Physiological and Yield Variability among the Elite Rice Germplasm

Salah H. Jumaa[1], Edilberto D. Redoña[2], and K. Raja Reddy[1]
Mississippi State University, Mississippi State, MS, USA

Rationale

- RICE is one of the most important cereal crops and provides the staple food for about half of the world's population.
- Rice is grown under different climatic and environmental conditions and the magnitude of plant response can be variable and species/cultivar dependent.
- A successful breeding program depends on the genetic diversity of a crop for traits that are important for achieving high crop productivity.
- Grain yield is a complex, polygenic, quantitative trait that is governed by many environmental and genetic factors.
- Assessing genetic variability for physiological and yield-related traits will have implications for selecting lines through breeding.
- Cumulative Vigor Response Index (**CVRI**) values for individual lines could be useful in rice breeding programs in developing new genotypes with higher productivity.

Objectives

- To assess morpho-physiological during reproductive stage and yield-related traits of **100** elite rice genotypes comprised of advanced breeding lines and released varieties.
- Develop a method to identify vigor variability among the rice genotypes and classify and rank rice lines based on vigor response indices during reproductive stages.

Experimentation and Measurements

- The experiment was conducted at the Rodney Foil Plant Science Research Facility of Mississippi State University, Mississippi State, MS **(Fig. 1A, B, and C)** during the **2015** growing season.
- Treated seeds were sown in **400** PVC plastic pots (**15.2** cm diameter and **60.5** cm height) filled with the sand with **500** g of gravel at the bottom of each pot.
- The genotypes were arranged randomly within each of the four replications.
- Plants were fertigated three times daily with full-strength Hoagland's solution delivered at **08:00**, **12:00** and **16:00** h to maintain favorable water and nutrient requirements.

Treatments

- **100** rice genotypes (Table1), **4** replications per genotype, grown in pots under sunlit conditions until maturity.
- Mid-season plant growth and development parameters were measured at **90** days after sowing and yield-related traits were measured at maturity.

Measurements

- Photosynthesis, stomatal conductance, and transpiration rates were measured using **LI-6400** (LICOR, NE) photosynthesis system during before flowering. Canopy-air temperature differential (CTD) was estimated from air and canopy temperatures after flowering.
- Cell membrane thermostability (**CMT**), chlorophyll stability, leaf chlorophyll, and carotenoids were estimated before and after flowering.
- Plant height, tiller number, and leaf number were measured at the final harvest. Plant component total dry weights were measured from all plants after oven drying at **75°C** for **72** hours. Yield and yield-related traits were measured for all plants.

Table.1. 100 genotypes were used in this study.

No.	Gen. Name	No.	Gen. Name	No.	Gen. Name	No.	Gen. Name	No.	Gen. Name	No.	Gen. Name	No.	Gen. Name	No.	Gen. Name	No.	Gen. Name	No.	Gen. Name
1	14CLPYT033	11	CL142-AR	21	GSOR100390	31	LA 2134	41	RU1204156	51	RU1304154	61	RU1401164	71	RU1402195	81	RU1404196	91	RU1504191
2	14CLPYT108	12	CL151	22	GSOR100417	32	LAKAST	42	RU1204197	52	RU1304156	62	RU1402005	72	RU1403107	82	RU1404198	92	RU1504193
3	14CVPYT094	13	CL152	23	GSOR101758	33	MERMENTAU	43	RU1301084	53	RU1305001	63	RU1402031	73	RU1403126	83	RU1504083	93	RU1504194
4	14CVPYT144	14	CL163	24	RU1104122	34	Presidio	44	RU1301093	54	RU1401067	64	RU1402065	74	RU1404122	84	RU1504100	94	RU1504196
5	COLORADO	15	CL172	25	CLJZMN	35	Rex	45	RU1301102	55	RU1401070	65	RU1402115	75	RU1404154	85	RU1504114	95	RU1504197
6	Bowman	16	CL271	26	INIA Tacuari	36	RoyJ	46	RU1302192	56	RU1401090	66	RU1402131	76	RU1404156	86	RU1504122	96	RU1504198
7	CAFFEY	17	Cocodrie	27	IRGA409	37	RU0603075	47	RU1303138	57	RU1401099	67	RU1402134	77	RU1404157	87	RU1504154	97	Sabine
8	CHENIERE	18	NIPONBARE	28	JES	38	RU1201024	48	RU1303181	58	RU1401102	68	RU1402149	78	RU1404191	88	RU1504156	98	Taggart
9	CL Jazzman	19	ANTONIO	29	JUPITER	39	RU1201047	49	RU1304114	59	RU1401145	69	RU1402174	79	RU1404193	89	RU1504157	99	Thad
10	CL111	20	El Paso 144	30	LA 2008	40	RU1201136	50	RU1304122	60	RU1401161	70	RU1402189	80	RU1404194	90	RU1504186	100	N-22

Fig.1. Experimental setup and design (A), Plant growth (B), and Panicle maturity (C).

Results and Discussion

A. Photosynthetic processes:

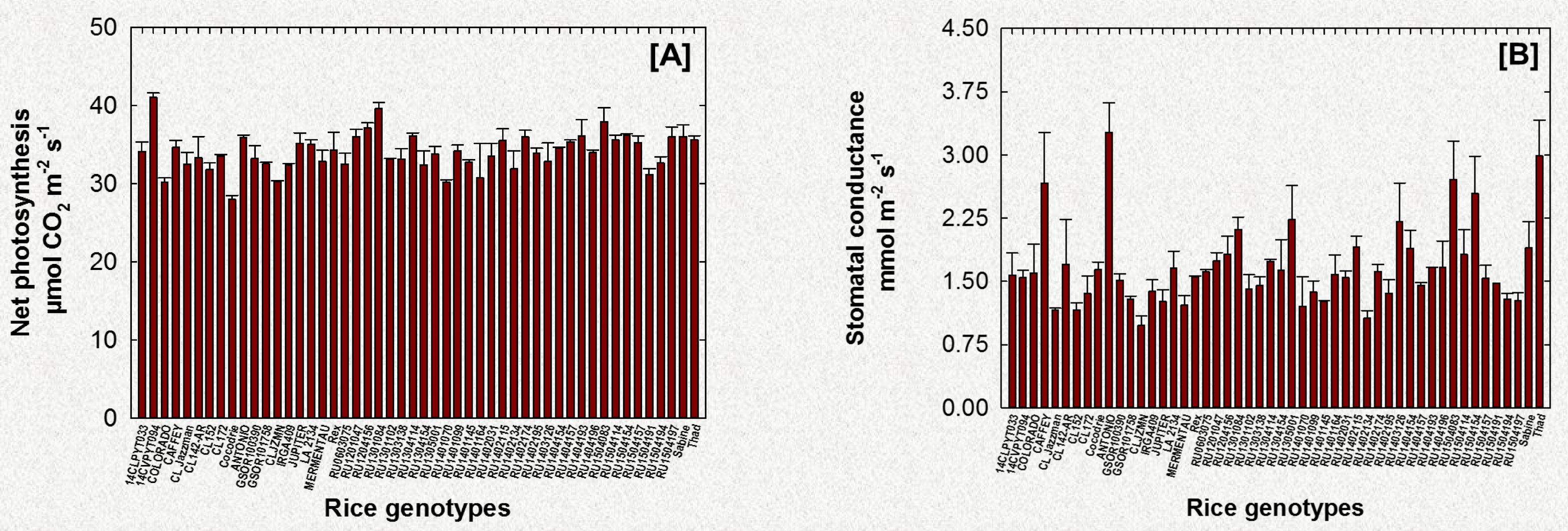

Fig. 2. Leaf photosynthesis (A) and stomatal conductance (B) of rice genotypes measured before flowering.

- Photosynthesis and stomatal conductance exhibited considerable variability among the rice genotypes. Photosynthesis varied from **41** (CLJZMN) to **28** μmol CO_2 m^{-2} s^{-1} (LAKAST) and stomatal conductance also varied from **3.7** (14CVPYT14) to **0.9 mmol m^{-2} s^{-1}** (RU1404191) **Fig. *2*A and B.**

B. Cell membrane thermostability and canopy-air temperature:

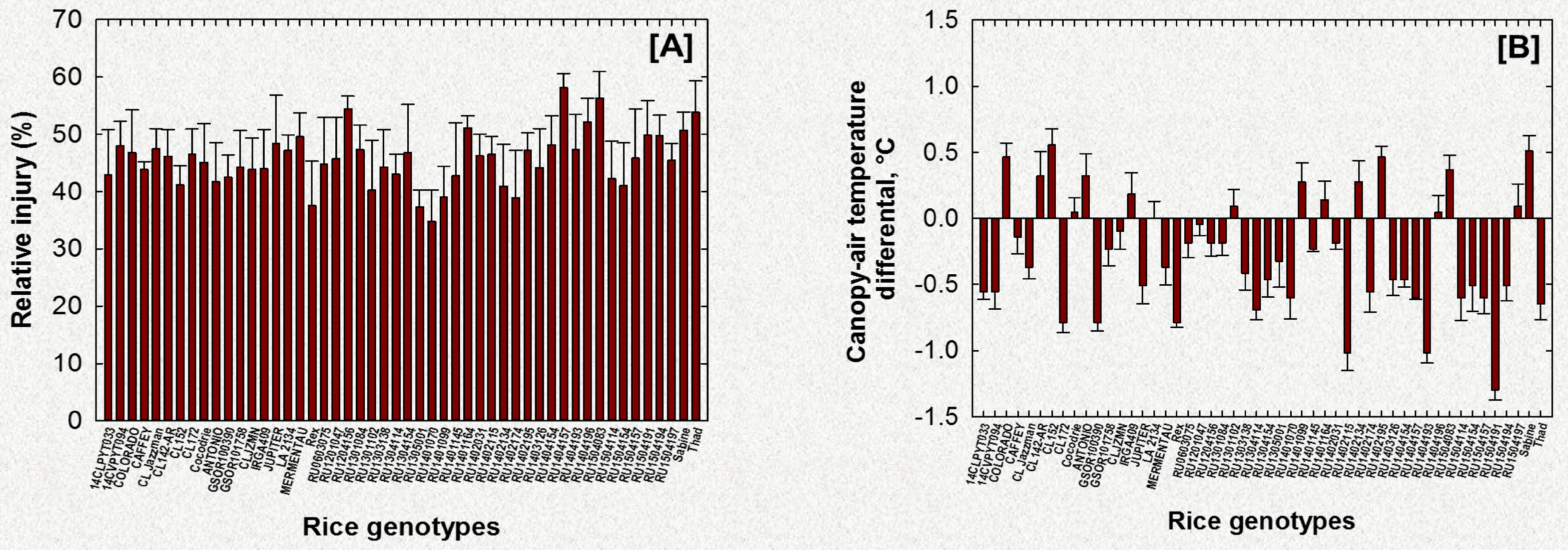

Fig. 3. Relative injury (A) and Canopy temperature (B) of rice genotypes after flowering.

- Maximum and minimum relative injury (**64** and **35%**) were observed in RU1504186 and RU1401070, respectively (**Fig. 3A**).
- Lower canopy temperature during grain filling period is an important physiological principle for high temperature tolerance and it varied from **0.5** (**NIPONBARE**) to **-1.3 °C** (**RU1504191**) **(Fig. 3B)**.

C. Yield and yield-related traits:

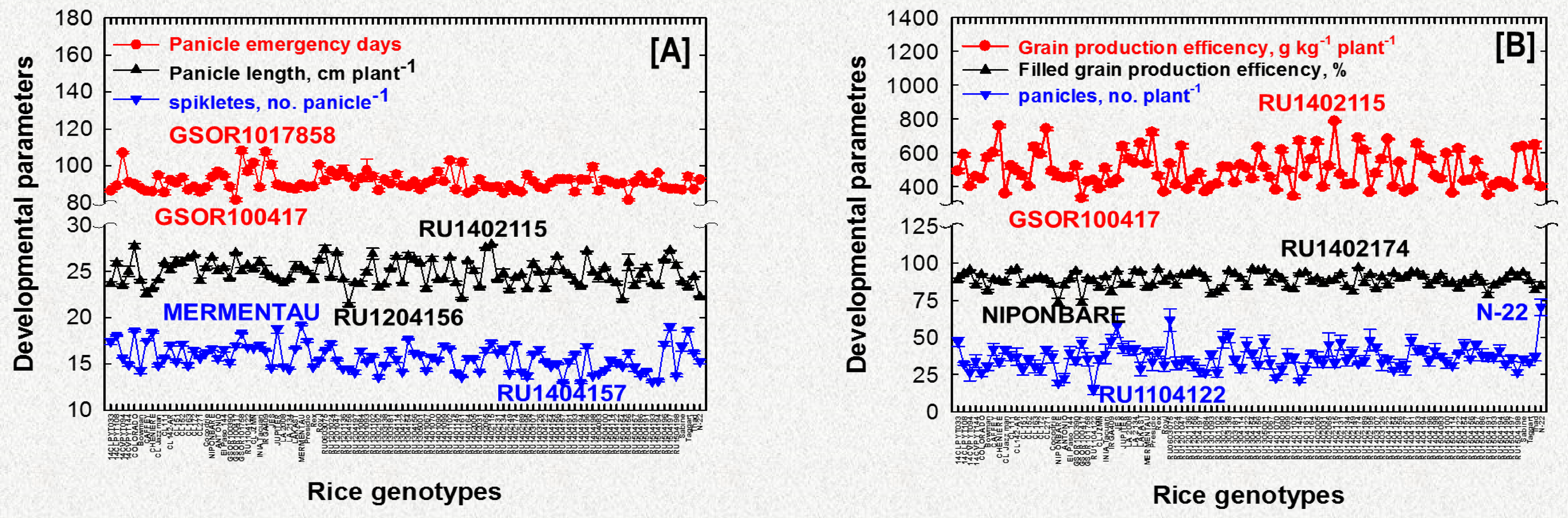

Fig.4. Panicle emergence, panicle length, and number of spikelet (A) and grain production efficiency, filled grain production efficiency, and number of panicles (B) of rice genotypes at maturity stage.

- Panicle emergence day, panicle length, and number of spikelet (**Fig. 4A**) exhibited considerable variability among rice genotypes ranging from **115.2** (**GSOR1017858**) to **81.7** days (GSOR100417), from **27.9** (**RU1402115**) to **21.4 cm** (**RU1204156**), and from **19.0** (**MERMENTU**) to **13.0** (**RU1404157**), respectively.
- Grain production efficiency ranged from **816.6** (**RU1402115**) to **375.7** g grain kg^{-1} total weight (**GSOR100417**), filled grain production efficiency (%) varied from **99.4** (**RU1402174**) to **72.0** (**NIPONBARE**), and number of panicles per plant from **75.0** (**N-22**) to **15** (**RU1104122**). **(Fig. 4B).**

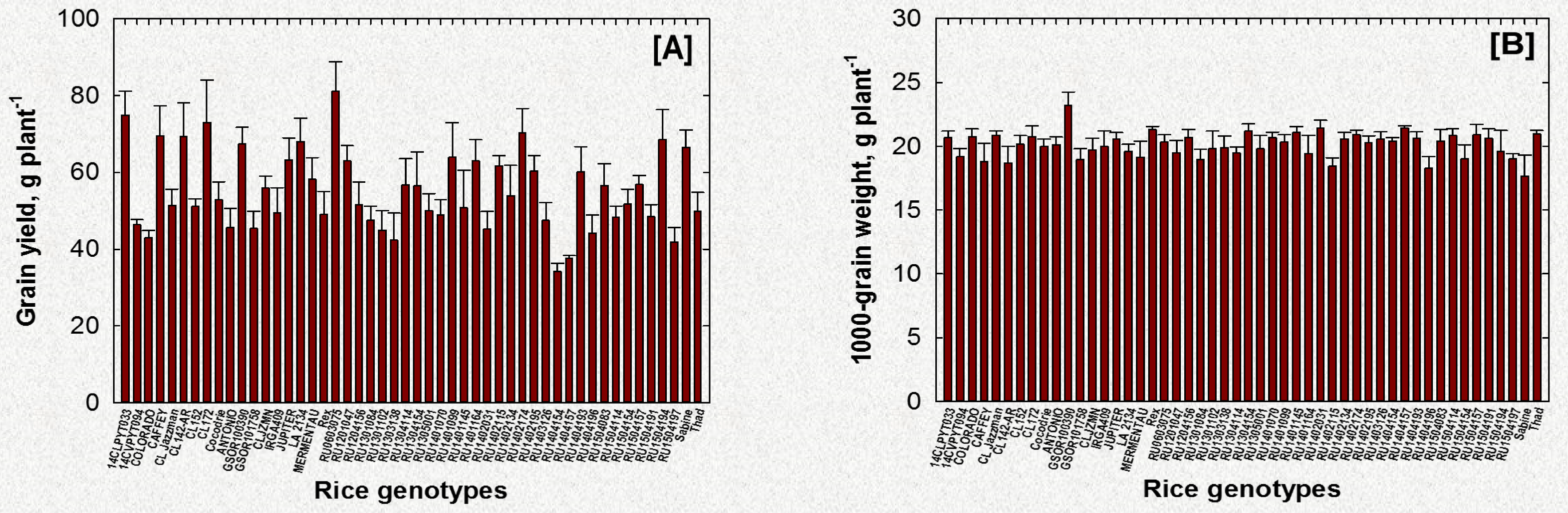

Fig. 5. Grain yield per plant (A) and 1000-grain weight (B) of rice genotypes.

- Grain yield per plant and 1000-grain weight exhibited considerable variability among the **100** rice genotypes. Grain yield (**Fig. 5A**) varied from **80.1** (**RU0603075**) to **34.9** g $plant^{-1}$ (**NIPONBARE**) while 1000-grain weight (**Fig. 5B**) ranged from **23.2** (**GSOR100390**) to **17.7** g $plant^{-1}$ (**Sabine**).

D. Cumulative response vigor index:

- The cumulative vigor response indices and standard deviation were used to classify the 100 genotypes into different groups such as;
- **Low** (less than min + 1SD).
- **Moderately low** [greater than (min CVRI + 1SD) but less than (min CVRI + 2SD).
- **Moderately high** [greater than (min CVRI + 2SD) but less than (min CVRI + 3SD).
- **High** [Greater than (min CVRI + 3SD).

Low (13.751-14.207)	Moderate low (14.208-14.585)	Moderate high (14.586-14.963)	High (14.964-15.341)
RU1104122 (13.755)	RU1401067 (14.216)	RU1402174 (14.595)	RU1201047 (14.965)
CAFFEY (13.757)	RU1401161 (14.224)	RU1303181 (14.600)	RU1401090 (14.992)
RU1504196 (13.855)	El Paso 144 (14.226)	RoyJ (14.635)	INIA Tacuari (15.070)
.	.	14CLPYT033 (14.666)	IRGA409 (15.081)
.	.	.	Rex (15.114)
.	.	.	N-22 (15.188)
Presidio (14.137)	RU1401102 (14.486)	.	RU1504083 (15.314)
RU1504194 (14.140)	RU1304154 (14.494)	RU1304156 (14.897)	
RU1504193 (14.154)	CL Jazzman (14.519)	RU1401070 (14.901)	7
RU1504157 (14.155)	RU1403126 (14.522)	RU1301093 (14.903)	
CHENIERE (14.161)	ANTONIO (14.537)	RU1201047(14.935)	
RU1402189 (14.196)	COLORADO (14.557)	14CLPYT108 (14.918)	
	RU1404196 (14.564)		
32	33	28	

- The genotype, **RU1504083** was identified as the highest vigor with **15.314**, while **RU1104122** was identified as the least vigor index with **13.755**.
- Based on the cumulative vigor indices values **33** and **28** genotypes were classified as **moderately low** and **moderately high** vigor index groups, respectively, while **7** and **32** rice genotypes were classified as having **high** and **low** vigor indices, respectively.

The high correlation (r^2 = 0.88) between the total vigor response index (TVRI) and physiological vigor response index indicates that physiological traits are important in assessing genotypic variability among the rice lines for vigor.

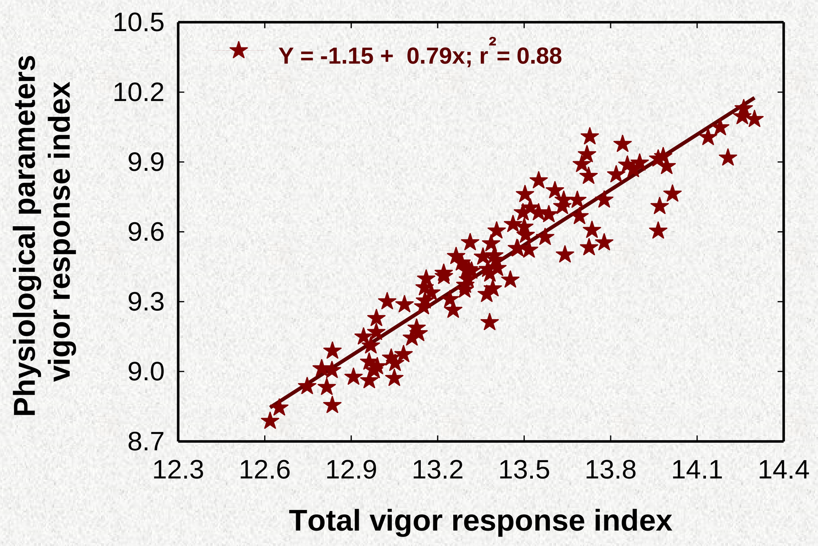

Fig.6. The relation between the TVRI and physiological vigor response index.

Summary and Conclusions

- The **100** rice genotypes exhibited substantial variability in their responses for all the measured traits.
- **Line RU1504083**, with the highest vigor index, is the best rice line among **100** genotypes tested at reproductive and yield relative to other lines.
- **35%** of rice genotypes were classified as **high** and **moderately high** vigor index category, while **65%** genotypes were classified **low** and **moderately low** vigor index values.
- The high and significant correlation between the total vigor response index (TVRI) and physiological vigor response index ($r^2 = 0.88$) indicated that physiology parameters could be used in screening rice lines for vigor.
- These physiological and yield related traits could be useful as selection criteria for the improvement of grain yield of rice through breeding.

References

- Pandey, P. and. Anurag P.R. 2010. Estimation of genetic parameters in indigenous rice. AAB Bioflux. 2: 79-84.
- Singh, R.K., Gautam, P.L., Saxena, S. and Singh S. 2000. Scented rice germplasm conservation, evaluation and utilization. In: Aromatic Rice, Singh, R.K., U.S. Singh and G.S. Khush (Eds.). Oxford and IBH Publishing, New Delhi, pp 107-133.

Acknowledgement

- We thank the Mississippi Rice Promotion Board and MSU-MAFES for funding and the Environmental Plant Physiology Lab staff and colleagues for help.