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ORIGINAL ARTICLE

Assessment of Grain Yield Correlation with some Morphological and physiological traits, yield components and Essential oil in Coriander (*Coriandrum sativum* L.)

Farhood Yeganehpoor*, Saeid Zehtab-Salmasi, Jalil Shafagh-Kolvangh, Kazem Ghassemi-Golezani and Soheila Dastborhan
Department of Plant Eco-physiology, Faculty of Agriculture, University of Tabriz, Tabriz, Iran
* Corresponding author Email: farhoodyeganeh@yahoo.com

ABSTRACT
One of the best ways to identify the important traits on yield is determination of correlation between these traits and yield. The traits with non-significant correlation with yield do not have a practical application in breeding programs. Therefore, this study was aimed in 2014 and 2015 to investigate the correlation among some morphological, physiological and yield components withgrain yield of coriander (Coriandrum sativum L.). The experiment was arranged as split plot-factorial based on randomized complete block (RCB) design with three replications. Treatments were three levels of water supply (irrigation after 60, 90 and 120 mm evaporation from class A pan) and four levels of fertilizer application (control, 100 kg.ha^{-1} Urea, biofertilizer (Nitrokara),and 50% Urea+Nitrokara), and foliar spray of salicylic acid (0 and 1 mM). Correlation analysis showed positive and significant relation of leaf area, proline content, chlorophyll content and leaf dry weight of coriander with grain yield. A significant positive correlation was also observed between grain yield and morphological traits (plant height, branchesand leaves per plant), especially number of branches per plant. The most important yield components that had a main impact on seed yield were number of umbels and grains per plant. The correlations between grain yieldwith grains per umbellet and 1000-grain weight werealso positive and significant. All qualitative studied traits in this research had significant correlationwith grain yield of coriander. Results revealed that leaf area (r=0.68), branches per plant (r=0.74), umbels per plant (r=0.72) and grains per plant (r=0.77) are the best selection criteria for improvement of coriander grain yield in similar conditions.
Keywords;*Coriander, Correlation, Grain yield, Morphological traits, Physiological traits,Yield components*

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INTRODUCTION

Grain yield in plants is the results of a number of complex morphological and physiological processes affecting each other and occurring at different growth stages.It is a quantitative and complex trait that highly influenced by many genetic factors and environmental fluctuations. In plant breeding programs, direct selection for yield could be misleading and successful selection depends upon the information on the genetic variability and association of morpho-agronomic traits with yield.Correlation studies provide a better understanding of the association of different characters with grain yield [14]. Therefore, selection should be done based on these component characters after assessing their correlation with the yield [32].The correlation studies among yield contributing traits may help in indirect selection of yield components. The correlation is a pragmatic approach to develop selection criteria for accumulating optimum combination of yield contributing traits in a simple genotype [24]. The analysis of correlation coefficients between different traits with grain yield helps to decide about the relative importance of these traits and their values as selection criteria[20] andtherefore, leads to a directional model for yield prediction [6]. According to Qureshi et al.[28], characters which positively and significantly correlate with yield can be used for indirect selection of high-yield genotypes without yield evaluating.Relationships of different traits with yield, among different traits and their direct and indirect effects on one another provides basis for a successful breeding programs[4]. Deb and Khaleque[11] 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. Yield components have a lot of inheritability; therefore,based on these traits the plant selection would be a confident and quick way for riddling all of the plants and improvement of the yield [35].

In many studies, grain yield of wheat was positively correlated with plant height[31,33], tillers per plant [24,33], leaf area [24,31], spikelets per spike[31,33], number of grain per spike[16,31], grains per plant [24], spike length[31,33] and 1000-grain weight [16,24,31].

A positive and significant correlation has also shown between grain yield of lentil and plant height, pods per plant,biomass [2,3], grains per pod and 100-grain weight[2].Okonkwo and Idahosa[25] also observed a significant positive correlation between grain yield and number of grains per pod, 100-grain weight, number of pods per plant and pod length in soybean.

In cumin, the numbers of grains per umbel and umbels per plant have been showed the highest correlation with yield and were considered as the most effective traits on yield[7].

Coriander (*Coriandrum sativum* L.) is an annual herb from *Apiaceae*,which possesses nutritional and medicinal properties, and also it is one of the most commonly used spices [19]. Coriander is commonly known as a culinary and medicinal plant native to the Mediterranean and Middle Eastern regions. It is a multipurpose herb grown mainly for its foliage and grains, which have numerous food-related biological activities and multiple functional uses [10]. The coriander fruits (grains) contain 10 to 27.7% fatty acids and up to 2.6% essential oils, which may be used for many industrial purposes [13]. Since the coriander grains have strong and typical scent, they are appreciated worldwide as basic ingredients of many traditional foods, particularly curry powder [21,29].According to Sravanthi *et al.* [32], grain yield in coriander exhibited a positive significant correlation with plant height, plant spread, fresh and dry weight, umbels per plant, umbellets per umbel, grains per umbellet, days to seed maturity and harvest index. Hence, grain yield can be improved by selecting the lines with these characters. Therefore, the aim of the current study was to determine the correlations among the grain yield and some morphological, physiological, yield components and essential oil of coriander.

MATERIELS AND METHODS

A split plot factorial experiment (using a randomized complete block design) with three replications was conducted in 2014 and 2015 at the Research Farm of Kermanshah, Iran (latitude 47°34′N, longitude 34°39′E, altitude 1200 m above sea level)to evaluate the effects of different irrigation levels on some physiological and biochemical traits of coriander. The climate of research area is characterized by mean annual precipitation of 350.5 mm, mean annual temperature of 10°C, mean annual maximum temperature of 17 °C and mean annual minimum temperature of 4.5°C. The soil was loamy with an EC of 0.4 dS m^{-1}, pH of 8.09 and field capacity of 28.4%. Soiltest results are shown in Table 1. Irrigation treatments (I_1, I_2 and I_3: irrigation after 60, 90 and 120 mm evaporation from class A pan, respectively) were located in main plots and fertilizers (control, Urea 100 $kg.ha^{-1}$, biofertilizer of Nitrokara, and 50% Urea + Nitrokara), and salicylic acid (0 and 1 mM) were allocated to sub plots.

Table 1. Physical and chemical characteristics of research field soil

Soil type	Sand (%)	**Clay** (%)	**Silt** (%)	EC ($ds.m^{-1}$)	pH	OC (%)	Fe (ppm)	K ($mg.kg^{-1}$)	P ($mg.kg^{-1}$)	N (%)
Loamy	29	26	45	0.4	8.09	2	1.38	232	14.1	0.2

OC: Organic carbon

Seeds were inoculated with Nitrokara, a biofertilizer containing *Azorhizobiu mcaulinad* bacteria with a formulation of Kara technique living industrial company. Urea was applied on the basis of soil test (1/3 at sowing date, 1/3 after thinning and 1/3 at vegetative stage). Two levels of salicylic acid (0 and 1mM) were sprayed on plants at two stages of stem elongation and flowering. All plots were irrigated immediately after sowing, but subsequent irrigations were carried out according to the treatments. Weeds were controlled by hand during plant growth and development as required. Each plot had 6 rows of 4 m length, spaced 20 cm apart. The seeds were sown by hand with a density of 40 seeds per m^2 (distance between plants within rows was 10 cm).

At flowering stage, leaf area and leaf chlorophyll content were measured using leaf area meter and portable chlorophyll meter, respectively. Free proline content was also measured according to Bates et al. [8].

At physiological maturity, plant height, stem diameter, branches per plant, root length, number of leaves and umbels per plant, number of umbellets per umbel, number of grains per umbellet, number of grains per plant, 1000-grain weight and dry weight of root and leaf were determined on 10 normal plants that randomly selected from the four middle rows of each plot. Also, the plants of $1m^2$ in the middle part of each plot were harvested and grain yield per unit area were obtained. Then, essential oil content was determined by hydro-distillation, using a modified Clevenger apparatus and subsequently essential oil yield for each treatment at each replicate was determined. Furthermore, seed oil percentage determined using soxhlet apparatus and subsequently oil yield was calculated. Finally, relationships between grain yield and other traits were determined using simple correlation coefficient analysis on the average data and analyzed by SPSS 16 software.

RESULTS AND DISCUSSION

Correlation between physiological traits and grain yield

Correlation analysis showed the positive and significant relation between grain yield and leaf area (r=0.68), proline content (r=0.35), chlorophyll content (r=0.51) and leaf dry weight (r=0.54) (Table 2).Therefore, increase in these traits can simultaneously improve grain yield. However, the most important physiological trait that had a main effect on coriander grain yield was leaf area. Indeed, plants with developed leaf produced higher grain yield. Among physiological traits, leaf area was significantly and positively correlated with leaf chlorophyll content (r = 0.55) and leaf dry weight (r = 0.61), while root dry weight had no relation with any studied traits (Table 2). According to Al-Tahir [5], grain yield of oat and wheat were significantly and positively correlated with leaf area and chlorophyll content. A significant positive correlation between grain yield and leaf area [24,31] and grain yield and chlorophyll content[12,17,18] was also reported in other plants.

Leaf area is an important physiological parameter, which reflects crop growth and predicts crop yield. Leaf area has great influence on plant yield [15] and is a good selection criteria for increase of grain yield. Thus, plants with higher value of leaf area can produce more grain yield. As the leaf area increases, a greater photo synthetically active surface area becomes available and it would therefore be expected that the production rate would be greater the higher the leaf area [5].

The chlorophyll content is positively associated with photosynthetic rate which increases biomass production and grain yield. Significant relationships between chlorophyll content and yield and yield components facilitate selection of high yield genotypes [27].In many studies, leaf chlorophyll value measured by SPAD chlorophyll meter was found closely related to grain yield [9, 22].

Table 2. The correlation between physiological traits and grain yield of coriander

Physiological traits	(1)	(2)	(3)	(4)	(5)	(6)
Leaf area (1)	1					
Prolinecontent (2)	0.19 ^{ns}	1				
Chlorophyll content (3)	0.55**	0.07 ^{ns}	1			
Root dry weight (4)	0.06 ^{ns}	0.05^{ns}	0.02 ^{ns}	1		
Leaf dry weight (5)	0.61**	0.12 ^{ns}	0.49**	0.10 ^{ns}	1	
Grain yield (6)	0.68**	0.35*	0.51**	0.05 ^{ns}	0.54**	1

^{ns}, * and ** : non-significant and significant at $p \leq 0.05$ and $p \leq 0.01$, respectively

Correlation between morphological traits and grain yield

Correlation coefficients between grain yield and morphological traits are shown in Table 3.There was a positive and significant correlation at $p \leq 0.01$between grain yield and plant height (r = 0.63), branches per plant (r = 0.74) and number of leaves per plant (r = 0.49), but correlation between grain yield and stem diameter and root length was not significant (Table 3).This result indicates that increasing of coriander grain yield was not due to thick stems or longer roots. Therefore, branches per plant, which has highest correlation with grain yield, is preferable for selection. In the other words, one suitable way to improve the yield of coriander is increase in the number of branches per plant. The present result is in agreement with Singh et al. [30] who reported the number of branches per plant, directly effecting grain yield, is particularly important in coriander breeding. A significant positive correlation between grain yield and plant height was also observed in maize [1], lentil [2] and wheat [12].

Table 3. The correlation between morphological traits and grain yield of coriander

Morphological traits	(1)	(2)	(3)	(4)	(5)	(6)
Plant height (1)	1					
Stem diameter (2)	0.60**	1				
Branches per plant (3)	0.58**	0.09 ns	1			
Root length (4)	0.07 ns	0.03 ns	0.01 ns	1		
Leaves per plant (5)	0.35 *	0.05 ns	0.45**	0.05 ns	1	
Grain yield (6)	0.63**	0.11 ns	0.74**	0.15 ns	0.49**	1

ns, * and ** : non-significant and significant at p ≤ 0.05 and p ≤ 0.01, respectively

Correlation between yield components and grain yield

On the basis of correlation analysis results (Table 4), grain yield of coriander showed significant positive correlation with number of umbels per plant, grains per umbellet, grains per plant and 1000-grain weight. Grain yield had the maximum correlation with grains per plant($r = 0.77^{**}$) and minimum correlation with 1000-grain weight ($r = 0.56^{**}$). In contrast, there was no significant relation between grain yield and umbellets per umbel (Table 4).In the other word, change in grain yield was not due to increase or decrease of umbellets per umbel in field conditions. These correlations indicated that higher number of umbels per plant, grains per umbellet and plant and 1000-grain weight lead to an increase in grain yield of coriander.

It was stated that yield components such as the number of branches and umbels affect directly grain yield [26, 34]. Thus, these characters could be selected and improved simultaneously for further enhancement of grain yield in coriander that contradicted the findings of Meena *et al.* [23] who reported significant positive correlation between number of umbels per plant and grain yield in this plant.

Table 4. The correlation between yield components and grain yield of coriander

Physiological traits	(1)	(2)	(3)	(4)	(5)	(6)
Umbels per plant (1)	1					
Umbellets per umbel(2)	0.22 ns	1				
Grains per umbellet(3)	0.66**	0.14 ns	1			
Grains per plant (4)	0.70 **	0.45*	0.01 ns	1		
1000-grain weight (5)	0.40*	-0.11 ns	0.08 ns	0.04 ns	1	
Grain yield (6)	0.72**	0.20ns	0.68**	0.77 **	0.56**	1

ns, * and ** : non-significant and significant at p ≤ 0.05 and p ≤ 0.01, respectively

Correlation between qualitative traits and grain yield

According to Table 5,grain yield of coriander was positively and significantly correlated with seed oil content ($r = 0.39$), seed oil yield ($r = 0.60$),essential oil percentage ($r = 0.58$) and essential oil yield ($r = 0.72$).The correlation between seed oil and seed oil yield ($r = 0.55$) and essential oil content and its yield ($r = 0.52$) were also positive and significant. However, there was no significant relation between oil and essential oil contents (Table 5).Since oil and essential oil yields are calculated as oil content × grain yield and essential oil × grain yield, respectively, the correlation between these traits and grain yield is expected.

Table 5. The correlation between qualitative traits and grain yield of coriander

Physiological traits	(1)	(2)	(3)	(4)	(5)
Seed oil (%) (1)	1				
Seed oil yield (2)	0.55 **	1			
Essential oil (%) (3)	0.01 ns	0.07 ns	1		
Essential oil yield (4)	0.04 ns	0.15 ns	0.52 **	1	
Grain yield (5)	0.39*	0.60 **	0.58 **	0.72 **	1

ns, * and ** : non-significant and significant at p ≤ 0.05 and p ≤ 0.01, respectively

CONCLUSION

Our results revealed positive and significant relation of grain yield of coriander with leaf area, proline and chlorophyll contents, leaf dry weight, plant height, branches and leaves per plant, umbels per plant, grains per umbellet, grains per plant and 1000-grain weight. However, Leaf area, branches and umbels per plant, and number of grains per plant had highest correlation with grain yield. Therefore, these traits are the best indirect selection criteria in coriander under conditions similar to this research and may be used in breeding studies.

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