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CORRELATION AND PATH COEFFICIENT ANALYSIS OF RICE CULTIVARS DATA

Mugemangango Cyprien[1] and Vinod Kumar[2]
[1]Basic Sciences department, Faculty of Agricultural Engineering and Environmental Sciences (FAEES), High Institute of Agricultural and Animal Husbandry (ISAE) - BUSOGO, Musanze, Northern Province, Republic of Rwanda
[2] Department of Maths, Stats. and Computer Science, G.B. Pant University of Agriculture and Technology, Pantnagar, India

Abstract

In this paper, correlation and path coefficient analysis of rice cultivars data has been carried out to determine the nature of relation between grain yield and yield components by partitioning the correlation coefficients between grain yield and its components into direct and indirect effects. In the path-coefficient analysis, panicle number, panicle weight (g), 1000-grain weight (g), days to 50% flowering and seed to seed days are considered as causal factors and their direct and indirect effects on grain yield are estimated under three experimental trials viz. AVT-2 (BT), AVT-2 (IM) and AVT-2 (ME).

Keywords: Correlation Coefficients, Path Coefficients, Panicle Number, Panicle Weight, 1000-Grain Weight, Days to 50% Flowering, Rice Grain Yield.

1. Introduction

Grain yield is a complex character and is controlled by many factors. Selection for desirable types should not only be restricted to grain yield alone but other components related to grain yield should also be considered. Path coefficient analysis is a statistical technique of partitioning the correlation coefficients into its direct and indirect effects, so that the contribution of each character to yield could be estimated. It is used in plant breeding programs to determine the nature of the relationships between yield and yield components that are useful as selection criteria to improve the crop yield. The goal of the path analysis is to accept descriptions of the correlation between the traits, based on a model of cause and effect relationship and to estimate the importance of the affecting traits on a specific trait. If the cause and effect relationship is well defined, it is possible to present the whole system of variables in the form of the diagram, known as path-diagram. Direct effects tell how a one unit change in X will affect Y, holding all other variables constant. However, it may be that other variables are not likely to remain constant if X changes, e.g. a change in X can produce a change in Z which in turn produces a change in Y. Putting another way, both the direct and indirect effects of X on Y must be considered if we want to know what effect a change in X will have on Y, i.e. we want to know the total effects (direct + indirect).

In most studies involving path coefficient analysis, researchers have considered the predictor characters as first-order variables in order to analyze their effects over a dependent variable such as yield. Since correlation coefficient measures the relationship between two characters and does not indicate relative importance of each factor, this study was conducted to determine the nature of relationship between grain yield and yield components. In the path-coefficient analysis, panicle number, panicle weight (g), 1000-grain weight (g), days to 50% flowering and seed to seed days were considered as causal factors and their direct and indirect effects on grain yield were estimated.

Dewey and Lu (1959) found that Simple correlation analysis that relates seed yield to a single variable may not provide a complete understanding about the importance of each component in determining seed yield. Akbar *et al.* (1995) carried out path coefficient analysis to study genetic variability and inter-relationships between agronomic traits in 24 bread wheat genotypes which revealed higher direct effect of number of grains per spike, followed by number of spikes and 1000-grain weight on grain yield. Uddin *et al* (1997) observed that grain yield per plant was positively and significantly correlated with spikelets per spike and 1000-grain weight; whereas, in path coefficient analysis high direct effect was observed for spikelets per spike and tillers per plant. Scheiner *et al* (2000) expanded current methods for calculating selection coefficients using path analysis and demonstrated how to analyse nonlinear selection. They demonstrated their method with an analysis of selection in an experimental population of *Arabidopsis thaliana* consisting of 289 individuals. They showed that path analysis has great promise for improving our understanding of natural selection but must be used with caution since coefficient estimates depend on the assumed causal structure.

Jedynski (2001) explained the correlation and path coefficient for grain yield and its components in wheat. He also obtained heritability estimates which were very high for plant height, high for 1000-grain weight, intermediate for number of grains per spike and very low for grain yield per plant. Kashif and Khaliq (2004) performed path coefficient studies in a 5 × 5 diallel cross of wheat. They investigated that plant height, flag leaf area, spike length and grains per spike had positive direct effects on grain yield. While fertile tillers per plant, spikelets per spike and 1000-grain weight exhibited negative direct effects on grain yield. The traits having positive direct effects on grain yield are considered to be suitable selection criteria for evolving high yielding genotypes. Royo *et al* (2004) investigated the genotypic and environmental effects on the pattern of leaf and green area development of durum wheat (Triticum turgidum L. cv. durum [T. durum]). Anwarmalik *et al.* (2007) conducted a study at the National Agriculture Research Center, Islamabad during summer of 2001 on 27 genotypes of soybean to determine the correlation and path analyses of yield and its components. Path coefficient analysis revealed that days to flowering completion had maximum direct contribution to yield followed by days to pod initiation, chlorophyll content, number of pods per plant and plant height. It was suggested that these characters can be considered as selection criteria in improving the bean yield of soybean genotypes. COŞGE *et al.* (2009) used correlation and path analysis to determine relationships between seed yield and some yield components of 20 sweet fennel (*Foeniculum vulgare* Mill. var *dulce*) lines. They suggested that single plant yield, number of umbellets and plant height are good phenotypic selection criteria to improve seed yield and essential oil percentage of sweet fennel. Dalkani *et al* (2010) performed the correlation and sequential path analysis in Ajowan. They Carried out an investigation on 10 populations of Ajowan to investigate the association among yield components and their direct and indirect effects on the seed yield of Ajowan. Positive and significant correlations were detected between single plant yield and most of the studied traits while the correlation between single plant yield and ripening period length was negative and significant ($r = -0.41$). It was concluded on the basis of sequential path analysis that the plant height and number of umbels can be used as selection criteria for improving seed yield in Ajowan breeding programs.

2. Materials and Methods

The present study was carried out to perform path analysis for rice cultivas data. Data were taken from following three trials.
(i) Nitrogen response trials on selected advanced varietal trial-2 Basmati type (AVT-2BT) rice cultures under high and low input management,
(ii) Nitrogen response trials on selected advanced varietal trial-2 Irrigated medium (AVT-IM) rice cultures under high and low input management and
(iii) Nitrogen response trials on selected advanced varietal trial-2 Medium early(AVT-2ME) (Aerobic)rice cultures under high and low input management.

Three trials were carried out at experimental area of the Department of Agronomy, College of Agriculture situated at Crop Research Centre (CRC) of G.B Pant University of Agriculture & Technology, Pantnagar during Kharif season 2010 under the supervision of Dr D.K Singh, Associate Professor, Department of Agronomy. The experiment was conducted in split plot design and the data generated by Nitrogen response trials on AVT-2(BT), AVT-2(IM) and AVT-2 (ME) were recorded. We have information on three nitrogen levels, a number of varieties with respect to grain yield (kg/plot), panicle no./sq.m., panicle weight (g), 1000-grain weight (g), days of 50% flowering and seed to seed days.

2.1 Nitrogen response trials on selected AVT-2 (BT) rice cultures (under high and low input management)

This experiment was laid out in a split-plot design with three replications. Three Nitrogen fertilizer treatments [N_1 (50%) = 50kg/ha, N_2 (100%) = 100kg/ha and N_3 (150%) = 150kg/ha] were randomized in the main plots and five rice varieties [IET 20827, IET 20847, Pusa Basmati-1, Taroari Basmati, Pant S Dhan-17] randomized in the sub plots. The data obtained from this experiment are given in Table 1.

Table 1: Data obtained on selected AVT-2 (BT) rice culture

Nitro-gen levels Main	Varieties (Sub-Plot)	Grain yield (kg/plot)			Panicle No. /sq.m.			Panicle weight (g)		
		R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
N_1	IET 20827	0.99	0.88	0.97	188	194	184	1.6	1.6	1.54
	IET 20847	0.85	0.91	1.05	194	186	200	1.53	1.09	1.83
	Pusa Basmati 1	1.05	1.13	1.25	195	200	210	1.34	1.55	1.74
	Taroari Basmati	0.70	0.75	0.90	191	196	202	1.35	1.92	1.19
	Pant S Dhan- 17	1.05	1.08	1.12	200	210	205	1.62	1.46	1.43
N_2	IET 20827	1.02	0.97	1.15	195	205	180	1.74	2.04	1.78
	IET 20847	1.20	0.88	0.99	183	189	210	1.79	1.64	1.88
	Pusa Basmati 1	1.26	1.17	1.33	195	210	205	2.06	2.29	1.66
	Taroari Basmati	0.93	0.85	0.88	193	205	207	1.87	1.34	1.43
	Pant S Dhan- 17	2.25	1.07	1.26	195	219	212	1.89	2.19	1.92

N_3	IET 20827	1.11	1.25	1.00	185	204	190	1.52	1.77	1.55
	IET 20847	1.10	0.91	0.98	180	203	190	2.1	1.19	1.81
	Pusa Basmati 1	1.24	1.16	1.25	243	203	205	1.7	2.02	1.6
	Taroari Basmati	0.73	0.73	0.75	192	204	216	1.34	1.13	1.12
	Pant S Dhan- 17	1.18	1.25	1.27	203	211	222	1.74	1.82	2

Nitro-gen levels Main	**Varieties (Sub-Plot)**	**1000- grain wt (g)**			**Days to 50% flowering**			**Seed to Seed (days)**		
		R_1	**R_2**	**R_3**	**R_1**	**R_2**	**R_3**	**R_1**	**R_2**	**R_3**
N_1	IET 20827	18.3	18.5	18.4	100	104	105	135	137	135
	IET 20847	18.7	19.5	19.0	107	109	108	139	141	138
	Pusa Basmati 1	20.4	19.2	19.8	104	106	107	135	141	138
	Taroari Basmati	22.7	22.8	22.1	108	112	108	138	142	140
	Pant S Dhan- 17	21.4	20.6	20.7	103	99	100	135	130	134
N_2	IET 20827	18.4	18.2	18.8	105	110	108	135	140	139
	IET 20847	18.8	19.6	19.3	112	108	110	143	140	142
	Pusa Basmati 1	19.2	20.5	19.1	108	109	108	136	139	141
	Taroari Basmati	21.8	23.1	22.1	110	109	108	140	141	140
	Pant S Dhan- 17	19.7	20.3	20.5	100	100	101	132	130	132
N_3	IET 20827	18.0	18.5	18.4	108	110	100	139	140	138
	IET 20847	19.1	19.4	19.4	109	110	109	142	140	139
	Pusa Basmati 1	20.0	19.9	19.3	108	106	109	138	136	139
	Taroari Basmati	21.9	21.7	21.8	110	111	112	140	142	144
	Pant S Dhan- 17	19.6	19.7	19.8	101	100	102	130	132	134

2.2 Nitrogen response trials on selected AVT-2 (IM) rice cultures (under high and low input management)

This experiment was laid out in a split-plot design with three replications. Three Nitrogen fertilizer treatments [N_1 (50%) = 60kg/ha, N_2 (100%) = 120kg/ha and N_3 (150%) = 180kg/ha] were randomized in the main plots and and twelve rice varieties (IET 20926, IET 20930, IET 20934, IET 20937, IET 20944, IET 20735, IET 20744, IET 20734, Jaya, KRH-2, Narendra 359, Local-PD-18) randomized in the sub plots. The replication-wise data obtained from the experiment are given in Table 2.

Table 2: Data obtained on selected AVT-2 (IM) rice culture

Nitrogen levels (Main)	**Varieties (Sub-plot)**	**Grain yield(kg/plot)**			**Panicle (No./sq.m)**			**Panicle weight(g)**		
		R_1	**R_2**	**R_3**	**R_1**	**R_2**	**R_3**	**R_1**	**R_2**	**R_3**
N_1	IET20926	1.37	1.40	1.45	148	153	162	2.96	2.76	2.80
	IET20930	1.28	1.25	1.52	158	151	162	2.44	2.35	2.90
	IET20934	1.38	1.68	1.25	180	170	158	2.69	2.35	2.09
	IET20937	1.55	1.60	1.45	180	178	168	2.41	2.28	2.65
	IET20944	2.48	1.38	1.25	185	191	177	2.37	2.046	2.26
	IET20735	1.30	1.60	1.45	192	202	169	2.34	2.48	2.28
	IET20744	1.20	1.15	1.50	154	154	142	3.12	2.68	2.46
	IET20734	1.40	1.50	1.25	153	153	166	2.90	2.75	2.60

	Jaya	1.25	1.38	1.35	1.73	158	159	2.08	2.67	2.46
	KRH-2	1.35	1.25	1.55	153	168	182	2.52	2.49	2.57
	Narendra359	1.05	1.48	1.35	158	158	180	2.37	2.47	2.28
	Local-PD-18	1.78	1.60	1.60	171	203	186	2.81	2.55	2.52
N_2	IET20926	1.88	1.70	1.48	173	190	195	2.44	3.06	2.56
	IET20930	1.68	1.40	1.45	172	184	190	2.22	2.31	2.72
	IET20934	1.78	1.65	1.50	200	210	205	2.17	2.30	3.59
	IET20937	1.88	1.60	1.65	179	164	180	3.15	2.54	2.74
	IET20944	1.63	1.75	1.35	205	189	188	2.65	2.14	2.41
	IET20735	1.85	2.00	1.75	181	190	200	2.35	3.04	3.36
	IET20744	1.45	1.65	1.75	188	164	155	2.94	2.63	2.65
	IET20734	1.85	1.68	1.75	190	183	179	2.95	2.23	2.36
	Jaya	1.58	1.45	1.65	180	178	175	2.78	2.70	2.91
	KRH-2	1.85	1.70	1.63	195	208	214	2.56	2.59	2.43
	Narendra359	1.38	1.65	1.45	175	182	191	2.68	2.20	2.65
	Local-PD-18	1.70	2.10	1.90	206	214	202	2.91	3.07	2.60
N_3	IET20926	1.68	1.83	1.60	198	191	202	2.63	2.46	2.87
	IET20930	1.25	1.80	1.38	180	172	190	2.36	2.30	2.63
	IET20934	1.45	1.78	1.50	208	188	195	2.25	2.33	2.56
	IET20937	1.28	1.55	1.60	192	170	180	2.22	2.23	2.68
	IET20944	1.51	1.68	1.30	200	205	195	2.04	2.44	2.63
	IET20735	1.80	1.95	1.50	188	195	199	2.61	3.21	2.74
	IET20744	1.53	1.65	1.40	183	178	179	2.83	2.37	2.29
	IET20734	1.45	1.68	1.38	198	190	195	2.36	2.11	2.56
	Jaya	1.68	1.78	1.56	192	198	200	2.19	2.45	2.75
	KRH-2	1.75	1.60	1.50	198	202	210	2.32	2.56	2.38
	Narendra359	1.60	1.53	1.25	182	185	194	2.19	2.25	2.55
	Local-PD-18	1.75	1.85	1.65	211	210	208	2.33	2.34	2.25

Nitrogen levels (Main)	**Varieties (Subplot)**	**1000- grain wt (g)**			**Days to 50% flowering**			**Seed to Seed (days)**		
		R_1	**R_2**	**R_3**	**R_1**	**R_2**	**R_3**	**R_1**	**R_2**	**R_3**
N_1	IET20926	22.80	22.80	23.05	126	124	126	158	159	156
	IET20930	17.85	17.75	18.05	110	109	112	142	144	142
	IET20934	22.92	23.20	23.36	104	105	107	135	136	138
	IET20937	16.85	17.21	16.95	108	108	107	140	142	140
	IET20944	17.40	17.65	17.30	107	106	107	138	140	141
	IET20735	23.45	23.25	23.65	108	108	109	142	141	143
	IET20744	24.78	25.00	24.83	103	102	104	135	137	135
	IET20734	22.30	22.50	23.00	104	104	106	136	134	136
	Jaya	27.30	27.45	27.80	104	104	105	136	134	135
	KRH-2	22.55	22.38	22.65	104	106	105	134	136	137
	Narendra359	26.65	26.90	26.35	105	106	106	137	136	136
	Local-PD18	26.65	26.85	27.01	104	104	103	134	134	133

N_2	IET20926	22.90	22.90	23.10	124	125	126	156	156	159
	IET20930	17.95	18.05	17.65	109	111	112	141	142	143
	IET20934	23.35	23.15	23.55	105	105	106	137	136	135
	IET20937	17.05	17.15	16.83	108	109	106	140	142	143
	IET20944	17.64	17.35	17.52	109	107	108	139	140	140
	IET20735	23.65	23.38	23.98	109	109	108	143	144	144
	IET20744	25.05	24.95	24.82	103	103	105	135	133	135
	IET20734	22.65	22.72	22.92	106	107	107	139	138	138
	Jaya	27.25	27.55	27.80	104	104	105	136	135	136
	KRH-2	12.50	22.45	23.01	104	105	105	135	137	137
	Narendra359	26.76	26.85	26.68	107	106	106	139	137	137
	Local-PD18	26.95	27.12	27.26	104	105	103	134	135	135
N_3	IET20926	22.95	22.80	23.05	124	124	126	156	156	158
	IET20930	17.89	18.50	18.00	112	112	110	143	140	142
	IET20934	23.55	23.29	23.38	106	107	105	139	138	138
	IET20937	16.85	16.88	17.05	107	106	106	139	139	140
	IET20944	17.70	17.55	17.60	107	106	107	138	139	138
	IET20735	23.65	23.35	23.65	109	108	109	142	141	143
	IET20744	25.25	24.65	24.95	104	104	103	137	136	136
	IET20734	22.80	22.65	22.58	109	107	108	141	139	140
	Jaya	27.45	27.60	27.78	105	104	105	136	138	107
	KRH-2	22.38	22.90	22.40	107	105	105	138	137	139
	Narendra359	26.45	27.01	26.68	108	107	107	139	138	139
	Local-PD-18	27.22	26.95	27.65	105	105	104	135	135	134

2.3 Nitrogen response trials on selected AVT-2(ME) (Aerobic) rice cultures (under high and low input management)

This experiment was laid out in a split-plot design with three replications. Three Nitrogen fertilizer treatments [N_1 (50%) = 50kg/ha, N_2 (100%) = 100kg/ha and N_3 (150%) = 150kg/ha] were randomized in the main plots and six rice varieties [IET 21205, IET 21208, IET 21214, IR-64, PD-12, PD-16] randomized in the sub plots. The data obtained from this experiment are given in Table 3.

Table 3: Data obtained on selected AVT-2 (ME) rice culture

Nitrogen levels (Main)	**Varieties (Subplot)**	**Grain yield(kg/plot)**			**Panicle (No./sq.m)**			**Panicle weight(g)**		
		R_1	**R_2**	**R_3**	**R_1**	**R_2**	**R_3**	**R_1**	**R_2**	**R_3**
N_1	IET21205	1.25	1.38	1.43	168	168	200	2.38	2.53	2.50
	IET21208	1.88	1.25	1.45	198	188	230	2.16	2.66	2.39
	IET21214	1.33	1.28	1.23	215	178	220	2.33	2.89	1.93
	IR-64	1.28	1.38	1.30	210	233	228	2.26	1.86	2.41
	PD-12	1.17	1.38	1.35	175	185	190	2.57	2.53	2.89
	PD-16	1.50	1.35	1.25	200	197	185	2.53	2.62	2.19

N_2	IET21205	1.63	1.38	1.48	195	178	193	2.69	2.83	2.46
	IET21208	1.48	1.68	1.82	215	208	235	2.79	2.78	2.66
	IET21214	1.78	1.38	1.29	145	210	225	2.65	2.26	2.33
	IR-64	1.35	1.75	1.55	240	268	260	2.08	1.68	1.83
	PD-12	1.65	1.58	1.38	210	183	193	1.90	2.73	2.84
	PD-16	1.75	1.45	1.53	290	260	280	1.90	1.92	2.32
N_3	IET21205	1.73	1.48	1.60	213	193	198	2.93	2.59	2.27
	IET21208	1.88	1.48	1.65	300	227	255	2.25	2.73	2.18
	IET21214	1.93	1.48	1.55	205	248	285	2.44	2.42	2.28
	IR-64	1.50	1.61	1.79	290	270	298	1.90	1.76	2.01
	PD-12	1.53	1.62	1.49	253	185	190	2.57	2.57	2.50
	PD-16	1.85	1.75	1.43	302	273	285	2.23	1.96	1.93

Nitrogen levels (Main)	**Varieties (Subplot)**	**1000- grain wt (g)**			**Days to 50% flowering**			**Seed to Seed (days)**		
		R_1	**R_2**	**R_3**	**R_1**	**R_2**	**R_3**	**R_1**	**R_2**	**R_3**
N_1	IET21205	21.5	21.2	20.4	94	94	92	125	124	125
	IET21208	27.3	26.4	27.7	92	94	96	125	127	127
	IET21214	22.75	21.8	25.2	93	94	97	126	127	128
	IR-64	24.4	24.8	24.7	91	91	92	124	124	125
	PD-12	24.8	24.2	24.2	93	92	94	124	125	125
	PD-16	26.75	24.5	25.5	94	97	95	129	126	128
N_2	IET21205	21.55	20.7	21	94	95	93	125	125	127
	IET21208	26.8	27.7	27.1	94	95	96	127	128	127
	IET21214	23.15	23.8	22.9	94	95	96	126	128	127
	IR-64	24.15	24.4	29.9	92	95	94	126	127	126
	PD-12	24.1	24.4	24.7	94	96	96	127	126	126
	PD-16	25.55	25	25.6	94	97	95	127	128	128
N_3	IET21205	21.2	21.8	20.5	92	96	93	126	127	126
	IET21208	26.9	27.7	27.2	93	96	94	128	126	127
	IET21214	22.9	23.5	23.3	96	96	92	126	127	127
	IR-64	24.85	23.9	24.2	94	93	95	128	129	127
	PD-12	24.8	23.9	24.3	96	96	95	127	127	128
	PD-16	25.3	25	25.6	95	95	95	129	128	127

3. Statistical techniques used for data analysis

To estimate the intensity of linear relationship between two variables x and y, Karl Pearson's coefficient of correlation known as correlation coefficient r_{xy} is used. It is based on the variance and covariance of the variables and ranges between -1 and +1. It is given by

$$r_{xy} = \frac{Cov(x,y)}{\sqrt{V(x)V(y)}}$$

Variances and covariance are calculated by the following formulae:

$V(x) = \frac{1}{n}\left[\sum x^2 - \frac{(\sum x)^2}{n}\right]$; $V(y) = \frac{1}{n}\left[\sum y^2 - \frac{(\sum y)^2}{n}\right]$;

$Cov(x,y) = \frac{1}{n}\left[\sum xy - \frac{(\sum x)(\sum y)}{n}\right]$

To test the significance of correlation coefficient, the calculated t-value can be compared with tabulated t-value at (n-2) degree of freedom (Snedecor and Cochran, 1967):

$$t_{cal} = \frac{r}{\sqrt{1-r^2}} \times \sqrt{n-2}$$

Path coefficient analysis

The genotypic correlation coefficients are partitioned into direct and indirect effects with the help of path coefficient analysis. One of the variables under study is taken as dependent variable (effect) which is assumed to be influenced by the other characters called independent characters or variables (causes). The path coefficient is estimated by solving following sets of simultaneous equations indicating the basic relationship between correlation and path coefficients.

$$r_{iy} = P_{iy} + r_{i1}P_{1y} + r_{i2}P_{2y} + \cdots\cdots\cdots\cdots + r_{i(i-1)}P_{iy} \quad ; i = 1, 2, 3\ldots\ldots\ldots,n$$

Where, n is the number of independent characters (causes); r_{1y} to r_{iy} denote coefficients of correlation between causal factors 1 to i and dependent character y, r_{12} to $r_{(i-1)i}$ the coefficients of correlation among all possible combinations of causal factors and P_{1y} to P_{iy} denote the direct effects of character *1* to i on the character y. The indirect effect of i^{th} variable through j^{th} variable on y-the dependent variable is computed as $P_{jy} \times r_{ji}$.

The above equation can be written in the form of following matrix:

$$\begin{array}{ccccc} A & & B & & C \\ \begin{bmatrix} r_{1Y} \\ r_{2Y} \\ r_{3Y} \\ r_{iY} \end{bmatrix} & = & \begin{bmatrix} 1 & r_{12} & r_{13} & r_{14} \ldots\ldots r_{1i} \\ & 1 & r_{23} & r_{24} \ldots\ldots r_{2i} \\ & & 1 & r_{34} \ldots\ldots r_{3i} \\ & & & r_{ii} \end{bmatrix} & & \begin{bmatrix} P_{1Y} \\ P_{2Y} \\ P_{3Y} \\ P_{iY} \end{bmatrix} \end{array}$$

Then $C = B^{-1}A$

Let

$$B^{-1} = \begin{bmatrix} B_{11} & B_{12} & B_{13} \ldots\ldots B_{1i} \\ & B_{22} & B_{23} \ldots\ldots B_{2i} \\ & & B_{33} \ldots\ldots B_{3i} \\ & & B_{ii} \end{bmatrix}$$

Then, the path coefficients are estimated as follows:

$$P_{1Y} = \sum_i B_{1i}\, r_{iY}, \qquad P_{2Y} = \sum_i B_{2i}\, r_{iY}, \qquad etc.$$

The effect of residual factor (z) which measures the contribution of remaining traits not included in the path coefficient analysis is estimated as follows:

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

Where,

$R^2 = \sum_i P^2_{iY} + 2\sum_i \sum_{i<j} P_{iY} P_{jY} r_{ij}$; R^2 is the coefficient of multiple determinations.

4. Results and Discussion

Estimates of inter character correlations

The various characters or components under study may have an association with each other that ultimately affect the yield. That association may be either in negative or positive direction. The value of Karl Pearson's correlation coefficient r helps in identifying the association between two characters. It should be noted that it does not measure the magnitude of the association but gives the idea about it. If it is closer to -1 or +1, there is high degree of linear relationship. If it is closer to 0, there is no linear relationship; there may be other type of relationship between them. Proc corr of SAS provides the computation of r and its test of significance. Table 4 shows the inter-character correlations among panicle number (PN), panicle weight (PW), 1000-grain weight (TW), days to 50% flowering (DFF) and seed to seed days (SSD) taken two at a time along with the corresponding p-values for AVT-2 (BT) trial.

Table 4 : Pearson Correlation Coefficients, N = 45; Prob > |r| under H_0: ρ=0

	PN	PW	TW	DFF	SSD	GY
PN	1	0.14024 0.3582	0.25944 0.0852	-0.14382 0.3459	-0.21814 0.1500	0.26670 0.07667
PW		1	-0.45369 0.0017	-0.20188 0.1835	-0.31284 0.0364	0.60300 <.0001
TW			1	0.18405 0.2262	0.12878 0.3992	-0.48635 0.0007
DFF				1	0.88840 <.0001	-0.36824 0.0128
SSD					1	-0.41324 0.0048
GY						1

The study of correlation coefficient from AVT-2 (BT) trial reveals that panicle number is not significantly correlated with any variable under study including grain yield. Highly significant positive correlation between panicle weight and grain yield is observed. 1000 grain weight, and seed to seed days each have a highly significant negative correlation to grain yield. Days to 50% flowering has also a significant (at 5%) negative correlation to grain yield. Panicle weight is highly negatively correlated with 1000-grain weight and significantly (at 5%) correlated with seed to seed days. There is a highly significant correlation between days to 50% flowering and seed to seed days.

Table 5 shows the inter character correlations among panicle number (PN), panicle weight (PW), 1000-grain weight (TW), days to 50% flowering (DFF) and seed to seed days (SSD) taken two at a time along with the corresponding p-values for AVT-2 (IM) trial.

Table 5: Pearson Correlation Coefficients, N = 108; Prob > |r| under H_0: ρ=0

	PN	**PW**	**TW**	**DFF**	**SSD**	**GY**
PN	1	-0.05031 0.6051	0.07408 0.4461	-0.05995 0.5377	-0.08181 0.4000	0.43434 <.0.001
PW		1	0.14387 0.1374	0.21008 0.0291	-0.16676 0.0845	0.17910 0.0637
TW			1	-0.15574 0.1075	-0.24039 0.0122	0.09857 0.3101
DFF				1	0.87577 <.0001	0.04866 0.6170
SSD					1	0.03031 0.7555
GY						1

It can be observed from Table 5 for AVT-2 (IM) trial that panicle number has highly significant positive correlation with grain yield and insignificant correlation with other characters. Panicle weight has significant (5%) correlation with days to 50% flowering and insignificant correlation with the other variables. 1000 grain weight and seed to seed days are significantly (5%) negatively correlated. High positive significant correlation has been observed between days to 50% flowering (DFF) and seed to seed days (SSD).

Table 6 shows the inter character correlations among panicle number (PN), panicle weight (PW), 1000-grain weight (TW), days to 50% flowering (DFF) and seed to seed days (SSD) taken two at a time along with the corresponding p-values for AVT-2 (ME) trial.

Table 6: Pearson Correlation Coefficients, N = 54; Prob > |r| under H_0: ρ=0

	PN	PW	TW	DFF	SSD	GY
PN	1	-0.51583 <.0001	0.33449 0.0134	0.03153 0.8209	0.47724 0.0003	0.43015 0.0012
PW		1	0.01112 0.9364	0.05401 0.6981	-0.23464 0.0877	-0.00375 0.9785
TW			1	0.17620 0.2025	0.35996 0.0075	0.18270 0.1861
DFF				1	0.43196 0.0011	0.05505 0.6926
SSD					1	0.29482 0.0305
GY						1

The results from Table 6 reveal that panicle number is highly positively correlated with seed to seed days (SSD) and grain yield (GY), positively correlated with 1000-grain weight and highly negatively correlated with panicle weight and uncorrelated with days to 50% flowering (DDF). Panicle weight is not significantly correlated with any other variable except panicle number. 1000-grain weight (TW) and days to 50% flowering (DFF) are highly positively correlated with seed to seed days SSD). Further, seed to seed days (SSD) is positively correlated (5%) with grain yield.

Path coefficient analysis

Path coefficient analysis provides an insight into the inter-relationship of various characters with grain yield. Considering grain yield as the artifact of all the causal characters [panicle number/m^2 (PN), panicle weight (PW), 1000-grain weight (TW), days to 50% flowering (DFF) and seed to seeds days (SSD)], the correlation coefficients of these causal factors with grain yield are partitioned into direct and indirect effects. Table 7 deals with the partitioning of correlation coefficients into direct and indirect effects of causal factors on grain yield for AVT-2 (BT) trial.

Table 7: Path coefficients showing direct and indirect effect for AVT-(BT) trial

Char -acter	Corr with GY	Direct effect	Indirect effect via				
			1 (PN)	2 (PW)	3 (TW)	4 (DFF)	5 (SSD)
PN	0.267	0.27666	-	0.04728	-0.09721	0.009925	0.030058
PW	0.603	0.3372	0.03879	-	0.16999	0.01393	0.043106
TW	-0.486	-0.3747	0.07178	-0.1530	-	-0.01270	-0.017753
DFF	-0.368	-0.3372	-0.03979	-0.0681	-0.069	-	-0.122415
SSD	-0.413	-0.1378	-0.06035	-0.1055	-0.04828	-0.06131	-

Residual factor = $\sqrt{0.4583}$ = 0.677

Among the component characters, panicle weight exhibits highest direct positive effect (0.3372) to grain yield along with all indirect positive effects of low magnitude through other characters. Panicle number exhibits positive direct effect (0.2766) to grain yield supported by positive indirect effect of low magnitude through panicle weight, days to 50% flowering and seed to seed days as well as negative indirect effect through 1000-grain weight. The other three yield components however have negative direct effect on the grain yield. Days to 50% flowering and seed to seed days show negative direct effect besides indirect negative effects through other variables. The correlation between grain yield and 1000-grain weight is negative due to summation of negative direct effect to yield, positive indirect effect via panicle number and negative indirect effects via panicle weight, days to 50% flowering and seed to seed day. Days to 50% flowering and seed to seed days are negatively correlated with the grain yield because of the negative direct effect to grain yield and all negative indirect effects via other characters. The residual factor value is found to be 0.677. Table 8 shows the partitioning of correlation coefficients into direct and indirect effects of causal factors on grain yield for AVT-2 (IM) trial.

Table 8: Path coefficient showing direct and indirect effect for AVT (IM) trial

Char-acter	**Correlation with GY**	**Direct effect**	**Indirect effect via**				
			1 (PN)	**2 (PW)**	**3 (TW)**	**4 (DFF)**	**5 (SSD)**
PN	0.434	0.44378	-	-0.0093	0.0037	-0.0006	-0.0032
PW	0.179	0.18569	-0.0223	-	0.0072	0.00206	0.00653
TW	0.099	0.04994	0.03288	0.02671	-	-0.0015	-0.0094
DFF	0.049	0.00978	-0.0266	0.03901	-0.0078	-	0.03430
SSD	0.030	0.03917	-0.0363	0.03097	-0.0120	0.00856	-

Residual factor = $\sqrt{0.7674}$ = 0.876.

Table 8 for AVT-2 (IM) trial reveals highest correlation of panicle number (PN) with the grain yield (GY) followed by panicle weight (PW), 1000-grain yield (TW), days to 50% flowering (DFF) and seed to seed days (SSD). Direct effects are also almost in the same order. Residual factor is equal to 0.876. Table 9 shows the partitioning of correlation coefficients into direct and indirect effects of causal factors on grain yield for AVT-2 (ME) trial.

Table 9: Path coefficient showing direct and indirect effect for AVT-(ME) trial

Char-acter	**Corr with GY**	**Direct effect**	**Indirect effect via**				
			1 (PN)	**2 (PW)**	**3 (TW)**	**4 (DFF)**	**5 (SSD)**
PN	0.430	0.53940	-	-0.1597	-0.0154	-0.00098	0.06682
PW	-0.004	0.30953	-0.2782	-	-0.0005	-0.00168	-0.0329
TW	0.183	-0.04604	0.18041	0.00344	-	-0.00547	0.05035
DFF	0.055	-0.03106	0.01701	0.01671	-0.0081	-	0.06048
SSD	0.293	0.14002	0.25741	-0.0727	-0.0166	-0.01342	-

Residual factor = $\sqrt{0.7380}$ = 0.86

The table 9 reveals the positive direct effects of panicle number (0.53940), panicle weight (0.30953), and seed to seed days (0.14002) on the grain yield. The other two components are observed to have negative direct effects of lower magnitude. The indirect effects of panicle weight on the grain yield through other characters are all negative. The residual factor is 0.86.

In the above three experiments, panicle number and panicle weight are found to have positive direct effects on the grain yield. The residual factors to grain yield are observed to be quite high in all the three trials. This means that the grain yield is much affected by other components e.g. weather, soil fertility, irrigation etc. than the components we have considered e.g. panicle number, panicle weight etc.

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