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CHARACTER ASSOCIATION OF YIELD ATTRIBUTING TRAITS IN LINSEED (*Linum usitatissimum* L.) GENOTYPES

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Abstract
The study was conducted to determine the genotypic and phenotypic correlations between different traits of linseed genotypes, and the direct and indirect effect of different traits on seed yield using simple lattice design with two replications during 2019 cropping season at Ambo University Guder Campus. In present study harvest index, number of seed per capsule, days to maturity, plant height and days to flowering and were manifested positive and highly significant (p ≤ 0.01) association with seed yield at both genotypic and phenotypic level. The genotypic correlation coefficients were higher than the phenotypic correlation coefficients demonstrating that, the observed relationships among the various traits were due to genetic causes indicating the phenotypic expression of correlations is reduced under the influence of the environment. Path coefficient analysis revealed that higher and positive direct effect on seed yield were exhibited by days to maturity, plant height and number of seeds per capsule at both genotypic and phenotypic level. The traits those have maximum positive direct effects indicates that a given other traits are kept constant, increasing one of those characters will increase seed yield. The analysis indicated that, days to maturity, plant height and number of seeds per capsule is the major contributors for the improvements of seed yield in linseed and might be used as key criteria in linseed selection.

Key Word: *Correlation, Direct effect, Indirect effect, Path coefficient, Seed yield*

Introduction

Linseed (*Linum usitatissimum* L., 2n=30) pertain to family linaceae and the genus Linum is one of the premier crop cultivated for its seeds and fibre. Almost every part of the linseed plant is utilized commercially either directly or after procedure (Paul *et al*., 2017). Among the oilseed crops, linseed assist an essential share to Ethiopian economy. Linseed covered 0.64% (about 80,353.74 hectares) of the grain crop area and 0.30% (about 879,116.55 quintals) of the grain production (CSA, 2017) in Ethiopia. Despite of its contribution to regional oil industry and hard currency earning, average productivity of linseed in Ethiopia during 2016/17 cropping season was 10.94 quintals per hectare (CSA, 2017), but in developed country more than 15 q/ha (FAO, 2018).

Existence of genetic diversity is essential for the extended advance of this crop as well as for its elaboration in the agricultural system and germplasm characterization is an important link between the conservation and utilization of plant genetic resources. The dissimilarity among genetic constitution may be assessed based on morphological and the genetic diversity is advert to the variety present within distinct genotypes of same species. This is due to compare alleles of a gene in distinct individuals exhibit contrasting phenotypes Mulusew, *et al*. (2014); Nag *et al.* (2015); Bhandari, *et al*. (2017). Intelligence on the extended and nature of interrelationship among characters help in formulating effectual scheme of multiple trait selection, but in Ethiopia, the information on these aspects in linseed is very deficient (Tadele *et al.,* 2009).

Correlation coefficient value grade of association of distinct constituting characters among themselves and with the yield. The relation meditation between different yield reputation with yield, supply a basis for further breeding scheme and Correlation among distinct agronomic and morphological characters is an important aspect for better delineation of selection programs and is also assistant in bound the components of complex trait like yield. In selection procedure for crop improvement, cognition of association of various characters is the most essential tool Desai *et al*. (1994); Sharma, *et al*. (2016).

Crop yield is a complex character restraint by several interact genotypic and environmental factors and subordinate on a number of variables. Being a polygenic trait it is much influenced by environmental fluctuations. To hold superior varieties with supercilious yielding efficacious, the plant breeder have to deal with characters, which are governed by polygenic systems and show continual variation. Selection at any scaffold is fruitful only if the breeder is acquainted with the nature and magnitude of variability, association of characters with yield and path coefficient analysis Tariq *et al*. (2014); Patial *et al*. (2018).

Path analysis is application in agriculture by plant breeders for identification of nature that can be necessity as choice criteria for improving grain yield (Bagheri *et al.,* 2011). The relation supply the information about the degree but not the source of association whereas; path coefficient analysis grants a accurate inquiry of various component characters assist towards the seed yield or any other final product. It moderation the referring consequence of each factor contributing towards seed yield (Patial *et al*., 2018).

The association of nature as possessed to by the shallow correlation coefficient may not afford a precise description of the relationship between yield and yield related traits. In comparison, path coefficient analysis let an exact search of precise direct and indirect expression of describe and extent the relative weight of each of them in bound the ultimate goal yield (Alehegn, 2020). The present study was carried out with the objectives of determining the genotypic and phenotypic correlations between different traits of linseed genotypes and to identifying the traits that can be used as indirect selection to improve linseed seed yield.

Materials and Methods

Experimental Materials and Management

Phenotypic and Genotypic Correlation Coefficients and Path Coefficient Analysis of 56 linseed genotypes for seed yield and other Agronomic traits were studiedat Ambo University, Gudarcompusduring 2019 cropping season. Among the studied materials 48 genotypes were taken from Ethiopian Institute of Biodiversity (EIBD), which was collected from different agro-ecology region of Ethiopia (Table 1), while 8 released varieties were collected from Sinan and Kulumsa Agricultural research center.

The experiment was conducted in simple lattice design with two replications at both sites. Each replication consisted of four rows of each genotype. Row to row distance was 20 cm with row length of 2 meter and plant distance was 10cm was maintained by thinning. Normal cultural practices were carried out as recommended for linseed.Data was recorded on ten randomly selected plants for plant height, number of primary branch, number of secondary branch, number of capsule per branch, number of seed capsule, characters while days to 50 per cent flowering, lodging percentage, days to maturity, harvest index and seed yield data was recorded on plot basis. Harvest index calculated as Harvest index

$$(\%)=\frac{Seedyieldperplot}{Aerialbiomassperplot}x100$$

Table 1: Description of the test genotypes collected from different Ethiopia regions

Geographical origin	No of Genotypes	Name of genotypes
Oromia	24	13628(2), 13756(4), 15475(7), 17417(8), 17597(9), 17598(10), 17603(11), 17607(12), 17608(13), 17610(14), 17615(15), 18792(16), 19008(17), 19009(18), 19010(19), 19013(20), 13755(3), 208360(25), 208749(26), 208801(27), 212512(28), 212854 (29), 219333(32), 219334(34), 216892 (31)
Amhara	6	13522 (1), 237491 (47), 235784 (46), 229802 (36), 226032 (37), 202501(22)
SNNP	4	13758 (5), 208358 (24), 211478 (30), 2406439 (33
Tigray	10	235170 (43), 238471 (44), 235177 (45), 235158 (41), 235277 (42) 219966 (35), 19079 (21), 15248 (6), 235784 (46), 233996 (48)
Benishangul Gumuz	4	23544 (39), 23545 (40), 207970 (23), 23534 (38)
National releases	7	Jitu (49), Belay-96 (50), Bekelcha (51), Yadeno (52), Kuma (53), Berene(54), Jeldu (55)
Local variety	1	Local

Notes: Serial numbers in bracket stand for designation in this study

Statistical Analysis

Analysis of Variance

All collected data were subjected to analysis of variance using appropriate computer software (SAS, version 9.3) and Tukey's range Test (critical difference) at probability of 0.05 was used to separate the means and ranges for significant parameters.

Phenotypic and Genotypic Correlation Analysis

Phenotypic correlation and genotypic correlations were computed following the method described by Miller *et al.* (1985):

$$rpxy = \frac{\sigma 2\ pxy}{\sqrt{(\sigma 2\ px)(\sigma 2\ py)}}$$

$$rgxy = \frac{\sigma 2\ gxy}{\sqrt{(\sigma 2\ gx)(\sigma 2\ gy)}}$$

Where r is replication, rpxy and rgxy are phenotypic and genotypic correlation coefficient, respectively; σpxy and σgxy are phenotypic covariance and genotypic covariance between x and y respectively; σ^2px and σ^2gx are phenotypic and genotypic variances for trait x and σ^2py and σ^2gy are phenotypic and genotypic variances for the traits y respectively.

The coefficient of correlations at the phenotypic level have been tested for their significance with the Table for simple correlation coefficient using (g-2) degrees of freedom as indicated by Gomez and Gomez, (1984) or using tTable,

Where $t = \frac{\sigma 2\ pxy\sqrt{(g-2)}}{\sqrt{1-rpxy)}}$

Where rpxy is the phenotypic correlation coefficient and g the number of genotypes. The calculated t -value were compared with the t- tabulated at (g-2) degrees of freedom. The genotypic correlation coefficient has been tested for its significance with the formula of Robertson, (1959):

Where $t = \frac{rgxy}{SErgxy}$

Where rgxy is the genotypic correlation coefficient and SErgxy is the standard error of the genotypic correlation coefficient.

Path Coefficient Analysis

Path coefficient Analysis has been undergone for parameters to partition the correlation coefficient to direct and indirect effects of the components on lint cotton yield and fiber strength as illustrated by Dewey and Lu (1959). The formula: rij = pij+∑rikpkj where, rij= Mutual association between the independent character (i) and dependent character (j) as measured by the correlation coefficient, pij=components of direct effects of the independent character (i) on the dependent character (j) as measured by the path coefficient and ∑rikpkj=summation of components of indirect effect of a given independent character (i) on the given independent character (j) via all other independent characters (k)

The residual effect (h) was estimated by the following; $h=\sqrt{(1-R^2)}$; where R^2=∑pijrijpij=components of direct effects of the independent character(i) on dependent character (j) as measured by the path coefficient.rij=mutual association between the dependent and independent character (i) and dependent character (j) as measured by the correlation coefficient.

Result and Discussion

The result showed the presence of significant differences among the tested genotypes for all characters considered, indicating the existence of variability among the tested genotypes.

Estimates of Correlation Coefficients at Phenotypic and Genotypic Levels

Estimates of phenotypic, and genotypic, correlation coefficients between each pair of traits are presented in

(Tables 2). The magnitudes of genotypic correlation coefficients for most of the traits were higher than their corresponding phenotypic correlation coefficients, except in a few parameters, which indicate the presence of inherent or genetic association among various traits and showed thatthe phenotypic expression of correlations is reduced under the influence of the environment.Similarly, (Kumar and Paul, 2016; Patial *et al*., 2018; Upadhyay, *et al*., 2019) also reported that genotypic correlation coefficients were higher than their respective phenotypic correlation coefficients for most of the characters in their studies.

At genotypic level, harvest index, number of seed per capsule, days to maturity, plant height and days to flowering and were manifested positive and highly significant ($p \leq 0.01$) correlations with seed yield, while percentage of lodging revealed negative and highly significant. Seed yield positively and significant associated with harvest index (rg = 0.98), number of seed per capsule (rg = 0.599), days to maturity (rg = 0.529), plant height (rg = 0.439), days to flowering (rg = 0.305), this indicate that the characters might be utilized as selection criteria for improving grain yield in linseed crop. But seed yield was negative and significantly associated with lodging (rg = -0.529), which should be considered as undesirable character in selection criteria.

On other hand harvest index, days to flowering, number of seed per capsule, and plant height were strongly and positively correlated with days to maturity (rg = 0.698 and rp = 0.676), (rg = 0.560 and rp = 0.525), seed per capsule (rg = 0.437 and rp = 0.454 and plant height (rg = 0.370 andrp = 0.354) in both genotypic and phenotypic (Table 2), this result is agree with Chaudhary *et al*. (2016) finding.

In homogenous ways, number of seed per capsule, days to maturity, harvest index, plant height, and days to flowering were manifested positive and highly significant ($p \leq 0.01$) correlations with seed yield, while percentage of lodging revealed negative and highly significant. Seed yield positively and significant associated with number of seed per capsule (rp = 0.541), days to maturity (rp = 0.488), harvest index (rp = 0.483) plant height (rp = 0.467), days to flowering (rp = 0.294) at phenotypic level, this indicate that the characters might be utilized as selection criteria for improving grain yield in linseed crop. Similarly (Reddy *et al*., 2013; Dash, *et al*., 2016) reported that high positive correlation of days to flowering, plant height, numbers of seed percapsule and days to maturity with seed yield in linseed at both phenotypic and genotypic level.

Table 2: Estimation of genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients between seed yield and other Agronomic traits among linseed 56 genotypes

Variable	FD	PH	PBr	SBr	CBr	LG	SC	MD	HI	SYD
FD	**1**	0.405**	-0.038	0.138	-0.375**	-0.354**	0.199	0.560**	0.191	0.305**
PH	0.339**	**1**	-0.204	0.024	-0.176	-0.277*	0.125	0.370**	0.088	0.439**
PBr	-0.005	-0.172	**1**	0.128	-0.007	0.059	0.173	0.012	0.201	-0.035
SBr	0.101	-0.030	0.082	**1**	0.255*	0.037	0.119	0.009	-0.061	0.096
CBr	-0.316**	-0.087	0.050	0.188*	**1**	0.279*	0.051	-0.498	-0.224	-0.140
LG	-0.335**	-0.254**	0.093	0.092	0.189*	**1**	-0.391**	-0.602**	-0.513**	-0.529**
SC	0.227*	0.226*	0.094	0.045	0.057	-0.356**	**1**	0.437**	0.626**	0.599**
MD	0.525**	0.354**	-0.032	-0.017	-0.393**	-0.539**	0.454**	**1**	0.698**	0.529**
HI	0.164	0.164	0.125	-0.059	-0.152	-0.442**	0.535**	0.676**	**1**	0.98**
SYD	0.294**	0.467**	-0.042	0.101	-0.043	-0.355**	0.541**	0.488**	0.483**	**1**

Notes: ***, **, * = Significant at *P*<0.001, 0.01 and 0.05 levels, respectively, Cbr = number of capsule per branch, FD = days to flower, MD = days to maturate, HI = harvest index, LG = lodging percent,Pbr = number of primary branch per plant, PH = plant height, Sbr = number of secondary branch per plant Sc = number of seed per capsule, Yldha = seed yield per hectare

Path Coefficient Analysis

Path coefficient analysis measures direct and indirect contribution of individual attributes towards seed yield. In order to find out the direct and the indirect contribution of different characters towards seed yield per plant, the path coefficient analysis was done at both genotypic and phenotypic level (Table 3 and Table 4) respectively.

Estimation of Direct and Indirect Effects of Different Traits on Seed Yield per Hectare at Genotypic Level (rg)

The path coefficient analysis at genotypic level revealed that days to maturity (0.4043), had the maximum positive direct effect followed by plant height (0.3326) andnumber of seed per capsule (0.3059) at genotypic level (Table 3). The correlation ofdays to maturity, plant height and number of seed per capsule with seed yield was also positive and highly significant, while lodging percentage manifested the highest negative direct effect with seed yield. The correlation of lodging percentage also negative and highly significant with seed yield. In similar way number of secondary branch had lower positive and direct effect on seed yield with positive association. Harvest index had negligible negative direct effect on seed yield, but due its positive indirect effect through a place days to maturity, number of seed per capsule and plant height it had significant positive association with seed yield per hectare. In contrast to this Kumar *et al*. (2017) reported that the direct positive effect of harvest index on grain yield. The analysis showed those days to maturity, numbers of seed per capsule and plant height are the important determinants of seed yield per hectare and selection for late maturity would bring about improvement in seed yield.

Days to flowering contributed positive indirect effect via plant height, primary branch per plant, secondary branch per plant, number of capsules per branch, lodging, number of seeds per capsule and days to maturity on seed yield (Table 3); Plant height contributed positive indirect effect via days to flowering, primary branch per plant, secondary branch per plant, number of capsules per plant , lodging, number of seed per capsule and days to maturity on seed yield (Table 3); primary branch per plant contributed positive indirect effect via secondary branch, number of capsules per branch, number of seeds per capsule and days to maturity on seed yield; secondary branch per plant contributed through a place days to flowering, plant height and number of seed per capsule on seed yield; number of capsule per branch contributed positive indirect effect via primary branch per plant, secondary branch per plant , number of seeds per capsule and harvest index on seed yield; lodging contributed positive indirect effect through a place secondary branch per plant and harvest index on seed yield; number of seed per capsule contributed positive indirect effect via days to flowering, plant height, secondary branch per plant, lodgingand days to maturity on seed yield; harvest index contributed positive indirect effect via days to flowering, plant height, secondary branch per plant, number of capsules per branch, lodging, number of seeds per capsule and days to maturity on seed yield; days to maturity contributed positive indirect effect via days to flowering, plant height, number of capsules per branch, lodging and number seeds per capsule on seed yield. Kumar and Paul (2016); Ankit, *et al*. (2019) also reported similar results the direct positive effect of days to flowering, days to maturity and plant height on seed yield at genotypic level.

Characters those have maximum positive direct effects indicates that a given other traits are kept constant, increasing one of those characters will increase seed yield, which implies that those traits are the major contributors for the improvements of seed yield per hectare in linseed at genotypic level. Similarly Kumar *et al*. (2017) reported that the positive direct effect of number of capsules per plant, days to maturity and plant height on grain yield per plant.

Table 3: Estimates of direct and indirect genotypic effects of different agronomic traits on seed yield

Variable	FD	PH	PBr	SBr	CBr	LG	SC	HI	MD	rg
FD	0.0148	0.1346	0.0039	0.0151	0.0210	0.0636	0.0612	-0.0862	0.0771	0.305**
PH	0.0060	0.3326	0.0210	0.0026	0.0099	0.0498	0.0383	-0.0570	0.0358	0.439**
PBr	-0.0006	-0.0680	-0.1029	0.0140	0.0004	-0.0106	0.0530	-0.0018	0.0814	-0.035
SBr	0.0021	0.0080	-0.0132	0.1094	-0.0143	-0.0067	0.0365	-0.0014	-0.0245	0.096
CBr	-0.0056	-0.0586	0.0007	0.0279	-0.0560	-0.0502	0.0155	0.0766	-0.0905	-0.140
LG	-0.0053	-0.0921	-0.0061	0.0041	-0.0156	-0.1797	-0.1196	0.0927	-0.2074	-0.529**
SC	0.0030	0.0416	-0.0178	0.0131	-0.0028	0.0703	0.3059	-0.0673	0.2532	0.599**
HI	0.0083	0.1230	-0.0012	0.0010	0.0279	0.1082	0.1336	-0.1540	0.2821	0.98**
MD	0.0028	0.0294	-0.0207	-0.0066	0.0125	0.0922	0.1915	-0.1075	0.4043	0.529**

Notes: - ***, **, * = Significant at $P<0.001$, 0.01 and 0.05 levels, respectively, Cbr = number of capsule per branch, FD = days to flower, MD = days to maturate, HI = harvest index, LG = lodging percent,Pbr = number of primary branch per plant, PH = plant height, Sbr = number of secondary branch per plant Sc = number of seed per capsule, Yldha = seed yield per hectare

Estimation of Direct and Indirect Effects of Different Traits on Seed Yield per Hectare at Phenotypic Level (rp)

The path coefficient analysis at phenotypic level revealed that plant height (0.3165) had the maximum positive direct effect followed by number of seed per capsule (0.2995) and days to maturity (0.2256) (Table 4). The association ofnumber of seed per capsule, plant height and days to maturity with seed yield was also positive and highly significant.. In similar way number of secondary branch and number of capsule per branch had lower positive and direct effect on seed yield with positive and negative association respectively.The positive direct effect of number of capsule per branch on seed yield was masked by it is negative indirect effect of days to maturity and result in negative correlation (rp = -0.043) with seed yield per hectare at phenotypic level. On other hands lodging percentage manifested the highest negative direct effect with seed yield and negative and highly significant association with seed yield. Although number of secondary branch per plant had positive direct effect on seed yield, but due its negative indirect effect via number of days to maturity, plant height and harvest index it had negative association with seed yield per hectare. Different researches are reported similar results viz Reddy *et al*. (2013); Bindra and Paul (2016) and Ankit *et al*. (2019)

Days to flowering contributed positive indirect effect via plant height, primary branch per plant, secondary branch per plant, lodging, number of seed per capsule, harvest index and days to maturity on seed yield (Table 4); Plant height contributed positive indirect effect through days to flowering, primary branch per plant, lodging, number of seeds per capsule, harvest index and days to maturity on seed yield; primary branch per plant contributed positive indirect effect via secondary branch per plant, number of capsules per branch, number of seeds per capsule and days to maturity on seed yield; secondary branch per plant contributed through a place days to flowering, number of capsules per branch and number of seeds per capsule on seed yield; number of capsule per branch contributed positive indirect effect via secondary branch per plant and number of seeds per capsule on seed yield; lodging contributed positive indirect effect through a place secondary branch per plant, and number of capsule per branch on seed yield; number of seed per capsule contributed positive indirect effect via days to flowering, plant height, secondary branch per plant, number of capsules per branch, lodging, harvest index and days to maturity on seed yield; harvest index contributed positive indirect effect via days to flowering, plant height, primary branch per plant, lodging , number of seeds per capsule and days to maturity on seed yield; days to maturity contributed positive indirect effect via days to flowering, plant height, lodging, number of seeds per capsule and harvest indexon seed yield. Similarly result was reported by Ibrar *et al*. (2016). Residual effect of 0.4 indicated that as 60% of variation on seed yield has been accounted for by the nine traits included as independent variables in this study.

The analysis showed that days to maturity, plant height and number of seed per capsule, are the important determinants of seed yield per hectare and selection for late maturity would bring about improvement in yield at phenotypic level, since they revealed maximum positive direct effect and significant positive association with seed yield per hectare. The traits those have maximum positive direct effects indicates that a given other traits are kept constant, increasing one of those characters will increase seed yield, which implies that those traits are the major contributors for the improvements of seed yield per hectare in linseed at phenotypic level. On other hands during path analysis character which revealed positive correlation with direct positive effect with low value on grain yield indicating that while selecting these characters seed yield per plant can't be improved through these traits (Sharma *et al.*, 2016).

Table 4: Estimates of direct and indirect phenotypic effects of different agronomic traits on seed yield

Variable	FD	PH	PBr	SBr	CBr	LG	SC	HI	MD	rp
FD	0.0350	0.1072	0.0003	0.0112	-0.0079	0.0114	0.0681	0.0318	0.0369	0.294**
PH	0.0118	0.3165	0.0084	-0.0033	-0.0022	0.0086	0.0676	0.0215	0.0369	0.467**
PBr	-0.0002	-0.0544	-0.0491	0.0091	0.0013	-0.0032	0.0283	-0.0020	0.0282	-0.042
SBr	0.0035	-0.0095	-0.0040	0.1105	0.0047	-0.0031	0.0133	-0.0010	-0.0134	0.101
CBr	-0.0111	-0.0275	-0.0025	0.0208	0.0250	-0.0064	0.0170	-0.0239	-0.0344	-0.043
LG	-0.0117	-0.0804	-0.0046	0.0101	0.0047	-0.0339	-0.1068	-0.0327	-0.0997	-0.355**
SC	0.0079	0.0714	-0.0046	0.0049	0.0014	0.0121	0.2995	0.0275	0.1208	0.541**
HI	0.0184	0.1122	0.00159	-0.0019	-0.0098	0.0183	0.1360	0.0606	0.1526	0.483**
MD	0.0057	0.0518	-0.0061	-0.0065	-0.0038	0.0150	0.1603	0.0410	0.2256	0.488**

Residual effect = 0.4, Notes: - ***, **, * = Significant at P<0.001, 0.01 and 0.05 levels, respectively, Cbr = number of capsule per branch, FD = days to flower, MD = days to maturate, HI = harvest index, LG = lodging percent, Pbr = number of primary branch per plant, PH = plant height, Sbr = number of secondary branch per plant Sc = number of seed per capsule, Yldha = seed yield per hectare

Conclusion

Linseed is one of most important oil crop in Ethiopia, but there is a lack of information on correlation and path analysis between seed yield and other agronomic traits to improve yield of the crop through selection as other cereal crops. The study was designed to determine the most determinant traits in seed yield improvement of the crop. In present study, harvest index, days to maturity, plant height, days to flowering and number of seed per capsule with seed yield manifested positive and highly significant association with seed yield at both genotypic and phenotypic level, indicating that selection on those characters will increase seed yield. In similar ways, days to maturity (0.4043), had the maximum positive direct effect followed by plant height (0.3326) and number of seed per capsule (0.3059) at genotypic level and plant height (0.1072) had revealed the maximum positive direct effect followed by number of seed per capsule (0.2995) and days to maturity (0.2256) at phenotypic level. Days to flowering, plant height, number of seeds per capsule and harvest index has major indirect positive effect contributors' traits at both genotypic and phenotypic level. The direct and indirect association of traits will not only, help to understand the desirable and undesirable relationship of economic traits but also help in assessing the scope of simultaneous improvement of two or more attribute (Reddy et al..,2013). The traits having positive direct effect on seed yield are considered to be suitable selection criteria in future linseed breeding program.

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