Relationship between seed traits and seedling parameters in rice wild species

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Abstract

Rice is everyday meal of about half of the world's population. Demand for rice is continuously growing because of increasing population. With the impact of climate change, rice crop needs to be diversified with direct seeded cultivation. Under direct seeded condition seeds of high seedling vigour and good crop stand are preferred. Therefore, the following study was undertaken to analyse the seed traits and its effect on seedling vigour and grain yield in rice wild species. It was found that large seeds have larger embryos and better seedling vigour. Significant positive correlation found between embryo area grain yield, germination percentage nodal root number and seedling height. The cultivated *Oryza sativa* genotypes had largest embryo area and seed area followed by *Oryza meridionalis*. *Oryza glaberrima* had the smallest embryo area. The seed size was observed to be evolved under selection pressure. Bigger seed sizes in the *Oryza sativa* cultivars indicate gradual selection for increased seed size and fitness under agronomic condition.

Introduction

Rice is one of the oldest crop being domesticated and has came long way from the wild Asian grass to a refined crop that became the staple diet of the half of the world's population (Callaway, 2014). It has 25 wild species out of which 23 are wild and only two are cultivated viz, *Oryza sativa* and *Oryza. glaberrima* placed in 5 different complexes based on their genomic constitution(Vijay and Roy, 2013). Modern day rice is believed to be evolved from the *Oryza rufipogan* perennial tufted wild rice. Molecular studies evidences domestication twice from the different *Oryza rufipogan* populations giving rise to two geographical races *Oryza sativa indica* and *Oryza sativa japonica* (Londo et al., 2006). The genus *Oryza* is widely distributed over the tropic and sub-tropic parts of the world.

Crop wild relatives are the vast sources of genetic diversity and helps in creating plethora of allelic variations. They are the valuable component of pre-breeding programmes and always been unquestionably acting as scavenger (Dempewolf et al. 2017). Seeds structure always have played important role in dispersion and evolution of the crop species. In increasingly anthropogenic settings, plants that have developed features to facilitate human-mediated seed distribution exhibit higher fitness (Spengler, 2020). Seed are of immense biological and economical importance. They are crucial input for crop production. Studies on kernel size of ancient cultivated rice have shown selection for long and plump kernels accompanied with change in harvesting tools (Kim et al. 2013).

Three aspects of seed quality including seed germination, vigour and seed size has greater influence on crop yield (Ellis 1992). Seed vigour is fundamental physiological seed characteristic associated with field stand establishment and crop productivity (Marcos-Filho 2015). Seedling vigour was found positively correlated with the seed size. In many studies it has found that larger seeds have tendency to produce more vigorous seedlings (Ambika et al. 2014). A strong correlation between germination potential and seedling vigour is reported in wheat (Kaur and Srivastava 1982) rice (Fauzi et al. 2021), sunflower (Gadewar et al. 2015). In rice the differences among the genotypes has proven genetic control in the manifestation of seed and seedling vigour (Akram et al. 2001). Apart from seed size other traits such as embryo size has been also reported to influence seed vigour (Ashby 1930; López-Castañeda et al. 1996; Richards and Luckas 2002).

Demand for rice is continuously growing because of increasing population. With the impact of climate change, rice crop needs to be diversified with direct seeded cultivation. Under direct seeded condition seeds of high seedling vigour and good crop stand are preferred. Keeping in mind, wild species always have been a good source of variation under marginal environments (Renzi et al. 2022). Seed traits in wild species are not studied thoroughly. Therefore the present investigation was made to study the effect of seed traits on seedling vigour. Also morphological characterization for seed size and its effect on the seedling vigour and yield in wild species will help in conservation of these species and their further exploitation in future. Here we estimated seedling vigour in terms of coleoptile length, first leaf length, seedling height, root length, nodal root number and germination percentage. We also evaluated the relationship between seed size, seedling vigour and seed yield.

Material And Methods

The field experiment was carried out in Randomised Block Design with 3 replications at Breeding farm, Department of Genetics and Plant Breeding (32.10º N, 76.54º E) in 2020. A total of 143 accessions of wild species were included in this study. Among the 143, only 25 accessions were able to flower under the Palampur weather condition. The 25 accessions of wild species along with checks are listed in supplementary Table I, of which 18 consisted of *Oryza nivara*, 3 of *Oryza glaberrima*, 2 of *Oryza barthii* and 2 of *Oryza meridionalis*. Out of 28 genotypes three of them were IR28, Hawa om, and HPR 1068(local check). The country of origin is provided in the Fig. 1. All of them belonged to the A genome (2n = 24). The nursery was grown in the month of June and transplanting was done in the month of July 2020, with 15 x 20 spacing. A total of five hills of each genotype was harvested and threshed after sun-drying for 2–3 days. Similarly data on various quantitative characters was recorded for the five hills.

Phenotyping Of Seed Characters

Seeds were dehulled with hands without breakage of the grains. Normally with the dehusker machine the embryos often get broken from the grain. Dehulled grains were then moistened in distilled water for overnight. Moistened seeds then treated with 0.5% Tetrazolium salt solution for 8 hours. Tetrazolium salt stains the viable areas *viz.*, embryo areas with dark red colour. The nonviable areas of seed (endosperm and aleurone layer) remain colourless. Staining procedure makes easier and accurate measurement of embryo area. Measurement of embryo length, width, area and seed area (endosperm area plus embryo area) was done under the stereomicroscope with the help of ocular micrometer (Olympus-LG-PS2, Japan) at 10x magnification. The embryo ratio was calculated as the embryo area divided by the seed area according to (Sakata et al. 2016). Also the seed size of five dehulled grains from each replication was recorded with Digital vernier calliper.

Germination Experiment

Germination test was conducted by top of paper method using germination paper. Thirty seeds of each genotype were replicated three times. Seeds were placed on moistened filter paper in petriplates and placed in incubator with T 27 ± 2 and RH 92%. Data on coleoptile length, first leaf length, shoot length, root length; nodal root number and germination percentage was recorded at 10 days after incubation (DAI).

Statistical analysis

Analysis of variance was performed in Microsoft excel 2010. Tukeys HSD test was performed in IBM SPSS statistics software with significance level $P < 0.05$. Pearson correlation was calculated in software R studio version 4.2

Table I. Details of the 28 wild species and checks used in this experiment

Sr. No.	Designation	Species Name	Genome	Country of Origin
1	W-2	*O. glaberrima (IR101800)*	AA	Nigeria
2	W-8	*O. glaberrima (IR102336)*	AA	Liberia
3	W-15	*O. glaberrima (IR102520)*	AA	Liberia
4	W-53	*O. barthii (IR104103)*	AA	Chad
5	W-72	*O. barthii (IR106295)*	AA	Chad
6	W-78	*O. nivara (IR80693)*	AA	India
7	W-79	*O. nivara (IR80722)*	AA	Mynamar
8	W-80	*O. nivara (IR80722)*	AA	Mynamar
9	W-84	*O. nivara (IR81859)*	AA	India
10	W-92	*O. nivara (IR100593)*	AA	Taiwan
11	W-116	*O. nivara (CR100021)*	AA	India
12	W-118	*O. nivara (CR100042A)*	AA	India
13	W-126	*O. nivara (CR100104A)*	AA	India
14	W-130	*O. nivara (CR 100106A)*	AA	India
15	W-141	*O. nivara (CR 100113A)*	AA	India
16	W-144	*O. nivara (CR100113A)*	AA	India
17	W-150	*O. nivara (CR 100122)*	AA	India
18	W-157	*O. nivara (CR 100127)*	AA	India
19	W-203	*O. nivara (CR 100316)*	AA	India
20	W-226	*O. nivara (CR100370)*	AA	India
21	W-234	*O. nivara (CR100427)*	AA	India
22	W-239	*O. nivara (CR 100463)*	AA	India
23	W-347	*O. nivara (IR92708)*	AA	Cambodia
24	W-1001	*O. meridionalis (IR105306)*	AA	Australia
25	W-1002	*O. meridionalis (IR105598)*	AA	Australia
26	IR28	*O. sativa var indica*	AA	India
27	Hawa om	*O. sativa var indica*	AA	India
28	HPR 1068	*O. sativa var indica*	AA	India

Result And Discussion

The present investigation was carried out to find the effect of seed sizes/embryo size on seedling vigour traits as well as agronomic traits. Among 25 wild species, most of them categorised under medium seed length. The average seed size (seed length) and seed shape (length to width ratio) of 25 wild species had shorter (6.53 ± 0.059 mm) and smaller (2.70 ± 0.038) than the local checks (7.33 ± 0.042 mm) and (2.80 ± 0.047) respectively (Table II). Most of the wild species had medium seed length. The seed traits and variation present between the wild species seeds can be grouped in to different groups using the standard evaluation system criteria outlined by IRRI (International Rice Research Institute). According to the criteria 28 wild species and checks were grouped into short (< 5.50 mm), medium (5.51–6.60 mm) and long (6.61–7.50 mm) seed sizes and two groups of seed shape i.e., slender (LWR > 3.0) and medium (LWR 2.1-3) (Table III).

Table II. Means of seed length (mm) and seed shape (length to width ratio) of 28 rice genotypes

Sr. No.	Genotype	Seed length (mm)				Length to width ratio (mm)			
1	W-2	6.76	±	0.030	def	2.24	±	0.003	mno
2	W-8	6.36	±	0.047	ghijkl	3.13	±	0.007	ab
3	W-15	5.74	±	0.071	no	2.40	±	0.022	lmn
4	W-53	6.55	±	0.064	efghij	3.10	±	0.110	abc
5	W-72	6.21	±	0.030	ijklm	2.79	±	0.032	efgh
6	W-78	6.20	±	0.040	jklm	2.70	±	0.038	fghijk
7	W-79	5.59	±	0.042	o	2.48	±	0.019	jklm
8	W-80	7.17	±	0.058	abc	3.38	±	0.015	a
9	W-84	6.48	±	0.079	fghijk	2.83	±	0.032	cdefg
10	W-92	6.88	±	0.079	cde	3.08	±	0.010	bcd
11	W-116	6.55	±	0.097	efghij	2.80	±	0.045	defgh
12	W-118	6.70	±	0.108	efg	3.06	±	0.062	bcde
13	W-126	6.00	±	0.040	lmn	2.58	±	0.022	ghijkl
14	W-130	6.45	±	0.079	fghijk	2.37	±	0.056	lmn
15	W-141	5.91	±	0.184	mno	2.49	±	0.015	ijklm
16	W-144	6.61	±	0.030	efgh	2.36	±	0.072	lmn
17	W-150	7.14	±	0.043	bcd	3.08	±	0.090	bcd
18	W-157	7.26	±	0.006	abc	2.97	±	0.035	bcdef
19	W-203	6.60	±	0.000	efghi	2.42	±	0.007	klm
20	W-226	5.60	±	0.108	o	2.45	±	0.026	jklm
21	W-234	5.91	±	0.050	mno	2.52	±	0.029	hijklm
22	W-239	6.17	±	0.038	jklm	2.77	±	0.104	fghi
23	W-347	7.55	±	0.097	a	3.13	±	0.054	ab
24	W-1001	6.13	±	0.021	klmn	2.06	±	0.021	o
25	W-1002	6.22	±	0.079	hijklm	2.13	±	0.009	no
26	IR28	7.51	±	0.009	ab	3.20	±	0.115	ab

Note: the numbers that followed the same letters in the same column are not significantly different at a 5% level Tukey/HSD test

Sr. No.	Genotype	Seed length (mm)				Length to width ratio (mm)			
27	Hawa om	7.20	±	0.088	abc	2.48	±	0.015	jklm
28	HPR 1068	7.28	±	0.029	ab	2.73	±	0.012	fghij
	Average	6.53	±	0.059		2.70	±	0.038	

Note: the numbers that followed the same letters in the same column are not significantly different at a 5% level Tukey/HSD test

Out of 28 genotypes five genotypes were grouped into short, 19 medium and four genotypes placed into long seed length group. While, only four genotypes had slender seed shape placing remaining 24 genotypes in medium seed shape. For seed length most of the wild species were placed in to short and medium group.

Table III. Group of size and shape rice seeds from 28 genotypes

Seed shape (length to width ratio)		Brown rice length (mm)		
		Short (< 5.50 mm)	Medium (5.51–6.60 mm)	Long (6.61–7.50 mm)
Slender LWR(> 3.0)	1		W-53	W-80
	2		W-92	
	3		W-347	
Medium (2.1-3)	4	W-15	W-2	W-157
	5	W-72	W-8	IR-28
	6	W-141	W-78	Hawaom
	7	W-226	W-79	
	8	W-234	W-84	
	9		W-116	
	10		W-118	
	11		W-126	
	12		W-130	
	13		W-144	
	14		W-150	
	15		W-203	
	16		W-239	
	17		W-1001	
	18		W-1002	
	19		HPR-1068	

Genotypes are grouped according to Standard Evaluation System of Rice (SES) by IRRI 2002

Table IV. Means of embryo length (EL), embryo breadth (EB), embryo area (EA), seed area (SA) and ratio of embryo area to seed area on percentage basis

Seed group	EL (mm)	EB (mm)	EA (mm^2)	SA (mm^2)	EA/SA (%)
Short	1.17 ± 0.00^{c}	0.72 ± 0.01	0.84 ± 0.02^{c}	13.67 ± 0.16^{c}	6.18 ± 0.02^{b}
Medium	1.36 ± 0.01^{b}	0.71 ± 0.02	0.98 ± 0.03^{b}	16.14 ± 0.08^{b}	6.02 ± 0.15^{b}
Large	1.61 ± 0.02^{a}	0.72 ± 0.00	1.17 ± 0.01^{a}	17.89 ± 0.15^{a}	6.56 ± 0.10^{a}
CV %	0.90	3.21	3.29	1.51	2.06
S	**	NS	**	**	**
Seed shape					
Slender	1.52 ± 0.02^{a}	0.67 ± 0.03	1.03 ± 0.05	15.67 ± 0.11	6.52 ± 0.32
Medium	1.33 ± 0.01^{b}	0.72 ± 0.01	0.98 ± 0.02	16.00 ± 0.03	6.06 ± 0.10
CV %	1.16	4.95	4.69	1.05	4.98
S	**	NS	NS	NS	NS

Note: The numbers that followed the same letters in the same column are not significantly different at α 5% level Tukey/HSD test.

Table V. Means of coleoptile length (CL), first leaf length (FLL), seedling length (SL), nodal root number (NRN), germination percentage (GP) and grain yield (GY)

Seed group	CL (cm)	FLL (cm)	SL (cm)	RL (cm)	NRN (Nos.)	GP (%)	GY (g)
Short	0.77 ± 0.01^{c}	2.04 ± 0.05^{c}	4.21 ± 0.05^{c}	6.21 ± 0.19^{b}	4.32 ± 0.09^{c}	86.22 ± 1.55^{b}	2.90 ± 0.04^{c}
Medium	0.93 ± 0.00 ^{b}	2.20 ± 0.01^{b}	5.61 ± 0.03^{b}	6.75 ± 0.1^{b}	4.85 ± 0.02^{b}	83.92 ± 0.62^{b}	3.74 ± 0.02^{b}
Long	1.04 ± 0.02 ^{a}	2.91 ± 0.03^{a}	7.24 ± 0.12^{a}	8.13 ± 013^{a}	6.16 ± 0.026 ^{a}	89.17 ± 0.84^{a}	4.85 ± 0.05^{a}
CV %	2.52	2.26	2.87	4.03	1.96	1.88	1.11
S	**	**	**	**	**	**	**
Seed shape							
Slender	0.99 ± 0.01^{a}	2.63 ± 0.02^{a}	6.91 ± 0.07^{a}	6.37 ± 0.14	4.23 ± 0.05^{a}	87.78 ± 1.39	1.87 ± 0.01
Medium	0.90 ± 0.00^{b}	2.22 ± 0.01^{b}	5.37 ± 0.0^{b}	6.93 ± 0.03	5.06 ± 0.03^{b}	84.63 ± 0.44	4.06 ± 0.03
CV %	0.64	1.20	1.88	2.58	1.77	1.35	0.99
S	**	**	**	NS	**	NS	**

Note: The numbers that followed the same letters in the same column are not significantly different at a 5% level Tukey/HSD test.

Analysis of variance for different seed group revealed that seed length had significant effect on embryo length, embryo area, seed area and ratio of embryo to seed area ($p < 0.05$). The difference was found between small and medium length seeds for ratio of embryo area to seed area but statistically insignificant. While seed shape had significant effect on only embryo length and all other seed traits were insignificant (Table IV). From these observations it was found that medium and longer seeds had longer embryos and larger embryo area.

Similarly analysis of variance for seedling parameters showed significant influence of seed length on coleptile length (CL), first leaf length (FLL), seedling length (SL), nodal root number (NRN), germination percentage (GP) and grain yield (GY).The larger seeds has strong influence on germination and biomass increment of a plant that contributes to yield increment. The effect of seed shape on root length (RL) and germination percentage was insignificant (Table V). The larger embryos produced longer coleoptiles than small embryos. These factor evaluated in terms of seedling vigour which is associated with the seed size ultimately has influence on the grain yield. Significant differences were found between small, medium and large size seeds for grain yield (table IV).

Grain yield showed strong positive correlation with seedling vigour traits except coleoptile length and first leaf length. This strong positive correlation of grain yield with germination percentage, nodal root number and seedling height explains the indirect contribution of vigorous seeds. Also embryo length and embryo area were correlated with germination percentage, nodal root number, seedling height. It was reported that longer and larger embryo seeds have greater vigour. Though differences in grain yield with seed size found significant, direct correlation between grain yield and seed area was negligible (Fig. 3).

Among five species *O. barthi*, *O. meridionalis*, *O. sativa* were vigorous in terms of above evaluated parameters. Species *O. glaberrima* was observed to be less vigorous than *O. nivara*. One of the factor that could be responsible for this reduced seedling vigour in these two species could be embryo length and area. When compared between species, the species with longer embryos and larger embryo area found to be more vigorous (Fig. 4&5). Seed germination was highest in *O. sativa* followed by *O. meridionalis* and lowest in *O. barthii* (Table VII). *O. glaberrima* and *O. nivara* were poor performing in terms of yield under Palampur condition. Highest embryo length, embryo area and seed area was found in *O sativa* followed by *O. meridionalis.*

Table VI. Mean values of coleoptile length (CL), first leaf length (FLL), seedling length (SL), nodal root number (NRN) of respective species.

Oryza spp.	CL (cm)	FLL (cm)	SL (cm)	RL (cm)	NRN (cm)
O. glaberrima	0.83 ± 0.02	1.79 ± 0.01	3.00 ± 0.06	4.39 ± 0.31	3.62 ± 0.04
O. barthi	1.40 ± 0.04	3.08 ± 0.04	7.09 ± 0.13	10.33 ± 0.17	5.56 ± 0.16
O. nivara	0.84 ± 0.01	2.42 ± 0.02	5.15 ± 0.03	6.08 ± 0.02	4.39 ± 0.02
O. meridionalis	0.93 ± 0.01	2.54 ± 0.04	7.44 ± 0.27	10.08 ± 0.06	5.98 ± 0.04
O. sativa	1.13 ± 0.03	2.61 ± 0.03	8.53 ± 0.04	9.46 ± 0.25	8.44 ± 0.14
CV %	4.45	2.04	3.59	4.44	3.28
S	**	**	**	**	**

Table VII. Mean values of germination percentage (GP), embryo length (EL), embryo area (EA), seed area (SA) and grain yield (GY) of respective species.

Oryza spp.	GP (%)	EL (mm)	EA (mm^2)	SA (mm^2)	GY (g/plant)
O. glaberrima	86.30 ± 0.04	1.29 ± 0.01	0.89 ± 0.02	15.69 ± 0.09	3.81 ± 0.12
O. barthi	91.11 ± 1.47	1.30 ± 0.03	0.90 ± 0.02	13.86 ± 0.16	4.27 ± 0.04
O. nivara	82.41 ± 0.84	1.31 ± 0.01	0.89 ± 0.02	15.41 ± 0.07	2.19 ± 0.02
O. meridionalis	92.22 ± 0.56	1.51 ± 0.02	1.29 ± 0.03	18.19 ± 0.17	7.96 ± 0.06
O. sativa	94.45 ± 0.64	1.66 ± 0.04	1.52 ± 0.03	19.34 ± 0.35	11.06 ± 0.12
CV %	1.74	2.23	2.11	2.16	2.46
S	**	**	**	**	**
Significance at P < 0.05					

Figure 4. graph plot of seedling traits of five species depicting coleoptiles length (CL), first leaf length(FLL), seedling length (SL), root length (RL), nodal root number (NRN), embryo length (EL), embryo area (EA) and grain yield (GY).

Discussion

Crop improvement programme in rice needs to be diversified. Growing of rice under direct seeded condition has a potential to tackle increasing global warming (Tao et al. 2016). Seedling vigour is considered as a desirable trait under such cultivation. Vigour is related to seed quality which explains rapid, uniform germination and seedling stand in any environment setting (Mahender et al. 2015). Wild species of crop plants harbours vast amount of genetic diversity and allelic variations. Seed and seedling vigour have been studied in many crops wild species like proso millet (Moore and Cavers 1985), vicia faba (Ortega et al. 1997), banana (Bohra et al. 2020). Wild species has proven to be tolerant to abiotic stresses. Previous studies on *O. glaberrima*, *O. barthii* and *O. meridionalis* has shown to be tolerant to heat and drought (Sanchez et al. 2013). In our study among wild species *O. meridionalis* was more vigorous followed by *O. barthii*. These wild species can be used in crossing programmes to develop mapping panels for seed vigour QTL's discovery.

Studies on seed characters of these wild and cultivated species showed enough variation for seed length (short, medium & long) and shape (slender & medium). *O. sativa* had largest seed area followed by *O. meridionalis*. Smallest seed area was observed for *O. barthii* (Table VII & Fig. 5). In evolutionary context it appears that seeds were naturally selected for larger size as they had higher probability of germination and plants produced from such seeds exhibited higher survival, higher fecundity than the plants form smaller seeds (Larios et al. 2014). This explains the longer length, larger size of cultivated varieties. A relationship between seed size and seedling vigour is positively correlated. Larger seeds exhibit better germination, have greater coleoptiles length, first leaf length, seedling height, root length and nodal root number. During development starch stored in endosperm is the main source of nutrition. This positive association between seed size and vigour could be probably due to large size seeds supply more sugar for growth of seedling and fuel rapid early growth (Cui et al. 2002). Germination percentage seems to be depending on the seed area viz., higher the seed area greater the seed germination (Fig. 5). Similar results were found in maize (Yusuf et al. 2014)

Positive correlation on embryo length and area with the germination percentage, nodal root number, seedling height and grain yield proves the role of embryo in controlling seedling vigour (Fig. 3). Apart from seed size previous reports supports the varietal genetic differences for embryo size among various species and eco-geographic races of rice (Pandey et al. 1994). Pandey et al. 1992, 1994 observed that longer seeds have larger embryos and good seed vigour with good germination. Results of this study found to be in agreement with them. Almost all of the seedling traits were significantly different for each seed group (Table IV & V). However, this was contradicted by (Fauzi et al. 2021) for the germination percentage. This variation in seedling traits may attributed to the embryo area (Mohsen, 2011) along with the availability of more amounts of food reserves provided to the embryonic plant (Ellis, 1992). It was suggested that embryos embedded inside of seed are the main drivers of germination vigour because it depends on the quality of the messenger RNA stored during embryo maturation on the mother plant (Rajjou et al. 2012). Our results showed that larger seeds with larger embryos had grater germination percentage which justifies the role of messenger RNA.

Conclusion

Rice wild species are very diverse considering the seed traits. Seed size in cultivated species has gradually increased from wild species. The relationship between seed size and seedling parameters seems to be positively correlated. The bigger sizes seeds have longest embryos, higher embryo area and shows good seedling vigour. These wild species can be used in breeding programmes to develop varieties with good seedling vigour. Further testing of this wild species for early vigour traits under direct seeded rice condition is needed for validation and their use in breeding programmes.

Declarations

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by [Kaldate supriya] [Uma Bharti] and [Shivani Bhatia]. The first draft of the manuscript was written by [Kaldate Supriya] and all authors commented on previous versions of the manuscript. Authors [Daisy Basandrai & Ashwini Basandrai] helped in revision of manuscript. All authors read and approved the final manuscript.

Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Supplementary Table I

Supplementary Table I is not available with this version

Figures

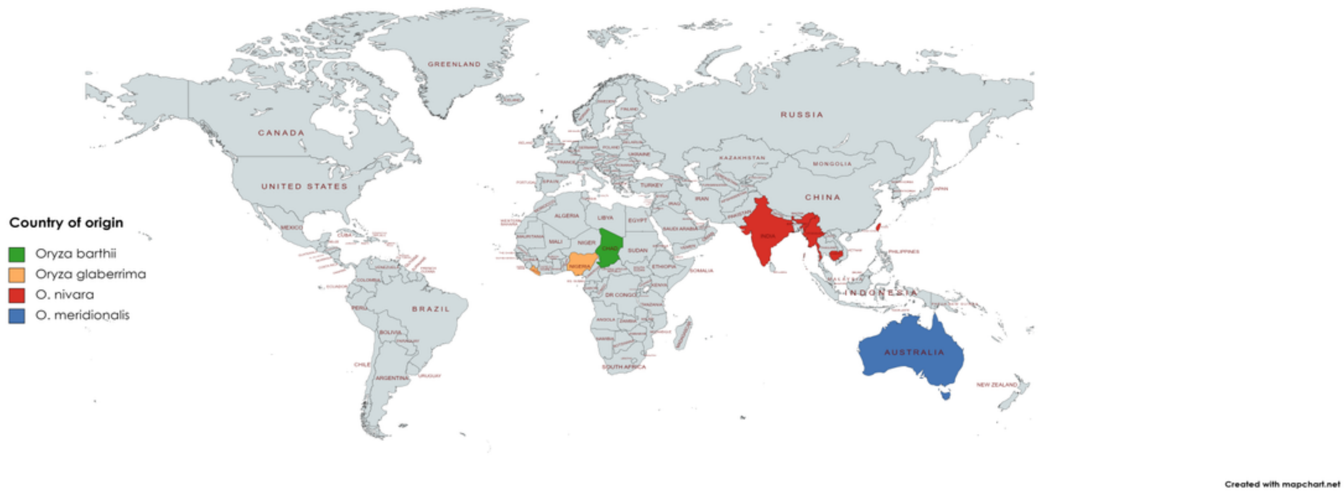

Figure 1

Map showing country of origin of wild species

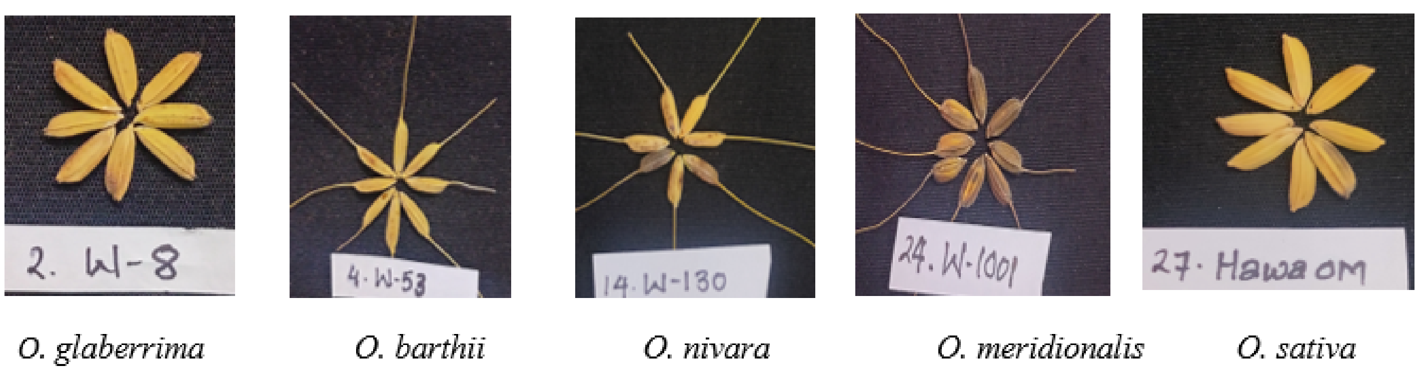

Figure 2

A representative seed images of five species of rice.

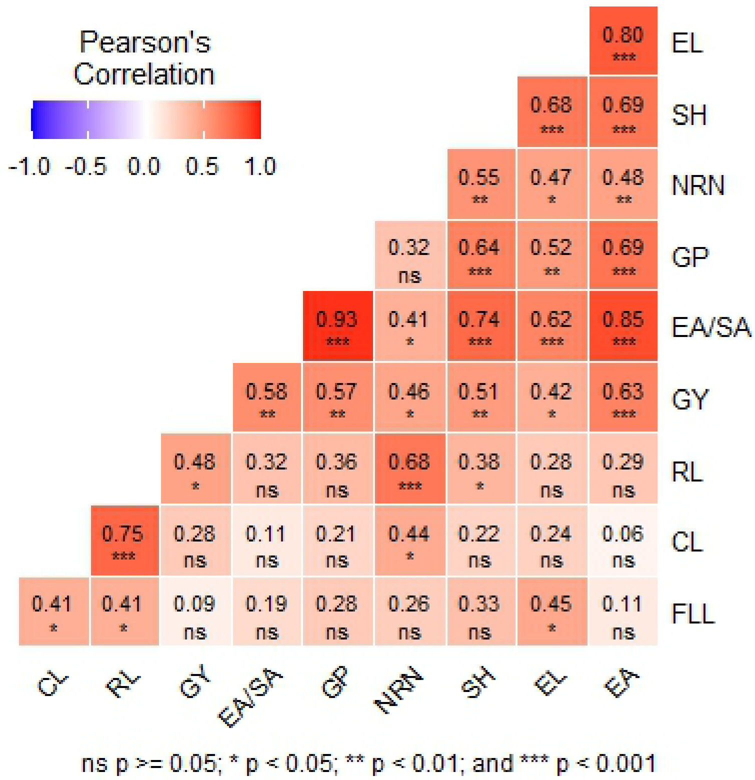

Figure 3

Correlation plot of different seedling parameters and seed traits of wild species

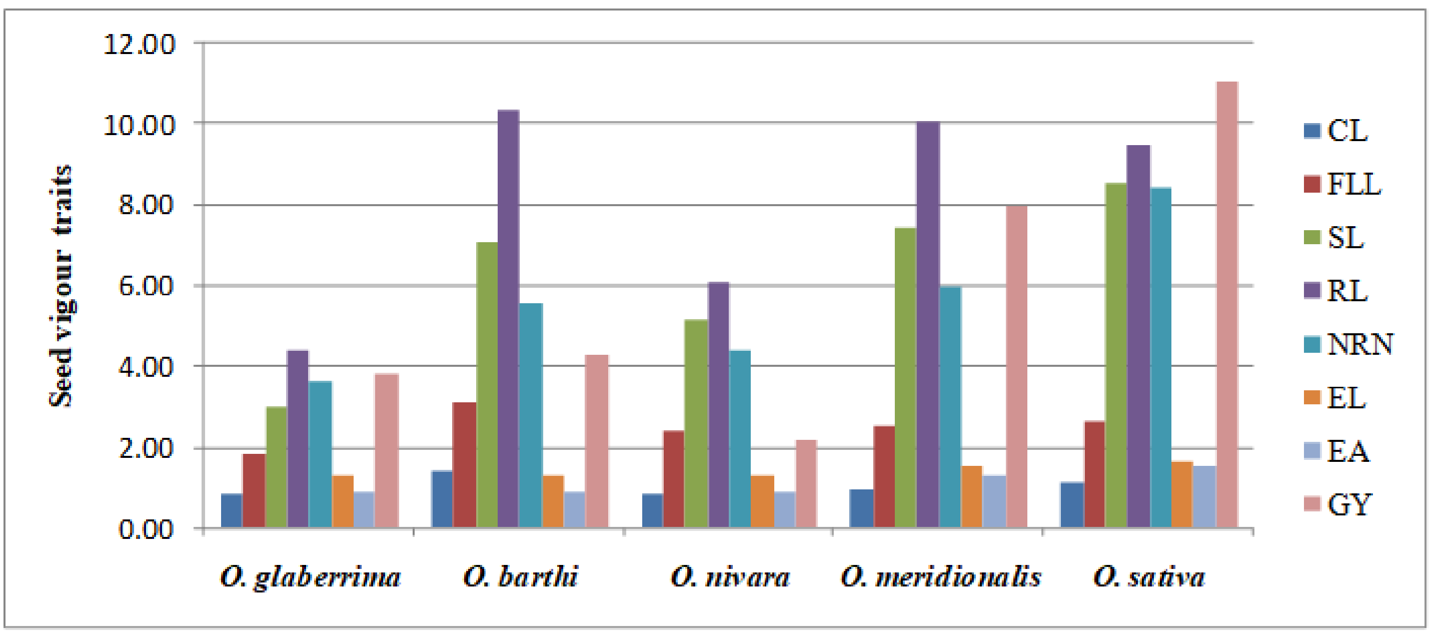

Figure 4

graph plot of seedling traits of five species depicting coleoptiles length (CL), first leaf length(FLL), seedling length (SL), root length (RL), nodal root number (NRN), embryo length (EL), embryo area (EA) and grain yield (GY).

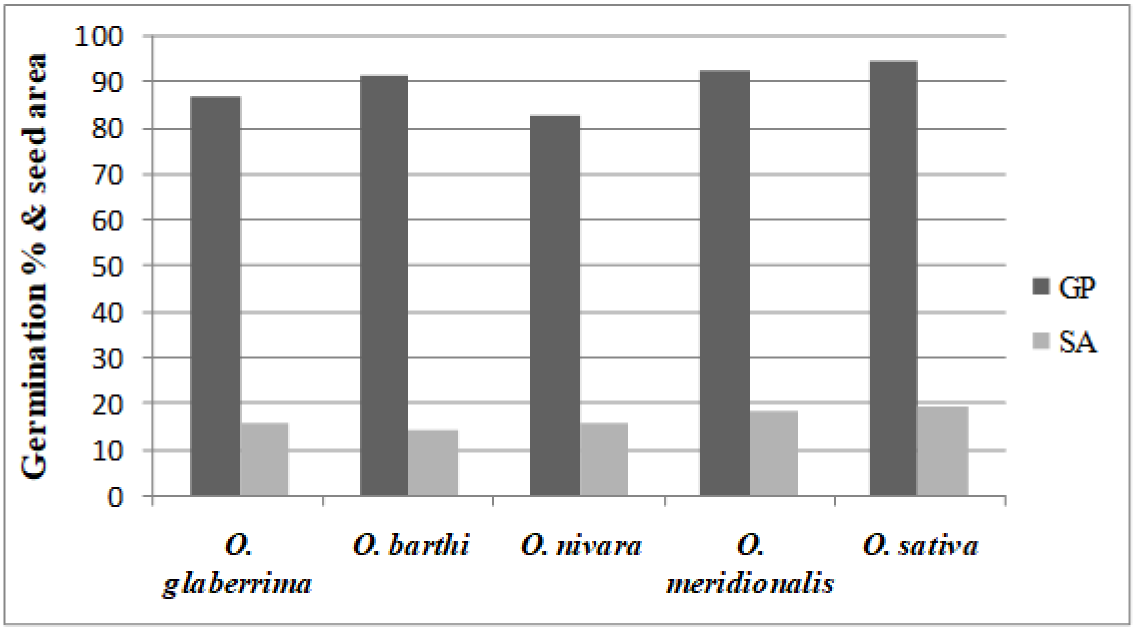

Figure 5

graph plot of germination percentage (GP) and seed area (SA) of five species of rice.