Path Analysis of Seed Yield in Garden Cress (*Lepidium sativum* L.)

Naser Sabaghnia[1]*, Mohsen Janmohammadi[2]
[1] Associate Professor, Department of Plant Production and Genetics, University of Maragheh, Maragheh, Iran;
[2] Associate Professor, Department of Plant Production and Genetics, University of Maragheh, Maragheh, Iran;
*Corresponding author: sabaghnia@maragheh.ac.ir

Abstract

This research uses path analysis to determine the interrelationships among seed yield and 16 related morphologic traits. Observations were recorded on 20 other canola traits. Correlation coefficient analysis revealed seed yield was positively correlated with all the traits except PH in the first year and except MAL and PH in the second year. Sequential path analysis identified the 1000-seed weight (TSW), number of siliques per plant (NSP) and height of first silique (HFS) as important first order traits that influenced seed yield in first year. Plant height, NSP and the TSW were important first order traits that influenced seed yield in the second year. This indicates that breeding programs should be based on these traits for further improvement of the garden cress. All direct effects were significant, as indicated by bootstrap analysis. The results suggest that TSW and NSP could be used as a selection criterion in selecting for increased for increased seed yield in garden cress.
***Keywords*: Bootstrap, Genetic variation, Garden cress**

Introduction

Garden cress (*Lepidium sativum* L.) is an annual herb which belongs to the Cruciferae family which grows in the Middle East, Europe and USA (Karazhiyan et al. 2009). It has gained more interest from different food consumers and vegetable producers worldwide, and can be a good choice for health promoting substances such as glucotropaeolin (Zhan et al. 2009) Garden cress is native to South west Asia and probably Iran and is cultivated in North America, parts of Europe and as culinary vegetable all over Asia (Doke and Guha 2014). Garden cress has been used in local traditional medicine and so it also highlights the good potential of garden cress seeds and its extracts for medicinal uses (Rehman et al. 2012). Its seeds have been used in traditional medicine to treat asthma, hypertension, hepatotoxicity, hyperglycemia, enuresis and fractures (Razmkhah et al., 2016).

Computation of correlation coefficients is a method to evaluate breeding materials for seed yield and to examine direct and indirect contributions to traits and yield via path analysis (Sabaghnia et al. 2010). Bedassa et al. (2013), reported that direct effects of number of seeds per plant, days to flowering initiation, biomass yield per plant, harvest index and 1000-seed weight on seed yield of garden cress were considerable and could help to identify genotypes with large seed yield production. The 1000-seed weight and biological yield showed to be the most correlated traits with seed yield by means of simple correlations with garden cress seed yield, and traits days to maturity and number of primary and secondary branches exhibited the maximum positive indirect influence passing through biological yield on seed yield Sabaghnia et al. (2015). Therefore, this investigation has been initiated in view of filling such information gap in relation to estimate Pearson correlation coefficients between seed yield and yield components for garden cress genotype and to investigate direct and indirect effects of yield components on seed yield via path coefficient analysis in 81 germplasm collections of garden cress for 16 traits.

Materials And Methods

A total of 77 accessions were chosen from the garden cress germplasm and four Iranian accessions named as Birjand, Tabriz, Kerman and Shiraz genotypes were used in this research. All accessions were planted experimental field of University of Maragheh, and grown in the two growing seasons 2012 and 2013, respectively. Each accession was grown in a plot of 3.6 m^2 (six 2 m long rows), planted 10 cm apart in and a row spacing of 30 cm. Standard agricultural practice was followed. For each trial, a replicated 9 × 9 simple lattice design with four replications was used and sowing was done in the May which is the optimal sowing time for its sowing. The 10 individuals were chosen randomly and marked for each accession to measure the height of first branch (HFB), height of first silique (HFS), main axis length (MAL), number of lateral branches (NLB), number of silique per lateral branches (NSL), number of siliques per main axis (NSM), number of siliques per plant (NSP), number of seeds per silique of lateral branches(SLB), number of seeds per silique of main axis (SMA), number of seeds of silique per plant (NSSP) and plant height (PH) Also, days to emergence (DE), days to flowering (DF) and flowering period (FP) were recorded as was as possible. Days to flowering were recorded when 50% of the plants in the plot had at least one open flower. The thousand-seed weight (TSW) was measured on a sub-sample of seed harvested from each plot. Stepwise regression was performed to determine the predictor variables into first, second and third order paths on the basis of their respective contributions to total variation in seed yield and minimal collinearity.

Results And Discussion

The results pertaining to direct effects of components traits on garden cress seed yield, where yield-related traits were considered as first order variables, with seed yield as the response variable, are shown in Table 1 as well as the results of two measures of multi-collinearity analysis (Tolerance and VIF) According to the common path analysis and multi-collinearity analysis, there are inconsistent relationships among the variables. Results from this analysis in the first year, where all traits were considered as first-order variables with seed yield as the response variable, indicated high multi-collinearity for some traits, particularly for those showing high direct effects such as NSP (VIF = 117.9), DE (VIF = 69.9), DF (VIF = 59.6), NSL (VIF = 49.3) and NLB (VIF = 32.9) These traits were therefore removed as first-order variables from the analysis in the first year. Similarly, in the second year (Table 1), the above mentioned traits (NSP, DE, DF, NSL and NLB) showed high multi-collinearity when all traits were considered as first-order variables with seed yield as the response variable and were removed as first-order variables from the analysis in the year 2013.

In the year 2012 among the TSW, NSP and HFS traits, the TSW had the greater direct effect (2.32) than other two traits on seed yield. The indirect effect of the TSW was high and negative (-1.135) via NSP but the indirect effect of the TSW was low and negative (-0.506) via HFS in the first year (Table 2) Also, the indirect effect of the NSP was high and positive (2.007) via TSW but the indirect effect of the TSW was low and negative (-0.373) via HFS. The indirect effect of the HFS was high and positive (1.694) via TSW but the indirect effect of the NSP was moderate and negative (-0.692) via NSP in the first year (Table 2). The results of sequential path analysis, when the second-order variables were used as predictors, and the first-order variables as response variables, indicated that NSSP and NLB positively impressed the TSW and accounted for more than 77% of the behold variation in the year 2012. The NSSP, NLB and NSL positively influenced NSP and accounted for more than 98% of the total variation while DE and HFB positively influenced the HFS.

Table 1- Measures of collinearity values (tolerance and variance inflation factor, VIF) for predictor variables in conventional path analysis (CPA) and sequential path analysis (SPA)

Year 2012					
Pred.	Res.	Tolerance		VIF	
		CPA	SPA	CPA	SPA
TSW	SY	0.086	0.151	11.6	6.6
NSP		0.008	0.230	117.9	4.3
HFS		0.211	0.429	4.7	2.3
NSSP	TSW	0.122	0.683	8.2	1.5
NLB		0.030	0.683	32.9	1.5
NSSP	NSP	0.122	0.367	8.2	2.7
NSL		0.020	0.511	49.3	2.0
NLB		0.030	0.637	32.9	1.6
DE	HFS	0.014	0.578	69.9	1.7
HFB		0.296	0.578	3.4	1.7
SLB	NSSP	0.086	0.487	11.6	2.1
SMA		0.274	0.487	3.6	2.1
SLB	NLB	0.086	0.795	11.6	1.3
MAL		0.356	0.795	2.8	1.3
NSM	NSL	0.208	0.717	4.8	1.4
SMA		0.274	0.476	3.6	2.1
DF		0.017	0.515	59.6	1.9
DF	DE	0.017	0.977	59.6	1.0
FP		0.103	0.977	9.7	1.0
DF	HFB	0.017	1.000	59.6	1.0

Year 2013					
Pred.	Res.	Tolerance		VIF	
		CPA	SPA	CPA	SPA
PH	SY	0.367	0.837	2.7	1.2
TSW		0.071	0.228	14.0	4.4
NSP		0.013	0.250	76.4	4.0
FP	PH	0.164	0.868	6.1	1.2
HFS		0.256	0.805	3.9	1.2
NSSP		0.280	0.863	3.6	1.2
SMA	TSW	0.205	0.688	4.9	1.5
NLB		0.037	0.796	27.3	1.3
NSL		0.031	0.715	32.6	1.4
NSL	NSP	0.031	0.864	32.6	1.2
NLB		0.037	0.864	27.3	1.2
MAL	FP	0.462	0.881	2.2	1.1
DE		0.025	0.098	40.2	10.2
DF		0.023	0.101	42.7	9.9
DE	HFS	0.025	0.807	40.2	1.2
HFB		0.488	0.807	2.0	1.2
DE	NSSP	0.025	0.917	40.2	1.1
SLB		0.396	0.917	2.5	1.1
DE	SMA	0.025	1.000	40.2	1.0
DE	NLB	0.025	0.917	40.2	1.1
SLB		0.396	0.917	2.5	1.1
NSM	NSL	0.406	1.000	2.5	1.0

In the year 2013 among the TSW, NSP and PH traits, the TSW had the greater direct effect (1.31) than other two traits on seed yield The indirect effect of the TSW was moderate and negative (-0.783) via NSP but the indirect effect of the TSW was low and positive (0.134) via PH in the second year and the indirect effect of the NSP was low and positive (0.074) via PH but the indirect effect of the NSP was high and positive (1.125) via TSW in the second year (Table 3) The indirect effect of the PH was low and negative (-0.176) via NSP but the indirect effect of the PH was moderate and positive (0.385) via TSW in the year 2013 (Table 3) The results of sequential path analysis, when the second-order variables were used as predictors, and the first-order variables as response variables, indicated that SMA, NLB and NSL positively affected the TSW and accounted for more than 83% of the total variation in the second year.

The observed positive correlation between seed yield and other measured traits can help to identify traits that could be used for indirect selection of the garden cress genotypes with higher yield. Obtaining high seed yield is one of the important breeding objectives in most genetic improvement programs but seed yield as a complex trait which is affected by many traits contributing in both positive and negative directions. Hence direct selection for seed yield of garden cress is not most effective due to its low heritability and so it is better to select indirectly. Seed yield had positive and significant correlation with SMA, NSSP, PH and TSW in this study, indicating simultaneous improvement of these traits is possible.

Table 2- Direct and indirect effects for the predictor variables in sequential path analysis in the first year (2012)

SY	TSW	NSP	HFS
TSW	2.316	-1.135	-0.506
NSP	2.007	-1.310	-0.373
HFS	1.694	-0.706	-0.692

NLB	NSSP	NSL	NSP
NSSP	0.123	0.406	0.303
NSL	0.083	0.603	0.119
NSP	0.069	0.133	0.537

NSL	NSM	SMA	DF
NSM	0.632	0.182	-0.109
SMA	0.325	0.354	-0.165
DF	0.286	0.243	-0.240

DE	DF	FP
DF	0.905	0.044
FP	0.137	0.289

TSW	NSSP	NLB
NSSP	0.641	0.190
NLB	0.361	0.337

HFS	DE	HFB
DE	0.469	0.248
HFB	0.305	0.382

NSSP	SLB	SMA
SLB	0.651	0.219
SMA	0.466	0.306

NLB	SLB	MAL
SLB	0.840	-0.147
MAL	0.380	-0.326

The present study is consistent with the results reported by Bedassa et al. (2013) where seed yield was observed to have positive and significant correlation with most of the above mentioned traits. Therefore, most of measured traits which were significantly correlated with seed yield may be important yield predictors in garden cress breeding. The positive association between plant height and days to flowering in both years can show that the longer the garden cress germplasm, in plant height, the more it can get into earlier maturation period.

Table 3- Direct and indirect effects for the predictor variables in sequential path analysis in the second year (2013)

SY	PH	TSW	NSP
PH	0.385	0.455	-0.176
TSW	0.134	1.310	-0.783
NSP	0.074	1.125	-0.912

PH	FP	HFS	NSSP
FP	0.461	-0.138	0.073
HFS	0.158	-0.404	0.110
NSSP	0.107	-0.141	0.315

TSW	SMA	NLB	NSL
SMA	0.436	0.178	0.145
NLB	0.179	0.432	0.106
NSL	0.220	0.159	0.287

FP	MAL	DE	DF
MAL	0.183	0.454	-0.183
DE	0.034	2.413	-2.123
DF	0.015	2.275	-2.251

NSP	NSL	NLB
NSL	0.612	0.214
NLB	0.226	0.580

HFS	DE	HFB
DE	0.410	0.131
HFB	0.180	0.299

NSSP	DE	SLB
DE	0.480	0.099
SLB	0.138	0.344

Bedassa et al. (2013) reported the highest strong direct effect of number of seeds per plant, days to flowering initiation, biomass yield, harvest index and 1000-seed weight on garden cress seed yield regarding common path coefficient analysis. Similarly, we found highest strong direct effect of TSW, NSP, HFS and PH on seed yield and there are relatively similar reports for path analysis of rapeseed and Indian mustard (Sabaghnia et al. 2010). Other yield components or important traits such as NSSP, NLB, NLS and NSM influenced indirectly as the second-order or the third-order variables. This study demonstrated the utility of sequential path analysis over common path analysis in discerning the direct and indirect effects of various yield-related traits and it could be concluded that the traits SMA, NLB, NSL, FP, NSSP, SLB, NSM, MAL, DF and HFB were identified as the first, second and third order variables in both years.

Conclusions

The study revealed that seed yield had strong positive correlation with DF, HFB, HFS, NLB, NSP, SLB, SMA, NSSP and TSW traits. Also, TSW, NSP, PH and HFS traits had direct effects on seed yield based on path analysis. These three traits were the key contributors to seed yield suggesting the need of more emphasis on these traits for genetic improvement of the seed grain yield in garden cress. In addition, both correlation and path analysis across two years confirmed that TSW and NSP are the most prominent traits for the breeding of garden cress for the higher seed yield.

References

Bedassa, T., Andargie, M. and Eshete M. 2013. Genetic variability and association among yield, yield related traits and oil content in Ethiopian garden cress (*Lepidium sativum* L.) genotypes. Journal of Plant Breeding and Crop Science; 5: 141–149.

Doke, S. and Guha, M. 2014. Garden cress (*Lepidium sativum* L.) Seed - An Important Medicinal Source: A Review. J. Nat. Prod. Plant Resou.4: 69–80.

Karazhiyan, H., Razavi, S.M.A. and Phillips, G.O. 2009. Extraction optimization of a hydrocolloid extract from cress seed (*Lepidium sativum*) using response surface methodology. Food Hydrocolloids; 25: 915–920.

Razmkhah, S., Razavi, S.M.A., Mohammadifar, M.A., Alec, M.T. and Gavlighid, H.A. 2016. Protein-free cress seed (*Lepidium sativum*) gum: Physicochemical characterization and rheological properties. Carbohydrate Polymers; 153: 14–24.

Rehman, N., Khan, A.U., Alkharfy, K.M. and Gilani, A.H. 2012. Pharmacological basis for the medicinal use of *Lepidium sativum* in airways disorders. Evidence-Based Complementary and Alternative Medicine; 17: 1–8.

Sabaghnia, N., Ahadnezhad, A. and Janmohammdi, M. 2015. Genetic variation in garden cress (*Lepidium sativum* L.) germplasm as assessed by some morphological traits. Genetic Resources and Crop Evolution; 62(5): 733-745.

Sabaghnia, N., Dehghani, H., Alizadeh, B. and Mohghaddam, M. 2010. Interrelationships between seed yield and 20 related traits of 49 canola (*Brassica napus* L.) genotypes in non-stressed and water-stressed environments. Spanish Journal of Agricultural Research; 8: 356–370.

Zhan, L.J., Fontana, E., Tibaldi, G. and Nicola, S. 2009. Qualitative and physiological response of minimally processed garden cress (*Lepidium sativum* L.) to harvest handling and storage conditions. Journal of Food, Agriculture and Environment; 7: 43–50.