Original Research Article

Path Coefficient Analysis of Rice (*Oriza sativa* L.) genotype under laboratory conditions

Abstract

The present investigation was conducted at Seed Testing Laboratory of Seed Technology Section, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.). The study was based on the germplasm evaluation of 45 germplasm including three checks viz., NDR-2065, BPT 5204 and Sambha sub1. Seedling length (0.366), speed of germination (0.132), Seed width (0.108), shoot length (0.082), seed weight (0.064), root length (0.061), vigour index-II (0.057) and L/B ratio (0.033) existed substantial positive effects on vigour index-I. Seeds weight (0.875), followed by seed width (0.610), exerted very high order positive in direct effects on vigour index-I seed weight substantial positive indirect effects on seed vigour index-I via seed width were also contributed by seed width (0.610), seedling length (0.552), L/B ratio (0.294), seedling dry weight (0.037) made considerable positive indirect on vigour index-I. The lowest and highest mean performance for root length (cm) was noted for B-4311 (10.50 cm) and HRT-m-20/3220 (31.20 cm) respectively. None of the 45 lines were statically inferior or superior than general mean for root length which 14.63 cm. out of 45 genotypes, nineteen were statistically at par with the best genotype is HRT-m-20/3220.

Keywords – *Direct Effect, Evolution, Germplasm, Vigour*

Introduction

Rice (*Oryza sativa* L. 2n= 24) is a self-pollinated crop belonging to the family of grasses, Poaceae (Gramineae).The genus Oryza includes a total of 25 recognized species out of which 23 are wild and two, *Oryza sativa* and *Oryza glabarrima* are cultivated species[1]. The Genetic evidence has shown that rice originates from a single domestication 8,200–13,500 years ago in the Pearl River valley region of China. Previously, archaeological evidence had suggested that rice was domesticated in the Yangtze River valley region in China. Rice was spread from East Asia to South east and South Asia. Rice was introduced to Europe through Western Asia, and to the Americas through European colonization. Rice is the seed of the grass species *Oryza sativa* (Asian rice) or *Oryza glabarrima*(African rice). The *Oryza sativa* is divided into three sub-species, viz. Indica (cultivated in Indian condition), Japonica (cultivated in Japan condition) and Javanica (cultivated in Indonesian condition) Indica.

Worldwide, 165.25 million hectares of land produce 503.27 MMT of rice year [2]. With a productivity of 2.8 thousand kg ha-1, India produces 124 MMT of rice overall [3]. The "Rice Bowl of India," Chhattisgarh, has 3.61 million hectares under rice, produces 7 million MT, and has a state productivity of 1.2 to 1.6 q ha-1 [2]. The state receives 1200–1600 mm of rain annually, making the monsoon its only source of income.The irrigated regions of Chhattisgarh, which cover approximately 74, 97, and 95 percent of the state's plain, Bastar plateau, and northern hill zones, respectively, are where rice is mostly farmed. The fact that rice is still the primary crop in Chhattisgarh is demonstrated by the rice's remarkable biodiversity. Governments find it difficult to ensure the food security of their populace due to population growth.

The cropping intensity is 153%. The state ranks 3rd in the country in production of rice. U.P. contributes about 18-20% to the national pool. As regards the per cent share of GSDP it is around 29.10%.There are three rice growing seasons in the state. These are wet season (Kharif), winter season (Boro) and summer season (Zaid). The growing periods of rice in different seasons share Kharif June -July to October-November; Boro October-November to April -May and Zaid February to May-June. Kharif is the main rice growing season in the state and more than 98% rice (around 5.8 m ha) is cultivated during this season covering early, medium and long duration varieties. A limited rice area around 35000-40000 ha in Zaid and hardly 3000-3500 ha area in boro season is being cultivated. During kharif season rice is cultivated in all the regions of the state while Boro rice is restricted to deeply flooded area of the eastern U.P. covering different districts viz. Gorakhpur, Basti, Deoria, Ballia, Ghazipur, Mirzapur and Varanasi. As regards the cultivation of Zaid rice in the state, it is grown only in tarairegions covering Pilibhit, Bareilly, Rampur, Bahraich, Saraasti, Balarampur, Siddharth Nagar, Kushinagar, Maharaj Ganj and Deoria districts of the state.

The principal causes of variations in rice seed vigour are aging, cultivars, time of harvest, weather during maturity, nutrition, position of seeds on the panicle, specific gravity, mechanical integrity, storage conditions and pathogens. Seed vigour is a complex trait and root length, shoot length and dry weight of seedling have been identified as good indica to seed vigour .The seed lot showing the higher seed vigour index (SVI) is considered to be more vigorous. Rice is one of the most important food crops in the world, and the cultivars with strong seed vigour are desirable for farmers to get optimum stand establishment in a direct-sowing culture system. Seed vigour is an important characteristic of seed quality, reflecting potential seed germination, seedling growth, seed longevity, and tolerance to adversity. Seeds with strong vigour may significantly improve the speed and uniformity of seed germination.

Material and Method

The experiment was conducted in Completely Randomized Block Design with three replications. The observations were recorded on five randomly selected competitive seedling of a genotype in a germination test in each replication for twelve characters in the experiment. The mean values of observations recorded on five plants of each line were used for analysis. Laboratory observations were recorded as per ISTA rules. The observations for different characters were recorded as follows: 1000-grain weight (g), Seed length (mm), Seed breadth (mm), L/B ratio, Germination (%), Speed of germination, Root length (cm), Shoot length (cm), Seedling length (cm), Seedling dry weight (g), Vigour Index-I, Vigour Index-II. The experimental data were compiled by taking mean of 5 selected plants for each germplasm. The data was subjected to Path coefficient analysis was carried out according to **Dewey and Lu (1959) [4].**

The equations used are as follows:

$$r_{ij} = P_{iy} + \sum_{j=1}^{17} r_{ij} P_{iy} \quad \text{for } i = 1,2\ldots\ldots\ldots17$$

$$r_{ij} = \sum_{j=1}^{17} r_{ij} P_{iy} \quad \text{for } r_{ij} = 1$$

Where,

A is column vector of correlations r_{ij}

B is the correlation matrix of r_{ij} and

C is the column vector of direct effect, P_{iy}

Residual factor was calculated as follows:

$$P_{xy} = \sqrt{1 - R^2}$$

Where,

$$R^2 = \sum_j P_{iy}\ r_{ij}$$

The r_{ij} i.e. $r_{1,2}$ to $r_{16,17}$ denote correlations between all possible combinations of independent characters P_{1y} to P_{17y} denote direct effects of various characters on character y.

r_{iy} = Correlation coefficient between i^{th} and y characters.

P_{iy}= Direct effect of i^{th} character on y.

Result and Discussion

The path-coefficient analysis was carried out by using phenotypic and genotypic correlation between 12 characters to find out direct and indirect effects of eleven characters on vigour index-I. The direct and indirect effects of different characters on vigour index-I at genotypic level are presented in Table 1. Seeds weight (0.875), followed by seed width (0.610), seedling length (0.552), L/B Ratio (0.294), seedling dry weight (0.037), exerted high order positive direct effect on vigour index while substantial negative direct effects were shown by root length (-0.994), germination per cent (-0.294), seed length (-0.186), speed of germination (-0.173), shoot length (-0.085), vigour index-II (-0.008). Seeds weight (0.875), followed by seed width (0.610), exerted very high order positive in direct effects on vigour index-I seed weight substantial positive indirect effects on seed vigour index-Ivia seed width were also contributed by seed width (0.610), seedling length (0.552), L/B ratio (0.294), seedling dry weight (0.037) made considerable positive indirect on vigour index-I.

The direct and indirect effects of different seed quality traits on vigour index-I at phenotypic level are presenting in table 2. Seedling length (0.366), speed of germination (0.132), Seed width (0.108), shoot length (0.082), seed weight (0.064), root length (0.061), vigour index-II (0.057) and L/B ratio (0.033) existed substantial positive effects on vigour index-I. The remaining estimates of indirect effects in the present analysis were two low to be considered important. The remaining estimates of indirect effect on path coefficient analysis at genotype level were too low to be considered incorporated. These characters have also been identified as major direct contributions towards vigour-index in different crops by earlier workers, Kumar *et al.* (2014),Devi *et al*. (2019),Saha *et al*. (2019) and Jan and Kashyap (2019), Vimal *et al*. 2023 [5,6,7,8, 9].

The mean performance of 45 genotypes for 12 characters is presented in Table 3. The general mean and range for all the traits study in the trial are given in the Table 3.

The 1000- seed weight ranged from (14.17g) in case of Shambha masuri to(28.66) for HRT-m-6/3207 with a general mean of 22.49g out of 45 genotypes 28 genotypes possessed significantly higher mean then general mean. The best nine entries among them were namely, HRT-m-1/3207, HRT-m-17/3210, HRT-m-15/322, DSN-9, HRT-m-3208, NSN-70, NDR-2065, HRT-m-22/3209, HRT-m-6/3207, HRT-m-1/3207 and HRT-m-17/3210 which also constituted top non-significant group for higher 1000-seed weight.

The general mean for seed length was 9.91mm. The observed genotype BPT-5204 showed lowest mean value (7.33mm) for the seed length, while highest mean value (11.23mm) was registered in case of HRT- m-15/322. Thirty out of the 45 lines, had significantly higher mean seed length than the general mean and the best five line among them were HRT- m-15/322, DSN-90, NSN-80, HRTM-m-3/3213 and NSN-120. The rice genotypes DSN-90 had seed length significantly at par with the best genotype HRT-m-15/322.

The mean seed width value varied from 1.55mm (BPT-5204) to 3.03mm (HRT-m-4/3218) with a general mean of 2.74mm. Thirty seven out of the 45 genotypes exhibited significantly higher seed width than the general mean. The four lines of rice, namely, NSN-70 (3.03 mm), HRT-m-4/3218 (3.03 mm), DSN-90 (2.90 mm) and HRT-m-21/3216 (2.95 mm) expressed seeds width at par with the best is germplasm, NSN-70 (3.03 mm).

The highest and lowest values for decorticated seed length were recorded in case of HRT-m-15/322 (11.23mm) and BPT-5204 (7.33mm), respectively. The general mean for this seed quality trait was 9.91mm. out of 45 entries, thirty had significantly higher decorticated seed length than the general mean and the best five entries among them were HRT-m-15/322,DSN-90,NSN-80,HRT-m-3/3213,NSN-120 genotype was statically at par with the best line,HRT-m-15/322. The general mean for seed width was 3.03 mm. Observed a wide range from 1.55 mm (BPT-5204) to 3.03 mm (HRT-m-4/3218) was observed for this character. Out of 45 genotypes

NSN-70, HRT-m-4/3218, DSN-90, HRT-m-21/3216 and NSN-41.The rice genotypes HRT-m-4/3218 had seed width significantly at par with the best genotype NSN-70.

The lowest and highest mean performance for root length (cm) was noted for B-4311 (10.50 cm) and HRT-m-20/3220 (31.20 cm) respectively. None of the 45 lines were statically inferior or superior than general mean for root length which 14.63 cm. out of 45 genotypes, nineteen were statistically at par with the best genotype is HRT-m-20/3220.

Conclusion

Path-coefficient analysis was identified at genotypic as well as phenotypic level identified seedling length and speed of germination as major direct contribution towards vigour index-I Seed width with seedling length germination percentage and L/B ratio emerged as most important indirect contribution to vigour index-I. The characters identified above as important direct and indirect components in vigour index-I merit due to consideration in formulating effective selection strategy in rice for improving overall seed quality. Considering the overall results, it is apparent that certain information obtained here will help in future for improving existing rice genotypes.

Abbreviations

MM	Millimetre
CM	Centimetre
Ha^{-1}	Hectare
G	Gram
SVI	Seed Vigour Index
L/B ratio	Length/Breath ratio
MMT	Million Metric Tonnes
ISTA	International Seed Testing Association

Table 1: Direct and indirect effects of different characters on vigour index-I at genotypic level in rice genotypes

Character	1000 seeds weight (g)	Seed length (mm)	Seed width (mm)	L/B ratio	Germination (%)	Speed of germination	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Seedling dry Weight (g)	Vigour index-II	Vigour index-I
1000 seed weight (g)	**0.875**	-0.741	0.200	0.623	-0.268	-0.064	-0.486	-0.565	0.727	0.019	-0.004	0.314
Seed length (mm)	0.696	**-0.186**	0.341	0.909	-0.962	-0.496	-0.467	-0.533	0.958	0.021	-0.005	0.276
Seed width (mm)	0.652	-0.821	**0.610**	0.381	-0.324	-0.073	-0.510	-0.595	0.997	0.019	-0.005	0.331
L/B ratio	0.421	-0.036	0.474	**0.294**	-0.348	-0.109	-0.499	-0.865	0.876	0.024	-0.005	0.226
Germination (%)	0.530	-0.288	0.679	0.016	**-0.443**	-0.127	-0.069	-0.065	0.119	0.028	-0.007	0.372
Speed of germination	0.323	-0.218	0.681	0.811	-0.324	**-0.173**	-0.250	-0.710	0.157	0.024	-0.005	0.315
Root length (cm)	0.427	-0.027	0.825	0.650	-0.254	-0.044	**-0.994**	-0.559	0.283	0.022	-0.005	0.324
Shoot length (cm)	0.727	-0.795	0.354	0.782	-0.368	-0.096	-0.503	**-0.085**	0.441	0.024	-0.006	0.477
Seedling length (cm)	0.671	-0.820	0.658	0.865	-0.389	-0.105	-0.639	-0.289	**0.552**	0.026	-0.006	0.524
Seedling dry Weight (g)	0.443	-0.261	0.250	0.860	-0.338	-0.115	-0.590	-0.032	0.104	**0.037**	-0.008	0.348
Vigour index-II	0.424	-0.709	0.886	0.825	-0.362	-0.612	-0.551	-0.091	0.504	0.034	**-0.008**	0.340

Table 2: Direct and indirect effects of different character on vigour index-I at phenotypic level in rice genotypes

Character	1000 seeds weight (g)	Seed length (mm)	Seed width (mm)	L/B ratio	Germination (%)	Speed of germination	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Seedling dry Weight (g)	Vigour index-II	Vigour index-I
1000 seed weight (g)	**0.064**	-0.144	0.073	0.015	-0.052	0.043	0.026	0.058	0.246	-0.038	0.026	0.315
Seed length (mm)	0.048	**-0.193**	0.089	0.024	-0.073	0.067	0.024	0.055	0.239	-0.042	0.026	0.261
Seed width (mm)	0.043	-0.158	**0.108**	0.014	-0.071	0.057	0.028	0.057	0.244	-0.040	0.026	0.308
L/B ratio	0.029	-0.137	0.045	**0.033**	-0.075	0.079	0.027	0.041	0.194	-0.050	0.030	0.216
Germination (%)	0.034	-0.146	0.079	0.026	**-0.097**	0.095	0.032	0.059	0.254	-0.056	0.039	0.318
Speed of germination	0.021	-0.098	0.046	0.020	-0.070	**0.132**	0.018	0.045	0.185	-0.050	0.032	0.281
Root length (cm)	0.027	-0.075	0.050	0.015	-0.052	0.039	**0.061**	0.044	0.200	-0.045	0.027	0.291
Shoot length (cm)	0.045	-0.128	0.074	0.016	-0.069	0.072	0.032	**0.082**	0.310	-0.048	0.033	0.419
Seedling length (cm)	0.043	-0.126	0.072	0.018	-0.067	0.067	0.033	0.070	**0.366**	-0.062	0.040	0.454
Seedling dry Weight (g)	0.028	-0.093	0.049	0.019	-0.063	0.076	0.031	0.046	0.258	**-0.087**	0.049	0.312
Vigour index-II	0.029	-0.087	0.049	0.018	-0.066	0.074	0.029	0.047	0.258	-0.074	**0.057**	0.333

Table-3: Mean performance of 45 rice genotypes

Genotypes	1000 seeds weight (g)	Seed length (mm)	Seed width (mm)	L/B ratio	Germination (%)	Speed of germination	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Seedling dry Weight (g)	Vigour index-I	Vigour index-II
BLB-6	22.78	10.22	2.18	4.70	92.00	20.77	14.40	12.70	28.00	0.072	2576.00	6.624
HRT-m-15/322	27.56	11.23	2.63	4.28	85.00	20.31	15.90	15.70	32.40	0.056	2754.00	4.76
NSN-41	25.71	10.03	2.90	3.46	93.00	22.49	14.30	13.16	30.10	0.066	2799.30	6.138
NSN-70	17.70	8.68	3.03	2.87	95.00	22.65	14.10	15.10	29.10	0.074	2764.50	7.03
HRT-m-10/3205	22.65	10.15	2.77	3.66	95.00	25.53	13.00	15.20	29.80	0.069	2831.00	6.555
DSN-100	17.36	9.58	2.90	3.30	90.00	18.15	14.90	14.13	33.70	0.067	3033.00	6.03
HRT-m-22/3209	25.46	10.20	2.83	3.61	84.00	19.89	15.70	15.80	31.50	0.051	2898.00	4.692
BLB-1	22.41	9.48	2.90	3.27	94.00	20.40	13.20	13.90	27.10	0.071	2547.40	6.674
NSN-30	18.70	10.23	2.75	3.72	86.00	20.43	14.50	14.10	28.60	0.067	2459.60	5.767
HRT-m-17/3210	28.54	9.88	2.75	3.59	87.00	18.18	15.20	14.80	30.00	0.069	2610.00	6.003
BLB-16	22.41	9.98	2.50	3.99	96.00	25.50	13.90	14.20	27.11	0.062	2140.80	5.952
NSN-40	19.54	9.95	2.83	3.52	96.00	22.55	15.30	16.00	31.30	0.062	3004.80	5.952
Shambha masuri	14.17	10.35	2.68	3.87	98.00	18.86	12.10	11.50	23.60	0.049	2322.60	4.802
NSN-200	18.66	7.53	2.92	2.58	91.00	20.64	15.60	15.70	31.13	0.064	2848.30	5.824
NSN-90	20.64	10.18	2.90	3.51	91.00	20.02	14.40	13.20	28.00	0.072	2639.00	6.552
NSN-80	20.50	10.75	2.90	3.87	92.00	21.47	14.10	14.40	28.70	0.061	2640.40	5.612
HRT-m-18/3202	25.39	10.25	2.78	3.66	90.00	22.67	14.80	14.50	30.40	0.054	2736.00	4.86
HRT-m-8/3211	22.06	10.25	2.80	3.71	97.00	24.20	14.80	14.10	29.20	0.056	2832.40	5.432
HRT-m-6/3207	25.27	10.30	2.78	3.58	91.00	20.18	14.40	14.40	22.60	0.070	2056.60	6.37
HRT-m-6/3207	28.66	10.38	2.90	3.01	89.00	23.19	15.30	15.60	31.00	0.069	2759.00	6.141
HRT-m-1/3201	24.00	8.65	2.88	3.49	97.00	21.00	15.50	15.80	31.30	0.073	3036.10	7.081
HRT-m-4/3208	26.15	9.85	2.83	3.60	90.00	20.29	14.90	16.60	31.40	0.072	2826.00	6.48
HRT-m-	23.32	10.25	2.85	3.61	97.00	23.56	14.10	14.50	28.90	0.063	2803.30	6.111

9/3221												
HRT-m-3/3213	19.26	10.65	2.95	3.36	89.00	22.52	12.60	11.40	24.00	0.057	2136.00	5.073
HRT-m-2/3204	22.91	9.90	2.95	3.38	89.00	26.75	15.50	14.00	29.10	0.074	2589.90	6.586
NSN-71	22.78	9.98	2.45	4.19	92.00	22.67	14.30	15.10	29.40	0.067	2704.80	6.164
NSN-90	22.99	10.28	2.10	4.35	91.00	20.02	14.40	13.20	27.30	0.072	2402.40	5.368
HRT-m-20/3220	22.85	9.13	2.90	3.58	92.00	14.69	31.20	13.40	27.90	0.071	2566.80	6.532
HRT-m-1/3212	25.12	9.90	2.85	3.47	90.00	21.10	15.50	15.40	31.00	0.068	9027.00	6.12
HRT.m-21/3216	24.30	10.30	2.95	3.49	86.00	23.94	13.90	14.50	28.00	0.074	2408.00	6.364
NSN-120	20.70	10.53	2.90	3.63	94.00	24.89	12.50	13.70	27.30	0.077	2566.20	7.238
NSN-200	22.80	8.98	2.48	3.63	91.00	20.64	15.60	15.70	31.30	0.064	2848.30	5.824
HRT-m-4/3218	28.11	10.28	3.03	3.40	90.00	20.29	14.90	16.60	31.40	0.072	2826.00	6.48
HRT-m 13/3217	19.74	10.20	2.68	3.81	81.00	20.64	15.50	13.30	27.60	0.075	1683.60	4.58
Check **NDR-2065**	25.50	10.63	2.62	4.07	98.00	24.43	13.00	18.60	31.60	0.076	3096.80	7.45
BPT-5204	14.26	7.33	1.55	4.73	93.00	29.07	15.30	12.60	25.00	0.074	2325.70	6.88
SAMB HA SUB-1	14.38	7.65	1.73	4.43	97.00	23.65	14.90	11.20	26.10	0.071	2531.70	6.89
Grand mean (∑X)	**22.49**	**9.91**	**2.74**	**3.65**	**91.42**	**21.34**	**14.63**	**14.51**	**28.89**	**0.065**	**2686.66**	**5.92**
Minimum range	**14.17**	**7.33**	**1.55**	**2.58**	**81.00**	**12.15**	**10.50**	**11.40**	**22.60**	**0.046**	**23.30**	**4.10**
Maximum range	**28.66**	**11.23**	**3.03**	**4.73**	**98.00**	**29.07**	**31.20**	**18.60**	**33.70**	**0.077**	**9027.00**	**7.45**
S .E(m)±	1.07	0.46	0.126	0.164	3.49	0.969	0.699	0.642	1.356	0.003	137.246	0.268
C.D(P=0.5)	3.12	1.34	0.366	0.478	10.15	2.819	2.034	1.868	3.943	0.008	399.058	0.778

Table 4: The most desirable genotype identified for 12 characters

Characters	Genotypes
1000- seed weight (g)	HRT-m-6/3207, HRT-m-17/3210, HRT-m-4/3210, HRT-m-15/322, DSN-90, HRT-m-4/3208, NSN-41, HRT-m-22/3209.
Seed length (mm)	HRT-m-15/322, NSN-80, HRT-m-3/3218, NDR-2065, NSN-120, Shmbha masuri, HRT-m-21/3216,HRT-m-14/3203.
Seed width (mm)	NSN-70, HRT-m-4/3218, DSN-90, HRT-m-3/3213, NSN-200, DSN-100, NSN-41.
L/B Ratio	BPT-5204, BLB-6, Sambha sub-1, NSN-90, BLB-16, NSN-70, Shambha masuri, NSN-80.
Germination (%)	Shambha masuri, NDR-2065, Shambha sub-1, HRT-m-9/3221, HRT-m-1/3201, HRT-m-18/3211, BLB -16, NSN-40.
Speed of germination	BPT-5204, HRT-m-2/3204, HRT-m-10/3204, HRT-m-10/3205, BLB-16, NSN-120,NSN-10, HRT-m-8/3218.
Root length (cm)	HRT-m-20/3220, HRT-m-15/322, HRT-m-22/3209, NSN-200, HRT-m-1/3201, HRT-m-2/3204, HRT-m-1/3212, NSN-200.
Seedling length (cm)	DSN-100, HRT-m-15/322, HRT-m-22/3209, NDR-2065, HRT-m-4/3208, HRT-m-1/3201, HRT-m-6/3207, NSN-40.
Seedling dry weight (g)	NSN-100, NDR-2065, NSN-70, HRT-m-2/3204, HRT-m-13/3217, HRT-m-21/3216, HRT-m-1/3201.
Vigour index-I	HRT-m-1/3212, NDR-2065, HRT-m-1/3201, DSN-100, NSN-40, NSN-200, NSN-10.
Vigour index-II	NDR-2065, NSN-120, NSN-70, HRT-m-1/3201, HRT-m-2/3204, HRT-m-20/3220, NSN-90, BLB-1.

References

1. Brar DS. and Khush GS. Utilization of wild species of genus Oryza in rice improvement. In: Nanda JS and Sharma DS, (ed.) Monograph on genus Oryza. Plymouth, UK: *Sanu Publishers*, 2003;283–289.

2. Anonymous, State level Agricultural Statistics, Directorate of Agriculture, Raipur, Chhattisgarh, *Annual Report*, 2021.

3. Anonymous, Food and Agriculture Organization of the United Nations, *Annual Report*, 2019.

4. Dewey RD and Lu KH. Correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. jour.*, 1959;52: 515–8.

5. Jan N and Kashyap S. (2019). Correlation and path analysis in rice (*Oryza sativa* L.) for seed and seed vigour traits. *Jour. of Pharmaco. and Phytochem.*, 2019;8 (1). 222-226

6. Kumar R, Bushan B, Pal R and Gaurav SS. Correlation and Path Coefficient Analysis for Quantitative Traits in Wheat (*Triticum aestivum* L.) under Normal Condition. *Annals of Agri-Bio Research*, 2014;19(3):447-450.

7. Devi S, Kumar Y, Kumar R, Paras D and Niva R. Correlation and Path Coefficients Studies of Some Morphological and Seed Vigour Traits in Barley Cultivars (*Hordeum vulgare* L.) under Two Sowing Conditions. *Int. J. Curr. Microbiol .App. Sci.,* 2019;8(10):2210-2222.

8. Saha S, Hassan L, Haque A, Md I. Genetic variability, heritability, correlation and path analyses of yield components in traditional rice (*Oryza sativa* L.*). landraces J. Bangladesh Agril. Univ.*, 2019;17(1): 26–32.

9. Vimal SC, Kumar A, Gupta R, Gupta, AK and Singh J. Genetic Diversity and Path Analysis in Rice (*Oryza Sativa* L.). *Inter. Jour. of Envir. and Clim. Change* , 2023, 13(12)1039-1049.