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CORRELATION STUDIES AND PATH COEFFICIENT ANALYSIS FOR SEED YIELD AND YIELD COMPONENTS IN ETHIOPIAN CORIANDER ACCESSIONS

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ABSTRACT

Coriander (*Coriandrum sativum* L.) is an annual spice herb that belongs to the family Umbelliferae. Even though Ethiopia is a centre of primary diversity for the crop, the current knowledge about its biology, variety development and agronomy is neither complete nor conclusive under Ethiopian conditions. To contribute to filling some of the existing gaps, a field experiment was conducted during the main rainy season of 2007-2008 at Wondo Genet and Kokate, southern Ethiopia. Data for 15 agronomic and quality traits were measured and statistically tested. More of the traits were found having high correlation coefficients at genotypic level than the phenotypic level, demonstrating intrinsic associations among the traits. Seeds plant^{-1} and thousand seeds weight were associated significantly and positively with seed yield plant^{-1} at phenotypic and genotypic levels. Essential oil and fatty oil contents were negatively associated with most of the trait studied. Path analysis revealed that days to end 50% flowering, longest basal leaf length, plant height, days to 50% maturity and seeds umbellet^{-1} exerted positive direct effect on seed yield plant^{-1}, indicating that selection using these traits would be effective in improving seed yield in coriander.

Key Words: *Coriandrum sativum*, essential oil, Ethiopia, fatty oil

RÉSUMÉ

Le Coriander (*Coriandrum sativum* L.) est une herbe d'épice annuelle qui appartient à la famille Umbelliferae. Même si l'Ethiope est un centre de sa diversité primaire, la connaissance actuelle de sa biologie, son développement variétal et son agronomie ne sont jamais exhaustif ni conclusive en conditions ethiopiennes. Pour contribuer à combler cette brèche, un essai en champ était effectué durant la principale saison de pluie 2007-2008 à Wondo Genet et Kokate, Sud Ethiopie. Les données de 15 traits agronomiques et traits de qualité étaient mesurées et statistiquement testées. Laplupart des traits ont manifesté des coefficients de corrélation élevée au niveau génotypique qu' au niveau phénotypique, témoignant des associations intrinsèques parmi les traits. Le nombre de grains par plante et le poids de mille grains étaient significativement associés et positivement avec le rendement en grains par plante aux niveaux phénotypiques et génotypiques. Les teneurs en huile essentielle et matière grasse étaient négativement associées à laplupart des traits étudiés. L'analyse du passage a révélé que les jours à 50% de la floraison, la plus longue base de la longueur des fueilles, la hauteur de plants, les jours à 50% de la maturité et le nombre de grains par umbellet ont excercé un effet positif direct sur le rendement en grains par plant, indicant que cette sélection par l'utilisation de ces traits pourrait être efficace en amelioration du rendement en grains coriander.

Mots Clés: *Coriandrum sativum*, huile essentielle, Ethiopie, huile grasse

INTRODUCTION

Discovery of genetic resources by Vavilov (1951), in line with the rapid development of genetics and its application in plant breeding, stimulated widespread interest in the study of variability and improvements in different crop species. Since there exists sufficient variability in agronomic and quality traits in Ethiopian coriander (Beemnet and Getinet, 2010), initiating a breeding programme, with this economically important but neglected or under-utilised aromatic spice herb contributes a magnificent role for its improvement with regard to cultivation and utilisation.

When initiating a breeding programme with any crop having genetic variation, it is important to gather information on the traits of agronomic importance in order to select and breed better varieties (Dubley and Moll, 1969). Relationships of different traits with yield, among different traits and their direct and indirect effects on one another provides basis for a successful breeding programme (Ali *et al.*, 2003).

Yield being a quantitative trait has complex inheritance, which is subjected to environmental fluctuations, requiring indirect selection of simply highly heritable traits for its improvement (Thakur and Saini, 1995). Deb and Khaleque (2009) stated that knowledge about the association and interaction of different traits with yield greatly helps the breeder in selection work with more precession and accuracy. The intensity and direction of association of the different traits with yield were estimated with genotypic and phenotypic coefficient of correlation (Mode and Robinson, 1959). The exact picture of the relative importance of direct and indirect influences of the component characters towards seed yield is determined by path analysis (Bhatt, 1973). Correlation and path analysis have been used in breeding studies in different aromatic plants (Gurubuz, 2001). Hence, correlation studies and path analysis provide detailed information to identify important characters to be considered in improvement programme through selection.

The present research work was undertaken to investigate the relative importance of direct and indirect influences of the component traits toward seed yield; and identify the important traits to be considered in coriander improvement programmes.

MATERIALS AND METHODS

The experiment was conducted in two locations of Southern Ethiopia, at Kokate and Wondo Genet, during the main cropping season of 2007-2008. Kokate is located at 6°532 N latitude and 37°522 E longitude with an altitude of 2100 m.a.s.l. It has a humid climate with an average annual temperature of 18°C, and average annual precipitation of about 1300 mm. The soil is sandy loam with a pH of 4.81. Wondo Genet is located at 7°192 N latitude and 38°382 E longitude with an altitude of 1780 m.a.s.l. The site receives mean annual rainfall of 1000 mm with a respective maximum and minimum temperature of 10 and 30°C. The soil is sandy clay loam with an average pH of 7.2 (Abayneh *et al.*, 2006).

The experiment included 49 accessions of coriander, which were maintained at Wondo Genet Agricultural Research Centre. A randomised complete block design with two replications was employed. The respective spacing between rows and plants were 40 cm and 30 cm. The plot size was 3.6 m^2 with 6 rows having 6 m length.

Seeds were directly drilled in rows on the prepared experimental units on July 15, 2007 at Kokate, and on July 18, 2007 at Wondo Genet. The experiment was conducted under rain fed conditions. Two hoeing and three weddings were carried out and no fertiliser and chemicals were applied. Samples were taken from the middle three rows of a plot, leaving the outer two border rows. Five plants were considered for characters measured on individual plant basis. The whole plant was harvested when 50% of the plants on a plot turned brown. Harvesting was carried out early in the morning and late in the afternoon in order to minimise the fruit losses due to shattering. Then the whole plant was sun-dried for three days and then threshed. The seeds were separated from the plant debris properly for the necessary measurements.

A total of 15 quantitative traits were recorded according to the descriptors of International Plant Genetic Resource Institute (IPGRI) (Diederichsen, 1996). These are basal leaf number, longest basal leaf, plant height at full maturity, days to start 50% flowering, days to end 50% flowering, days to 50% maturity, umbels plant^{-1}, one thousand seed weight, umbellets plant^{-1}, seed umbellets^{-1}, seeds plant^{-1}, seed yield plant^{-1}, seed yield (kg ha), essential oil content and fatty oil content.

Essential oil content was determined on volume by dry weight (v/w) basis from 50-100 g sun-dried composite seeds from three middle row plants of a plot. Essential oil was produced by hydro-distillation as illustrated by Guenthere (1972). Fatty oil content was determined from an oven-dried 22 g composite seed samples taken from the three middle rows of each plot by subjecting it to the Nuclear Magnetic Resonance Spectrometer reader (NMRS) at Holeta Agricultural Research Centre.

Phenotypic and genotypic correlation coefficients were estimated according to Johanson *et al*. (1955), Miller *et al*. (1958) and Singh and Chavdhury (1985).

$$r_{p_{xy}} = \frac{PCOV_{XY}}{\sqrt{\sigma_{P_X}^{2} . \sigma_{P_Y}^{2}}}$$

$$r_{g_{xy}} = \frac{GCOV_{XY}}{\sqrt{\sigma_{g_X}^{2} . \sigma_{g_Y}^{2}}}$$

Where:

$r_{p\,xy}$ = Phenotypic correlation coefficient between traits x and y;

$r_{g\,xy}$ = Genotypic coefficient of variation between traits x and y;

$PC0V_{xy}$ = Phenotypic covariance between variable x and y; and

$GCOVxy$ = Genotypic covariance between variable x and y.

The coefficient of correlation at phenotypic level was tested using tabulated 'r' value at (a-2) degree of freedom, where 'a' is number of accessions. The coefficient of variation at genotypic level was tested for their significance using the formula proposed by Robertson (1959).

$$t = \frac{r_{g_{xy}}}{SEr_{g_{xy}}}$$

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

Where:

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

Where, h^2_{x-} and h^2_y are heritability for character x and y

Path coefficient analysis. For the PCA, seed yield plant^{-1} was taken as the dependent variable while the rest characters were considered as the independent variables. The direct and indirect effects of the independent characters on seed yield plant^{-1} was estimated by simultaneous equation using the formula as applied by Deway and Lu (1959):

$r_{ij} = p_{ij} + \Sigma r_{ik} p_{kj}$

Where;

r_{ij} = mutual association between the i^{th} independent character and the j^{th} dependent characters as measured by the genotypic correlation coefficient;

P_{ij} = components of direct effects of the i^{th} independent character on the j^{th} independent character as measured by the genotypic path coefficients; and

"$r_{ik}p_{kj}$ = summation of components of indirect effects of a given i^{th} independent characters on given j^{th} dependent via all other k independent characters.

RESULT AND DISCUSSION

Correlation studies. More traits were found having high correlation coefficients at genotypic level than at phenotypic level, indicating the inherent association among the traits studied (Table 1). In agreement with the current study, higher genotypic correlation coefficients than their respective phenotypic correlation coefficients were reported by several researchers (Johnson *et al.*, 1955; Agedew, 2006) for soybean (*Glycine max* L.), Adam (2006) for black cumin (*Nigella sativa* L.) and Wassihun (2006) for sorghum (*Sorghum bicolar* L.).

Seed yield plant^{-1} was strongly and positively correlated with basal leaf number (r=0.98**), plant height (r=0.99**), seed plant^{-1} (r=1.00**) and one thousand seed weight (r=0.47**) at genotypic level. It was also positively and significantly (P<0.05) associated at genotypic level with long basal leaves and umbels plant^{-1} (Table 1). Seed yield plant^{-1} significantly and positively correlated with seeds plant^{-1} (P<0.01) and one thousand seed weight (P<0.05) at phenotypic correlation coefficient level. The result is in agreement with that of Bahandari and Gubta (1991) and Tripathi *et al.* (2000), who reported positive association of plant height, days to flowering, days to maturity and umbels with seed yield in coriander. Jindla *et al.* (1985) also reported a positive association of days to flowering, plant height, umbels plant^{-1}, umbellets umbel^{-1} and seed umbel^{-1} with seed yield in coriander. Singh and Mital (2003) similary reported positive and significant association of plant height, number of umbel plant^{-1} and 1000 seed weight with seed yield plant^{-1} in sweet fennel. Hence, selection of coriander plants having these features will facilitate coriander seed yield improvement.

Essential oil content was negatively and significantly associated with long basal leaves (r=-0.34*), plant height (r=-0.35**), thousand seed weight (r=-0.49**), umbels plant^{-1} (r=-0.39**) and seeds plant^{-1} (r=-0.28*); and non-significantly with the rest of the traits at the genotypic level. Essential oil correlated negatively and significantly with thousand (P<0.05) and negatively and non-significantly with all the characters except its positive and non-significant association with plant height, days to end 50% flowering, days to harvest and number of seeds umbellets^{-1} at phenotypic level. The result are in line with Adam's (2006) findings of a negative association of essential oils with different yield contributing traits in black cumin. Essential oil content was associated negatively with seed yield plant^{-1}. On the contrary, Vijayalatha and Chezhiyan (2004) reported positive and significant association of essential oil content with seed yield on 90 coriander accessions grown in India. This difference might be due to the difference in the accessions, growing environment and the interaction effects between accessions and environment.

Fatty oil content was negatively and significantly correlated with plant height (r=-1.00**), thousand seed weight (r=-0.78**), umbels plant^{-1} (r=-0.33*), seeds umbellate^{-1} (r=-1.00**), seeds plant^{-1} (r=-1.00**) and seed yield plant^{-1} (r=-0.47**); positively with umbellates umbel^{-1} (r=0.84**) and essential oil content (r=0.83**) at genotypic level. At phenotypic correlation levels, non-significant association was observed for fatty oil content with days to maturity and umbels plant^{-1}, and very low negative association with most of the traits.

The positive association of fatty oil content with essential oil content will facilitate simultaneous improvement through selection for the two traits. However, simultaneous improvement of oil content and seed yield in coriander is very difficult due to the negative association of essential oil content and fatty oil content with seed yield; hence, an independent selection should be done for the improvement of such traits.

Path analysis. The path coefficients for direct and indirect effects of the characters studied on seed yield are presented in Table 2. Days to 50% flowering had the highest direct positive effect on seed yield plant^{-1} (0.84). The result is in agreement with Tripathi *et al.* (2000), who reported days to end flowering is important character in making selection in coriander seed yield. It also gave high indirect negative effects *via* days to start 50% flowering and umbellets umbel^{-1}, and negligible negative indirect effects through seeds plant^{-1}. It also scored considerably high positive indirect effects *via* plant height, thousand seed weight and days to 50% maturity; and small positive indirect effect through umbels plant^{-1} and seeds umbellet^{-1}. The low positive association of days to end 50% flowering with seed plant^{-1}, which is not as such important on

TABLE 1. Phenotypic (below diagonal) and genotypic (above diagonal) correlation coefficients of 14 traits of 49 coriander accessions tested at Wondo Genet and Kokate during the main cropping season of 2007/2008

	LBLL	BLN	PH	TSW	DSF	DEF	DM	UNPPL	UNPU	SNPU	SNPPL	SYPL	EO	FO
LBLL		1**	1**	-0.16	0.75**	0.87**	1**	0.25	0.95**	0.45**	0.02	0.28*	-0.33*	-0.16
BLN	0.75**		1**	-0.32*	1**	1**	1**	0.38**	1**	1**	0.36*	0.98**	0.23	-0.23
PH	0.63**	0.64**		-0.31*	0.97**	1**	1**	-0.44**	1**	0.97**	0.13	0.99**	-0.35**	-1.00**
TSW	-0.06	-0.01	-0.08		-0.64*	-0.6**	-0.23	-0.02	-0.39**	-0.18	0.37*	0.47**	-0.49**	-0.78**
DSF	0.62**	0.49**	0.51**	-0.31*		0.75**	1**	-0.07	0.59**	0.69**	0.03	0.04	-0.18	-0.08
DEF	0.65**	0.62**	0.63**	0.09	0.72**		1**	-0.14	0.83**	0.71**	0.02	0.12	0.26	0.16
DM	0.73**	0.60**	0.60**	-0.16	0.71**	0.74**		0.29*	0.73**	0.56**	0.15	0.11	0.06	0.16
UNPPL	0.17	0.14	0.11	0.07	0.01	-0.02	0.16		-0.04	-0.20	0.15	0.33*	-0.39**	-0.33
UNPU	0.72**	0.60**	0.75**	-0.18	0.52**	0.53**	0.53**	0.05		0.39**	-0.10	0.00	-0.06	0.84**
SNPU	0.28*	0.25	0.33*	-0.17	0.44**	0.40**	0.45**	-0.11	0.24		0.09	0.11	-0.06	-1.00**
SNPPL	0.10	0.19	0.18	0.16	0.02	0.04	0.09	0.14	-0.05	0.10		1**	-0.28*	-1.00**
SYPL	0.1145	0.2405	0.1935	0.34*	-0.013	0.0042	0.09	0.17	-0.06	0.06	0.97**		-0.26	-0.47**
EO	-0.17	-0.04	0.02	-0.36*	-0.09	0.21	0.02	-0.16	-0.02	0.02	-0.15	-0.23		0.83**
FO	-0.13	-0.05	0.08	-0.014	-0.16	-0.11	-0.24	-0.24	-0.10	-0.04	0.04	-0.02	0.12	

LBLL = Longest basal leaf length, BLN = Basal leaf number, PH = Plant height, TSW = Thousand seeds weight, DSF = Days to start 50% flowering, DEF = Days to end flowering, DM = Days to 50% maturity, UNPP= Umbel number/plant, UNPU = Umbellets number/umbel, SNPU = Seed number/umbellets, SNPPL = Seed number/plant, SYPL = Seed yield/plant, EO = Essential oil content on volume by dry weight basis in percent and FO= Fatty oil content in percent

TABLE 2. Estimates of genotypic direct effect (bold and diagonal), indirect effect of individual trait on seed yield/plant via other 11 independent traits of 49 coriander accessions tested during the main cropping season of 2007/2008 at Wondo Genet and Kokate in Ethiopia

	LBLL	BLN	PH	TSW	DSF	DEF	DM	UNPPL	UNPU	SNPU	SNPPL	rg
LBLL	0.66	-0.35	0.48	0.14	-0.64	0.77	0.23	0	-1.11	0.06	0.03	0.28*
BLN	0.79	-0.39	0.57	0.33	-0.78	0.97	0.32	0.06	-1.08	0.18	0	0.98**
PH	0.77	-0.28	0.44	0.26	-0.77	0.95	0.3	0.19	-1.1	0.16	0.07	0.99**
TSW	-0.02	0.21	-0.06	-0.61	0.66	-0.43	0.04	0.08	0.55	0.1	-0.05	0.47**
DSF	0.48	-0.4	0.42	0.38	-0.91	0.62	0.18	0	-0.72	0.01	-0.02	0.04
DEF	0.54	-0.42	0.41	0.35	-0.71	0.84	0.16	-0.01	-1.03	0.01	-0.04	0.12
DM	0.67	-0.38	0.45	0.15	-0.9	0.85	0.19	-0.04	-0.88	0.04	-0.04	0.11
UNPPL	0.24	-0.08	-0.13	0.08	0.13	-0.05	0.13	-0.17	0.11	0.05	0.02	0.33*
UNPU	0.62	-0.4	0.43	0.23	-0.54	0.69	0.13	0	-1.21	0.01	0.03	0.01
SNPU	0.3	-0.39	0.43	0.11	-0.63	0.59	0.11	0.03	-0.47	0.05	-0.03	0.11
SNPPL	0.16	0.01	0.21	-0.08	0.13	0.16	0.18	0.13	0.27	0.15	-0.35	1.00**

LBLL = Longest basal leaf length, BLN = Basal leaf number, PH = Plant height, TSW = Thousand seeds weight, DSF= Days to start 50% flowering, DEF= Days to end flowering, DM = Days to 50% maturity, UNPP = Umbel number plant^{-1}, UNPU = Umbellets umbel^{-1}, SNPU = Seeds umbellets^{-1}, SNPP L= Seeds plant^{-1}

the basis of correlation estimates, was revealed as one of the major positive direct and indirect contributor to seed yield plant^{-1} by path analysis. Moreover, it also scored high heritability and genetic advance as percent of mean. Hence, selecting plants with longer duration to end 50% flowering would contribute for rapid progress in coriander seed yield improvement programmes.

The longest basal leaf length had high positive direct effect (0.66) on seed yield plant^{-1}. In addition, it had positive and significant (P<0.01) associating with seed yield plan^{t-1}. This is in agreement with Diedrichesen (1996), who reported that coriander genotypes with long basal leaves had high seed yield. Its high negative indirect effects *via* basal leaf number, days to start 50% flowering and umbellets umbel^{-1}; and negligible indirect negative effect through umbels plant^{-1} and seeds plant^{-1}, were counter balanced by high direct and indirect positive influence through plant height, thousand seed weight, days to end 50% flowering, days to 50% maturity and seeds umbellets^{-1}, caused the net effect of overall correlation between longest basal leaf length and seed yield plant^{-1} to be high and positive. Therefore, it is important to consider long basal leaves in improving seed yield in coriander, as it was strongly and positively associated with seed yield plant^{-1} and its direct and indirect positive effect through yield contributing traits to seed yield plant^{-1}

The direct effect of plant height on seed yield plant^{-1} was positive and comparatively high (0.44) (Table 2). Positive direct effect of plant height on seed yield was also reported by Jindla *et al*. (1985) in coriander. Nevertheless, the indirect effect of plant height on seed yield plant^{-1} through basal leaf number, days to start 50% flowering and umbellets umbel^{-1} was high and negative. On the other hand, the indirect influence through one-thousand seed weight, days to end 50% flowering and days to 50% maturity were high and positive. The net effect in the system of inverse influences of negative indirect effects counter balanced with direct and indirect positive effects, making the overall correlation between plant height and seed yield plant^{-1} strong and positive. Therefore, making an allowance for plant height in a selection programme for seed yield would be very important in coriander.

Days to 50% maturity registered positive direct influence on seed yield plant^{-1} (0.19) (Table 2). The result is in agreement with Tripathi *et al.* (2000) who reported days to maturity is the major yield component in coriander. It exerted moderately high indirect positive effects *via* plant height, thousand seed weight and days to end 50% flowering. However, it put forth very high indirect negative influence through basal leaf number, days to start 50% flowering and umbellets umbel^{-1}. The net effect of 5 negative and 6 positive values counter balanced the total correlation value of days to 50% maturity and seed yield/plant to be positive. Therefore, it is important to consider this trait for improving coriander seed yield.

Seeds umbellet^{-1} had positive direct effect (0.05) on seed yield plant^{-1} (Table 2). Positive direct contribution of seeds umbellet^{-1} was also reported by Bahandari and Gubta (1991) and Singh and Mittal (2003). It had high indirect negative effect *via* basal leaf number, plant height, days to start 50% flowering and umbellets umbel^{-1}; and indirect positive effect through longest basal leaf number, plant height, thousand seed weight, days to end 50% flowering and days to 50% maturity to seed yield plant^{-1}. Due to its positive direct and high indirect positive effect through different yield contributing traits, number of seeds umbellet^{-1} was found an important character to be considered in coriander seed yield improvement programme.

Even though umbelletes umbel^{-1} had high positive indirect effect to seed yield plant^{-1} *via* the longest basal leaf length, plant height, thousand seed weight, days to end 50% flowering and days to 50% maturity (Table 2); its high negative direct effect (-1.21) and indirect effect through basal leaf number and days to start 50% flowering make the overall correlation of umbellets umbel^{-1} with seed yield plant^{-1} low and negative. On the contrary, Jindla *et al*. (1985) reported the positive and direct contribution of umbellet umbel^{-1} to seed yield plant^{-1}. Therefore, considering only the number of umbellet umbel^{-1} in selection programme is not important due to its very high negative direct effect and indirect effect to seed yield plant^{-1}. Hence, tall plants bearing long basal leaves, long reproductive stage and umbellets with big seeds are advisable to be considered during selection in coriander seed yield improvement programme.

The direct effect of days to start 50% flowering on seed yield plant^{-1} was high and negative (-0.91). In contrast, Jindla *et al*. (1985) found that days to flowering had positive direct effect on seed yield plant^{-1}. Its low correlation value with yield plant^{-1} was due to its high direct and indirect negative effect through basal leaf number, umbellet umbel^{-1} and seeds plant^{-1} on plant seed yield. Nevertheless, moderately high indirect positive effects were recorded via plant height, thousand seed weight, days to end 50% flowering, days to 50% maturity, umbels plant^{-1} and seeds umbellet^{-1}.

Thousand seed weight had direct negative effect (-0.61) on seed yield plant^{-1} (Table 2). On the contrary, a positive direct effect of thousand seed weight on seed yield was reported by Singh and Mittal (2003) in coriander. It had high indirect positive effect through days to start 50% flowering and umbellets umbe^{-1}; whereas high indirect negative effect was registered for days to end 50% flowering. Even though the one thousand seed weight and seed yield plant^{-1} had positive and significant correlation ($P<0.05$), path analysis revealed its moderately high negative direct and indirect effect to seed yield plant^{-1}. Hence, considering only thousand seed weight in coriander seed improvement is not practical.

The number of seeds per plant had a perfect positive association with seed yield plant^{-1} (r=1**) (Table 1). This positive association did not contributed to yield directly, but indirectly through longest basal leaf length, plant height, days to end 50% flowering, days to 50% maturity and umbellets umbel^{-1}. Therefore, looking for tall plants with long basal leaves, late flowering and maturing, and umbellets having many seeds is very important to improve seed yield in coriander.

Basal leaf number had positive and significant association ($P<0.05$) with seed yield plant^{-1} (Table 1) which is in agreement with the report of Diedrichsen (1996). This association was due to its indirect positive effect through longest basal leaf length, plant height, thousand seed weight, days to end 50% flowering and days to 50% maturity. Considering only this trait following correlation estimates is not practical in coriander seed yield improvement programme.

The number of umbel per plant had a small negative direct (-0.17) effect on seed yield plant^{-1} (Table 2). Against to the current result, Sanker and Khader (1991) reported highest direct positive effect of umbels plant^{-1} on seed yield plant^{-1}. Its negative indirect effect on seed yield plant^{-1} *via* basal leaf number, plant height, days to end 50% flowering, seeds umbellate^{-1} and seeds plant^{-1} was counter balanced by its positive indirect contribution via longest basal leaf length, thousand seed weight, days to start 50% flowering, days to 50% maturity and umbellets umbel^{-1} made the overall correlation high and positive with seed yield plant^{-1}.

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