Correlation coefficient and path coefficient analysis for yield and its component traits in common bean (*Phaseolus vulgaris L.*) germplasm

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Abstract
The present experiment was carried out to evaluate genetic variability and correlation among different components of *Phaseolus vulgaris* L. germplasm. An earthen pot experiment was established by utilizing forty common bean accessions at University of Agriculture, Faisalabad, Pakistan in 2019-2020. For this purpose complete randomized design with four replications was followed in this trial. Data was statistically analyzed for correlation co-efficient and path co-efficient analysis that revealed high genetic diversity among common bean accessions for seventeen components that were under study. Co-efficient of variation for genetic and phenotypic variability showed highly significant observations. Seed weight per plant showed highly significant and variable relationship with days to harvesting, stem and leaf area, number of leaves/plant, branches/plant, pods/plant, pod length and width, no of seeds/pod, root length, shoot length, root fresh and root dry mass. Seed mass/plant showed positive and direct effect with days to pod development, pods/plant and pod length. The observed outcomes obtained from correlation co-efficient and path co-efficient analysis showed differential results and recognized seed mass/plant and seed yield as an effective components of common bean that should be increased through selection criterion.
Key words: Common bean *(Phaseolus vulgaris* L.), germplasm, genotypic and phenotypic variability, correlation

Introduction

Common bean is a dual purpose and historically legume crop which is densely rich in its nutritional value (Bitocchi *et al*. 2012). Beans from fabaceae family with genus *Phaseolus* L. commonly recognized as kidney bean with 22 number of chromosomes. This highly variable legume crop has bush as well as pole varieties (Raggi *et al*. 2019). It has variety of common names in different parts of world; gewone boon (Dutch), maharage (Swahili), fagiolo (Italy), fasulye (Turkey), string beans (English), vainita (Spanish), feijoeiro (Portuguese), buncis (Indonesia) (Sherasia *et al*., 2017). Short and curved hairy stem, trifoliate leaves, bisexual keeled multicolored flowers, seed pods with different sized and colored seeds made common beans more unique (Brink and Belay, 2006; Wortmann, 2006; Freytag and Debouck, 2002). Due to its Mesoamerican origin, this dual purpose crop species is an important distinguished model for evolutionary investigations and is also under study for its high genetic variability (Bitocchi *et al*., 2012).

Phaseolus vulgaris L. the most diverse crop can be utilized as fodder and as well as a grain crop and this diversity made this crop more difficult to describe (Kwak and Gepts, 2009). Worldwide its production is effectively increased. Mexico, India, China and Brazil are the major producers for green and dry beans (Gentry, 1969). About 25 MT of beans are being cultivated per year throughout the world. China is distinguished as major producer for green beans with annual production of 19MT and India as the major producer for dry bean production with 62MT annually (FAOSTAT, 2020). Thailand, America and Turkey are also considered as major producers for kidney beans. In Pakistan, common bean is considered as a minor legume and grown on small area as a non-conventional crop. Only red kidney beans are cultivated on small area. It is cultivated in Chitral, Dir, Kohistan, Shangla, Punjab and Sindh province with 6912KT annual production. Increased population rate, unsustainable management practices, unawareness about its nutritional rich values, fluctuating weather conditions are the main reasons for its reduced harvest (Jabbar and Malick, 1994).

As variability is an important measurement of inclination of individual genotypes to differentiate from other populations. Though, by checking genetic variations present among different accessions, a breeder has many options for selecting a healthy and suitable crop for future use. As variability is an important parameter, it helps to build selection criteria for future breeding programs (Sharma *et al*., 2009). Yield is an important factor to determine the crop improvement. Common bean seed yield is controlled by many traits like pod number per plant, pod length, per pod seed number and seed mass, all are important in plant breeding and these traits are related to genetic variability and heritability among varieties (Nechifor, 2011).

Genetic variability is a key concept to develop better cultivars. Population factors and the major processes that enhanced genetic variations are in need to be sharped (Bhushan *et al*., 2008). For improvement in yield, selection process is based on component characters and various other traits that show mutual relationships, correlation coefficient analysis is followed by plant breeders (Songsri *et al*., 2008). Correlation analysis is frequently used statistical approach for evaluation of conflicting characters to seed yield (Singh *et al*., 2009). To study genotypic and phenotypic variations, correlation studies helps in selecting desirable character and it is a basic technique to describe relationship among independent traits (Bitew, 2016; Kamboj, 2007). For obtaining sustainable and profitable yields, common beans could be recommended to farmers for utilization to enhance yield and to maximize their profits ((Ndakidemi *et al*., 2006). Common bean producers have concern towards increasing pods per plant by selecting a favorable accession in our changing climate due to global warming. Hence, variability among genotypes is a major need of time. This unaccomplished but potential crop in Pakistan needed to be focused and considered as a star crop in developing countries.

Materials and Methods

Germplasm collection

Total 40 common bean accessions were under observation in this experiment. This germplasm was collected from National Agriculture Research Centre (NARC), Islamabad, Pakistan. Germplasm with code number and picture is presented in Table 1.

Experimental conditions

These forty accessions were planted in earthen pots at research area of Plant Breeding and Genetics Department, University of Agriculture, Faisalabad. Complete Randomized design was followed for this purpose with four replications. Seeds were sown in earthern pots during the month of September, 2019. Diammonium phosphate (DAP) was applied to soil during pot filling. Soil analysis is given here by calculating average values for five different samples in Table 2. All normal crop management practices were carried out properly by following weeding,

disease and pest examinations to protect plant from any kind of damage. Weather data during research period is presented in Table 3.

Recorded data

Seventeen characters were studied for each common bean accession. After 40 days of sowing data were recorded for individual plant. Recorded characters are presented in Table 4 with their codes and measurement procedures.

Statistical analysis

For analyzing different agronomic characters, recorded data were subjected to correlation co-efficient and path co-efficient analysis for complete randomized design. Correlation coefficients were examined for their significance at the probability levels of 0.05. Path coefficient analysis was done based on the genotypic correlation coefficient. Seed weight per plant was observed as the dependent variable and the other characters as descriptive independent variables. The path analysis was carried out as given by the method of Dewey and Lu (1959).

Table 1: Germplasm description by code number, color and source.

Serial No.	Accession code	Seed Color	Source
1	36121	Dark brown patches	NARC, Islamabad
2	36122	Purple	NARC, Islamabad
3	36131	Brown	NARC, Islamabad
4	36139	Light Pink	NARC, Islamabad
5	36140	Pinkish green	NARC, Islamabad
6	36141	Cream color	NARC, Islamabad
7	36144	Black	NARC, Islamabad
8	36148	White	NARC, Islamabad
9	36153	Skin color	NARC, Islamabad
10	36156	Dark Blue	NARC, Islamabad
11	36160	White	NARC, Islamabad
12	36161	Purple	NARC, Islamabad
13	36165	Purple	NARC, Islamabad
14	36166	Purple with dark dots	NARC, Islamabad
15	36170	Black	NARC, Islamabad
16	36172	Pink	NARC, Islamabad
17	36173	Pink with dark patches	NARC, Islamabad
18	36177	Purple	NARC, Islamabad
19	36179	Brown	NARC, Islamabad
20	36180	Black	NARC, Islamabad
21	36182	Skin	NARC, Islamabad
22	36185	Black	NARC, Islamabad
23	36193	Black	NARC, Islamabad
24	36194	Cream	NARC, Islamabad
25	36199	Skin	NARC, Islamabad
26	36202	Black	NARC, Islamabad
27	36203	Black	NARC, Islamabad
28	36213	Purplish white	NARC, Islamabad
29	36214	Black	NARC, Islamabad
30	36220	Pink with dark patches	NARC, Islamabad
31	36223	Dark brown	NARC, Islamabad
32	36229	Light brown	NARC, Islamabad
33	36230	Skin	NARC, Islamabad
34	36234	Light brown	NARC, Islamabad
35	36236	Cream	NARC, Islamabad
36	36237	Skin with dark patches	NARC, Islamabad
37	36241	Dark brown patches	NARC, Islamabad
38	26242	Skin with dark patches	NARC, Islamabad
39	36243	Half white	NARC, Islamabad
40	36248	Purple	NARC, Islamabad

Table 2: Parameters with abbreviated codes and sampling methods.

Abbreviation	Parameter	Sampling Method
RDW	Root dry weight	After sundry, carefully measured in grams
RFW	Root fresh weight	Immediately after harvesting and separating from the main stem, measured in grams on weighing balance
RL	Root length	After harvesting, measured in cm from downside of main stem below the ground surface to the tip of the root
SWPP	Seed weight per pod	Per plant seed weight in grams and average values for 5 plants recorded.
SPP	Seeds per pod	Average Seed number counted per randomly selected pods from sample plants
DH	Days to harvesting	Counted Number of days from sowing to harvesting
PW	Pod width	Measured in mm from up and down corners and middle of the pods (from 3 sites) by using vernier caliper after maturation
PL	Pod length	At physiological maturity, pod apex to peduncle, pod length measured in cm after harvesting
PPP	Pods per plant	Average pods number counted after maturity from randomly selected sample flora.
DPF	Days to pod formation	Days counted from flowering to 50% pod formation.
DF	Days to flowering	Days from emergence to 50% flowering on selected plants.
BPP	Branches per plant	Number of main branches counted from main stem above the ground.
LA	Leaf area	Three individual values for Length and width of selected healthy leaves from sample plants in cm.
LPP	Leaves per Plant	Total number of leaves counted per sample plants and then average values recorded.
SA	Stem Area	Plant height multiplied with width that was measured from three different sites and average values estimated.
PH	Plant Height	From surface above the ground to the tip of the stem measured in cm.
DE	Days to Emergence	From days of sowing to the number of days to 50% emergence of seeds.

Table 3: Soil Analysis

Sample Depth (cm)	EC mS/cm	Soil pH	Organic Matter (%)	Available phosphorus (ppm)	Available potassium (ppm)	Saturation (%age)	Texture	Gypsum required (tone/acre)
0-30	2.24	5	1.19	6.06	216	33.6	Loam	1.42

Table 4: Weather record during experimental period of common bean

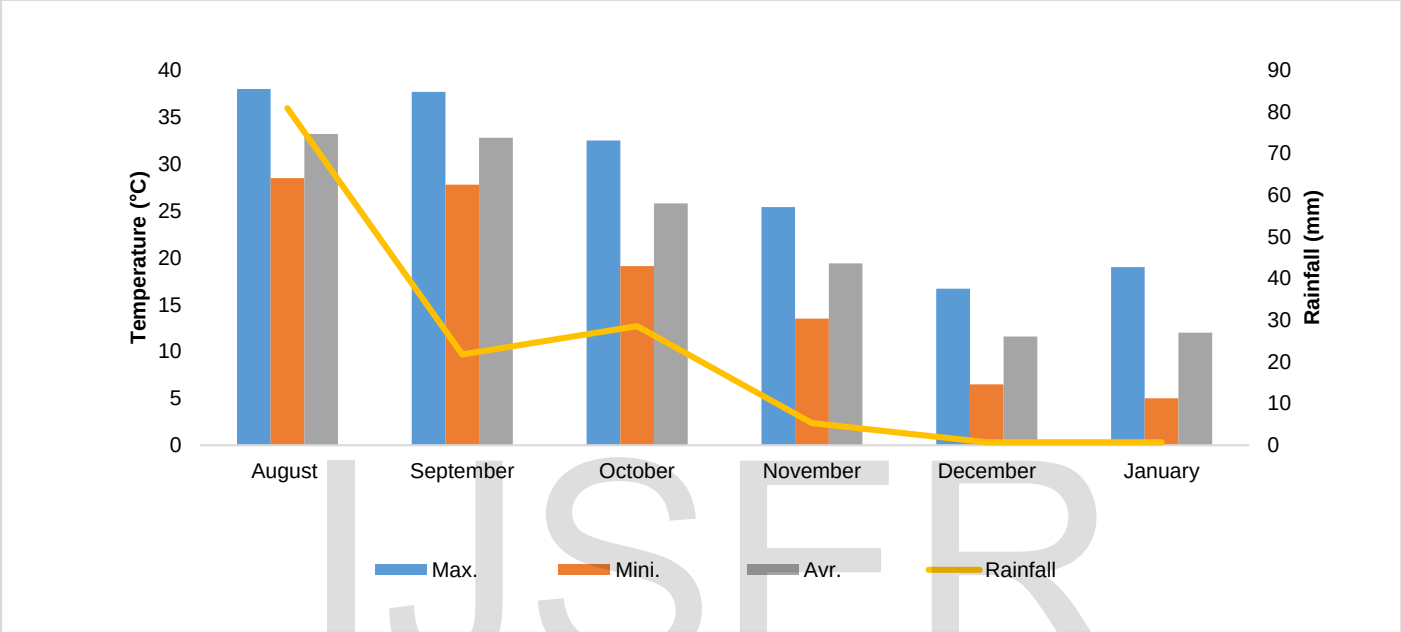

Table 5(a): Genotypic Correlation coefficient of quantitative and qualitative traits in common bean accessions.

	DE	PH	SA	LA	LPP	BPP	DF	DPF	PPP	PL	PW	SPP	SWPP	DH	RFW	RDW
PH	-0.247**															
SA	-0.264**	0.961**														
LA	-0.197**	0.338**	0.396**													
LPP	-0.108	0.752**	0.744**	0.394**												
BPP	-0.056	0.773**	0.777**	0.419**	0.954**											
DF	0.126	-0.182*	-0.188*	0.008	-0.205**	-0.225**										
DPF	-0.008	-0.083	-0.025	0.193**	-0.016	-0.053	0.866**									
PPP	-0.333**	0.277**	0.351**	0.428**	0.314**	0.313**	-0.141	0.143								
PL	-0.322**	0.536**	0.558**	0.489**	0.451**	0.462**	-0.168*	0.104	0.641**							
PW	-0.384**	0.461**	0.458**	0.380**	0.366**	0.394**	-0.216**	-0.018	0.408**	0.724**						
SPP	-0.234**	0.457**	0.508**	0.475**	0.426**	0.477**	-0.168*	0.108	0.752**	0.843**	0.601**					
SWPP	-0.394**	0.502**	0.598**	0.483**	0.476**	0.487**	-0.185*	0.080	0.793**	0.757**	0.657**	0.718**				
DH	0.060	0.098	0.109	0.396**	0.285**	0.284**	0.204**	0.389**	0.340**	0.309**	0.101	0.312**	0.161*			
RFW	-0.129	0.480**	0.532**	0.326**	0.258**	0.344**	-0.034	0.008	0.391**	0.425**	0.250**	0.436**	0.365**	0.131		
RDW	-0.160	0.448**	0.462**	0.170*	0.107	0.175*	-0.052	-0.057	0.297**	0.412**	0.217**	0.375**	0.285**	0.037	0.848**	
RL	-0.023	0.413**	0.426**	0.287**	0.445**	0.488**	-0.212**	-0.037	0.419**	0.594**	0.479**	0.561**	0.366**	0.323**	0.639**	0.465**

DE = Days to Emergence, **PH** = Plant Height, **SA** = Stem Area, **LPP** = Leaves per Plant, **BPP** = Branches Per Plant, **RFW** = Root Fresh Weight, **RDW** = Root Dry Weight, **DF** = Days to Flowering, **DPF** = Days to Pod Formation, **DH** = Days to Harvesting, **PPP** = Pods Per Plant, **PL** = Pod Length, **SPP** = Seed Per Pod, **SWPP** = Seed Weight Per Plant, **LA** = Leaf Area, **PW** = Pod Width, **RL** = Root Length, * = Significant, ** = Highly Significant

Table 5(b): Phenotypic Correlation coefficient of quantitative and qualitative traits in common bean accessions.

	DE	PH	SA	LA	LPP	BPP	DF	DPF	PPP	PL	PW	SPP	SWPP	DH	RFW	RDW
PH	-0.240**															
SA	-0.259**	0.959**														
LA	-0.193*	0.336**	0.394**													
LPP	-0.105	0.743**	0.735**	0.391**												
BPP	-0.055	0.766**	0.770**	0.417**	0.945**											
DF	0.124	-0.179*	-0.185*	0.009	-0.200**	-0.221**										
DPF	-0.004	-0.081	-0.025	0.191*	-0.014	-0.048	0.853									
PPP	-0.323**	0.272**	0.345**	0.422**	0.309**	0.309**	-0.132	0.139								
PL	-0.314**	0.530**	0.552**	0.485**	0.446**	0.457**	-0.159*	0.105	0.631**							
PW	-0.358**	0.440**	0.436**	0.364**	0.347**	0.377**	-0.201**	-0.006	0.391**	0.684**						
SPP	-0.223**	0.440**	0.489**	0.455**	0.413**	0.459**	-0.145	0.111	0.732**	0.819**	0.554**					
SWPP	-0.385**	0.498**	0.593**	0.480**	0.472**	0.483**	-0.181*	0.076	0.785**	0.751**	0.620**	0.694**				
DH	0.059	0.097	0.108	0.382	0.270**	0.281**	0.199**	0.370**	0.328**	0.295**	0.097	0.298**	0.156*			
RFW	-0.127	0.473**	0.525**	0.323**	0.256**	0.341**	-0.034	0.007	0.383**	0.421**	0.230**	0.413**	0.362**	0.129**		
RDW	-0.156*	0.439**	0.451**	0.165*	0.108	0.176*	-0.049	-0.052	0.292**	0.400**	0.205**	0.356**	0.277**	0.062	0.827**	
RL	-0.023	0.404**	0.415**	0.281**	0.430**	0.477**	-0.205**	-0.036	0.410**	0.579**	0.450**	0.533**	0.359**	0.315**	0.622**	0.453**

DE = Days to Emergence, **PH** = Plant Height, **SA** = Stem Area, **LPP** = Leaves per Plant, **BPP** = Branches Per Plant, **RFW** = Root Fresh Weight, **RDW** = Root Dry Weight, **DF** = Days to Flowering, **DPF** = Days to Pod Formation, **DH** = Days to Harvesting, **PPP** = Pods Per Plant, **PL** = Pod Length, **SPP** = Seed Per Pod, **SWPP** = Seed Weight Per Plant, **LA** = Leaf Area, **PW** = Pod Width, **RL** = Root Length, * = Significant, ** = Highly Significantly

Table 6: Path co-efficient analysis (Direct and indirect effect)

	DE	PH	SA	LA	LPP	BPP	DF	DPF	PPP	PL	PW	SPP	DH	RFW	RDW	RL
DE	**9.3560**	0.0051	-0.0350	-0.0272	0.0254	-0.0158	-0.0149	-0.0020	-0.1369	-0.1101	0.0352	0.1050	-0.0081	0.0078	0.0125	-0.0004
PH	-2.3062	**-0.0207**	0.1273	0.0466	-0.1769	0.2200	0.0215	-0.0203	0.1139	0.1834	-0.0422	-0.2052	-0.0132	-0.0290	-0.0350	0.0075
SA	-2.4725	-0.0199	**0.1326**	0.0547	-0.1751	0.2212	0.0221	-0.0061	0.1442	0.1912	-0.0420	-0.2279	-0.0145	-0.0322	-0.0362	0.0078
LA	-1.8460	-0.0070	0.0525	**0.1380**	-0.0928	0.1192	-0.0009	0.0474	0.1762	0.1673	-0.0348	-0.2129	-0.0529	-0.0197	-0.0133	0.0052
LPP	-1.0119	-0.0155	0.0987	0.0544	**-0.2353**	0.2716	0.0242	-0.0039	0.1290	0.1545	-0.0335	-0.1911	-0.0381	-0.0156	-0.0084	0.0081
BPP	-5.2029	-0.0160	0.1030	0.0578	-0.2246	**0.2845**	0.0265	-0.0129	0.1289	0.1583	-0.0361	-0.2142	-0.0380	-0.0208	-0.0137	0.0089
DF	1.1824	0.0038	-0.0249	0.0011	0.0483	-0.0641	**-0.1178**	0.2123	-0.0578	-0.0574	0.0198	0.0752	-0.0273	0.0020	0.0041	-0.0039
DPF	-7.5615	0.0017	-0.0033	0.0267	0.0038	-0.0150	-0.1020	**0.2452**	0.0590	0.0354	0.0017	-0.0486	-0.0520	-0.0005	0.0045	-0.0007
PPP	-3.1123	-0.0057	0.0465	0.0591	-0.0738	0.0892	0.0165	0.0351	**0.4115**	0.2194	-0.0373	-0.3372	-0.0455	-0.0236	-0.0233	0.0076
PL	-3.0079	-0.0111	0.0740	0.0674	-0.1062	0.1315	0.0197	0.0254	0.2637	**0.3424**	-0.0663	-0.3783	-0.0413	-0.0257	-0.0322	0.0108
PW	-3.5952	-0.0095	0.0608	0.0524	-0.0862	0.1122	0.0254	-0.0045	0.1677	0.2480	**-0.0916**	-0.2697	-0.0135	-0.0151	-0.0170	0.0087
SPP	-2.1903	-0.0095	0.0673	0.0655	-0.1002	0.1358	0.0197	0.0266	0.3092	0.2887	-0.0550	**-0.4487**	-0.0417	-0.0264	-0.0293	0.0102
DH	5.6355	-0.0020	0.0144	0.0546	-0.0670	0.0808	-0.0241	0.0953	0.1400	0.1059	-0.0092	-0.1401	**-0.1337**	-0.0079	-0.0029	0.0059
RFW	-1.2099	-0.0099	0.0705	0.0449	-0.0606	0.0979	0.0040	0.0020	0.1609	0.1455	-0.0229	-0.1956	-0.0176	**-0.0605**	-0.0663	0.0116
RDW	-1.5008	-0.0093	0.0613	0.0234	-0.0252	0.0499	0.0061	-0.0140	0.1223	0.1411	-0.0199	-0.1684	-0.0049	-0.0513	**-0.0782**	0.0085
RL	-2.1507	-0.0085	0.0565	0.0396	-0.1048	0.1389	0.0250	-0.0091	0.1725	0.2032	-0.0438	-0.2517	-0.0432	-0.0386	-0.0364	**0.0182**

DE = Days to Emergence, **PH** = Plant Height, **SA** = Stem Area, **LPP** = Leaves per Plant, **BPP** = Branches Per Plant, **RFW** = Root Fresh Weight, **RDW** = Root Dry Weight, **DF** = Days to Flowering, **DPF** = Days to Pod Formation, **DH** = Days to Harvesting, **PPP** = Pods Per Plant, **PL** = Pod Length, **SPP** = Seed Per Pod, **SWPP** = Seed Weight Per Plant, **LA** = Leaf Area, **PW** = Pod Width, **RL** = Root Length, * = Significant, ** = Highly Significantly

Results

Correlation co-efficient analysis

Seed weight per plant (Seed yield) in *Phaseolus vulgaris* L. is a quantitative character with multiplex nature, which is controlled by genes (major and minor) and affected by variations in the environmental impact. This correlation develop a criteria for the direct selection of seed yield that is a complex process. With seed mass per plant, another trait is also selected that correlate with its effect and it will facilitate the selection methods more smoothly (Goncalves et al. 2003). Therefore, it is mandatory to explain the inter-relationship between seed weight per plant with its related parameters in common bean. To study genotypic and phenotypic variations on yield and its related traits of common bean, correlation co-efficient analysis are presented in table 4 (a) and (b). Seed mass plant -1 showed positive and highly variable correlation with plant length (0.498), seed/pod (0.694), pods/plant (0.785), pod length (0.751) and pod width (0.620) at phenotypic level and expressed positive and significant relationship with plant height (0.502). Pods plant -1 (0.793), pod length with 0.757, pod width (0.667) and seed weight/plant (0.718) at genotypic extent. These outcomes indicated strong interrelationship with these yield attributing characters. Yield of common beans can be enhanced by suggesting these traits in crop yield improvement strategies. Plant height showed positive correlation with pods/plant (0.277), pod length (0.536), pod width (0.461) at genotypic extent and seeds/pod (0.440), seed mass/plant with 0.498, pods/plant (0.272), branches plant -1 (0.766) at phenotypic level. Seeds/pod represented positive variable association with seed weight plant-1 (0.718), pod length (0.843), pod width (0.601) and pod length (0.843), plant height (0.457) at genotypic correlation co-efficient while on the other hand, at phenotypic level, seeds pod -1 also exhibited positive correlation with plant height (0.440), branches /plant (0.459) and pod width (0.554). Pods per plant positively correlated with branches/plant (0.309), pod length (0.631) and pod width (0.391) at phenotypic extent. On the other hand, at genotypic level, it also showed positive and variable link with seeds/pod (0.732), seed mass/plant (0.785), plant height (0.272) and with days to harvesting (0.328). These observations suggested to select some higher parameters that are expected to boot seed mass in common bean germplasm. Plant length and number of pods/plant have observed as correlated with seed yield/plant. These outcomes find out the true association with seed weight and considered as seed mass/plant predictors, according to which we can select plants with more height directly and with more number of pods/plant that can perform better and enhance seed yield/plant. Gonçalves et al. (2017) also observed stated these desired traits with strong correlation are crucial for selection in plant breeding. Significant results were observed in Anunda et al. (2019) findings with common beans. Studies of Aklade et al. (2018) on French bean also contributed in variable findings with present outcomes. Positive and significant results were also described by Alghamdi, 2007 in Phaseolus vulgaris L. plant height, pods/plant, and branches/plant and with other characters. Variable outcomes of Shah et al. (1996); Rai et al. (2004); Bhushan et al. (2007) were also observed in bush beans. Positive and variable results of Kumar et al. (2014); Ballat and Araby, (2019) were also in accordance with present study findings.

Path analysis

Association between variable parameters is measured by correlation co-efficient. However, an indirect effect of a third character may be a reason of association between two traits and there is a possibility of ambiguous results. So, it is mandatory to evaluate the source and its effective link among variables. Path co-efficient analysis splits the correlation between different parameters into direct and indirect effects by utilizing independent variables (Ahmed and Kamal Uddin, 2013). Path analysis was performed to evaluate direct and indirect effects of depending variable with independent characters. In path analysis, seed weight plant -1 was taken as dependent while others were taken as independent variables. In selection of high yielding plants, path analysis proved as a better technical approach. Table 5 represented direct and indirect effects of path co-efficient analysis for variable character with other parameters. Seed weight plant -1 showed direct and positive effect with days to pod formation (0.2452), pods per plant (0.4115) and with pod length (0.3424). Positive and direct relationship was observed in pods plant -1 with seed weight/plant. Goncalves et al. (2003) observed grain yield per plant and number of pods/plant were also as explanatory parameters. Direct relationship was also observed with pods length. Similar results were observed with Aklade et al. (2018) findings. Awan et al. (2014) also observed same outcomes. Ahmed and Kamal Uddin, (2013) also reported same results with seed yield, seeds/pod, plant height and other variable characters. Onder et al. (2013) observed results were same as present outcomes in French beans. Positive and direct results were find out as observed in this present study. Ribeiro et al. (2016) observations were also in accordance with present findings. Kumar et al. (2014) also reported similar variable results. Alemu et al. (2017) and Ejara et al. (2017) also presented variably and significant findings with present experimental observation.

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CONCLUSION

In current study, highly significant outcomes observed for genetic variability among 40 common bean accessions for all studied characters. In correlation co-efficient and path co-efficient analysis, remarkable results were found. In present study, 36180, 36202, 36182, 36156, 36165, 36193 accession numbers are selected as high yielding genotypes. The inter-association among morphological, phenological yield related and quantitative parameters are of vital importance in selecting the best accession of common bean for breeding programs.

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