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Correlation and Path Analysis of Yield and Seedling Vigour Related Traits in Wild Introgression Lines

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Early establishment of crop plants are highly influenced by resource availability in its environment. Seedling early vigour refers to the ability of seeds to germinate quickly and uniformly, resulting in the robust crop establishment especially under stress environments. Modern cultivars which are bred for transplanting under irrigated conditions with semi-dwarf architecture lacks early seedling vigour, required under stress situations. Vigorous seedlings have additional advantage of better nutrient uptake by smothering weed plants and inhibit their growth. Improving rice plant architecture with high seedling vigour is a major breeding objective in the context of climate change effect. Backcross Introgression Lines derived from interspecific crosses were screened for seedling vigour traits and yield related traits and correlation analysis was employed to assess the trait association.

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Among all the 31 traits studied for correlation concluded that positively significant correlation was observed for panicle length, panicle weight, filled grains, total number of grains. Genotypic and phenotypic correlation revealed that the traits panicle length, panicle weight, filled grains, total number of grains, days to 50% flowering have shown significant correlation with single plant yield. Path analysis concluded that days to 50% flowering, number of tillers, fresh weight, dry weight, germination percentage and total number of grains had shown a positive direct effect with single plant yield. Days to 50% flowering, panicle weight, total numbers of grains had a positive significant and direct contribution towards yield improvement. Therefore, these traits are given more weightage while selecting the genotypes, for further utilization in crop improvement programmes.

Keywords: Rice; seedling vigour; correlation; BILs; wild species.

1. INTRODUCTION

Rice (*Oryza sativa*) is a staple food crop that supports over half of the world's population. To meet the increasing demand for rice and adapt to changing climate and environmental conditions, researchers have turned to study the genetic divergence within and beyond the cultivated species [1]. Wild rice species often possess traits that confer superior seedling vigor compared to cultivated varieties, making them ideal sources for genetic improvement. One promising approach involves the development of rice wild introgression lines, which integrate beneficial traits from wild rice species into cultivated varieties. These introgression lines are valuable for exploring novel genetic variations that can enhance important agronomic traits. Therefore, introducing the novel genetic variability contributed by wild species in the background of adapted popular cultivars help in achieving stable yield as well as better crop stand in the field conditions. The incorporation of wild rice genes into cultivated rice through introgression lines can lead to the enhancement of seedling vigor [2-5]. However, the relationship between seedling vigor and other agronomic traits is complex and studies are very limited in this direction.

Seedling vigour is a critical trait for early plant development and establishment. It influences the plant's ability to compete with weeds, withstand environmental stresses, and ultimately achieve higher yields. The incorporation of wild rice genes into cultivated rice through introgression lines can lead to the enhancement of seedling vigor [6,7]. However, the relationship between seedling vigor and other agronomic traits is complex. Understanding these relationships requires detailed statistical analyses, including correlation and path analysis. Correlation analysis helps in identifying the strength and direction of relationships between seedling vigor and various traits. Path coefficient analysis is a key tool for understanding the direct and indirect effects of yield contributing traits on grain yield. It helps identify which traits have the most significant direct impact on yield and how traits interact with each other. By revealing these relationships, path coefficient analysis guides effective selection strategies and improves breeding programs. This technique helps in understanding how different traits contribute to seedling vigor and allows researchers to identify which traits have the most significant impact.

2. MATERIALS AND METHODS

The present study was carried out using 164 backcross introgression lines derived from a cross between MTU1010 and *Oryza rufipogon* which were developed at ICAR- IIRR (Rao et al., 2022) and phenotypic and genotypic correlation between yield and seedling vigour traits were estimated. The materials were raised during Kharif-2023 at ICAR-IIRR field in Augmented block design to estimate yield related traits. The same set of lines were examined for seedling vigour and related traits in paper roll towel method in laboratory. The data was collected on characters viz germination percentage, shoot length, root length, fresh weight, dry weight, seedling vigour index-I, seedling vigour index-II at 7^{th} and 14^{th} day of germination.

2.1 Phenotyping of Yield-Related Traits

Trait evaluation was conducted with three randomly selected plants per genotype in each replication. The average results were statistically evaluated. Phenotyping was done for the following traits: plant height (cm), tiller number (TN), productive tiller number (PTN), panicle length (PL cm), panicle weight (PW g), total number of grains per panicle (TG), filled grains per panicle (FG), unfilled grains per panicle (UFG), test weight (TW g), and Single plant yield (SPY g).

2.2 Phenotyping of Seedling Vigour-Related Traits

Germination test: The germination test was conducted using the petriplate method. 100 well-dried seeds were put on a sterilized petriplate lined with Whatman filter paper, with enough moisture for seedling emergence at room temperature. The germination percentage was obtained by counting the number of seeds germinated on the third and seventh day.

Seedling growth test: To determine seedling vigour, a paper roll test was used. Ten seeds were evenly distributed on a brown germination sheet with water-absorbing capacity. The sheet was carefully rolled with two distal edges tied using rubber bands and placed vertically in a tray filled with water. The tray was then incubated at room temperature. On the 7th and 14th day of incubation, 10 seedlings from each genotype were measured for shoot and root length. Seedlings were oven-dried and their dry matter weight was assessed. Seedling vigour is assessed in a controlled lab environment using several factors.

Seedling vigour index: At random, five seedlings were chosen from each replication, and on the seventh and fourteenth day following planting, observations concerning the duration of seedling were made. The seedlings were oven dried and measured for dry shoot and root weight. The seedling vigour indicators were determined using the Kharb et al. [8] method.

Seedling vigour index-I was estimated using germination percentage and seedling length on the 7th and 14th day.

Seedling vigour index- I:

$$\frac{\text{Seedling germination percent x Seedling length (cm)}}{100}$$

Seedling vigour index- II was estimated using germination percentage and seedling dry weight on the 7th and 14th day.

Seedling vigour index- II:

$$\frac{\text{Seedling germination percent x Seedling dry weight (g)}}{100}$$

3. RESULTS AND DISCUSSION

3.1 Correlation of Mean Phenotypic Data

A positively significant correlation was observed for panicle length, panicle weight, filled grains, total grains with single plant yield. Positively non- significant correlation was observed between the traits dry weight on the 7th day, unfilled grains, grain width, grain area, seedling vigour index-I on the 14th day, root length on the 14th day, spikelet fertility and total length on the 14th day.

Negative correlation as observed for germination on the 7th day, seedling vigour index-I on the 7th day, seedling vigour index-II on the 7th day, germination on the 14th day, shoot length on the 14th day, fresh weight on the 14th day, dry weight on the 14th day, seedling vigour index-II on the 14th day, thousand grain weight, grain length, shoot length on the 7th day, root length on the 7th day, total length on the 7th day, fresh weight on the 7th day with single plant yield (Table 1).

3.2 Genotypic Correlation using Replicated Data

A positively significant genotypic correlation was observed for characters panicle length, panicle weight, grain area, total number of grains, filled grains, days to 50% flowering with single plant yield and similar results were reported by Deepthi et al. [9], Vanisree et al. [10] and Rachana et al. [11]. The traits, germination on the7th day, number of productive tillers, shoot length on the7th day, root length on the 7th day, total length on the 7th day, seedling vigour index - I on the 7th day, dry weight 7th on the day, root length on the14th day, total length on the14th day, seedling vigour index - I on the 14th day, fresh weight on the14th day, seedling vigour index - II on the14th day, plant height, number of tillers, unfilled grains, spikelet fertility, 1000 grain weight and grain width showed a positive correlation with single plant yield this results are in accordance with the reports of Lakshmi et al. [12], Madakemohekar et al. [13]. Fresh weight on the 7th day, germination on the14th day, shoot length on the14th day, seedling vigour index - II at 7th day, dry weight on the14th day and grain length exhibited a negatively non-significant genotypic correlation with single plant yield and are presented in (Table 2, Fig. 1a).

Table 1. Correlation of mean yield and seedling vigour related traits of MTU1010/ *Oryza rufipogon* BILs during Kharif 2023

	FW14	DW14	SVI 14	SVII 14	PL	PW	FG	UFG	TG	SF	TGW	GL	GW	GA
DFF	0.0642	0.1294	0.0131	0.0459	0.011	0.1499	0.2506	0.3775*	0.3455*	-0.2978	-0.3335*	-0.243	-0.0419	-0.1795
PH	0.0273	-0.0463	0.1843	0.0837	0.4736**	0.1637	0.2023	0.111	0.2069	-0.0621	-0.1321	-0.0107	-0.1115	-0.0783
NT	-0.1577	-0.1644	0.0858	-0.1259	0.2008	-0.0467	-0.033	0.0679	-0.0017	-0.0607	-0.1175	0.0066	-0.1622	-0.147
NPT	-0.1445	-0.1602	0.0908	-0.1094	0.2111	-0.0314	-0.0158	0.0731	0.0143	-0.0609	-0.128	0.0021	-0.1518	-0.1428
SPY	-0.0191	-0.0932	0.0014	-0.0147	0.3474*	0.3479*	0.3471*	0.0993	0.321*	0.0231	-0.0271	-0.032	0.0719	0.0441
G7	0.1228	-0.0567	0.5904**	0.2367	0.1386	0.1672	0.1309	0.0989	0.1439	-0.0557	0.0178	0.0214	0.053	0.0302
SL7	0.233	0.0521	0.4857**	0.2976	0.0962	0.0724	0.0804	0.0629	0.0892	-0.0442	-0.0626	-0.0623	-0.056	-0.0721
RL7	0.1954	0.0625	0.5678**	0.2918	0.0769	0.1566	0.1445	0.1042	0.157	-0.0771	-0.0656	-0.1569	0.0972	-0.0185
TL7	0.2138	0.0614	0.5613**	0.3036*	0.0856	0.1354	0.1291	0.0946	0.1409	-0.0693	-0.0668	-0.1323	0.0522	-0.036
FW7	0.2062	0.1033	0.1475	0.1937	-0.0167	-0.014	-0.0042	0.018	0.0033	-0.0401	-0.0092	-0.1388	0.0223	-0.0728
DW7	0.1259	-0.0049	0.1742	0.121	0.0273	0.0481	0.059	0.1855	0.1173	-0.1263	-0.0774	0.0245	-0.1416	-0.1184
SVI 7	0.2393	0.0502	0.5901**	0.329*	0.0984	0.1466	0.1355	0.0849	0.1425	-0.0491	-0.0329	-0.1006	0.054	-0.0167
SVII 7	0.2202	0.0171	0.1929	0.1898	0.0203	0.0238	0.0431	0.0434	0.0514	-0.0372	-0.0173	-0.1417	0.052	-0.0819
G14	0.0693	-0.2402	0.8148**	0.2223	0.1176	0.117	0.0533	0.0733	0.0709	-0.0888	0.0909	0.0192	0.0834	0.0792
SL14	0.3637*	0.0178	0.8701**	0.4678**	0.115	0.1304	0.1077	0.1019	0.1261	-0.0851	0.0035	-0.0718	0.0967	0.0304
RL14	0.2444	0.0406	0.897	0.3914*	0.0943	0.1691	0.1098	0.0011	0.0903	-0.0153	0.037	-0.0917	0.2149	0.1225
TL14	0.3267*	0.0332	0.9701**	0.4667**	0.1137	0.1664	0.1194	0.051	0.1167	-0.0512	0.0239	-0.0906	0.1772	0.0888
FW14	1	0.3894*	0.2721	0.877**	-0.1216	0.0599	0.0781	-0.0044	0.0623	0.0592	-0.0177	-0.1654	0.143	-0.0078
DW14		1	-0.0608	0.5498**	-0.0798	0.0096	-0.0377	-0.0003	-0.031	0.0094	-0.0334	0.0011	0.0024	0.0594
SVI 14			1	0.4227*	0.1047	0.1584	0.1006	0.055	0.1028	-0.0595	0.0587	-0.0496	0.1563	0.1005
SVII 14				1	-0.0575	0.1253	0.1111	0.0295	0.1019	0.031	0.0068	-0.0917	0.1021	0.0307
PL					1	0.5437**	0.4908**	0.2013	0.4766**	-0.0463	0.0494	0.056	-0.0583	0.0254
PW						1	0.9117**	0.2248	0.8299**	0.0707	-0.0746	-0.1074	0.063	0.0048
FG							1	0.3148*	0.9356**	0.0548	-0.3374	-0.203	-0.0699	-0.1614
UFG								1	0.6295**	-0.849	-0.3633	-0.0645	-0.1367	-0.1325
TG									1	-0.2708	-0.4113	-0.1902	-0.108	-0.1814
SF										1	0.2106	0.0115	0.0669	0.0349
TGW											1	0.3392*	0.3639*	0.5106**
GL												1	-0.0875	0.578**
GW													1	0.6536**
GA														1

	G7	SL7	RL7	TL7	SVI.I7	FW7	DW7	SVI.II7	G14	SL14	RL14	TL14	SVI.I14	FW14	DW14	SVI.II14
G7	1	0.5151**	0.6799**	0.649**	0.7171**	0.0741	0.1241	0.1928	0.8167**	0.5515**	0.6711**	0.6686**	0.7162**	0.1002	-0.0223	0.2792
SL7		1	0.8613**	0.9312**	0.9249**	0.6047**	0.5542**	0.6881**	0.4476*	0.598**	0.3618*	0.51**	0.5222**	0.2522	0.0754	0.3435*
RL7			1	0.9873**	0.9676**	0.5263**	0.3621*	0.5968**	0.5829**	0.5829**	0.5696**	0.6247**	0.6344**	0.2075	0.091	0.3351*
TL7				1	0.9839**	0.5671**	0.4333*	0.6437**	0.5584**	0.6054**	0.5222**	0.6079**	0.6187**	0.2276	0.0887	0.3478*
SVI.I7					1	0.533**	0.4421*	0.6236**	0.6084**	0.6335**	0.555**	0.6411**	0.6622**	0.2534	0.089	0.3854*
FW7						1	0.4992**	0.9739**	-0.0063	0.2496	0.0762	0.1688	0.1345	0.2866	0.0454	0.1958
DW7							1	0.6671**	0.1772	0.3457*	0.0614	0.2067	0.2227	0.2645	-0.064	0.2215
SVI.II7								1	0.1167	0.3453*	0.1423	0.2551	0.2347	0.3173*	0.0299	0.2499
G14									1	0.6017**	0.7637**	0.7481**	0.8344**	0.1632	-0.1688	0.336*
SL14										1	0.6972**	0.9067**	0.887**	0.4835**	0.0753	0.5581**
RL14											1	0.9344**	0.9257**	0.3397*	0.1251	0.5075**
TL14												1	0.985**	0.4399*	0.1111	0.5757**
SVI.I14													1	0.3846*	0.0214	0.533**
FW14														1	0.4304*	0.9307**
DW14															1	0.6072**
SVI.II14																1

***Significance at o.5%, *Significance at 1%, Note:G7=Germination on the 7th day, SL7= Shoot length on 7th day, RL7= Root length 7th day,TL7=Total length on the 7th day, FW7=Fresh weight on the 7th day,DW7= Dry weight on 7th day, , G14=Germination on the 14th day, SL14= Shoot length on 14th day, RL14= Root length on 14th day, TL14=Total length on the 14th day, DW14= Dry weight on 14th day, FW14=Fresh weight on the 14th day , SVI-1-7= Seedling vigour index 1 on 7th day, SVI-1-14= Seedling vigour index 1 on 14th day, , SVI-2-7= Seedling vigour index 2 on 7th day, SVI-2-14= Seedling vigour index 2 on 14th day, DFF= Days to 50% flowering, PH=Plant height,NT= Number of tillers, NPT= Number of productive tillers, PL= Panicle length, PW= Panicle weight, TG= Total number of grains per panicle, FG= Total number of filled grains per panicle, UFG= Total number of unfilled grains per panicle, SF=Spikelet fertility, SPY= Single plant yield, TGW= Thousand grain weight, GL=Grain length, GW=Grain width, GA=Grain area.*

Table 2. Genotypic Correlation of yield and seedling vigour-related traits of MTU1010/ *Oryza rufipogon* BILs during Kharif 2023

	PH	NT	NPT	PL	PW	FG	UFG	TG	SF	TGW	GL	GW	GA	SPY
G7	0.1559	0.2208	0.2358	0.1752	0.1954	0.1317	0.1318	0.1504	-0.0938	0.1051	0.0543	0.0363	-0.8422	0.0054
SL7	0.2913	0.1517	0.1544	0.1209	0.0713	0.074	0.1034	0.0978	-0.0982	0.999**	-0.0889	-0.097	0.0364	0.0126
RL7	0.2	0.1691	0.1824	0.1085	0.1812	0.161	0.1404	0.1763	-0.1231	0.5018**	-0.2126	0.1225	0.1069	0.0243
TL7	0.2347	0.1688	0.1792	0.1157	0.1523	0.1402	0.133	0.1572	-0.119	0.3232*	-0.1806	0.0575	0.0889	0.0212
SVI.I7	0.2698	0.1721	0.1827	0.1308	0.1675	0.1457	0.1184	0.1565	-0.092	0.3765*	-0.1408	0.0573	0.0069	0.0008
FW7	0.1466	-0.043	-0.0477	0.0168	-0.0254	-0.0168	0.0129	-0.0082	-0.0434	0.2098	-0.2395	0.1252	-0.5893**	-0.0975
DW7	0.2605	-0.078	-0.0909	-0.0172	0.0357	0.143	0.1682	0.1719	-0.0801	0.4957**	-0.1047	-0.1327	-0.5241**	0.1027
SVI.II7	0.191	-0.0312	-0.0346	0.0242	0.0018	0.0219	0.0618	0.0393	-0.0704	0.1546	-0.218	0.0819	-0.5788**	-0.0698
G14	0.1487	0.2116	0.221	0.1341	0.1321	0.0443	0.0839	0.0642	-0.129	0.2949	0.0202	0.1004	-0.3431*	-0.014
SL14	0.3022*	0.0797	0.0911	0.1435	0.117	0.0986	0.1279	0.1225	-0.1346	0.5938**	-0.128	0.1222	0.3096*	-0.0013
RL14	0.0742	0.0371	0.0468	0.1307	0.2114	0.1389	-0.0328	0.0977	0.0051	0.5644**	-0.1645	0.2921	-0.0104	0.028
TL14	0.1936	0.0617	0.073	0.1476	0.1809	0.1306	0.0442	0.118	-0.0637	0.3339*	-0.1624	0.2317	0.1474	0.0158
SVI.I14	0.2158	0.0942	0.1046	0.1273	0.1668	0.0994	0.0567	0.098	-0.086	0.3592*	-0.0939	0.2	-0.0151	0.0122
FW14	0.1028	-0.1784	-0.1656	-0.13	0.0635	0.1036	0.0074	0.0846	0.0808	0.1697	-0.3181*	0.2042	-0.1038	0.0315
DW14	-0.0467	-0.2285	-0.2247	-0.0946	0.0479	0.0281	0.0409	0.0366	0.0078	0.1032	-0.0968	0.0077	0.4094*	-0.0712
SVI.II14	0.1069	-0.152	-0.1379	-0.0829	0.1116	0.1069	0.0393	0.0983	0.0328	0.1536	-0.231	0.1735	-0.0053	0.0024
DFF	0.6456**	0.999**	0.999**	0.999**	0.999**	0.6159**	0.9861**	0.7493**	-0.0581	-0.3434*	0.999**	0.999**	-0.3534*	0.8349**
PH	1	0.3379*	0.3479*	0.5497**	0.2005	0.2425	0.1143	0.2315	-0.0606	-0.1383	-0.0258	-0.1571	0.3977*	0.2934
NT		1	0.999**	0.255	-0.0338	-0.0183	0.0843	0.0153	-0.0886	0.3587*	0.0134	-0.1924	-0.6885**	0.0669
NPT			1	0.2661	-0.0222	0.0004	0.0933	0.0332	-0.0889	0.3398*	0.0122	-0.1847	-0.6299**	0.0717
PL				1	0.5142**	0.496**	0.2581	0.4813**	-0.1059	0.9631**	0.0532	-0.0902	-0.3511*	0.3961*
PW					1	0.9524**	0.3529*	0.8744**	-0.0411	0.999**	-0.1466	0.0511	-0.8652**	0.4219*
FG						1	0.4611*	0.9504**	-0.0962	-0.6518**	-0.2774	-0.1124	-0.9546**	0.4397*
UFG							1	0.7147**	-0.8834**	-0.656**	-0.1026	-0.2073	0.1399	0.1165
TG								1	-0.3853*	-0.7769**	-0.2572	-0.1618	-0.7034**	0.3881*
SF									1	0.6847**	0.0499	0.1202	-0.8906**	0.0502
TGW										1	0.999**	0.999**	0.0134	0.1403
GL											1	-0.14	-1	-0.1511
GW												1	0.601**	0.0536
GA													1	0.528**
SPY														1

***Significance at o.5%, *Significance at 1%, Note:G7=Germination on the 7th day, SL7= Shoot length on 7th day, RL7= Root length 7th day,TL7=Total length on the 7th day, FW7=Fresh weight on the 7th day,DW7= Dry weight on 7th day, , G14=Germination on the 14th day, SL14= Shoot length on 14th day, RL14= Root length on 14th day, TL14=Total length on the 14th day, DW14= Dry weight on 14th day, FW14=Fresh weight on the 14th day , SVI-1-7= Seedling vigour index 1 on 7th day, SVI-1-14= Seedling vigour index 1 on 14th day, , SVI-2-7= Seedling vigour index 2 on 7th day, SVI-2-14= Seedling vigour index 2 on 14th day, DFF= Days to 50% flowering, PH=Plant height,NT= Number of tillers, NPT= Number of productive tillers, PL= Panicle length, PW= Panicle weight, TG= Total number of grains per panicle, FG= Total number of filled grains per panicle, UFG= Total number of unfilled grains per panicle, SF=Spikelet fertility, SPY= Single plant yield, TGW= Thousand grain weight, GL=Grain length, GW=Grain width, GA=Grain area.*

3.3 Phenotypic Correlation Using Replicated Data

A positively significant association was observed for traits panicle length, panicle weight and filled grains, total number of grains, days to 50% flowering with single plant yield and similar results were reported by Deepthi et al. [9] for panicle length and total number of filled grains, Vanisree et al. [10] and Rachana et al. [11] for total number of grains, Parimala et al. [14], Elizabeth et al. (2011) for panicle length and panicle weight.

The traits germination on the 7th day, root length on the 7th day, total length on the 7th day, dry weight 7th on the day, shoot length on the 14th day, root length on the 14th day, total length on the 14th day, seedling vigour index - I on the 14th day, fresh weight on the 14th day, seedling vigour index - II on the 14th day, plant height, number of tillers, number of productive tillers, unfilled grains, spikelet fertility, and 1000 grain weight, grain width, grain area had shown a positive and nonsignificant correlation with single plant yield and this results was in accordance with the results of Lakshmi et al. [12], Madakemohekar et al. [13]. While seedling vigour index - I on the 7th day, fresh weight on 7th day, seedling vigour index - II on the 7th day), germination on the 14th day, dry weight on the 14th day, grain length have shown a negatively non-significant phenotypic correlation with single plant yield (Table 3, Fig. 1b).

3.4 Path Coefficient Analysis

Path coefficient analysis distinguishes between direct and indirect impacts of yield components on grain yield. Path analysis gives a comprehensive image of character relationships, enabling effective selection strategies. Path coefficient analysis distinguishes itself from basic correlation by identifying the causes and their relative importance and cause. The impact of various plant characteristics on seed output at both phenotypic and genotypic levels. The direct and indirect effects of different characters on gain yield per plant are presented Fig. 2.

In the present investigation conducted on yield and its related traits the highest positive direct effect on single plant yield was exhibited by days to 50% flowering, plant height, number of tillers, number of productive tillers, panicle length, panicle weight, number of filled grains, number of unfilled grains, spikelet fertility, grain length, grain width and grain area (Fig. 1), similar results were also reported by Madhavilatha et al. [15], Naseer et al. [16], Babu et al. [17], Kishore et al. [18], Kumar et al. [19], Manohora et al. [20], Edukondalu et al. [21], Kumari and Parmar et al. [22] and Archana et al. [23].

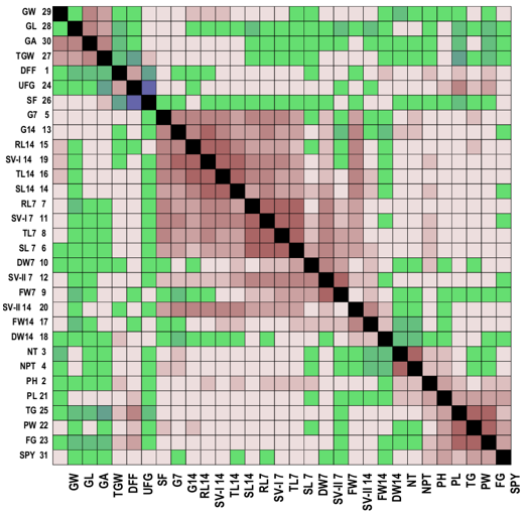


Fig. 1(a). Genotypic Correlogram

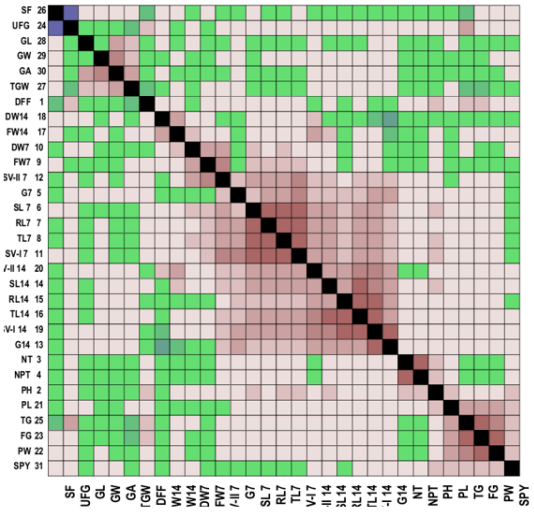
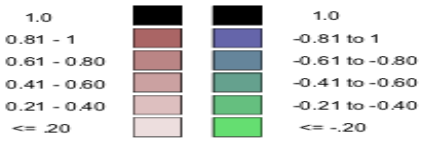


Fig. 1(b). Phenotypic Correlogram



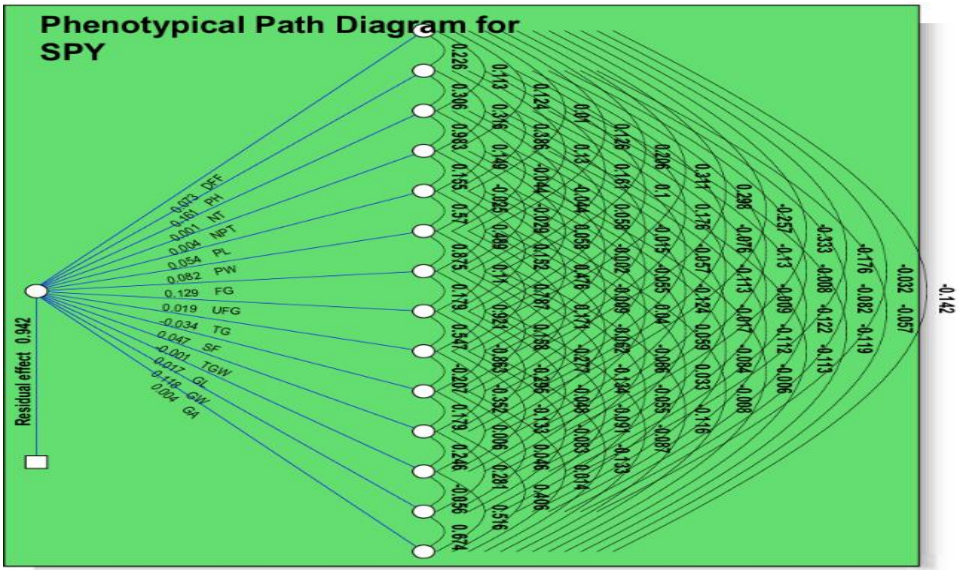


Fig. 2(a). Path diagram for yield related traits

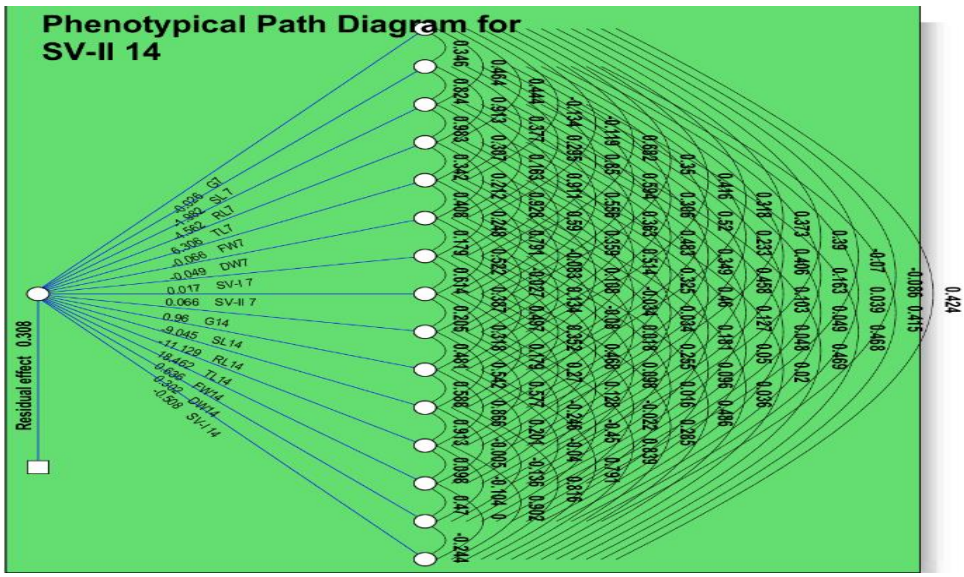


Fig. 2(b). Path diagram for Seedling vigour related traits

Among seedling vigour and its related traits the highest positive direct effect on single plant yield was exhibited by total length on the 7th day, seedling vigour index-I on the 7th day, seedling vigour index-II on the 7th day, germination on the 14th day, total length on the 14th day, fresh weight on the 14th day, dry weight on the14th day (Fig. 2), as reported by Madhavilatha et al. [15], Naseer et al. [16], Babu et al. [17], Kishore et al. [18], Kumar et al. [19], Manohora et al. [20], Kumari and Parmar et al. [21]. Negative direct effects on single plant yield was exhibited by germination on the 7th day, shoot length on the 7th day, root length on the 7th day, fresh weight on the 7th day, dry weight on the 7th day, shoot length on the 14th day, root length on the 14th day, seedling vigour index on the 14th day. The residual effect for yield and seedling vigour related traits were 0.942 and 0.308 respectively. High residual effects for yield related traits indicates the consideration of additional parameters that are strongly effecting the grain yield apart from the traits studied. Prioritizing the traits showing highest positive direct effects on single plant yield during breeding programmes will increase the single plant yield as these traits are significant contributors to crop improvement [24].

Table 3. Phenotypic Correlation of yield and seedling vigour-related traits of MTU1010/ *Oryza rufipogon* BILs during Kharif 2023

	G7	SL7	RL7	TL7	SVI.I7	FW7	DW7	SVI.II7	G14	SL14	RL14	TL14	SVI.I14	FW14	DW14	SVI.II14
G7	1	0.4579**	0.614**	0.5856**	0.6843**	0.0743	0.1116	0.1822	0.6535**	0.455*	0.5516**	0.5573**	0.5919**	0.0897	-0.0051	0.2353
SL7		1	0.8486**	0.9246**	0.9054**	0.5356**	0.4568**	0.6137**	0.3911*	0.5663**	0.3148*	0.4689**	0.4828**	0.2146	0.0694	0.3033*
RL7			1	0.9861**	0.9547**	0.4755**	0.3196*	0.5432**	0.4971**	0.5448**	0.4856**	0.5616**	0.5707**	0.1791	0.0876	0.2955
TL7				1	0.9713**	0.5104**	0.3733*	0.5836**	0.4805**	0.5697**	0.4483*	0.5513**	0.5622**	0.1961	0.0847	0.3077*
SVI.I7					1	0.469**	0.3733*	0.5595**	0.5156**	0.5788**	0.4708**	0.5694**	0.5907**	0.2099	0.0812	0.334*
FW7						1	0.511**	0.9743**	0.0286	0.2261	0.084	0.162	0.1391	0.2425	0.0634	0.1858
DW7							1	0.6639**	0.1291	0.2739	0.0616	0.1719	0.1779	0.2657	0.0286	0.2353
SVI.II7								1	0.1213	0.3051*	0.1382	0.2336	0.2209	0.2655	0.0526	0.2285
G14									1	0.5615**	0.6849**	0.6903**	0.8137**	0.0363	-0.2362	0.219
SL14										1	0.6599**	0.8908**	0.8685**	0.3727*	0.0535	0.4753**
RL14											1	0.9292**	0.8976**	0.2341	0.0571	0.4023*
TL14												1	0.97**	0.3248*	0.0609	0.477**
SVI.I14													1	0.2595	-0.0395	0.4278*
FW14														1	0.4868**	0.9333**
DW14															1	0.6251**
SVI.II14																1

	DFF	PH	NT	NPT	PL	PW	FG	UFG	TG	SF	TGW	GL	GW	GA	SPY
G7	0.2659	0.1417	0.1864	0.2015	0.1298	0.158	0.126	0.1047	0.1416	-0.0629	0.096	0.0237	0.0322	-0.1599	0.0081
SL7	0.999**	0.2775	0.1387	0.1434	0.0964	0.0642	0.0732	0.0759	0.0878	-0.0607	0.999**	-0.0555	-0.0604	0.0055	0
RL7	0.999**	0.1913	0.1505	0.166	0.0795	0.1561	0.1429	0.1126	0.1582	-0.0877	0.4749**	-0.1541	0.1032	0.0078	0.0145
TL7	0.999**	0.2247	0.1518	0.1645	0.0875	0.1325	0.126	0.1048	0.1415	-0.082	0.3069*	-0.1283	0.0553	0.0074	0.0104
SVI.I7	0.999**	0.2565	0.1523	0.1639	0.0976	0.1409	0.1307	0.096	0.1421	-0.0628	0.3563*	-0.0959	0.0508	0.0063	-0.0122
FW7	0.5272**	0.1261	-0.0387	-0.0378	-0.008	-0.0249	-0.0139	0.0122	-0.0067	-0.0295	0.1815	-0.1554	0.0769	-0.0655	-0.0668
DW7	0.999**	0.2124	-0.066	-0.0685	-0.0268	0.0096	0.0712	0.1225	0.1034	-0.0655	0.4063*	-0.0312	-0.0703	-0.0447	0.0937
SVI.II7	0.4319*	0.1666	-0.0295	-0.0273	-0.0008	-0.0046	0.0129	0.0504	0.0293	-0.0514	0.1357	-0.1366	0.0544	-0.0618	-0.048
G14	0.1837	0.1314	0.1888	0.1907	0.1135	0.1068	0.0449	0.0802	0.0663	-0.0983	0.26	0.0267	0.0773	-0.0089	-0.0028
SL14	0.999**	0.2722	0.0901	0.0979	0.1133	0.1152	0.0947	0.1129	0.119	-0.0992	0.5419**	-0.0579	0.0894	0.055	0.0089
RL14	0.999**	0.0657	0.0352	0.0378	0.0882	0.1596	0.1027	0.0037	0.0851	-0.0191	0.4973**	-0.0868	0.2107	0.0129	0.022
TL14	0.7235**	0.1736	0.0657	0.0711	0.1091	0.1532	0.1086	0.0577	0.11	-0.0603	0.3021*	-0.081	0.1714	0.0349	0.0177
SVI.I14	0.6124**	0.1951	0.0959	0.1004	0.0997	0.1439	0.0886	0.0643	0.0961	-0.0719	0.328*	-0.0385	0.1499	0.0247	0.0118
FW14	0.493**	0.0803	-0.1442	-0.1289	-0.1063	0.0398	0.0623	0.0074	0.0535	0.0469	0.1381	-0.1624	0.1154	-0.0069	0.0218
DW14	0.7808**	-0.0431	-0.1779	-0.1706	-0.104	0.0199	-0.0028	0.0206	0.0052	0.0063	0.0865	-0.0413	-0.0045	0.0296	-0.0415
SVI.II14	0.3754*	0.0897	-0.1249	-0.11	-0.0736	0.0842	0.0734	0.0351	0.0728	0.0172	0.1335	-0.1156	0.1056	0.0054	0.0061
DFF	1	0.6428**	0.999**	0.999**	0.999**	0.999**	0.5436**	0.8539**	0.6843**	-0.0476	-0.3434*	0.999**	0.999**	-0.0484	0.7445**
PH		1	0.3264*	0.3361*	0.4794**	0.1741	0.212	0.0999	0.2099	-0.0471	-0.1377	-0.0197	-0.1228	0.047	0.2595
NT			1	0.9938**	0.212	-0.034	-0.0247	0.067	0.0046	-0.0592	0.3476*	0.0003	-0.1514	-0.0957	0.058
NPT				1	0.2207	-0.02	-0.008	0.072	0.0201	-0.0591	0.3293*	-0.0041	-0.1438	-0.0966	0.0636
PL					1	0.5389**	0.4912**	0.2038	0.4762**	-0.0466	0.8494**	0.0562	-0.1018	0.0027	0.3048*
PW						1	0.9127**	0.237	0.8322**	0.062	0.999**	-0.0981	0.0288	-0.0467	0.3374*
FG							1	0.3265*	0.9367**	0.0457	-0.5753**	-0.1952	-0.0895	-0.097	0.3428*
UFG								1	0.6366**	-0.8468**	-0.5681**	-0.0735	-0.1475	0.0573	0.0754
TG									1	-0.2762	-0.7096**	-0.1864	-0.1277	-0.0579	0.3076*
SF										1	0.5602**	0.0226	0.0744	-0.1317	0.0488
TGW											1	0.999**	0.999**	0.0018	0.1252
GL												1	-0.0892	-0.224	-0.0768
GW													1	0.044	0.077
GA														1	0.0253
SPY															1

***Significance at o.5%, *Significance at 1%, Note:G7=Germination on the 7th day, SL7= Shoot length on 7th day, RL7= Root length 7th day,TL7=Total length on the 7th day, FW7=Fresh weight on the 7th day,DW7= Dry weight on 7th day, , G14=Germination on the 14th day, SL14= Shoot length on 14th day, RL14= Root length on 14th day, TL14=Total length on the 14th day, DW14= Dry weight on 14th day, FW14=Fresh weight on the 14th day , SVI-1-7= Seedling vigour index 1 on 7th day, SVI-1-14= Seedling vigour index 1 on 14th day, , SVI-2-7= Seedling vigour index 2 on 7th day, SVI-2-14= Seedling vigour index 2 on 14th day, DFF= Days to 50% flowering, PH=Plant height, NT= Number of tillers, NPT= Number of productive tillers, PL= Panicle length, PW= Panicle weight, TG= Total number of grains per panicle, FG= Total number of filled grains per panicle, UFG= Total number of unfilled grains per panicle, SF=Spikelet fertility, SPY= Single plant yield, TGW= Thousand grain weight, GL=Grain length, GW=Grain width, GA=Grain area*

4. CONCLUSION

Among all the 31 traits studied for correlation and path analysis with single plant yield, the positive significant correlation was observed for the traits panicle length, panicle weight, filled grains, total number of grains. Genotypic and phenotypic correlation reveals that the traits panicle length, panicle weight, filled grains, total number of grains, days to 50% flowering showed significant correlation with single plant yield. Results of path analysis concluded that, days to 50% flowering, number of tillers, fresh weight, dry weight, germination percentage and total number of grains had shown a positive direct effect with single plant yield. The, traits days to 50% flowering, filled grains, total numbers of grains have proved a positive significant and direct contribution towards yield improvement. Therefore, these traits are given more importance while selecting the genotypes and promoting for generation advancement as well as in breeding programmes for crop improvement for yield and seedling vigour.

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 writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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