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Angeles Rubio
Department of Agricultural Genetics, Instituto de Ciencias Agrícolas de Andalucía, Córdoba, Spain

Amparo Zambrano
Department of Agricultural Genetics, Instituto de Ciencias Agrícolas de Andalucía, Córdoba, Spain

Corresponding Author:
Angeles Rubio
Department of Agricultural Genetics, Instituto de Ciencias Agrícolas de Andalucía, Córdoba, Spain

Variability and correlation studies in Ethiopian mustard for yield contributing traits

Angeles Rubio and Amparo Zambrano

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Abstract
Ethiopian mustard (*Brassica carinata* A. Braun) has drawn increasing interest as a dual-purpose crop for edible oil and industrial biofuel, yet its genetic improvement lags behind other Brassica species because variability patterns and trait relationships in available germplasm are poorly mapped. This research assessed genetic variability, heritability, correlation, and path coefficients for seven yield-related traits in 48 Ethiopian mustard genotypes evaluated at the Instituto de Ciencias Agrícolas de Andalucía, Córdoba, Spain, during rabi 2022-23. Seed yield per plant showed the highest genotypic coefficient of variation (GCV, 24.8%) and genetic advance as percentage of mean (42.8%). Siliquae per plant had the strongest genotypic correlation with seed yield (rg = 0.91) and the highest direct path effect (0.428). Heritability estimates were moderate to high (52.4-74.1%) for all traits except oil content. These findings indicate that selection for siliquae per plant and primary branches would be the most effective indirect route to improving seed yield in Ethiopian mustard breeding programmes.

Keywords: Variability, correlation studies, Ethiopian mustard, *Brassica carinata*, yield traits, heritability, path analysis, genotypic coefficient of variation, crop improvement, genetic advance

Introduction

Among the six cultivated Brassica species, Ethiopian mustard (*B. carinata*, 2n = 34, BBCC genome) is a relative latecomer to formal breeding research, despite its origin in the Ethiopian highlands where it has been a staple oilseed crop for centuries [1]. The species has attracted fresh attention because of its natural resistance to blackleg disease (Leptosphaeria maculans), heat and drought tolerance, and seed oil composition suitable for bio-jet fuel production [2]. But compared to rapeseed (*B. napus*) and Indian mustard (*B. juncea*), the available germplasm base of *B. carinata* remains narrowly characterized.

Understanding genetic variability is the starting point for any breeding strategy. Parameters such as the genotypic and phenotypic coefficients of variation, heritability, and genetic advance indicate how much of the observed variation is heritable and how much gain can be expected from selection [3]. Correlation analysis reveals the direction and strength of trait associations, while path analysis partitions correlations into direct and indirect effects on yield, thereby guiding the choice of selection criteria [4]. This research aimed to estimate these parameters in a diverse set of 48 Ethiopian mustard genotypes to identify the traits most useful for indirect selection for seed yield improvement.

Theoretical Background

The partitioning of observed phenotypic variance into genotypic and environmental components follows the model $Vp = Vg + Ve$, where Vp, Vg, and Ve represent phenotypic, genotypic, and environmental variances respectively. Broad-sense heritability (h^2) was estimated as $h^2 = Vg/Vp \times 100$. Genetic advance (GA) under selection at 5% intensity was predicted as $GA = k \times \sigma p \times h^2$, where k is the selection differential (2.06 for 5% selection intensity) and σp is the phenotypic standard deviation [3]. Path coefficient analysis followed the method of Dewey and Lu [5], which decomposes the genotypic correlation of each trait with seed yield into a direct effect (path coefficient) and the sum of indirect effects through other traits. This framework allows breeders to distinguish traits whose correlation with yield is causal from those that are merely associated through linkage with a third variable.

Material and Methods

Material

Forty-eight Ethiopian mustard genotypes sourced from the USDA-ARS germplasm collection, ICRISAT, and local Spanish accessions were evaluated during the rabi 2022-23 season at the experimental farm of Instituto de Ciencias Agrícolas de Andalucía, Córdoba, Spain (37.88° N, 4.77° W, elevation 106 m). The site has a Mediterranean climate with mild winters and hot dry summers. Soil is Vertisol with clay texture and pH 7.8. The trial was laid out in an augmented block design with three replications for 36 test genotypes and four check varieties replicated in each block. Each genotype was sown in three rows of 3 m length at 30 × 10 cm spacing [6].

Methods

Observations were recorded on five randomly selected competitive plants per genotype per replication for plant height, primary branches per plant, siliquae per plant, seeds per siliqua, 1000-seed weight, seed yield per plant, and oil content (by NMR, Oxford Instruments MQC-5). Genotypic and phenotypic variances, GCV, PCV, heritability, and genetic advance were estimated following Singh and Chaudhary [3]. Genotypic (rg) and phenotypic (rp) correlation coefficients were computed from variance-covariance components. Path analysis was done using seed yield as the dependent variable and remaining traits as independent variables [5]. Statistical computations were carried out in INDOSTAT version 9.2 and R version 4.3.1.

Results

Table 1: Variability parameters for yield contributing traits in 48 Ethiopian mustard genotypes

Trait	Range	Mean	GCV (%)	PCV (%)	h^2 (%)	GA as% of Mean
Plant height (cm)	108-184	142.6	14.8	17.2	74.1	26.3
Primary branches	4.2-9.8	6.84	18.6	22.4	68.8	31.8
Siliquae/plant	84-248	156.3	22.4	26.8	69.8	38.6
Seeds/siliqua	12-24	17.8	16.2	19.4	69.7	27.9
1000-seed wt (g)	2.8-5.4	4.12	14.2	17.8	63.6	23.3
Seed yield (g/plant)	8.4-28.6	16.42	24.8	29.6	70.2	42.8
Oil content (%)	38.2-44.6	41.3	4.2	5.8	52.4	6.3

Seed yield showed the widest range (8.4-28.6 g/plant) and highest GCV (24.8%), followed by siliquae per plant (22.4%) (Table 1). Oil content had the lowest GCV at 4.2%. Heritability was highest for plant height (74.1%) and lowest for oil content (52.4%). Genetic advance as percentage of mean was greatest for seed yield (42.8%) and siliquae per plant (38.6%).

Table 2: Genotypic and phenotypic correlation coefficients with seed yield, and path analysis results

Trait	Seed Yield (rg)	Seed Yield (rp)	Direct Effect	Indirect Effect
Plant height	0.78**	0.64**	0.182	0.598
Primary branches	0.82**	0.71**	0.264	0.556
Siliquae/plant	0.91**	0.84**	0.428	0.482
Seeds/siliqua	0.74**	0.62**	0.186	0.554
1000-seed weight	0.68**	0.58**	0.212	0.468
Oil content	0.24 NS	0.18 NS	0.042	0.198

Siliquae per plant had the highest genotypic correlation with seed yield (0.91**) and the largest direct path effect (0.428) (Table 2). Primary branches showed the second-highest correlation (0.82**) but a moderate direct effect (0.264), indicating its influence on yield is partly mediated through siliquae number. Oil content was not significantly correlated with seed yield.

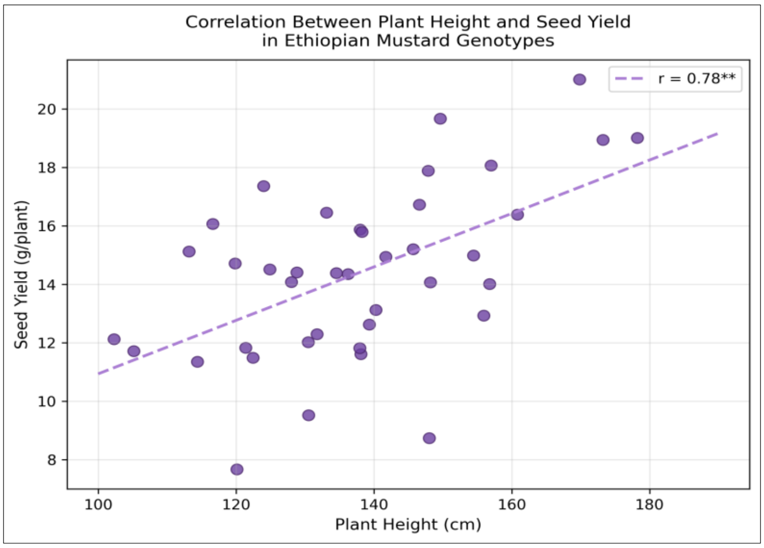

Fig 1: Scatter plot showing the genotypic correlation between plant height and seed yield in 48 Ethiopian mustard genotypes

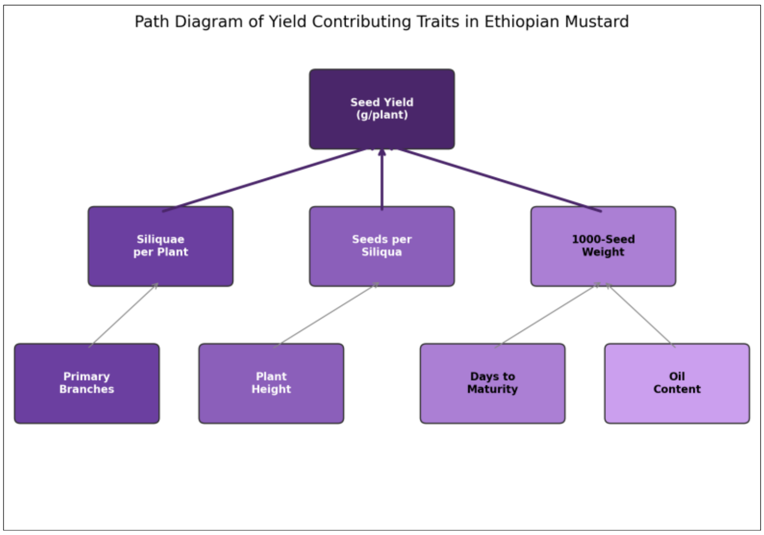

Fig 2: Path diagram illustrating direct and indirect effects of yield contributing traits on seed yield in Ethiopian mustard

Comprehensive Interpretation

The combination of high GCV, high heritability, and high genetic advance for seed yield and siliquae per plant indicates that additive gene action governs these traits and that direct phenotypic selection would be effective. The residual effect of the path model was 0.184, meaning the six traits accounted for 81.6% of the total variation in seed yield.

Discussion

The high GCV and heritability observed for seed yield and siliquae per plant are consistent with reports from Ethiopian and Indian germplasm collections of *B. carinata* and confirm that the species retains ample exploitable variation for improvement [1, 6]. The dominance of siliquae per plant in both correlation and path analyses matches findings in related species (*B. juncea*, *B. napus*), where reproductive sink capacity is typically the primary yield determinant [4].
That oil content showed low GCV and non-significant correlation with seed yield is a practical advantage, as it implies breeders can select for higher yield without inadvertently reducing oil concentration [2].
The moderate heritability of 1000-seed weight (63.6%) and its positive but indirect contribution to yield suggest that seed size improvement could be a useful secondary selection target, particularly if combined with selection for siliquae number. From a breeding standpoint, index selection incorporating siliquae per plant, primary branches, and 1000-seed weight should deliver the fastest yield gains in this germplasm pool [3].

Conclusion

Among the 48 Ethiopian mustard genotypes evaluated, seed yield and siliquae per plant exhibited the highest genetic variability, heritability, and genetic advance. Siliquae per plant had the strongest direct effect on yield in path analysis and should be the primary selection criterion. Primary branches and 1000-seed weight contribute indirectly and may be included in a selection index. Oil content appears to be independently controlled and unlikely to change as a correlated response to yield selection. These findings provide a quantitative foundation for trait-based selection in Ethiopian mustard breeding programmes aimed at improving seed yield without compromising oil quality.

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