

Genotypic and phenotypic correlation and Path analysis of Yield and Seedling Vigour Related Traits in wild introgression lines

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. 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

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 (Mia et al. 2009). 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 (Falconer et al. 1996, Jan et al. 2019, Sunday et al. 2007, Panse et al. 1954). 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 (Foolad et al. 2007, Savage et al. 2016). 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.

Materials & 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 7th and 14th day of germination.

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).

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. (1994) method.

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

Seedling vigour index- I: $\frac{\text{Seedling germination percent} \times \text{Seedling length (cm)}}{100}$

100

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

Seedling vigour index- II: $\frac{\text{Seedling germination percent} \times \text{Seedling dry weight (g)}}{100}$

100

Results and Discussion

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).

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 Deepthiet *al.* (2022), Vanisreeet *al.* (2013) and Rachanaet *al.* (2018). The traits, germination on the 7th day, number of productive tillers, shoot length on the 7th 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 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, 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.*(2020), Madakemohekaret *al.* (2015). Fresh weight on the 7th day, germination on the 14th day, shoot length on the 14th day, seedling vigour index - II at 7th day, dry weight on the 14th day and grain length exhibited a negatively non-significant genotypic correlation with single plant yield and are presented in (Table 2, Fig.1a).

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 Deepthiet *al.* (2022) for panicle length and total number of filled grains, Vanisreeet *al.* (2013) and Rachanaet *al.* (2018) for total number of grains, Parimalaet *al.* (2020), 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.*(2020), Madakemohekaret *al.*(2015). 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).

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 grain 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. (2013), Naseer et al. (2013), Babu et al. (2015), Kishore et al. (2018), Kumar et al. (2018), Manohora et al. (2015), Edukondalu et al. (2017), Kumari and Parmar et al. (2020) and Archana et al. (2018).

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 the 14th day (Fig 2), as reported by Madhavilatha et al. (2013), Naseer et al. (2013), Babu et al. (2015), Kishore et al. (2018), Kumar et al. (2018), Manohora et al. (2015), Kumari and Parmar et al. (2020). 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 affecting 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.

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.

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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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	DFD	PH	NT	NPT	SPY	G7	SL7	RL7	TL7	FW7	DW7	SVI7	SVII7	G14	SL14	RL14	TL14
DFD	1	0.2282	0.1189	0.1305	0.1062	0.024	0.0193	0.0976	0.0761	0.0704	0.0028	0.0539	0.0468	-0.0489	0.056	-0.0008	0.0271
PH		1	0.3253*	0.3353*	0.2874	0.1369	0.2634	0.1835	0.2148	0.1279	0.2232	0.2455	0.1841	0.1242	0.2584	0.0623	0.1652
NT			1	0.9938**	0.0888	0.1806	0.1346	0.1497	0.1499	-0.0148	-0.074	0.1491	-0.0176	0.1815	0.079	0.0283	0.056
NPT				1	0.0914	0.1967	0.1393	0.1653	0.1626	-0.0157	-0.0721	0.1611	-0.0196	0.1839	0.0872	0.0314	0.0619
SPY					1	-0.0001	-0.0191	-0.0053	-0.0097	-0.1084	0.0023	-0.0279	-0.0613	-0.0111	-0.0141	0.0321	0.0124
G7						1	0.458**	0.6125**	0.5849**	0.0577	0.0914	0.6842**	0.1547	0.6528**	0.4528*	0.551**	0.5557**
SL7							1	0.8478**	0.9243**	0.5015**	0.285	0.9054**	0.5825**	0.3942*	0.5671**	0.3157*	0.4703**
RL7								1	0.986**	0.4537*	0.2012	0.9543**	0.5233**	0.4961**	0.5414**	0.4825**	0.5581**
TL7									1	0.484**	0.2345	0.9713**	0.5596**	0.481**	0.5678**	0.4464*	0.5494**
FW7										1	0.334*	0.4442*	0.8996**	0.0113	0.2271	0.1035	0.1745
DW7											1	0.2349	0.4382*	0.1237	0.2501	0.0735	0.1678
SVI7												1	0.535**	0.5162**	0.5774**	0.4692**	0.5678**
SVII7													1	0.1047	0.2837	0.1079	0.2051
G14														1	0.5646**	0.6864**	0.6925**
SL14															1	0.6607**	0.8918**
RL14																1	0.9288**
TL14																	1
FW14																	
DW14																	
SVI14																	
SVII14																	
PL																	
PW																	
FG																	
UFG																	
TG																	
SF																	
TGW																	
GL																	
GW																	
GA																	

Table1. Correlation of mean yield and seedling vigour related traits of MTU1010/ *Oryza rufipogon*BILs during Kharif 2023

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**Significance at 0.5%, *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.

	G7	SL7	RL7	TL7	SVL.I7	FW7	DW7	SVL.II7	G14	SL14	RL14	TL14	SVL.II4	FW14	DW14	SVL.III4	DFE
G7		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	0.2912
SL7			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*	0.999**
RL7				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*	0.999**
TL7					0.9839**	0.5671**	0.4333*	0.6437**	0.5584**	0.6054**	0.5222**	0.6079**	0.6187**	0.2276	0.0887	0.3478*	0.999**
SVL.I7						0.533**	0.4421*	0.6236**	0.6084**	0.6335**	0.555**	0.6411**	0.6622**	0.2534	0.089	0.3854*	0.999**
FW7							0.4992**	0.9739**	-0.0063	0.2496	0.0762	0.1688	0.1345	0.2866	0.0454	0.1958	0.6092**
DW7								0.6671**	0.1772	0.3457*	0.0614	0.2067	0.2227	0.2645	-0.064	0.2215	0.999**
SVL.II7									0.1167	0.3453*	0.1423	0.2551	0.2347	0.3173*	0.0299	0.2499	0.492**
G14										0.6017**	0.7637**	0.7481**	0.8344**	0.1632	-0.1688	0.336*	0.2084
SL14											0.6972**	0.9067**	0.887**	0.4835**	0.0753	0.5581**	0.999**
RL14												0.9344**	0.9257**	0.3397*	0.1251	0.5075**	0.999**
TL14													0.985**	0.4399*	0.1111	0.5757**	0.7996**
SVL.II4														0.3846*	0.0214	0.533**	0.6707**
FW14															0.4304*	0.9307**	0.6056**
DW14																0.6072**	0.9316**
SVL.III4																	0.4319*
DFE																	
PH																	
NT																	
NPT																	
PL																	
PW																	
FG																	
UFG																	
TG																	
SF																	
TGW																	
GL																	
GW																	
GA																	
SPY																	

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

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**Significance at 0.5%, *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 3 Phenotypic Correlation of yield and seedling vigour-related traits of MTU1010/ *Oryza rufipogon* BILs during Kharif 2023

	G7	SL7	RL7	TL7	SVL.I7	FW7	DW7	SVL.II7	G14	SL14	RL14	TL14	SVL.II4	FW14	DW14	SVL.III4
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			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				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					0.9713**	0.5104**	0.3733*	0.5836**	0.4805**	0.5697**	0.4483*	0.5513**	0.5622**	0.1961	0.0847	0.3077*
SVL.I7						0.469**	0.3733*	0.5595**	0.5156**	0.5788**	0.4708**	0.5694**	0.5907**	0.2099	0.0812	0.334*
FW7							0.511**	0.9743**	0.0286	0.2261	0.084	0.162	0.1391	0.2425	0.0634	0.1858
DW7								0.6639**	0.1291	0.2739	0.0616	0.1719	0.1779	0.2657	0.0286	0.2353
SVL.II7									0.1213	0.3051*	0.1382	0.2336	0.2209	0.2655	0.0526	0.2285
G14										0.5615**	0.6849**	0.6903**	0.8137**	0.0363	-0.2362	0.219
SL14											0.6599**	0.8908**	0.8685**	0.3727*	0.0535	0.4753**
RL14												0.9292**	0.8976**	0.2341	0.0571	0.4023*
TL14													0.97**	0.3248*	0.0609	0.477**
SVL.II4														0.2595	-0.0395	0.4278*
FW14															0.4868**	0.9333**
DW14																0.6251**
SVL.III4																
DFF																
PH																
NT																
NPT																
PL																
PW																
FG																
UFG																
TG																
SF																
TGW																
GL																
GW																
GA																
SPY																

Contd....

UNDER PEER REVIEW

**Significance at 0.5%, *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

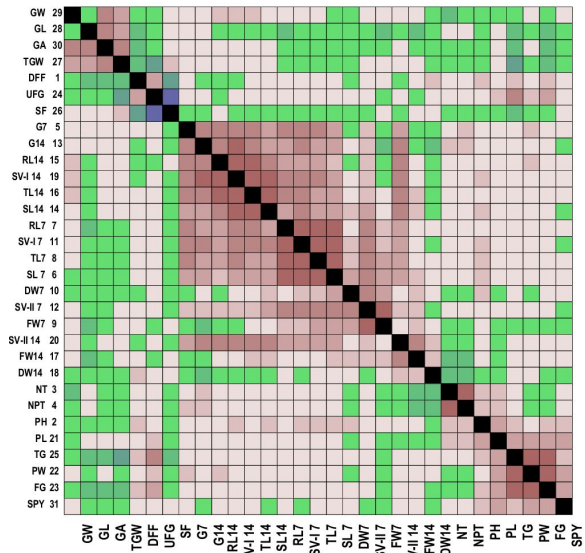


Fig 1(a): Genotypic Correlogram

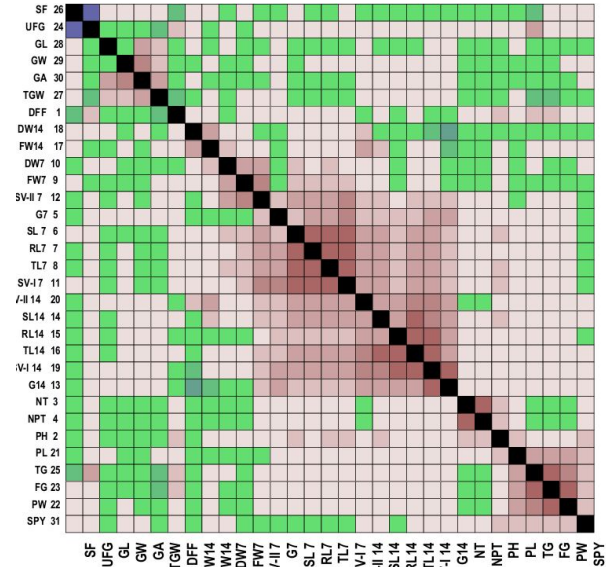
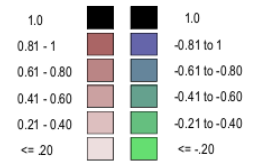


Fig 1(b): Phenotypic Correlogram



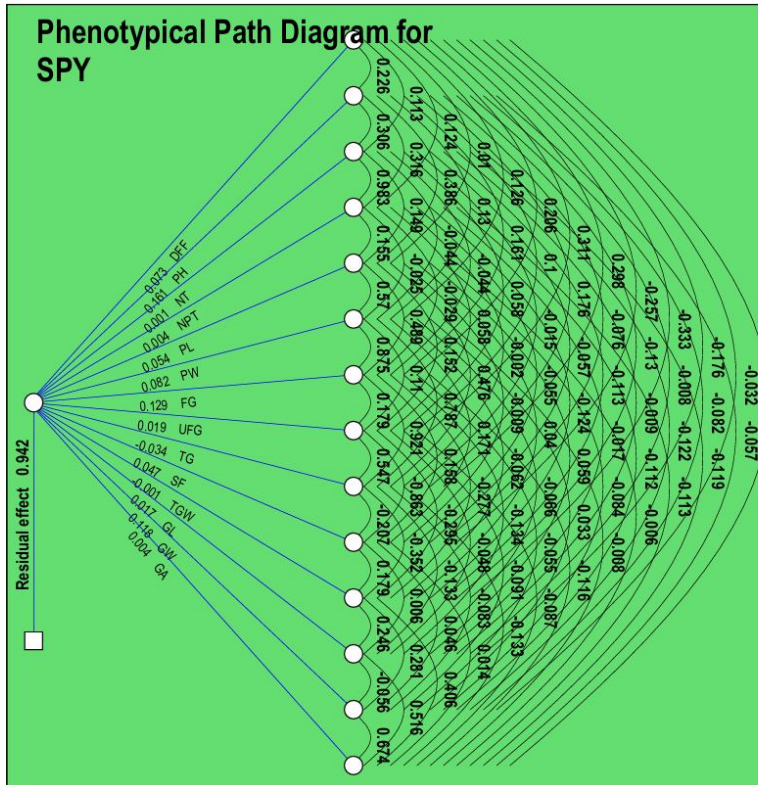


Fig 2 (a): Path diagram for yield related traits

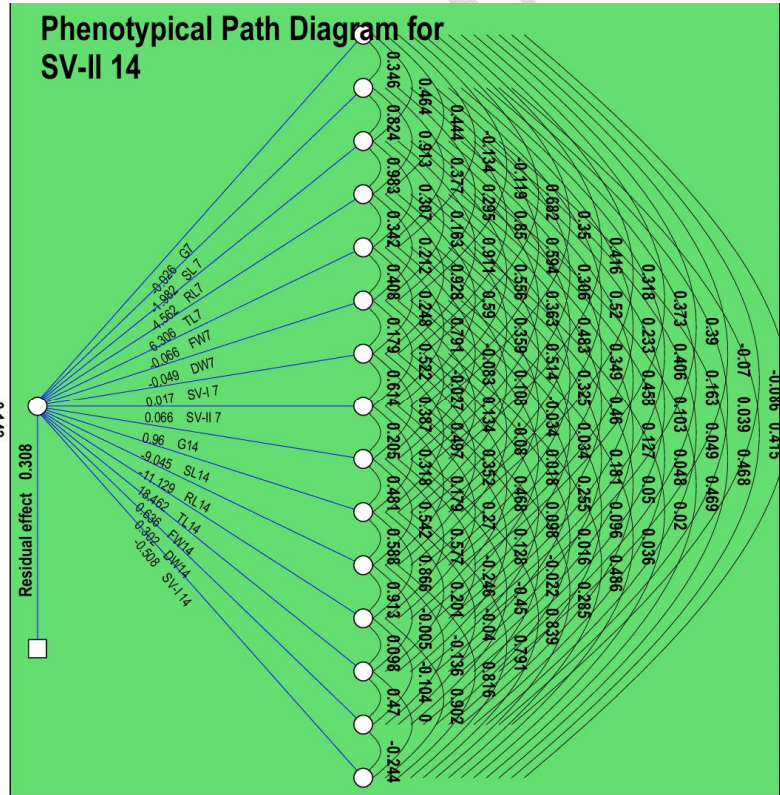


Fig 2 (b): Path diagram for Seedling vigour related traits