronic conditions such as diabetes and cancer. As health awareness has risen among rice consumers in recent years, there has been a growing focus on rice varieties with red and black pericarp, which are rich in antioxidants [3,4]. This has led to an increasing demand for these specific rice genotypes. However, to meet the growing demand for colored rice, it is essential to improve the yields and develop high-yielding colored rice varieties. Agro-morphological characterization should ultimately establish a system for recording and storing valuable data, making it easily accessible and available to others, and supporting the planning of breeding programs. Morphological observation is the taxonomy-based observation to find out the plant properties. Considering the importance of coloured rice in the regular diet and introduction of the coloured rice genotypes in new agro-ecology, this study was setup to investigate the individual vigour indices, cumulative vigour response indices and then total vigour response indices. Using the total vigour response indices, the genotypes were classified in different viour groups.

**2. MATERIALS AND METHODS**

**2.1. Plant Materials**

Thirty nine traditional coloured rice cultivars were used in this endeavour and the cultivars and their place of collection have been listed in Table 1. The field experiment was carried out during *Kharif* 2022 and *Kharif* 2023 at the Experimental Farm of Uttar Banga Krishi Viswavidyalaya,Pundibari, Cooch Behar to investigate the yield and yield attributing characters. The geographical coordinates of the site are 26°19′86′′ N latitude and 89°23′53′′ E longitude, with an elevation of 43 meters above sea level.

 Thirty one days old seedling, were transplanted in 4 m × 4 m plots in a Randomized Block Design with two replications. Row to row spacing was 30 cm, and plant to plant spacing was 20 cm. To achieve good crop stand, standard agronomic techniques appropriate for the Tarai Zone’s humid tropic climate were used [5]. To suppress the emergence of weeds after transplanting, a shallow water layer of 4-6 cm was always maintained in the field. Most of the irrigation was done after the monsoon as the region experienced heavy rainfall. Ten plants at random from each cultivar of each replication were chosen to record the data in accordance with IRRI rules [6]. Data were recorded for 11 parameters for this piece of research work.

**Table 1. Rice cultivars used in this research work and their place of collection**

|  |  |  |
| --- | --- | --- |
| **Sl. No.** | **Name of the cultivars** | **Place of collection/ source of the seed** |
| 1. | Lalmala | Jalpaiguri district, West Bengal |
| 2. | Sungabara | Alipurduar district, West Bengal |
| 3. | Kaliaphulo | Lower western part of West Bengal |
| 4. | Birohi | Tarai Research Society, AlipurDuar, West Bengal |
| 5. | Boichi | Alipurduar district, West Bengal |
| 6. | Balam | Alipurduar district, West Bengal |
| 7. | Legadhan | Tarai Research Society, Alipurduar, West Bengal |
| 8. | Jhora | Lower western part of West Bengal |
| 9 | Kharadhan | PSBSG, Sitalkuchi, Cooch Behar, West Bengal |
| 10. | Sadamala | Tarai Research Society, Alipurduar, West Bengal |
| 11. | Kalaboichi | Cooch Behar district, West Bengal |
| 12. | Jaldhyapa-3 | Tarai Research Society, Alipurduar, West Bengal |
| 13. | Kalawati | Lower western part of West Bengal |
| 14. | Laldhyapa | Tarai Research Society, Alipurduar, West Benga |
| 15. | Kagey | Kalimpong, Darjeeling district, West Bengal |
| 16. | BDO Nagara | Lower western part of West Bengal |
| 17. | UN-1 | Coch Behar, West Bengal |
| 18. | Jaldhyapa | Tarai Research Society, Alipurduar, West Bengal |
| 19. | Sathiyabora | ICAR-CPRI- Kahikuchi, Kamrup, Assam |
| 20. | ChakhaoPoireiton | Central Agriculture University, Imphal, Manipur |
| 21. | JalnaryBunni | Uttar Dinajpur district, West Bengal |
| 22. | Jasowa | Alipurduar district, West Bengal |
| 23. | Betho | Tarai Research Society, AlipurDuar, West Bengal |
| 24. | Deshi | Tarai Research Society, Alipurduar, West Bengal |
| 25. | Uttar Banga Local-18 | Tarai Research Society, Alipurduar, West Bengal |
| 26. | Binni | Tarai Research Society, Alipurduar, West Bengal |
| 27. | Adminal Black Rice | Central Agriculture University, Imphal, Manipur |
| 28. | SadabhatKalo | PSBSG, Sitalkuchi, Cooch Behar, West Bengal |
| 29. | ChakhaoAgangabi | Central Agriculture University, Imphal, Manipur |
| 30. | Jugal | PSBSG, Sitalkuchi, Cooch Behar, West Bengal |
| 31. | ChakhaoAgangaba (Red) | Central Agriculture University, Imphal, Manipur |
| 32. | ChakhaoAgangaba (Black) | Central Agriculture University, Imphal, Manipur |
| 33. | Chakhao Selection-1 | UBKV, Pundibari, Cooch Behar, West Bengal |
| 34. | Upendra | UBKV, Pundibari, Cooch Behar, West Bengal |
| 35. | Chakhao Selection-3 | UBKV, Pundibari, Cooch Behar, West Bengal |
| 36. | Chakhao Selection-2 | ICAR-CPRI- Kahikuchi, Kamrup, Assam |
| 37. | Wairi | Central Agriculture University, Imphal, Manipur |
| 38. | ChakhaoBoiton | Central Agriculture University, Imphal, Manipur |
| 39. | ChakhaoAmubi | Central Agriculture University, Imphal, Manipur |

**2.2. Statistical Analysis**

The experimental plan used a randomized block design with 39 treatments (traditional coloured rice cultivars) per replication and two replications in a total of 78 experimental units. Statistical analysis of data was conducted with absolute values. The data were subjected to standard statistical method of analysis of variance (ANOVA) by using Rstudio-2022.2-576.exe software R version 4.2.1 (2022-06-23 ucrt). The individual vigour indices (IVI), cumulative vigour response indices (CVRI) and then total vigour response indices (TVRI) were calculated using Microsoft Excel as outlined by Jumma et al. [7] and Al-Mafraji et al. [8].

**IVI** = Vi/Vx

Whereas, **Vi:** Value of each genotype; **Vx:** Maximum value

**CVRI (2022)** = (PHi/PHx) + (DFi/DFx) + (NPi/NPx) + (PLi/PLx) + (FGi/FGx) + (NCi/NCx) + (TGi/TGx) + (STi/STx) + (TWi/TWx) + (KWi/KWx) + (GYi/GYx)

**CVRI (2023)** = (PHi/PHx) + (DFi/DFx) + (NPi/NPx) + (PLi/PLx) + (FGi/FGx) + (NCi/NCx) + (TGi/TGx) + (STi/STx) + (TWi/TWx) + (KWi/KWx) + (GYi/GYx)

Whereas, **PH:** Plant height; **DF:** Days to 50% flowering; **NP:** Numberof panicles per hill; **PL:** Panicle length**; FG:** Number of filled grains per panicle; **NC:** Number of chaffy grain per panicle; **TG:** Number of total grains per panicle; **ST:** Spikelet sterility; **TW:** Test weight; **KW:** 1000-kernel weight; **GY:** Grain yield

**TVRI =** CVRI (2022) + CVRI (2023)

**3. RESULTS AND DISCUSSION**

**3.1. Analysis of Variance**

Analysis of variance revealed highly significant differences among cultivars (Table 2). Significant variation among the genotypes is the indication of having scope to select the desirable genotype(s) for direct recommendation for cultivation or further use of the identified desirable character of the cultivars for rice improvement.

 Genetic variation among the cultivars can be used as a screening tool during rice growth stages for vigour related traits [9-11]. The genotypes with high or above-average values for morphological parameters can be identified as vigourous cultivars [7,12].

**Table 2. Analysis of variance (from pooled data) of quantitative characters of** **39 Farmers’ Varieties of rice**

|  |  |  |  |
| --- | --- | --- | --- |
| **Source of variation** | **Mean Sum of Square** | **CV** | **LSD/CD** |
| **Replication** | **Genotypes** | **Residuals** |
| **D.F.** | 1 | 38 | 38 |
| **Days to 50% flowering** | 39.49 | 346.12 \*\*\* | 13.98 | 3.229 | 7.569 |
| **Plant height** | 46.85 | 670.95 \*\*\* | 12.92 | 2.149 | 7.276 |
| **Number of panicles per hill** | 6.2051 | 10.5001 \*\*\* | 1.1270 | 6.946 | 2.149 |
| **Panicle length** | 1.4621 | 7.6576 \*\*\* | 0.4015 | 2.534 | 1.282 |
| **Number of filled grains** | 75.03 | 1434.53 \*\*\* | 20.39 | 3.347 | 9.141 |
| **Number of chaffy grains** | 6.96 | 727.69 \*\*\* | 11.33 | 7.755 | 6.814 |
| **Spikelt sterility %** | 0.524 | 166.104 \*\*\* | 2.365 | 6.410 | 2.024 |
| **Grain length** | 0.01231 | 0.34399 \*\*\* | 0.01292 | 1.421 | 0.230 |
| **Grain breadth** | 0.070862 | 0.181670 \*\*\* | 0.048746 | 7.665 | 0.446 |
| **Grain thickness** | 0.0003201 | 0.0305953 \*\*\* | 0.0017403 | 2.126 | 0.084 |
| **Kernel length** | 0.012489 | 0.143938 \*\*\* | 0.004869 | 1.149 | 0.141 |
| **Kernel breadth** | 0.000065 | 0.110448 \*\*\* | 0.000983 | 1.245 | 0.063 |
| **L:B ratio** | 0.027564 | 0.242516 \*\*\* | 0.033431 | 6.494 | 0.370 |
| **Kernel thickness** | 0.006964 | 0.044208 \*\*\* | 0.000733 | 1.485 | 0.054 |
| **1000-Grain weight** | 0.7327 | 30.4910 \*\*\* | 0.1752 | 1.717 | 0.847 |
| **1000-Kernel weight** | 2.2712 | 19.4375 \*\*\* | 0.3029 | 2.616 | 1.114 |
| **Yield** | 0.5841 | 3.2828 \*\*\* | 0.2383 | 10.858 | 0.988 |

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’

**3.2. Individual Vigour Indices**

The individual vigour indices (IVIs) were calculated following the formula used by Jumma et al. [7]. The parameters used for calculation of IVIswereplant height, days to 50% flowering, number of panicle per hill, panicle length, number of filled grains per panicle, number of chaffy grains per panicle, total grains per panicle, sterility, test weight, 1000-kernel weight and grain yield per plotfor the data of*Kharif* 2022 (Table 3&4).The IVIs ranged for plant height from 0.77 to 1.00, for days to 50% flowering from 0.69 to 1.00, for number of panicle per hill from 0.55 to 1.00, for panicle lengthfrom 0.67 to 1.00, for number of filled grains per paniclefrom 0.37 to 1.00, for number of chaffy grains per panicle from 0.13 to 1.00, for total grains per panicle from 0.41 to 1.00, for sterilityfrom 0.19 to 1.00, for test weight from0.51 to 1.00, for 1000-kernel weightfrom 0.54 to 1.00 and for grain yield per plot from 0.42 to 1.00.

 The IVIs was also calculated for all morpho-physiological traits for the data of*Kharif* 2023 (Table 3&4). The IVIs of individual trait ranged for plant height from 0.74 to 1.00, for days to 50% flowering from 0.70 to 1.00, for number of panicle per hill from 0.58 to 1.00, for panicle lengthfrom 0.69 to 1.00, for number of filled grains per paniclefrom 0.46 to 1.00, for number of chaffy grains per panicle from 0.19 to 1.00, for total grains per panicle from 0.46 to 1.00, for sterilityfrom 0.24 to 1.00, for test weight from0.51 to 1.00, for 1000-kernel weightfrom 0.54 to 1.00 and for grain yield per plot from 0.36 to 1.00.

 Vigour indices of each trait provide information about the growth rate and uniform development of cultivars under varied environmental conditions [13]. Plants with high vigour usually compete successfully under limited environmental resources, influencing crop stand establishment and ultimately grain yield [7].

The IVIs were used to calculate cumulative vigour response indices (CVRIs) and then total vigour response indices (TVRIs). TVRIs were used to classify the coloured rice cultivars in different categories.

**Table3.Individual vigour indices plant height, days to 50% flowering, number of panicle per hill, panicle length, number of filled grains per panicle and number of chaffy grains per panicle**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cultivars | Plant height | Days to 50% flowering | No. of panicle/ hill | Panicle length | No. of filled grains/ panicle | No. of chaffy grains/ panicle |
| 2022 | 2023 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 |
| 1. | 1.00 | 0.99 | 0.96 | 1.00 | 0.75 | 0.67 | 0.82 | 0.80 | 0.61 | 0.57 | 0.81 | 0.67 |
| 2. | 0.81 | 0.74 | 1.00 | 1.00 | 0.79 | 0.84 | 0.80 | 0.77 | 0.82 | 0.73 | 0.33 | 0.35 |
| 3. | 0.96 | 0.82 | 1.00 | 0.80 | 0.93 | 0.99 | 0.81 | 0.81 | 0.80 | 0.76 | 0.44 | 0.56 |
| 4. | 0.96 | 0.89 | 0.72 | 0.94 | 0.72 | 0.83 | 0.76 | 0.79 | 0.84 | 0.78 | 0.35 | 0.31 |
| 5. | 0.92 | 0.92 | 0.89 | 0.91 | 0.90 | 0.95 | 0.85 | 0.78 | 0.78 | 0.72 | 0.58 | 0.45 |
| 6. | 0.88 | 0.92 | 0.92 | 0.81 | 0.90 | 0.96 | 0.84 | 0.83 | 0.45 | 0.48 | 0.54 | 0.52 |
| 7. | 0.91 | 0.86 | 0.76 | 0.79 | 1.00 | 0.90 | 0.89 | 0.86 | 0.84 | 0.78 | 0.26 | 0.28 |
| 8. | 0.88 | 0.90 | 0.71 | 0.73 | 0.94 | 0.96 | 0.94 | 0.94 | 0.79 | 0.77 | 0.60 | 0.58 |
| 9. | 0.95 | 0.91 | 0.74 | 0.85 | 0.80 | 0.91 | 0.95 | 0.93 | 0.82 | 0.76 | 0.59 | 0.52 |
| 10. | 0.86 | 0.91 | 0.79 | 0.90 | 0.73 | 0.80 | 0.84 | 0.80 | 0.74 | 0.78 | 0.20 | 0.25 |
| 11. | 0.84 | 0.84 | 0.89 | 0.90 | 0.67 | 0.82 | 0.87 | 0.84 | 0.78 | 0.71 | 0.65 | 0.67 |
| 12. | 0.92 | 0.85 | 0.88 | 0.93 | 0.86 | 0.89 | 0.81 | 0.83 | 0.81 | 0.76 | 0.65 | 0.59 |
| 13. | 0.92 | 0.89 | 0.85 | 0.87 | 0.96 | 1.00 | 0.87 | 0.87 | 0.88 | 0.75 | 0.33 | 0.33 |
| 14. | 0.94 | 0.90 | 0.92 | 0.94 | 0.67 | 0.81 | 0.80 | 0.79 | 0.65 | 0.62 | 0.92 | 1.00 |
| 15. | 0.77 | 0.79 | 0.98 | 1.00 | 0.67 | 0.75 | 0.81 | 0.83 | 0.48 | 0.51 | 0.60 | 0.57 |
| 16. | 0.83 | 0.81 | 0.80 | 0.84 | 0.55 | 0.58 | 0.79 | 0.80 | 0.42 | 0.49 | 0.26 | 0.28 |
| 17. | 0.96 | 0.89 | 0.94 | 0.94 | 0.81 | 0.86 | 0.85 | 0.81 | 0.74 | 0.64 | 0.97 | 0.92 |
| 18. | 0.93 | 0.94 | 0.85 | 0.85 | 0.70 | 0.69 | 0.79 | 0.80 | 0.85 | 0.74 | 0.19 | 0.19 |
| 19. | 0.95 | 0.96 | 0.82 | 0.94 | 0.57 | 0.71 | 0.80 | 0.81 | 0.82 | 0.76 | 0.50 | 0.56 |
| 20. | 0.95 | 0.88 | 0.82 | 1.00 | 0.71 | 0.73 | 0.75 | 0.74 | 0.63 | 0.53 | 0.13 | 0.21 |
| 21. | 0.93 | 0.91 | 0.98 | 0.81 | 0.59 | 0.69 | 0.87 | 0.90 | 0.67 | 0.57 | 0.31 | 0.47 |
| 22. | 0.97 | 1.00 | 0.76 | 0.91 | 0.77 | 0.87 | 0.67 | 0.69 | 0.41 | 0.48 | 0.22 | 0.23 |
| 23. | 0.87 | 0.95 | 0.92 | 0.81 | 0.79 | 0.89 | 0.73 | 0.72 | 0.47 | 0.46 | 0.24 | 0.22 |
| 24. | 1.00 | 0.89 | 0.69 | 0.94 | 0.58 | 0.74 | 0.82 | 0.83 | 0.75 | 0.70 | 0.85 | 0.90 |
| 25. | 0.85 | 0.91 | 0.90 | 0.70 | 0.66 | 0.69 | 0.80 | 0.80 | 0.85 | 0.76 | 0.19 | 0.20 |
| 26. | 0.91 | 0.91 | 0.71 | 0.90 | 0.69 | 0.72 | 1.00 | 0.98 | 0.84 | 0.77 | 0.18 | 0.23 |
| 27. | 0.89 | 0.88 | 0.71 | 0.70 | 0.60 | 0.82 | 0.88 | 0.90 | 0.91 | 0.83 | 0.56 | 0.49 |
| 28. | 0.88 | 0.83 | 0.90 | 0.73 | 0.78 | 0.82 | 0.85 | 0.89 | 0.76 | 0.68 | 0.39 | 0.42 |
| 29. | 0.84 | 0.89 | 0.72 | 0.70 | 0.56 | 0.65 | 0.85 | 0.89 | 0.86 | 0.75 | 0.58 | 0.51 |
| 30. | 0.93 | 0.85 | 0.71 | 0.91 | 0.77 | 0.89 | 0.83 | 0.82 | 0.77 | 0.68 | 0.53 | 0.47 |
| 31. | 0.86 | 0.97 | 0.89 | 0.70 | 0.93 | 0.91 | 0.87 | 0.87 | 0.68 | 0.66 | 1.00 | 0.83 |
| 32. | 0.88 | 0.84 | 0.72 | 0.73 | 0.60 | 0.74 | 0.83 | 0.75 | 0.64 | 0.50 | 0.76 | 0.77 |
| 33. | 0.93 | 0.86 | 0.69 | 0.70 | 0.77 | 0.92 | 0.84 | 0.87 | 0.96 | 1.00 | 0.57 | 0.53 |
| 34. | 0.94 | 0.91 | 0.73 | 0.70 | 0.61 | 0.66 | 0.76 | 0.76 | 0.95 | 0.83 | 0.62 | 0.55 |
| 35. | 0.97 | 0.94 | 0.71 | 0.75 | 0.57 | 0.68 | 0.87 | 1.00 | 0.91 | 0.73 | 0.63 | 0.57 |
| 36. | 0.89 | 0.93 | 0.70 | 0.70 | 0.63 | 0.66 | 0.82 | 0.82 | 0.90 | 0.81 | 0.38 | 0.41 |
| 37 | 0.91 | 0.84 | 0.76 | 0.74 | 0.67 | 0.74 | 0.91 | 0.92 | 0.99 | 0.89 | 0.49 | 0.49 |
| 38. | 0.93 | 0.93 | 0.74 | 0.75 | 0.59 | 0.66 | 0.91 | 0.97 | 1.00 | 0.92 | 0.57 | 0.52 |
| 39. | 0.94 | 0.91 | 0.73 | 0.70 | 0.58 | 0.72 | 0.84 | 0.84 | 0.37 | 0.47 | 0.76 | 0.77 |
| Range | 0.77-1.00 | 0.74-1.00 | 0.69-1.00 | 0.70-1.00 | 0.55-1.00 | 0.58-1.00 | 0.67-1.00 | 0.69-1.00 | 0.37-1.00 | 0.46-1.00 | 0.13-1.00 | 0.19-1.00 |

**Cultivars**

**1:**Lalmala; **2:**Sungabara; **3:**Kaliaphulo; **4:**Birohi; **5:**Boichi; **6:**Balam; **7:**Legadhan; **8:**Jhora; **9:**Kharadhan; **10:**Sadamala; **11:**Kalaboichi; **12:**Jaldhyapa-3; **13:**Kalawati; **14:**Laldhyapa; **15:**Kagey; **16:**BDO Nagara; **17:**UN-1; **18:**Jaldhyapa; **19:**Sathiyabora; **20:**ChakhaoPoireton; **21:**JalnaryBunni; **22:**Jasowa; **23:**Betho; **24:**Deshi; **25:**Uttar Banga Local-18; **26:**Binni; **27:**Adminal Black Rice; **28:**SadabhatKalo; **29:**ChakhaoAgangabi; **30:**Jugal; **31:**ChakhaoAgangaba (Red); **32:**ChakhaoAgangaba (Black); **33:**Chakhao Selection-1; **34:**Upendra; **35:**Chakhao Selection-3; **36:**Chakhao Selection-2; **37:**Wairi; **38:**ChakhaoBoiton; **39:**ChakhaoAmubi

**Table 4.Individual vigour indices for total grains per panicle, sterility, test weight, 1000-kernel weight, grain yield per plot and cumulative vigour response indices**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cultivars | Total grains/ panicle | Sterility | Test weight | 1000-kernel weight | Grain yield/ plot | CVRI |
| 2022 | 2023 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 |
| 1. | 0.78 | 0.70 | 0.78 | 0.81 | 0.65 | 0.65 | 0.71 | 0.72 | 0.68 | 0.48 | 8.55 | 8.07 |
| 2. | 0.76 | 0.71 | 0.32 | 0.41 | 0.56 | 0.56 | 0.54 | 0.54 | 0.52 | 0.40 | 7.23 | 7.04 |
| 3. | 0.79 | 0.82 | 0.42 | 0.58 | 0.86 | 0.86 | 0.96 | 0.96 | 0.46 | 0.41 | 8.44 | 8.37 |
| 4. | 0.79 | 0.74 | 0.34 | 0.36 | 0.70 | 0.70 | 0.73 | 0.73 | 0.76 | 0.59 | 7.68 | 7.67 |
| 5. | 0.83 | 0.75 | 0.53 | 0.51 | 0.79 | 0.79 | 0.77 | 0.77 | 0.52 | 0.47 | 8.36 | 8.04 |
| 6. | 0.56 | 0.58 | 0.73 | 0.76 | 0.61 | 0.61 | 0.57 | 0.57 | 0.49 | 0.41 | 7.49 | 7.47 |
| 7. | 0.76 | 0.73 | 0.26 | 0.32 | 0.77 | 0.77 | 0.78 | 0.77 | 0.76 | 0.60 | 7.98 | 7.65 |
| 8. | 0.85 | 0.84 | 0.54 | 0.59 | 0.55 | 0.55 | 0.60 | 0.61 | 0.73 | 0.62 | 8.13 | 8.09 |
| 9. | 0.87 | 0.80 | 0.51 | 0.55 | 0.76 | 0.76 | 0.65 | 0.65 | 0.68 | 0.54 | 8.32 | 8.18 |
| 10. | 0.66 | 0.72 | 0.23 | 0.30 | 0.57 | 0.57 | 0.55 | 0.55 | 0.82 | 0.73 | 7.01 | 7.31 |
| 11. | 0.85 | 0.81 | 0.57 | 0.70 | 0.76 | 0.76 | 0.82 | 0.81 | 0.52 | 0.46 | 8.22 | 8.31 |
| 12. | 0.88 | 0.83 | 0.56 | 0.61 | 0.74 | 0.74 | 0.87 | 0.88 | 0.44 | 0.37 | 8.41 | 8.28 |
| 13. | 0.81 | 0.72 | 0.31 | 0.39 | 0.63 | 0.63 | 0.64 | 0.64 | 0.58 | 0.40 | 7.79 | 7.49 |
| 14. | 0.86 | 0.86 | 0.81 | 0.98 | 0.82 | 0.82 | 0.85 | 0.84 | 0.42 | 0.36 | 8.67 | 8.94 |
| 15. | 0.61 | 0.61 | 0.75 | 0.78 | 0.57 | 0.57 | 0.66 | 0.66 | 0.61 | 0.45 | 7.52 | 7.53 |
| 16. | 0.43 | 0.49 | 0.46 | 0.48 | 0.56 | 0.55 | 0.61 | 0.60 | 0.46 | 0.44 | 6.16 | 6.39 |
| 17. | 0.95 | 0.85 | 0.78 | 0.92 | 0.70 | 0.70 | 0.80 | 0.80 | 0.70 | 0.55 | 9.20 | 8.87 |
| 18. | 0.74 | 0.67 | 0.19 | 0.24 | 0.91 | 0.91 | 0.82 | 0.82 | 0.48 | 0.42 | 7.44 | 7.26 |
| 19. | 0.83 | 0.82 | 0.45 | 0.58 | 0.81 | 0.81 | 0.82 | 0.82 | 0.80 | 0.64 | 8.18 | 8.40 |
| 20. | 0.54 | 0.50 | 0.19 | 0.35 | 0.72 | 0.72 | 0.73 | 0.73 | 0.60 | 0.51 | 6.77 | 6.90 |
| 21. | 0.64 | 0.63 | 0.37 | 0.63 | 0.75 | 0.76 | 0.69 | 0.69 | 0.92 | 0.73 | 7.71 | 7.79 |
| 22. | 0.41 | 0.47 | 0.41 | 0.41 | 0.73 | 0.73 | 0.88 | 0.88 | 0.94 | 0.86 | 7.18 | 7.54 |
| 23. | 0.46 | 0.46 | 0.39 | 0.42 | 0.51 | 0.51 | 0.57 | 0.59 | 0.60 | 0.53 | 6.54 | 6.56 |
| 24. | 0.91 | 0.89 | 0.71 | 0.86 | 0.73 | 0.73 | 0.86 | 0.86 | 0.66 | 0.50 | 8.56 | 8.83 |
| 25. | 0.74 | 0.69 | 0.19 | 0.25 | 1.00 | 1.00 | 1.00 | 1.00 | 0.44 | 0.40 | 7.63 | 7.39 |
| 26. | 0.73 | 0.70 | 0.19 | 0.27 | 0.74 | 0.74 | 0.65 | 0.65 | 0.60 | 0.54 | 7.23 | 7.42 |
| 27. | 0.93 | 0.85 | 0.46 | 0.49 | 0.66 | 0.66 | 0.72 | 0.72 | 0.97 | 0.83 | 8.30 | 8.18 |
| 28. | 0.75 | 0.70 | 0.40 | 0.51 | 0.69 | 0.69 | 0.79 | 0.79 | 1.00 | 0.77 | 8.19 | 7.82 |
| 29. | 0.90 | 0.79 | 0.49 | 0.55 | 0.66 | 0.66 | 0.75 | 0.75 | 0.60 | 0.50 | 7.81 | 7.64 |
| 30. | 0.81 | 0.72 | 0.50 | 0.55 | 0.69 | 0.69 | 0.76 | 0.76 | 0.92 | 0.70 | 8.22 | 8.04 |
| 31. | 0.91 | 0.83 | 0.83 | 0.85 | 0.63 | 0.63 | 0.77 | 0.77 | 1.00 | 0.93 | 9.37 | 8.94 |
| 32. | 0.79 | 0.68 | 0.74 | 0.97 | 0.53 | 0.53 | 0.80 | 0.81 | 0.97 | 1.00 | 8.25 | 8.31 |
| 33. | 0.97 | 1.00 | 0.45 | 0.45 | 0.63 | 0.63 | 0.84 | 0.84 | 0.92 | 0.77 | 8.55 | 8.57 |
| 34. | 0.98 | 0.87 | 0.48 | 0.54 | 0.54 | 0.55 | 0.80 | 0.81 | 0.68 | 0.70 | 8.09 | 7.87 |
| 35. | 0.95 | 0.80 | 0.50 | 0.61 | 0.60 | 0.60 | 0.65 | 0.65 | 0.85 | 0.67 | 8.23 | 7.99 |
| 36. | 0.85 | 0.80 | 0.34 | 0.43 | 0.56 | 0.56 | 0.59 | 0.59 | 0.94 | 0.77 | 7.61 | 7.49 |
| 37 | 0.96 | 0.89 | 0.38 | 0.46 | 0.70 | 0.70 | 0.76 | 0.76 | 1.00 | 0.77 | 8.55 | 8.19 |
| 38. | 1.00 | 0.93 | 0.43 | 0.47 | 0.74 | 0.74 | 0.74 | 0.73 | 0.84 | 0.73 | 8.50 | 8.35 |
| 39. | 0.58 | 0.65 | 1.00 | 1.00 | 0.80 | 0.80 | 0.80 | 0.73 | 0.93 | 0.81 | 8.33 | 8.39 |
| Range | 0.41-1.00 | 0.46-1.00 | 0.19-1.00 | 0.24-1.00 | 0.51-1.00 | 0.51-1.00 | 0.54-1.00 | 0.54-1.00 | 0.42-1.00 | 0.36-1.00 | 6.16-9.37 | 6.39-8.94 |

**CVRI:** Cumulative Vigour Response Index

**Cultivars**

**1:**Lalmala; **2:**Sungabara; **3:**Kaliaphulo; **4:**Birohi; **5:**Boichi; **6:**Balam; **7:**Legadhan; **8:**Jhora; **9:**Kharadhan; **10:**Sadamala; **11:**Kalaboichi; **12:**Jaldhyapa-3; **13:**Kalawati; **14:**Laldhyapa; **15:**Kagey; **16:**BDO Nagara; **17:**UN-1; **18:**Jaldhyapa; **19:**Sathiyabora; **20:**ChakhaoPoireton; **21:**JalnaryBunni; **22:**Jasowa; **23:**Betho; **24:**Deshi; **25:**Uttar Banga Local-18; **26:**Binni; **27:**Adminal Black Rice; **28:**SadabhatKalo; **29:**ChakhaoAgangabi; **30:**Jugal; **31:**ChakhaoAgangaba (Red); **32:**ChakhaoAgangaba (Black); **33:**Chakhao Selection-1; **34:**Upendra; **35:**Chakhao Selection-3; **36:**Chakhao Selection-2; **37:**Wairi; **38:**ChakhaoBoiton; **39:**ChakhaoAmubi

**3.3. Cumulative Vigour Response Index**

Cumulative vigour response indices (CVTIs) of *Kharif* 2022 and *Kharif* 2023 were calculated using the formula of Jumma et al. [7] and Al-Mafraji et al. [8]. CVRIs varied from 12.55 to 18.32 (Table 5).In this study, individual CVRI was used for classification of the coloured rice cultivars into different categories. CVRI was also used to study the effect of cold tolerant on maize hybrids, the effect of soil moisture on rice cultivars, the effect of drought on Indica rice genotypes, the effect of high-low temperature on rice cultivars, and the effect of salinity on Japonica rice genotypes [7,14-18].

**Table 5. Cumulative vigour response index and total vigour response index of 39 coloured rice cultivars**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sl. No. | Cultivars | TVRI | Sl. No. | Cultivars | TVRI |
| 1. | Lalmala | 16.61 | 21. | JalnaryBunni | 15.50 |
| 2. | Sungabara | 14.27 | 22. | Jasowa | 14.72 |
| 3. | Kaliaphulo | 16.81 | 23. | Betho | 13.10 |
| 4. | Birohi | 15.35 | 24. | Deshi | 17.39 |
| 5. | Boichi | 16.40 | 25. | Uttar Banga Local-18 | 15.02 |
| 6. | Balam | 14.96 | 26. | Binni | 14.65 |
| 7. | Legadhan | 15.63 | 27. | Adminal Black Rice | 16.47 |
| 8. | Jhora | 16.22 | 28. | SadabhatKalo | 16.02 |
| 9. | Kharadhan | 16.50 | 29. | ChakhaoAgangabi | 15.45 |
| 10. | Sadamala | 14.32 | 30. | Jugal | 16.26 |
| 11. | Kalaboichi | 16.53 | 31. | ChakhaoAgangaba (Red) | 18.32 |
| 12. | Jaldhyapa-3 | 16.69 | 32. | ChakhaoAgangaba (Black) | 16.56 |
| 13. | Kalawati | 15.28 | 33. | Chakhao Selection-1 | 17.13 |
| 14. | Laldhyapa | 17.61 | 34. | Upendra | 15.95 |
| 15. | Kagey | 15.04 | 35. | Chakhao Selection-3 | 16.22 |
| 16. | BDO Nagara | 12.55 | 36. | Chakhao Selection-2 | 15.10 |
| 17. | UN-1 | 18.07 | 37 | Wairi | 16.75 |
| 18. | Jaldhyapa | 14.71 | 38. | ChakhaoBoiton | 16.85 |
| 19. | Sathiyabora | 16.59 | 39. | ChakhaoAmubi | 16.72 |
| 20. | ChakhaoPoireton | 13.67 | Range | - | 12.55-18.32 |

**TVRI:** Total Vigour Response Index

**3.4. Classification Based on Total Vigour Response Indices**

CVRIs varied from 12.55 to 18.32. Classification of rice cultivars is a multifaceted process. It involves morphological, ecological, genetic makeup, geographic origin, genetic levels of improvement, duration, season, both quantitative and qualitative characteristics for classification of rice cultivars [7,19-23].

In this endeavour, the CVRI values for *Kharif* 2022 and *Kharif* 2023 for each rice cultivar were derived by summing individual vigour response indexes for all the characters (Tale 3&4).The CVRI-based technique was used to identify the coloured rice cultivars that were very low, low, moderate, high, and very high in terms of their vigour response index [7].

The 39 coloured rice cultivars were classified into five groups on the basis of CVRI (Table 6). Three rice cultivars (BDO Nagara, Betho, ChakhaoPoireton) were classified as having ‘very low’ vigour response, five were (Sungabara, Sadamala, Binni, Jaldhyapa, Jasowa) classified as having ‘low’vigour response.

Tenrice cultivars (Balam, Uttar Banga Local-18, Kagey, Chakhao Selection-2, Kalawati, Birohi, ChakhaoAgangabi, JalnaryBunni, Legadhan, Upendra) were classified as having ‘moderate’ vigour response, 17 rice cultivars (SadabhatKalo, Jhora, Chakhao Selection-3, Jugal, Boichi, AdminalBlack Rice, Kharadhan, Kalaboichi, ChakhaoAgangaba (Black), Sathiyabora, Lalmala, Jaldhyapa-3, ChakhaoAmubi, Wairi, Kaliaphulo, ChakhaoBoiton, Chakhao Selection-1) were classified as having ‘high’ vigour response and four rice cultivars [Deshi, Laldhyapa, UN-1, ChakhaoAgangaba(Red)]were classified as having ‘very high’ vigour response. The rice cultivars with moderate, high and very high vigour responses are cultivars with superior productivity potential [7].Thus, ChakhaoAgangaba (Red), ChakhaoAgangaba (Black), Wairi, Chakhao Selection-1, Adminal Black Rice, ChakhaoBoiton, Jugal, ChakhaoAmubi, Chakhao Selection-3, Sathiyabora, Jhora, UN-1, Kharadhan and Upendra were identified as having high vigour and high grain yield. Those coloured rice cultivars may be useful for yield increment as genetic donors to develop new cultivars.

**Table 6. Classification of 39 coloured rice cultivars based on total vigour response index for morpho-physiological traits**

|  |  |  |  |
| --- | --- | --- | --- |
| Classification | Cultivars | No. of cultivars | Frequency (%) |
| Very low(12.55-13.70) | BDO Nagara (12.55), Betho (13.10), ChakhaoPoireton (13.67) | 03 | 7.69 |
| Low(13.70-14.85) | Sungabara (14.27), Sadamala (14.32), Binni (14.65), Jaldhyapa (14.71), Jasowa (14.72) | 05 | 12.82 |
| Moderate(14.85-16.00) | Balam (14.96), Uttar Banga Local-18 (15.02), Kagey (15.04), Chakhao Selection-2 (15.10), Kalawati (15.28), Birohi (15.35), ChakhaoAgangabi (15.45), JalnaryBunni (15.50), Legadhan (15.63), Upendra (15.95) | 10 | 25.64 |
| High(16.00-17.15) | SadabhatKalo (16.02), Jhora (16.22), Chakhao Selection-3 (16.22), Jugal (16.26), Boichi (16.40), AdminalBlack Rice (16.47), Kharadhan (16.50), Kalaboichi (16.53), ChakhaoAgangaba (Black) (16.56), Sathiyabora (16.59), Lalmala (16.61), Jaldhyapa-3 (16.69), ChakhaoAmubi (16.72), Wairi (16.75), Kaliaphulo (16.81), ChakhaoBoiton (16.85), Chakhao Selection-1 (17.13) | 17 | 43.59 |
| Very High(17.15-18.32) | Deshi (17.39), Laldhyapa (17.61), UN-1 (18.07), ChakhaoAgangaba (Red) (18.32) | 04 | 10.26 |

**4. CONCLUSION**

The present study demonstrated substantial genetic variability among traditional coloured rice cultivars with respect to yield and associated traits. By calculating individual vigour indices, cumulative vigour response indices, and total vigour response indices, cultivars were effectively classified into five vigour groups: *very low*, *low*, *moderate*, *high*, and *very high*. Specifically, three cultivars exhibited very low vigour, five were categorized as low, ten as moderate, seventeen as high, and four as very high. Cultivars belonging to the moderate, high, and very high vigour groups demonstrated superior productivity potential. Notably, cultivars such as Chakhao Agangaba (Red), Chakhao Agangaba (Black), Wairi, Chakhao Selection-1, Adminal Black Rice, Chakhao Boiton, Jugal, Chakhao Amubi, Chakhao Selection-3, Sathiyabora, Jhora, UN-1, Kharadhan, and Upendra showed both high vigour and high grain yield. These coloured rice genotypes may serve as valuable genetic donors in future breeding programs aimed at developing high-yielding, nutritionally rich rice varieties.

**COMPETING INTERESTS DISCLAIMER**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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