P.ISSN: 0971-8184 II E ISSN: 0976-1926
DOI: https://doi.org/10.56093/ijpgr.v39i2.175071

Indian Journal of Plant Genetic Resources

RESEARCH ARTICLE

Correlation and Path Analysis for Seed Yield and Components Traits in Mothbean [*Vigna aconitifolia* (Jacq) Marechal] under Arid Environment

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Abstract

Among pulses, the mothbean is an important pulse crop of hot arid regions of India and adapts to extreme ecological niches, particularly extreme drought and hot climatic conditions. Being a pulse crop, it is a cheap source of vegetable protein for balancing the nutritional deficiency, most commonly cultivated on less productive soils, on which, financially less equipped, a great portion of people have been depending on their livelihood. A field experiment was conducted with 36 genotypes evaluated in a randomized block design, three replications during *kharif* 2020 at Swami Keshwanand Rajasthan Agricultural University, Bikaner, to study the correlation and path coefficient analysis for seed yield and its component traits. Each genotype was sown in double rows of 3-meter length and plant-to-plant distance at 12-15 cm. For each of the 26 traits studied, genotypes differed significantly. Seed yield per plant was positively correlated with agro-morphological characters such as number of pods per plant and harvest index, as well as physiological and seed characteristics such as chlorophyll-a, chlorophyll-b, total chlorophyll content, relative water content, bulk density, and particle/true density. Days to maturity, pod length, biological yield per plant, harvest index, bulk density, particle density, seedling vigour index at 40°C, and seedling dry weight at 40°C had a positive direct effect on seed yield in mothbean. This suggests a strong hereditary link between seed yield and these traits, indicating that selection for these features may improve mothbean yield.

Keywords: Arid environment, Correlation, Mothbean, Path analysis, Seed yield

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Received: 10/01/2026

Revised: 05/05/2026

Accepted: 20/05/2026

How to cite this article: Meena S, NK Sharma, P Yadav, R Chawla and AK Meena (2026) Correlation and Path Analysis for Seed Yield and Components Traits in Mothbean [*Vigna aconitifolia* (Jacq) Marechal] under Arid Environment. *Indian J. Plant Genet. Resour*. 39(2): 105-113.

DOI: https://doi.org/10.56093/ijpgr.v39i2.175071

Introduction

Pulses are an important part of the diet because they are rich in protein (20-25%) and can help alleviate health issues such as obesity, diabetes, and malnutrition. The mothbean is a popular pulse crop in India's hot, dry regions, and it responds to a variety of ecological niches, including low rainfall (250-450 mm) and hot weather. Mat bean, Matki, Turkish gram, and Dew bean are all names for the same thing (Yaqoob *et al.,* 2015). It belongs to the family Leguminaceae/Fabaceae, sub-family Papilionaceae, and is a self-pollinated diploid crop with 2n=2x=22 chromosomes (Verdcourt, 1970). Dal (Mogar) and sprouts are the most common forms of consumption. It's the main ingredient in Bikaneri Bhujiya, a popular spicy snack. It's also used in the making of various foods, including papad, namkeen, mangori, and dal vada, among others. Agri-industries in Bikaner consume almost 80% of Rajasthan's mothbean production (Sharma, 2016). The cultivation of mothbean is integral to arid agro-ecosystems, as it significantly contributes to crop diversification and long-term sustainability of agricultural production (Sharma, 2016).

Materials and Methods

Plant material and experimental details

The current study was undertaken at the experimental farm of Swami Keshwanand Rajasthan Agricultural University in Bikaner, with sowing done during the month of July of *kharif* 2020. Under normal soil and water conditions, the experimental material, which consisted of 36 genotypes, was examined in a randomised block design with three replications, accommodating a 3-metre length, two rows in each replication, at 30 cm spacing and plant-to-plant distance of 12-15 cm.

Data recording

Observations were recorded for 26 characters *viz.,* days to 50 percent flowering, days to maturity, plant height, number of pods per plant, number of seeds per pod, pod length, 100-seed weight, biological yield per plant, harvest index, seed yield per plant, chlorophyll-a, chlorophyll-b, total chlorophyll content (estimated by the method of Hiscox and Israelstom,1979), membrane stability index (estimated by the method of Premchand *et al.,* (1990) and modified by Sairam *et al.,* (1997) , relative water content, seed volume (liquid displacement technique – Shepherd and Bhardwaj, 1986), bulk density (method reported by Singh and Goswami, 1996 and Gupta and Das, 1997), particle/true density (Toluene displacement method, Mohsenin, 1986 and Singh and Goswami, 1996), porosity (formula used by Singh and Goswami, 1996), water absorption capacity (recorded by formula, Mohsenin, 1986), water absorption index recorded by formula Williamsa *et al.,* 1993), and seedling vigour index at 40°C (determined by the multiplying the seedling length with concerned germination percentage by the following formula, Iqbal and Rahmati, 1992).

Statistical analysis

The Dewey and Lu (1959) approach was used to calculate phenotypic and genotypic correlations and path coefficients of variation.

Results and Discussion

The analysis of variance demonstrated significant variation in seed yield and yield-contributing factors across 36 mothbean genotypes (Table 1) for all 26 characters studied, indicating that there is scope for change in seed yield and yield-contributing characters through selection (Table 2).

Table 1: List of 36 genotypes and source of mothbean genotypes included in the present study

S. NO.	Name of germplasm	Source of procurement
1	IC 983	NBPGR, Regional Station, Jodhpur
2	IC 120966	NBPGR, Regional Station, Jodhpur
3	IC 120968	NBPGR, Regional Station, Jodhpur
4	IC 121005	NBPGR, Regional Station, Jodhpur
5	IC 121064	NBPGR, Regional Station, Jodhpur
6	IC 121065	NBPGR, Regional Station, Jodhpur
7	IC 140616	NBPGR, Regional Station, Jodhpur
8	IC 140663	NBPGR, Regional Station, Jodhpur
9	IC 251877	NBPGR, Regional Station, Jodhpur
10	IC 310670	NBPGR, Regional Station, Jodhpur
11	IC 311396	NBPGR, Regional Station, Jodhpur
12	IC 311399	NBPGR, Regional Station, Jodhpur
13	IC 324034	NBPGR, Regional Station, Jodhpur
14	IC 329040	NBPGR, Regional Station, Jodhpur
15	IC 370469	NBPGR, Regional Station, Jodhpur
16	IC 415104	NBPGR, Regional Station, Jodhpur
17	IC 415116	NBPGR, Regional Station, Jodhpur
18	IC 415138	NBPGR, Regional Station, Jodhpur
19	IC 415167	NBPGR, Regional Station, Jodhpur
20	GP- 47	Agricultural Research Station, Bikaner
21	GP-387	Agricultural Research Station, Bikaner
22	GP-722	Agricultural Research Station, Bikaner
23	GP-940	Agricultural Research Station, Bikaner
24	PLMO- 16	NBPGR, Regional Station, Jodhpur
25	MOTH- 259	NBPGR, Regional Station, Jodhpur
26	Jadiya	NBPGR, Regional Station, Jodhpur
27	Jwala	NBPGR, Regional Station, Jodhpur
28	RMO- 40	NBPGR, Regional Station, Jodhpur
29	RMO- 225	Agricultural Research Station, Bikaner
30	RMO-2251	Agricultural Research Station, Bikaner
31	RMO- 257	Agricultural Research Station, Bikaner
32	RMO- 423	NSP, SKRAU, Bikaner
33	RMO- 435	Agricultural Research Station, Bikaner
34	RMB- 25	NSP, SKRAU, Bikaner
35	FMM-12-6-134	NBPGR, Regional Station, Jodhpur
36	CAZARI-MOTH-2	NSP, SKRAU, Bikaner

Table 2: Analysis of variance (mean sum of squares) for various characters in mothbean genotypes

S.No.	Characters	Sources of variation		
		Replications	Genotypes	Error
	D.F.	2	35	70
1	Days to 50 percent flowering	44.6203	388.6052**	0.9727
2	Days to maturity	34.4814	195.5013**	7.3862
3	Plant height (cm)	71.76584	103.9436**	26.3914
4	Number of pods per plant	62.9242	486.7185**	26.8773
5	Number of seeds per pod	0.0708	0.6557**	0.2731
6	Pod length (cm)	0.0605	0.1753**	0.084
7	100-seed weight (g)	0.0338	0.2785**	0.0916
8	Biological yield per plant (g)	49.5988	696.4172**	16.6979
9	Harvest index (%)	0.0078	193.9523**	2.7607
10	Seed yield per plant (g)	1.2872	9.5413**	0.427
11	Chlorophyll-a (mg/g)	0.1101	0.1465**	0.0353
12	Chlorophyll-b (mg/g)	0.0023	0.0013**	0.0006
13	Total chlorophyll content (mg/g)	0.0616	0.154**	0.0198
14	Membrane stability index	13.919	329.4652**	27.7779
15	Relative water content (%)	204.1605	143.7202**	70.9955
16	Seed volume (µl/seed)	15.2358	25.6626**	5.9301
17	Bulk density (g/cm^3)	0.0013	0.0092**	0.0029
18	Particle/ true density (g/cm^3)	0.0028	0.0503**	0.0153
19	Porosity (%)	8.7161	36.8021**	11.4868
20	Water absorption capacity (mg/seed)	18.1545	145.8899**	21.3937
21	Water absorption index (WAI)	0.0007	0.1024**	0.0254
22	Germination percentage at 40°c	137.037	228.2275**	103.7037
23	Seedling length (cm) at 40°c	10.0051	8.48101**	3.2079
24	Seedling fresh weight (mg) at 40°c	0.0065	0.0163**	0.0008
25	Seedling dry weight (mg) at 40°c	0.0005	0.0004**	0.0001
26	Seedling vigour index at 40°c	50395.8867	105176.5874**	16838.2189

*Significant at P = 0.05, ** Significant at P = 0.01.

Correlation analysis

Correlation analysis provided a measure of genetic association among traits and normally used in selection, while environmental as well as genetic architecture of a genotype playa great role in achieving higher yield combined with better quality (Chawla *et al.,* 2024). At phenotypic level, Days to 50 percent flowering exhibited a positive and significant correlation with days to maturity (0.9677**) and plant height (0.7049**). Number of pods per plant (-0.6130**), harvest index (-0.5360**) and seed yield per plant (-0.5889**) depicted negative significant correlation with days to 50 percent flowering only at phenotypic level. Days to maturity had a significant and negative relationship with the number of pods per plant (-0.6149**), harvest index (-0.5136**) and seed yield per plant (-0.5690**). The traits, namely harvest index (0.6971**) and seed yield per plant (0.9018**) showed significant and positive correlation with number of pods per plant at phenotypic level. Pod length possessed significant positive relationship with 100 seed weight (0.4377**) at phenotypic level. Pod length (0.4377**) showed a significant and positive correlation with 100-seed weight at phenotypic level. Harvest index showed significant positive correlation with number of pods per plant (0.6971**) and seed yield per plant (0.8451**); while significant negative correlation exhibited by days to 50 percent flowering (-0.5360**), days to maturity (-0.5136**), plant height (-0.6811**) and biological yield per plant (-0.5780**) at phenotypic level, whereas it had significant and negative correlation with days to 50 percent flowering (-0.5889**), days to maturity (-0.5690**) and plant height

Table 3: Estimates of phenotypic and genotypic correlation coefficient for agro-morphological characters of mothbean genotypes

Characters		Days to 50 percent flowering	Days to maturity	Plant height	No. of pods per plant	No. of seeds per pod	Pod length	100-seed weight	Biological yield per plant	Harvest index
Days to 50 percent flowering	P	1								
	G	1								
Days to maturity	P	0.9677**	1							
	G	0.9889	1							
Plant height	P	0.7049**	0.6449**	1						
	G	0.8151	0.7634	1						
No. of pods per plant	P	-0.613**	-0.615**	-0.69**	1					
	G	-0.6311	-0.642	-0.86	1					
No. of seeds per pod	P	0.0736	0.1104	0.0441	-0.081	1				
	G	0.0956	0.1465	0.0377	-0.12	1				
Pod length	P	-0.0062	-0.028	-0.013	0.0325	0.2024	1			
	G	-0.007	-0.035	-0.084	0.043	0.0976	1			
100-seed weight	P	0.059	-0.02	0.1296	-0.171	-0.111	0.4377**	1		
	G	0.067	0.0134	0.3001	-0.205	-0.098	0.7988	1		
Biological yield per plant	P	0.1456	0.0906	0.2068	0.0084	-0.197	0.0609	0.08	1	
	G	0.1485	0.0942	0.2259	0.001	-0.245	0.089	0.1136	1	
Harvest index	P	-0.536**	-0.514**	-0.68**	0.6971**	0.2267	0.0305	-0.124	-0.578**	1
	G	-0.541	-0.524	-0.808	0.7023	0.2965	0.0471	-0.145	-0.588	1
Seed yield per plant	P	-0.5889**	-0.569**	-0.75**	0.9018**	0.0592	0.0339	-0.187	-0.143	0.8451**
	G	-0.6029	-0.591	-0.937	0.909	0.0841	0.0484	-0.213	-0.157	0.85

*Significant at P = 0.05, ** Significant at P = 0.01.

(-0.7536**) at also phenotypic level (Table 3).

A wide number of other component traits contribute to yield, a complicated polygenic trait. Based on phenotypic correlation coefficients among agro-morphological characters, the number of pods per plant and the harvest index showed positive and significant relationships with seed yield per plant. Kohakade *et al.,* (2017[a]), Ramakrishnan *et al.,* (2018), Singh *et al.,* (2018), Asari *et al.,* (2019), and B.B. Dhunde *et al.,* (2021) previously reported a significant positive correlation in seed yield per plant and number of pods per plant. Garg *et al.,* (2017), Sahoo *et al.,* (2018), Choudhary and Lal (2019) and Saran *et al.,* (2020) previously reported a significantly positive correlation between seed yield per plant and harvest index. The phenotypic correlation coefficient of physiological and seed parameters demonstrated a positive and significant relationship between seed yield per plant and chlorophyll a, chlorophyll b, total chlorophyll content, relative water content, bulk density, and particle/true density (Table 4). Therefore, these characters may be emphasized for the mothbean breeding programme.

The phenotypic correlation coefficients of days to 50% flowering, days to maturity, plant height, seedling fresh weight at 40°C, and seed yield per plant were found to be significant and negative, suggesting that they might be used in breeding programmes for earliness and dwarfism (Table 5). Raturi *et al.,* (2015), Kanavi *et al.,* (2019) and Choudhary *et al.,* (2019) showed similar findings at 50 percent flowering. Choudhary *et al.,* (2021) and BB Dhunde *et al.,* (2021) found a significant negative correlation between seed yield per plant and days to maturity, and Kakani *et al.,* (2003) found a significant negative correlation between seed yield per plant and plant height.

Path coefficient analysis

Path coefficient analysis was used to determine the impact of different characters on seed yield by dividing the correlation coefficient into direct and indirect effects using seed yield as the dependent variable. For

Table 4: Estimates of phenotypic and genotypic correlation coefficientsfor physiological and seed characters of mothbean

Characters		CHL- a	CHL-b	Total CHL	MSI	RWC	Seed volume	Bulk density	Particle density	porosity
CHL- a	P	1								
	G	1								
CHL-b	P	0.796**	1							
	G	0.9638	1							
Total CHL	P	0.9773**	0.8894**	1						
	G	1.0063	1.0204	1						
MSI	P	-0.227	-0.254	-0.224	1					
	G	-0.242	-0.358	-0.235	1					
RWC	P	-0.15	0.2494	0.0215	0.1581	1				
	G	-0.274	0.8172	0.0901	0.2498	1				
Seed volume	P	-0.253	-0.221	-0.224	0.1453	0.3271*	1			
	G	-0.325	-0.371	-0.276	0.1944	0.4536	1			
Bulk density	P	0.5403**	0.7203**	0.6463**	-0.146	0.5034**	0.0357	1		
	G	0.7531	1.1255	0.8254	-0.185	0.9306	-0.004	1		
Particle density	P	0.4994**	0.6101**	0.5803**	0.0276	0.3793*	0.0097	0.8257**	1	
	G	0.6434	0.941	0.712	0.0384	0.7001	0.0225	1.0295	1	
Porosity	P	0.3443*	0.3335*	0.3753*	0.3266*	0.0166	-0.255	0.2528	0.5563**	1
	G	0.4951	0.6311	0.5044	0.4198	0.0682	-0.27	0.3417	0.5697	1
WAC	P	-0.086	-0.114	-0.117	0.2716	-0.19	0.1341	-0.207	-0.108	-0.017
	G	-0.088	-0.111	-0.115	0.3264	-0.334	0.1745	-0.309	-0.133	0.023
WAI	P	-0.054	-0.107	-0.094	0.2795	-0.213	0.0919	-0.069	0.0832	0.169
	G	-0.053	-0.125	-0.098	0.367*	-0.379	0.123	-0.161	0.1302	0.3053
Yield	P	0.3942*	0.5988**	0.513**	-0.268	0.4876**	-0.105	0.681**	0.5311**	0.1286
	G	0.4434	0.8114	0.5469	-0.28	0.6971	-0.112	0.8241	0.6699	0.1726

*Significant at P = 0.05, ** Significant at P = 0.01.
CHL-a; Chlorophyll-a, CHL-b; Chlorophyll-b, Total CHL; Total chlorophyll content, MSI; Membrane stability index, RWC; Relative water content.

Table 5: Estimates of phenotypic and genotypic correlation coefficient for seedling characters of mothbean at 40°C temperature

Characters		Germination percentage	Seedling length	Seedling fresh weight	Seedling dry weight	Seedling vigour index	Yield per plant
Germination percentage	P	1					
	G	1					
Seedling length	P	0.0413	1				
	G	0.1705	1				
Seedling fresh weight	P	0.1421	0.1606	1			
	G	0.458	0.089	1			
Seedling dry weight	P	0.2494	0.3897*	0.5622**	1		
	G	0.4433	0.5092	0.5361	1		
Seedling vigour index	P	0.734**	0.6529**	0.2109	0.3572*	1	
	G	0.9239	0.6748	0.2636	0.4354	1	
Yield per plant	P	0.204	-0.103	-0.342*	-0.05	0.0857	1
	G	0.2969	-0.13	-0.45	-0.042	0.0966	1

*Significant at P = 0.05, ** Significant at P = 0.01.

agro-morphological traits, at phenotypic level the highest positive direct effect on seed yield per plant was found for harvest index (0.7764) followed by biological yield per plant (0.3210), number of pods per plant (0.3192), days to maturity (0.2434) and pod length (0.0138); while the highest negative direct effect was found for days to 50 percent flowering (-0.1941), plant height (-0.0825), 100-seed weight (-0.0457) and number of seeds per pod (-0.0447). At genotypic level, the highest positive direct effect on seed yield per plant was found for days to maturity (1.0212), harvest index (0.9237), biological yield per plant (0.4273), number of pods per plant (0.2091) and pod length (0.0005); while the highest negative direct effect on seed yield per plant was found for days to 50 percent flowering (-0.9439), number of seeds per pod (-0.1167), plant height (-0.1087) and 100-seed weight (-0.0143) (Table 6) (Fig.1).

For physiological and seed traits, at phenotypic level the highest positive direct effect on seed yield per plant was reported for total chlorophyll content (3.5986), bulk density (0.1672), water absorption index (0.1420), relative water content (0.1374) and

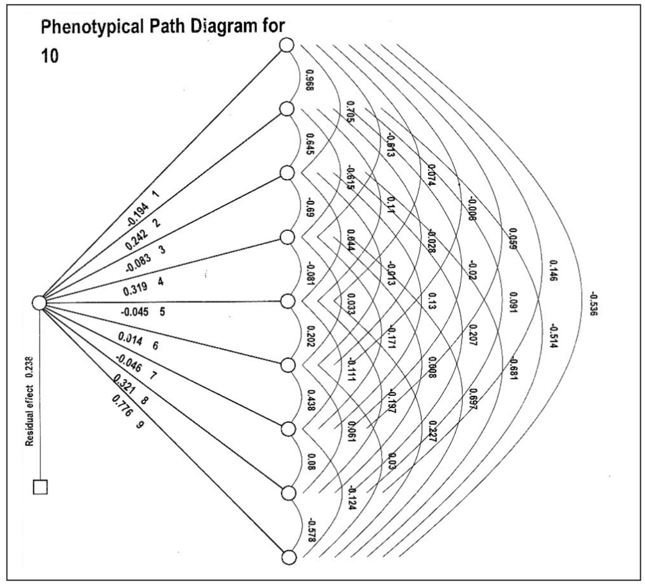

Fig. 1: At phenotypic level, path diagram of mothbean genotypes based on agro-morphological characters for seed yield.
1, Days to 50 percent flowering; 2, Days to maturity; 3, Plant height; 4, Number of pods per plant; 5, Number of seeds per pods; 6, Pod length; 7, 100-seed weight; 8, Biological yield per plant; 9, Harvest index; 10, Seed yield per plant.

Table 6: Estimation of phenotypic and genotypic path coefficient on seed yield for agro-morphological characters in mothbean

Characters		DF	DM	PH	NPP	NSP	PL	SW	BYP	HI
Days to 50 percent flowering	P	-0.194	-0.188	-0.137	0.119	-0.014	0.0012	-0.012	-0.028	0.104
	G	-0.944	-0.933	-0.769	0.5956	-0.09	0.0066	-0.063	-0.14	0.5106
Days to maturity	P	0.2345	0.2434	0.1563	-0.149	0.0268	-0.007	-0.005	0.022	-0.125
	G	1.0099	1.0212	0.7796	-0.655	0.1496	-0.036	0.0137	0.0962	-0.535
Plant height	P	-0.058	-0.053	-0.083	0.0569	-0.004	0.0011	-0.011	-0.017	0.0562\
	G	-0.089	-0.083	-0.109	0.0936	-0.004	0.0091	-0.033	-0.025	0.0879
No. of pods per plant	P	-0.196	-0.196	-0.22	0.3192	-0.026	0.0104	-0.055	0.0027	0.2225
	G	-0.132	-0.134	-0.18	0.2091	-0.025	0.009	-0.043	0.0002	0.1468
No. of seeds per pod	P	-0.003	-0.005	-0.002	0.0036	-0.045	-0.009	0.0049	0.0088	-0.01
	G	-0.011	-0.017	-0.004	0.014	-0.117	-0.011	0.0114	0.0286	-0.035
Pod length	P	-0.0001	-0.0004	-0.0002	0.0004	0.0028	0.0138	0.006	0.0008	0.0004
	G	0.00	0.00	0.00	0.00	0.0001	0.0005	0.0004	0.00	0.00
100-seed weight	P	-0.003	0.0009	-0.006	0.0078	0.005	-0.02	-0.046	-0.004	0.0057
	G	-0.001	-0.0002	0.0043	0.0029	0.0014	-0.011	-0.014	-0.002	0.0021
Biological yield per plant	P	0.0467	0.0291	0.0664	0.0027	-0.063	0.0196	0.0257	0.321	-0.186
	G	0.0634	0.0402	0.0965	0.0004	-0.105	0.038	0.0485	0.4273	-0.251
Harvest index	P	-0.416	-0.399	-0.529	0.5412	0.176	0.0236	-0.096	-0.449	0.7764
	G	-0.5	-0.484	-0.747	0.6488	0.2739	0.0435	-0.134	-0.543	0.9237
Seed yield per plant	P	-0.589**	-0.569**	-0.754**	0.9018**		0.0339	-0.187	-0.143	0.8451**
	G	-0.603	-0.591	-0.937	0.909	0.0841	0.0484	-0.213	-0.157	0.85

*Significant at P = 0.05, ** Significant at P = 0.01.
DF- Days to 50% flowering, DM-Days to maturity, PH-Plant height, NPP- No. of pods per plant, NSP- No. of seeds per pod, PL- Pod length, SW-100-seed weight, BYP-Biological yield per plant, HI- Harvest index.

particle/true density (0.1186); while the highest negative direct effect on seed yield per plant was reported for Chlorophyll-a (-2.7550), Chlorophyll-b (-0.6627), seed volume (-0.2140), porosity (-0.1891), membrane stability index (-0.1675) and water absorption capacity (-0.1332). At genotypic level, the highest positive direct effect on seed yield per plant was reported for particle density (2.3821), Chlorophyll-a (2.0344), water absorption capacity (1.5180), porosity (0.3707), bulk density (0.1130) and Chlorophyll-b (0.1128); while highest negative direct effect on seed yield per plant was found for total chlorophyll content (-3.7167), water absorption index (-2.1284), relative water content (-0.4441), membrane stability index (-0.4308) and seed volume (-0.1059) (Table 7) (Fig. 2).

For seedling traits at 40°C temperature, at phenotypic level, the highest positive direct effect on seed yield per plant was recorded for seedling vigour index (0.3549) and seedling dry weight (0.2457). In

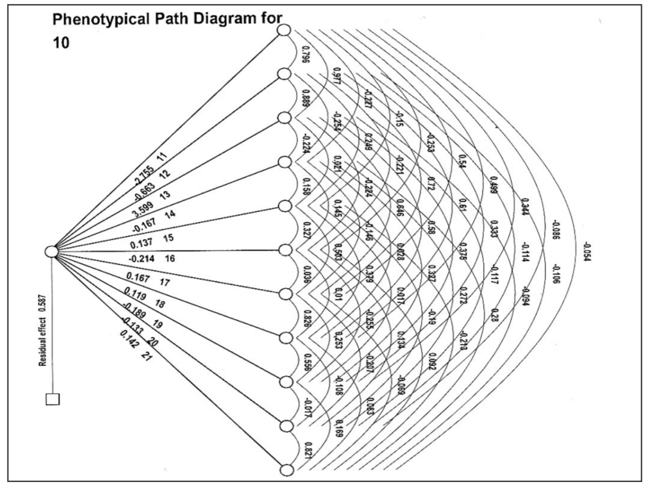

Fig. 2: At phenotypic level, path diagram of mothbean genotypes based on physiological and seed characters for seed yield.
10, Seed yield per plant; 11, Chlorophyll-a; 12, Chlorophyll-b; 13, Total chlorophyll content; 14, Membrane stability index; 15, Relative water content; 16, Seed volume; 17, Bulk density; 18, Particle/true density; 19, Porosity; 20, Water absorption capacity; 21, Water absorption index.

Table 7: Estimation of phenotypic and genotypic path coefficient on seed yield for physiological and seed characters in mothbean

Characters		CHL- a	CHL-b	Total CHL	MSI	RWC	Seed volume	Bulk density	Particle density	Porosity	WAC	WAI
CHL- a	P	-2.755	-2.193	-2.693	0.6248	0.4136	0.6966	-1.489	-1.376	-0.949	0.2362	0.1486
	G	2.0344	1.9608	2.0472	-0.492	-0.558	-0.662	1.532	1.3089	1.0072	-0.179	-0.108
CHL-b	P	-0.528	-0.663	-0.589	0.1681	-0.165	0.1462	-0.477	-0.404	-0.221	0.0757	0.0706
	G	0.1087	0.1128	0.1151	-0.04	0.0922	-0.042	0.1269	0.1061	0.0712	-0.013	-0.014
Total CHL	P	3.5171	3.2008	3.5986	-0.805	0.0772	-0.805	2.3257	2.0882	1.3506	-0.421	-0.34
	G	-3.74	-3.792	-3.717	0.8742	-0.335	1.0265	-3.068	-2.646	-1.875	0.4274	0.3648
MSI	P	0.038	0.0425	0.0374	-0.168	-0.027	-0.024	0.0244	-0.005	-0.055	-0.046	-0.047
	G	0.1042	0.154	0.1013	-0.431	-0.108	-0.084	0.0795	-0.017	-0.181	-0.141	-0.158
RWC	P	-0.021	0.0343	0.0029	0.0217	0.1374	0.0449	0.0691	0.0521	0.0023	-0.026	-0.029
	G	0.1218	-0.363	-0.04	-0.111	-0.444	-0.201	-0.413	-0.311	-0.03	0.1483	0.1682
Seed volume	P	0.0541	0.0472	0.0479	-0.031	-0.07	-0.214	-0.008	-0.002	0.0547	-0.029	-0.02
	G	0.0344	0.0393	0.0292	-0.021	-0.048	-0.106	0.0004	-0.002	0.0286	-0.019	-0.013
Bulk density	P	0.0904	0.1205	0.1081	-0.024	0.0842	0.006	0.1672	0.1381	0.0423	-0.035	-0.012
	G	0.0851	0.1272	0.0933	-0.021	0.1051	-0.0004	0.113	0.1163	0.0386	-0.035	-0.018
Particle density	P	0.0593	0.0724	0.0688	0.0033	0.045	0.0012	0.098	0.1186	0.066	-0.013	0.0099
	G	1.5327	2.2415	1.6961	0.0914	1.6678	0.0536	2.4524	2.3821	1.3571	-0.316	0.3101
Porosity	P	-0.065	-0.063	-0.071	-0.062	-0.003	0.0483	-0.048	-0.105	-0.189	0.0032	-0.032
	G	0.1836	0.234	0.187	0.1556	0.0253	-0.1	0.1267	0.2112	0.3707	0.0085	0.1132
WAC	P	0.0114	0.0152	0.0156	-0.036	0.0253	-0.018	0.0276	0.0144	0.0023	-0.133	-0.109
	G	-0.134	-0.169	-0.175	0.4955	-0.507	0.2649	-0.468	-0.202	0.0349	1.518	1.2161
WAI	P	-0.008	-0.015	-0.013	0.0397	-0.03	0.0131	-0.01	0.0118	0.024	0.1167	0.142
	G	0.1127	0.2666	0.2089	-0.781	0.8063	-0.262	0.3427	-0.277	-0.65	-1.705	-2.128
Yield	P	0.3942*	0.5988**	0.513**	-0.268	0.4876**	-0.105	0.681**	0.5311**	0.1286	-0.27	-0.217
	G	0.4434	0.8114	0.5469	-0.28	0.6971	-0.112	0.8241	0.6699	0.1726	-0.305	-0.267

*Significant at P = 0.05, ** Significant at P = 0.01.
CHL-a; Chlorophyll-a, CHL-b; Chlorophyll-b, Total CHL; Total chlorophyll content, MSI; Membrane stability index, RWC; Relative water content.

contrast, the highest negative direct effects on seed yield per plant were recorded for seedling fresh weight (-0.4945), seedling length (-0.3498) and germination percentage (-0.0330). At genotypic level, the highest positive direct effect on seed yield per plant was reported for seedling vigour index (0.7917) and seedling dry weight (0.5444). In contrast, the highest negative direct effect on seed yield per plant was reported for seedling length (-0.8417), seedling fresh weight (-0.7999) and germination percentage (-0.1659) (Table 8) (Fig. 3).

Harvest index, biological yield per plant, number of pods per plant, days to maturity, and pod length have all been shown to have a direct and positive effect on seed production per plant. Physiological and seed parameters, such as total chlorophyll, bulk density, water absorption index, relative water content, and particle density, have been shown to have a direct and positive effect on seed yield per plant. At 40°C, seedling parameters such as germination per cent, seedling vigour index, and seedling dry weight had a direct and positive effect on seed yield per plant.

Direct positive effects on seed yield per plant through harvest index and biological yield per plant have previously been reported by Sahoo *et al.,* (2018), Walle *et al.,* (2018), and Choudhary and Lal (2019). A direct positive effect on seed yield via the number of pods per plant has previously been reported by Khandait *et al.,* (2016), Kohakade *et al.,* (2017), Ramakrishnan *et al.,* (2018), Manivelan *et al.,* (2019)and Dhunde *et al.,* (2021). A direct positive effect on seed yield per plant via days to maturity was previously

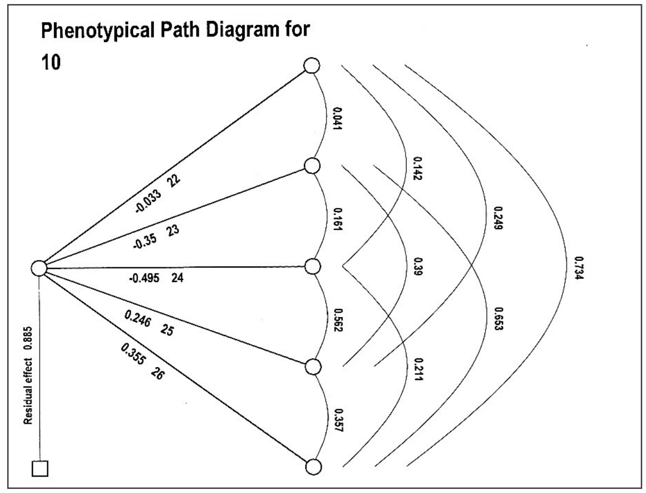

Fig. 3: At phenotypic level, path diagram of mothbean genotypes based on seedling characters at 40°C for seed yield.
10, Seed yield per plant; 22, Germination percentage at 40°C; 23, Seedling length at 40°C; 24, Seedling fresh weight at 40°C; 25, Seedling dry weight at 40°C;26, Seedling vigour index at 40°C.

reported by Sahoo *et al.,* (2018) and Walle *et al.,* (2018). Direct positive effect on seed yield per plant through pod length was previously reported by Khandait *et al.,* (2016) and Dhunde *et al.,* (2021).

Conclusion

The residual effect in path analysis was low for agro-morphological characters and moderate for physiological and seed characters, indicating that the characters included in this study could explain the majority of the effects on seed yield in mothbean. Based on the current study, the harvest index, biological yield

Table 8: Estimation of phenotypic and genotypic path coefficient on seed yield for seedling characters in mothbean at 40°C temperature regime

Characters		Germination percentage	Seedling length	Seedling fresh weight	Seedling dry weight	Seedling vigour index
Germination percentage	P	-0.033	-0.001	-0.005	-0.008	-0.024
	G	-0.166	-0.028	-0.076	-0.074	-0.153
Seedling length	P	-0.014	-0.35	-0.056	-0.136	-0.228
	G	-0.144	-0.842	-0.075	-0.429	-0.568
Seedling fresh weight	P	-0.07	-0.079	-0.495	-0.278	-0.104
	G	-0.366	-0.071	-0.8	-0.429	-0.211
Seedling dry weight	P	0.0613	0.0958	0.1382	0.2457	0.0878
	G	0.2413	0.2772	0.2918	0.5444	0.237
Seedling vigour index	P	0.2605	0.2317	0.0749	0.1268	0.3549
	G	0.7314	0.5342	0.2087	0.3447	0.7917
Seed yield per plant	P	0.204	-0.103	-0.342*	-0.05	0.0857
	G	0.2969	-0.13	-0.45	-0.042	0.0966

*Significant at P = 0.05, ** Significant at P = 0.01.

per plant, number of pods per plant, days to maturity, and pod length had the highest direct positive effects on seed yield per plant. Thus, selection for such characteristics may prove effective for increasing mothbean seed yield.

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