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Correlation and path coefficient analysis of yield and yield components of some Ethiopian faba bean (*Vicia faba* L.) accessions

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Correlation and path coefficient analysis of yield and yield components of some Ethiopian faba bean (*Vicia faba* L.) accessions

Abstract: The knowledge of correlation and path coefficient analysis allow crop breeders to practice indirect selection to improve traits like grain yield which are complex in nature. The objectives of the present study were to measure association among yield and yield related traits and to identify important traits for indirect selection to improve faba bean grain yield. Eighty-one faba bean accessions were evaluated following 9 × 9 simple lattice design at one of the Bahir Dar University research sites at Mecha district in 2019 rainy cropping season. The result of correlation analysis revealed that grain yield had highly significant ($p < 0.01$) and positive phenotypic and genotypic correlations with plant height, pod length, number of pods per plant, number of branches per plant, biomass yield, 100-seed mass and harvest index indicating the possibility of simultaneous improvement of grain yield with these traits through selection. Path coefficient analysis demonstrated that higher positive direct effects were exerted by biomass yield and harvest index on grain yield both at phenotypic and genotypic levels, as a result, these traits could be used as indirect selection criteria to improve faba bean grain yield.

Key words: correlation; faba bean; indirect selection; path analysis; selection criteria

Korelacijska in usmerjene multipla regresijska analiza pridelka in njegovih komponent nekaterih etiopskih akcesij boba (*Vicia faba* L.)

Izvleček: Poznavanje korelacije in usmerjene multiple regresijske analize omogoča žlahtniteljem posreden izbor za izboljšanje lastnosti kot je pridelek zrnja, na katerega vplivajo v naravi številni dejavniki. Namen te raziskave je bil izmeriti povezave med pridelkom in z njim povezanimi lastnostmi in določiti pomembne lastnosti za posreden izbor izboljšanja pridelka zrnja pri bobu. Enainosemdeset akcesij boba je bilo ovrednotenih v 9 × 9 nepopolnem bločnem poskusu na raziskovalnem polju Bahir Dar University, v območju Mecha, v deževni dobi pridelovalne sezone 2019. Rezultati korelacijske analize so odkrili, da je pridelek zrnja visoko značilno ($p < 0.01$) in pozitivno feno-in genotipsko povezan z višino rastlin, dolžino strokov, številom strokov na rastlino, številom poganjkov na rastlino, biomaso, maso 100-semen. Usmerjena multipla regresijska analiza je pokazala, da so bili večji neposredni pozitivni učinki na pridelek zrnja izraženi s pridelkom biomase in žetvenim indeksom na feno- in genotipski ravni. Na osnovi teh rezultatov bi se te lastnosti lahko uporabile kot posredni selekcijski kriteriji za za izboljšanje pridelka zrnja pri bobu.

Ključne besede: korelacija; bob; posredna selekcija; usmerjena multipla regresijska analiza; selekcijski kriteriji

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1 INTRODUCTION

Faba bean (*Vicia faba* L.), is one of the earliest domesticated food legumes in the world (Singh et al., 2013). Faba bean is one of the most important legume crops and is believed to have originated in the Near East and cultivation started early in Neolithic times, 8000 B.C. (Cubero, 1974; Torres et al., 2006; Karkanis et al., 2018).

Ethiopia is the second largest producer of faba bean in the world after China (Mussa Jarso and Gemechu Keneni, 2006). According to CSA (2016), a faba bean is important pulse covering 3.56 % (about 443,966.09 hectares) of the grain crop area. The report also revealed that the production obtained from faba bean, was 3.18 % (about 848654.57 ton) of the grain production. Between 2007 and 2017 the area under faba bean cultivation was decreased from 520,519 to 437,106 ha (16.02 %) whereas the production and productivity during the corresponding period was increased from 0.69 to 0.92 million ton (25 %) and 1.323 to 2.109 t ha^{-1}(37.27 %), respectively (CSA, 2017). Faba bean has a versatile use and it is an important source of dietary protein to the majority of population in Ethiopia (Mussa Jarso and Fasil Assefa, 2014), while its dry seeds, green haulm and dry straw are used as animal fodder. Faba bean seeds contain proteins, carbohydrates, vitamin B, antioxidants and minerals. Protein content in different varieties varies from 26 % to 41 % (Picard, 1977). Carbohydrate contents varies from 51 % to 68 %, of which major proportion is contributed by starch (41–53 %) (Cerning et al., 1975).

Studies on genotypic and phenotypic correlations among traits of crop plants are useful in planning, evaluating and setting selection criteria for the desired traits in breeding programs (Johanson et al., 1955). Correlations between different traits of crops may arise either from genotypic or environmental factors. Environmental correlations arise from the effect of environmental factors that vary at different environments. Correlations due to genetic causes are mainly pleiotropic effects and linkage between genes affecting different traits (Falconer and Mackay, 1996). When more traits are considered in correlation studies, correlations of traits become more complex; therefore, correlation study followed by path analysis will help to identify yield attributing traits.

Path analysis provides precise picture of character associations for formulating efficient selection strategy. It differs from simple correlation in that it points out the causes and their relative importance, whereas the later measures the mutual association ignoring the causation. The concept of path coefficient was developed by Wright (1921) and it was first used for plant selection by Dewey and Lu (1959). Path coefficient analysis is a standardized partial regression which measures the direct and indirect contribution of independent traits on a dependent trait. Hence, it measures the influence of a trait up on another; and permits the separation of the correlation coefficient into components of direct and indirect effects (Dewey and Lu, 1959). Therefore, the present study was conducted to assess association among yield and yield related traits and to identify important traits for indirect selection to improve faba bean grain yield.

2 MATERIALS AND METHODS

2.1 EXPERIMENTAL SITE, MATERIALS AND DESIGN

The experiment was conducted at one of Bahir Dar University research sites in Mecha district of West Gojjam zone of Amhara region, Ethiopia in 2019 main cropping season. Mecha is located about 525 km Northeast of Addis Ababa and 34 km Southwest of Bahir Dar. It is located at latitude of 10°30’ N and longitude of 37°29’ E. It receives annual rainfall of 1572 mm. The mean temperature ranges between 24 °C and 27 °C; and the altitude is 2009 m. a. s. l.

The faba bean genotypes used in the present study include seventy-eight accessions obtained from Ethiopian Biodiversity Institute, two standard checks obtained from Adet Agricultural Research Center, and a local check from local source; 81 in total (Table 1).

The experimental design used was 9 × 9 simple lattice. Each accession was planted on two-row plot. Spacing between rows and between plants were 40 cm and 10 cm, respectively. The plot size was 0.8 m x 1 m (0.8 m^2). Spacing between blocks was 1 meter.

2.2 DATA COLLECTION AND ANALYSES

2.2.1 Data collection

Depending on the nature of traits data were collected on plot and plant basis. Plant height (cm), pod length (cm), number of pods per plant, number of branches were collected on plant basis for which mean of five plants from each plot was used for analysis. Days to 50 % flowering, grain yield (g/plot), 100-seed mass (g), biomass yield (g/plot), harvest index (%), diseases score were gathered on plot basis. Diseases score include the incidence of ascochyta blight, chocolate spot and rust diseases. Each disease was scored using 1-9 score method (where 1 refers highly resistance and 9 indicate highly susceptible) according to Bernier et al. (1993).

Table 1: List of the 81 faba bean accessions used in the study

Number	Accession	Collection Region	District	Number	Accession	Collection Region	District
1	212565	Amhara	Siyadebrina Wayu	42	235709	SNNP	Dirashe Special
2	27279	Amhara	Machakel	43	219089	Oromiya	Amigna
3	25299	SNNP	Angacha	44	25338	SNNP	Meskanena Mareko
4	245140	SNNP	Dila Zuria	45	215748	Amhara	Dessie Zuria
5	212566	Oromiya	Wuchalena Jido	46	213211	Oromiya	Tiro Afeta
6	25006	Amhara	Hulet Ej Enese	47	25336	SNNP	Meskanena Mareko
7	212568	Amhara	Siyadebrina Wayu	48	226125	Amhara	Legambo
8	25018	Oromiya	Wuchalena Jido	49	240497	SNNP	Decha
9	27052	Oromiya	Kofele	50	25346	SNNP	Meskanena Mareko
10	25274	Oromiya	Becho	51	25328	SNNP	Selti
11	229303	Amhara	Lay Betna Tach Bet	52	213214	Oromiya	Limu Seka
12	212567	Amhara	Siyadebrina Wayu	53	25335	SNNP	Meskanena Mareko
13	25298	SNNP	Angacha	54	25340	SNNP	Meskanena Mareko
14	219355	Oromiya	Adolana Wadera	55	25339	SNNP	Meskanena Mareko
15	208085	Amhara	Weremo Wajetuna Mida	56	215129	Amhara	Mama Midrina Lalo
16	212811	Amhara	Wegera	57	215128	Amhara	Mama Midrina Lalo
17	203105	Oromiya	Dedesa	58	228607	Amhara	Goncha Siso Enese
18	235955	Amhara	Debark	59	25337	SNNP	Meskanena Mareko
19	25279	SNNP	Cheha	60	25341	SNNP	Meskanena Mareko
20	208114	Amhara	Weremo Wajetuna Mida	61	25331	SNNP	Selti
21	229310	Amhara	Weremo Wajetuna Mida	62	235433	Tigray	Kola Temben
22	212572	Amhara	Weremo Wajetuna Mida	63	Tumsa		
23	25003	Oromiya	Kuyu	64	25325	SNNP	Selti
24	25323	SNNP	Selti	65	25329	SNNP	Selti
25	25022	Oromiya	Kuyu	66	25309	SNNP	Angacha
26	25280	SNNP	Cheha	67	25304	SNNP	Angacha
27	235956	Amhara	Debark	68	25330	SNNP	Selti
28	220079	Tigray	Adwa	69	25307	SNNP	Angacha
29	212576	Amhara	Lay Betna Tach Bet	70	25334	SNNP	Selti
30	212575	Amhara	Lay Betna Tach Bet	71	25306	SNNP	Angacha
31	25277	SNNP	Cheha	72	25311	SNNP	Angacha
32	220076	Tigray	Adwa	73	25332	SNNP	Sodo
33	27290	Oromiya	Jimma Arjo	74	25310	SNNP	Angacha
34	25264	Oromiya	Becho	75	25333	SNNP	Selti
35	25292	SNNP	Limo	76	25302	SNNP	Angacha
36	25270	Oromiya	Becho	77	25327	SNNP	Selti
37	212580	Amhara	Mama Midrina Lalo	78	Dosha		
38	25017	Amhara	Enarj Enawga	79	25303	SNNP	Angacha
39	212578	Amhara	Geramidirna Keya	80	25301	SNNP	Angacha
40	25010	Oromiya	Gerar Jarso	81	Local		
41	25290	SNNP	Limo				

2.2.2 Correlation analysis

Phenotypic correlation, the observable correlation between variables, which is the sum of genotypic and environmental effects were calculated from variance and covariance components using the formula of Miller et al. (1958) as follows:

Genotypic correlation= $\sigma_g xy / \sqrt{(\sigma^2_g x \, \sigma^2_g y)}$

Phenotypic correlation= $\sigma_p xy / \sqrt{(\sigma^2_p x \, \sigma^2_p y)}$

Where $\sigma_{p\,xy}$ = phenotypic covariance between character x and y, σ^2_p x = phenotypic variance for character x, σ^2_p y = phenotypic variance for character y, $\sigma_{g\,xy}$ = genotypic covariance between characters x and y, σ^2_g x = genotypic variance for character x, and σ^2_g y = genotypic variance for character y

The significance of phenotypic correlation coefficients was tested by the formula of Singh and Chaudhary (1985): $t' = r_p xy \sqrt{(n-2 / 1-r_p^2 xy)}$

The computed t' value was tested against the tabulated t-value at n-2 degree of freedom where n was the number of genotypes studied; whereas the correlation coefficient at genotypic level was tested for significance using the formula proposed by Robertson (1959).

$$t = \frac{rgxy}{SE\ rgxy}$$

The calculated 't' value was compared with 't' tabulated at (n-2) degree of freedom at 1 % and 5 % levels of significances.

Where

$$SE_{r_{gxy}} = \sqrt{\frac{(1-r^2)^2}{2H_x.H_y}}$$

Where $SEr_g xy$ is the standard error of genotypic correlation coefficient; Hx and Hy are heritability for traits x and y, respectively.

2.2.3 Path coefficient analysis

Path coefficient analysis is a tool to partition the observed correlation coefficient into direct and indirect effects of yield components on grain yield. Based on correlation, path coefficient which refers to the direct and indirect effects of the yield attributing traits (independent trait) on grain yield (dependent trait) were calculated as per Dewey and Lu (1959) as follows:

$rij = Pij + \Sigma\, rikpkj$

Where rij = mutual association between the independent character (i) and dependent character (j) as measured by the genotypic correlation coefficients. Pij = direct effects of the independent character (i) on the dependent variable (j) as measured by the genotypic path coefficients, and Σrikpkj = Summation of components of indirect effects of a given independent character (i) on a given dependent character (j) via all other independent characters (k).

Residual factor (R^2), the contribution of the remaining unknown factor was estimated using Singh and Chaudhury (1985) method:

$R^2 = \sqrt{(1 - \Sigma Pij\ rij)}$

3 RESULTS AND DISCUSSION

Mean squares of the 14 traits from analysis of variance (ANOVA) as presented below in Table 2 highly significant ($p < 0.01$) differences among accessions were observed for all traits except days to maturity and number of seeds per pod. This highly significant difference indicates the existence of variability among accessions for traits studied. The presence of variability in the accessions offers an opportunity in improvement of yield and its contributing traits through selection in faba bean. Similar results were obtained by Gemechu Keneni et al. (2005) in 160 faba bean accessions.

3.1 CORRELATION AMONG TRAITS

The interrelationship among the 12 traits was estimated through correlation coefficient at genotypic and phenotypic levels are presented in Table 2.

3.2 PHENOTYPIC CORRELATION OF GRAIN YIELD WITH OTHER TRAITS

The result of correlation analysis revealed that grain yield had highly significant ($p < 0.01$) and positive phenotypic correlations with plant height, pod length, number of pods per plant, number of branches per plant, biomass yield, 100-seed mass and harvest index. These results indicate that accessions with high plant height, pod length, number of pods per plant, number of branches per plant, biomass yield, 100-seed mass and harvest index produce high grain yield and vice versa. Therefore, these traits emerged as most important associates of grain yield in faba bean. The results suggested that selection of these traits may have good impact on yield improvement. Similarly, Lal (2019) reported that grain yield had highly significant and positive phenotypic correlations with plant height, number of pods per plant, number of branches per plant, biomass yield, 100-seed mass and harvest index. Kumar et al. (2013) reported highly significant and positive correlation of seed yield with number of branches per plant, number of pods per plant, biomass yield and

Table 2: Analysis of variance for 14 traits of eighty-one faba bean accessions

Traits	Mean square				CV (%)	R^2	R.E. to RCBD
	Rep (DF = 1)	Accessions (DF = 80)	Rep x Block (16)	Error (DF = 64)			
DF	0.10^{ns}	18.57**	3.02^{ns}	2.21	3.30	0.92	101.87
DM	43.56^{ns}	25.29^{ns}	28.53^{ns}	18.28	3.64	0.68	103.76
PH	365.70^{ns}	230.18**	212.36**	109.68	10.75	0.77	108.26
PL	2.57**	0.53**	0.24^{ns}	0.19	11.74	0.80	101.12
NPP	1.03^{ns}	45.44**	7.25^{ns}	6.74	22.36	0.89	100.10
NSP	1.81**	0.17^{ns}	0.09^{ns}	0.12	12.32	0.68	95.91
NBP	0.00^{ns}	0.61**	0.26*	0.17	24.16	0.81	103.24
BY	24966.00^{ns}	9567533.60**	817978.00^{ns}	691793.00	10.23	0.95	100.55
GY	31441.00^{ns}	810072.84**	10553.00^{ns}	14290.00	5.72	0.99	94.77
HSM	6.97^{ns}	173.27**	47.64*	28.96	12.93	0.89	104.69
HI	3.21^{ns}	106.81**	16.36^{ns}	12.71	14.44	0.90	101.23
AB	12.20^{ns}	532.02**	0.04^{ns}	6.19	7.07	0.99	97.23
CS	3.05^{ns}	547.10**	0.33^{ns}	24.49	15.07	0.96	104.92
RT	76.22*	590.28**	0.12^{ns}	14.48	14.30	0.98	100.00

NOTE: ** = Highly significant ($p < 0.01$), * = Significant ($p < 0.05$), ns = Non-significant, CV = Coefficient of variation, DF = days to flowering, DM = days to maturity, PH = plant height(cm), PL = pod length, NPP = number of pods per plant, NSP = number of seeds per pod, NBP = number of branches per plant, BY = biomass yield, GY = grain yield, HSM = 100 seed mass, HI = harvest index, AB = ascochyta blight, CS = chocolate spot, RT = rust disease, R.E to RCBD = relative efficiency to RCBD

harvest index. Verma et al. (2015) also found highly significant and positive correlation of seed yield with harvest index and biomass yield.

Grain yield had highly significant ($p < 0.01$) and negative phenotypic correlations with ascochyta blight, chocolate spot and rust disease scores. These results indicate that as disease severity increase grain yield becomes highly reduced. In addition, grain yield had significant ($p < 0.05$) and negative phenotypic correlations with days to flowering. This result showed that the early flowering accessions have high yield potential than those of late flowering ones, indicating the scope for developing short-cycle varieties. The finding agrees with that of Nchimbi and Mduruma (2007) who reported negative association of days to flowering with grain yield in common bean.

3.3 PHENOTYPIC CORRELATION AMONG OTHER TRAITS

Rust disease score showed highly significant ($p < 0.01$) and positive correlations with ascochyta blight and chocolate spot, indicating that diseases are complementary to each other. Rust disease had highly significant negative correlations with plant height, pod length, number of pods per plant, number of branches per plant, biomass yield and100 seed mass. This indicates that rust is negatively associated with these traits. Chocolate spot had highly significant negative correlations with plant height, pod length, number of pods per plant, biomass yield and100 seed mass. Ascochyta blight had highly significant and negative correlations with plant height, pod length, biomass yield and100 seed mass and significant negative correlations with number of pods per plant. Generally, the results suggested that disease related traits were complementary to each other and negatively affected growth and yield related traits.

Harvest index showed highly significant ($p < 0.01$) positive phenotypic correlations with number of pods per plant. This showed that accessions with high number of pods per plant producing high harvest index. However, harvest index had highly significant negative phenotypic correlations with biomass yield and then significant negative phenotypic correlations with days to flowering. Negative correlations arise due to competition among traits for common precursors which are having restricted supply (Madhur and Jinks, 1994). Hundred-seed mass had highly significant ($p < 0.01$) positive phenotypic correlations with plant height, pod length, biomass yield and significant ($p < 0.05$) positive phenotypic correlations with number of pods per plant. Days to flowering had high significant negative phenotypic correlations with 100-seed mass. Similarly, Alghamdi (2007) and Mulualem et al. (2013) reported a positive and significant phenotypic correlation between pod length and thousand-seed mass. Similar results were also obtained by Lal (2019) that hundred-seed mass had highly significant positive phenotypic correlations with pod length and biomass yield.

Biomass yield had highly significant ($p < 0.01$) positive phenotypic correlations with plant height, pod length, number of pods per plant and number of branches per plant. These traits had positive correlation with biomass yield which augurs well for providing correlated response during selection for improving biomass yield. These observations of positive associations between biomass yield and plant height, pod length, number of pods per plant and number of branches per plant are in agreement with the reports made previously (Kumar et al., 2013; Singh et al., 2015; Verma et al., 2015; Kumar et al., 2017) on faba bean. Similar results were obtained by Lal (2019) that biomass yield had highly significant positive phenotypic correlations with plant height, number of pods per plant and number of branches per plant.

Positive and highly significant ($p < 0.01$) phenotypic correlation was recorded between number of branches per plant with days to flowering, plant height, pod length, number of pods per plant. Similarly, Lal (2019) obtained number of branches per plant had highly significant and positive phenotypic correlations with plant height and number of pods per plant.

Number of pods per plant showed highly significant and positive correlation with plant height and pod length. Azarpour et al. (2012), Sharifi (2014) and Abdalla et al. (2015) reported positive and significant phenotypic correlation of number of pods per plant with plant height. Pod length shows highly significant ($p < 0.01$) positive phenotypic correlations with plant height. Plant height negatively correlated with days to flowering.

3.4 GENOTYPIC CORRELATION OF GRAIN YIELD WITH OTHER TRAITS

In the present study, grain yield had highly significant ($p < 0.01$) and positive genotypic correlations with plant height, pod length, number of pods per plant, number of branches per plant, biomass yield, 100-seed mass and harvest index. These results indicated that accessions with high plant height, pod length, number of pods per plant, number of branches per plant, biomass yield, 100-seed mass and harvest index produce high grain yield. Singh et al. (2017) reported that seed yield had highly significant and positive genotypic correlations with number of pods per plant, 100-seed mass and harvest index. Similar result was reported by Zakira et al. (2010) for harvest index in field pea. Grain yield had highly significant ($p < 0.01$) and negative genotypic correlations with

Table 3: Estimates of phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients of 12 traits of 81 faba bean accessions

Traits	DF	PH	PL	NPP	NBP	BY	GY	HSM	HI	AB	CS	RT
DF	1	-0.198*	-0.066^{ns}	-0.089^{ns}	0.293**	0.016^{ns}	-0.179*	-0.248**	-0.192*	0.072^{ns}	0.132^{ns}	0.102^{ns}
PH	-0.178^{ns}	1	0.542**	0.588**	0.333**	0.456**	0.576**	0.491**	0.111^{ns}	-0.206**	-0.412**	-0.398**
PL	-0.071^{ns}	0.560**	1	0.287**	0.280**	0.390**	0.360**	0.709**	-0.026^{ns}	-0.239**	-0.289**	-0.263**
NPP	-0.078^{ns}	0.628**	0.271*	1	0.446**	0.518**	0.755**	0.175*	0.228**	-0.186*	-0.348**	-0.394**
NBP	0.381**	0.369**	0.312**	0.454**	1	0.229**	0.336**	0.109^{ns}	0.077^{ns}	-0.028ns	-0.092^{ns}	-0.248**
BY	0.026^{ns}	0.524**	0.438**	0.538**	0.238*	1	0.562**	0.396**	-0.458**	-0.244**	-0.505**	-0.561**
GY	-0.190^{ns}	0.680**	0.407**	0.789**	0.374**	0.579**	1	0.352**	0.418**	-0.281**	-0.483**	-0.413**
HSM	-0.252*	0.510**	0.789**	0.136^{ns}	0.061^{ns}	0.418**	0.362**	1	-0.009^{ns}	-0.301**	-0.411**	-0.263**
HI	-0.227*	0.173^{ns}	-0.007^{ns}	0.272*	0.108^{ns}	-0.427**	0.438**	-0.009^{ns}	1	0.003^{ns}	-0.032^{ns}	0.189*
AB	0.075^{ns}	-0.247*	-0.289**	-0.206^{ns}	-0.041^{ns}	-0.255*	-0.286**	-0.329**	0.004^{ns}	1	0.339**	0.332**
CS	0.142^{ns}	-0.516**	-0.373**	-0.373**	-0.116^{ns}	-0.514**	-0.499**	-0.458**	-0.060^{ns}	0.348**	1	0.413**
RT	0.105^{ns}	-0.495**	-0.332**	-0.429**	-0.294**	-0.578**	-0.422**	-0.283**	0.199^{ns}	0.338**	0.428**	1

** = Highly significant ($p < 0.01$), * = Significant ($p < 0.05$), ns = Non significant, DF = days to flowering, PH = plant height, PL = pod length, NPP = number of pods per plant, NBP = number of branches per plant, BY = biomass yield, GY = grain yield, HSM = 100-seed mass, HI = harvest index, AB = ascochyta blight, CS = chocolate spot, RT = rust disease score ascochyta blight, chocolate spot and rust disease scores. This indicates disease plays a vital role in reduction of grain yield.

3.5 GENOTYPIC CORRELATION AMONG OTHER TRAITS

Days to flowering were positively and highly significantly ($p < 0.01$) correlated with number of branches per plant. The result shows late flowering accessions are expected to produce high number of branches per plant. Days to flowering negatively correlated with 100-seed mass and harvest index. This result showed that the late flowering accessions have less yield potential than those of early flowering ones. These findings are in concurrence with Alghamdi (2007), Tofiq et al. (2016). Kumar et al. (2020) also reported negative correlation of days to flowering with 100-seed mass.

Plant height had positive and highly significant ($p < 0.01$) genotypic correlation with pod length, number pods per plant, number of branches per plant, biomass yield and 100-seed mass. These indicate accessions that have high plant height also had high pod length, number of pods per plant, number of branches per plant, biomass yield and 100-seed mass. Results by Lal (2019) revealed that number of branches per plant and biomass yield had positive and highly significant correlation with plant height in faba bean. Plant height had negative and highly significant ($p < 0.01$) correlation with chocolate spot and rust disease scores, and negatively correlated with ascochyta blight. This indicates disease plays a vital role in reduction of plant height.

Pod length had positive and highly significant ($p < 0.01$) correlation with number of branches per plant, biomass yield and 100-seed mass and positive significant correlation with number of pods per plant. In harmony with the present finding, Lal (2019) reported positive and highly significant correlation of pod length with 100-seed mass. Pod length also had negative and highly significant correlation with ascochyta blight, chocolate spot and rust disease scores. Number of pods per plant had positive and highly significant ($p < 0.01$) correlation with number of branches per plant, biomass yield and positive and significant correlation with harvest index. Improving these traits increases number of pods per plant that support to increases grain yield. This result agrees with Singh et al. (2017) who reported number of pods per plant had positive and highly significant correlation with number of branches per plant and harvest index. Similar result also reported by Fikreselassie and Soboka (2012). Number of pods per plant had negative and highly significant ($p < 0.01$) correlation with chocolate spot and rust disease scores. Number of branches per plant had positive and significant correlation with biomass yield and negative highly significant correlation with rust disease score.

Biomass yield had positive and highly significant ($p < 0.01$) genotypic correlation with 100-seed mass. This indicates that breeding for increased biomass yield might result in bold seeds. This implies that the trait has positive impact on faba bean improvement. Biomass yield had negatively significant ($p < 0.01$) genotypic correlation with harvest index, chocolate spot and rust disease scores and negative significant correlation with ascochyta blight. This implies that these traits inversely correlated with biomass yield. Hundred-seed mass had negative and highly significant correlation with ascochyta blight and chocolate spot diseases but negative significant correlation with rust. These indicate that hundred-seed mass negatively affected by disease and leads to low yield. Ascochyta blight had positive and highly significant correlation with chocolate spot and rust disease scores and also chocolate spot had positive and highly significant correlation with rust disease. This result indicates the occurrence of one disease simply favores another.

3.6 PATH COEFFICIENT ANALYSES

Path coefficient analyses separated the phenotypic and the genotypic correlation coefficients into the corresponding direct and indirect effects. The phenotypic and genotypic direct and indirect effects of different traits on grain yield are presented in Table 3 and 4, respectively.

3.6.1 Phenotypic path coefficients

In the present study, the path coefficient analysis was carried out by using phenotypic correlation coefficients among twelve traits. Plant height, pod length, number of pods per plant, number of branches per plant, biomass yield and harvest index had positive direct effects on grain yield. Higher positive direct effects on grain yield, however, were exerted by biomass yield (0.856) and harvest index (0.778) (Table 3). The results indicate biomass yield and harvest-index are most important traits to which emphasis should be given during simultaneous selection aimed at improving grain yield in faba bean. These results are in close association with previous workers (Bora et al., 1998; Kumar et al., 2013 Lal, 2019) for biomass yield and harvest-index in faba bean.

Biomass yield exerted considerable positive indirect effects on grain yield via number of pods per plant, plant height, pod length and 100-seed mass. Harvest index exhibited high positive indirect effects on grain yield via number of pods per plant and plant height. These results suggested the importance of these traits in selection for the improvement of faba bean grain yield. However, biomass yield exerted considerable negative indirect effects on grain yield via harvest index chocolate spot and rust disease scores and harvest index exhibited high order of negative indirect effects on grain yield via biomass yield. Similarly, Lal (2019) observed biomass yield exerted considerable positive indirect effects on grain yield via number of pods per plant, number of branches per plant and plant height. Harvest index exhibited high order of positive indirect effects on grain yield via number of pods per plant and biomass yield on faba bean. In addition to the important direct contributions, biomass yield and harvest index had considerable positive indirect effects via different traits, implying that biomass yield and harvest index are important traits to be considered during devising selection strategy aimed at developing high yielding varieties in faba bean. Ulukan et al. (2003) and Tadesse et al. (2011) also observed the highest positive direct effect of number of pods per plant together with plant height. Kumar et al. (2017) also reported that the number of branches per plant, number of pods per plant and pod length exhibited positive direct effects on yield. On the contrary, days to flowering, 100-seed mass, ascochyta blight and rust disease scores had negative direct effects on grain yield. Tofiq et al. (2016) also reported negative direct effect of 100-seeds mass on yield.

The magnitude of residual effect (0.297) indicated that the traits included in the study accounted for most of the variability present in grain yield, indicating that the contribution of traits considered was 70.3 % and the rest 29.7 % was the contribution of other traits which were not considered in the present study.

3.6.2 Genotypic path coefficients

The high positive direct effects on grain yield were exerted by biomass yield (0.844) and harvest index (0.756) (Table 4). Thus, biomass yield and harvest-index emerged as most important yield components on which emphasis should be given during simultaneous selection aimed at improving grain yield in faba bean. These results are in close agreement with those of Bora et al. (1998) and Kumar et al. (2013). Similar results also obtained by Lal (2019). The direct effects of the remaining traits were low to be considered important. Biomass yield exerted considerable positive indirect effects on grain yield via number of pods per plant, plant height, pod length and 100-seed mass but biomass yield exerted considerable negative indirect effects on grain yield via harvest index, chocolate spot and rust disease scores. Harvest index exhibited high order of positive indirect effects on grain yield via number of pods per plant and plant height but harvest index exhibited high order of negative indirect effects on grain yield via biomass yield. Similar results were obtained by Lal (2019) for biomass yield and harvest index. In addition to their very high positive direct effects on grain yield, biomass yield and harvest index, having considerable positive indirect effects via different traits, also appeared as most important indirect yield components.

In the present study, path analysis identified bio-

Table 4: Phenotypic direct (bold and diagonal) and indirect effects of 11 traits on grain yield of 81 faba bean accessions

Traits	DF	PH	PL	NPP	NBP	BY	HSM	HI	AB	CS	RT
DF	-0.052	-0.007	-0.001	-0.008	0.013	0.014	0.011	-0.149	-0.005	0.006	-0.002
PH	0.010	0.034	0.006	0.053	0.014	0.390	-0.022	0.087	0.013	-0.019	0.008
PL	0.003	0.019	0.011	0.026	0.012	0.333	-0.032	-0.020	0.016	-0.013	0.005
NPP	0.005	0.020	0.003	0.090	0.019	0.443	-0.008	0.178	0.012	-0.016	0.008
NBP	-0.015	0.011	0.003	0.040	0.043	0.196	-0.005	0.060	0.002	-0.004	0.005
BY	-0.001	0.016	0.004	0.047	0.010	0.856	-0.018	-0.356	0.016	-0.023	0.012
HSM	0.013	0.017	0.008	0.016	0.005	0.339	-0.045	-0.007	0.020	-0.019	0.005
HI	0.010	0.004	0.000	0.021	0.003	-0.392	0.000	0.778	0.000	-0.001	-0.004
AB	-0.004	-0.007	-0.003	-0.017	-0.001	-0.209	0.014	0.003	-0.065	0.015	-0.007
CS	-0.007	-0.014	-0.003	-0.031	-0.004	-0.432	0.018	-0.025	-0.022	0.045	-0.009
RT	-0.005	-0.014	-0.003	-0.035	-0.011	-0.480	0.012	0.147	-0.022	0.019	-0.021

Residual factor = 0.297. DF = days to flowering, PH = plant height, PL = pod length, NPP = number of pods per plant, NBP = number of branches per plant, BY = biomass yield, HSM = 100 seed mass, HI = harvest index, AB = ascochyta blight, CS = chocolate spot, and RT = rust disease score

Table 5: Genotypic direct (bold and diagonal) and indirect effects of 11 traits on grain yield for 81 faba bean accessions

Traits	DF	PH	PL	NPP	NBP	BY	HSM	HI	AB	CS	RT
DF	**-0.061**	-0.011	0.001	-0.005	0.026	0.022	0.008	-0.172	-0.005	0.009	-0.002
PH	0.011	**0.061**	-0.006	0.042	0.025	0.442	-0.017	0.131	0.017	-0.034	0.008
PL	0.004	0.034	**-0.010**	0.018	0.021	0.370	-0.026	-0.005	0.020	-0.024	0.006
NPP	0.005	0.038	-0.003	**0.066**	0.031	0.454	-0.004	0.206	0.014	-0.024	0.007
NBP	-0.023	0.022	-0.003	0.030	**0.067**	0.201	-0.002	0.082	0.003	-0.008	0.005
BY	-0.002	0.032	-0.004	0.036	0.016	**0.844**	-0.014	-0.323	0.017	-0.034	0.010
HSM	0.015	0.031	-0.008	0.009	0.004	0.353	**-0.032**	-0.007	0.023	-0.030	0.005
HI	0.014	0.010	0.000	0.018	0.007	-0.361	0.000	**0.756**	0.000	-0.004	-0.003
AB	-0.005	-0.015	0.003	-0.014	-0.003	-0.215	0.011	0.003	**-0.068**	0.023	-0.006
CS	-0.009	-0.031	0.004	-0.025	-0.008	-0.434	0.015	-0.046	-0.024	**0.066**	-0.007
RT	-0.006	-0.030	0.003	-0.029	-0.020	-0.488	0.009	0.150	-0.023	0.028	**-0.017**

Residual factor = 0.297. DF = days to flowering, PH = plant height, PL = pod length, NPP = number of pods per plant, NBP = number of branches per plant, BY = biomass yield, HSM = 100 seed mass, HI = harvest index, AB = ascochyta blight, CS = chocolate spot, and RT = rust disease score

mass yield followed by harvest-index as most important direct as well as indirect yield contributing traits. These indicate that both traits had true association with grain yield and their importance in determining this complex trait. Therefore, important consideration should be given while practicing selection aimed at the improvement of grain yield in faba bean. These results were in accordance with the result of Jivani et al. (2013) who reported the highest direct effects of harvest index and biomass yield on grain yield in chickpea. Plant height, number of pods per plant and number of branches per plant had positive direct effects on grain yield at genotypic level but days to flowering, pod length, 100-seed mass, ascochyta blight and rust disease scores had negative direct effects on grain yield.

The residual effect shows how much the explanatory variables represent the variability of the dependent variable (Singh and Chaudhary, 1985). The residual effect at the genotypic path coefficient analysis was 0.272; as a result, the studied traits explained 72.8 % of the variability in the seed yield and show that few traits were not consider which are related to grain yield.

Residual factor = 0.272. DF = days to flowering, PH = plant height, PL = pod length, NPP = number of pods per plant, NBP = number of branches per plant, BY = biomass yield, HSM = 100 seed mass, HI = harvest index, AB = ascochyta blight, CS = chocolate spot, RT = rust disease.

4 CONCLUSION

Grain yield had highly significant ($p < 0.01$) and positive phenotypic and genotypic correlation with plant height, pod length, number of pods per plant, number of branches per plant, biomass yield, 100-seed mass and harvest index. These results indicated the possibility of simultaneous improvement of grain yield with these traits through selection. Path coefficient analysis showed that harvest index and biomass yield had the highest direct effects on yield both at phenotypic and genotypic levels, indicating the importance of these traits for indirect selection of faba bean accessions for improvement of grain yield.

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