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ORIGINAL ARTICLE

Analysis of Yield and Yield Components in Sesame (*Sesamum indicum* L.)

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ABSTRACT
Yield and yield component analysis was carried out for some characters such as capsule per node, branch per plant, capsule per plant, capsule length, plant height, height at first capsule and branching height in 16 genotypes of sesame (Sesamum indicum L.)*. The materials were grown in a randomized complete block design with three replications, at Seed and Plant Improvement Institue, Karaj, Iran during 2005-6. Capsule per plant, plant height and capsule length, respectively, had the highest positive and significant correlation with yield, but remained in stepwise regression only plant height and capsule per plant. The results of the ordinary path analysis indicated the highest direct effect on the yield for capsule per plant followed by plant height and about all indirect effects on the yield were employed through capsule per plant. Sequential path model, constructed according to real relationships between the traits, showed direct effects for branch per plant, capsule length, capsule per plant and plant height. Capsule per node, branch per plant, capsule length and plant height had indirect effects through capsule per plant. Thus, it is suggested to focus on capsule per plant (and plant height in the next order) for an efficient breeding program for sesame.*
Key words: *Path analysis, Stepwise regression, Direct effects, Genotypes.*

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INTRODUCTION

Sesame with a variety of excellent characters such as high oil quantity and quantity and relative drought tolerance has a wide adaptability in Iran. It is assumed the crop had been the oldest oil crop in Iran and probably in the world [1]. The architecture of yield and other related characters help to formulate a meaningful breeding strategy for developing improved genotypes [2]. On the other hand, dissecting of a complex trait like yield into some simple characters with known physiological aspects and then modifying the most effective ones by conventional breeding or genetic engineering (*e.g.* Pathway engineering) would help to alter the most effective and bottleneck processes involved in the final performance (*e.g.* yield) [1].

Simple correlation and regression analysis are tools for detecting the most correlated characters with yield. However, they don't provide any information about kind of effects directly or indirectly between yield components and the yield. Path analysis, as described by Li, is an efficient mean for investigating the rate limiting characters in yield formation, as well as partitioning the kind of effects of yield components on the yield, *e.g.* direct and indirect effects [3]. In fact the method has been developed as a technique to deal with a system of inter-related variables [4].

The original idea of path analysis was to combine the knowledge of causal relationships among variables with the degree of relationship measured by correlation coefficient to determine the direct influence along each separate path and the degree to which variation of a given effect is determined by each particular cause [5] and as it had been confirmed by many investigators, the yield components when considered as variables show inter-related nature [6, 7, 8].

Yield components develop sequentially, with later-developing components under control of earlier developing ones. It seems doubtful, therefore, that yield components developing relatively late, can exert significant influence on a component that developed earlier [9]. The sequential path analysis considers the sequential nature of the yield components [6, 9]. According to the mentioned subjects, this study was conducted to investigate the relationship between yield and yield components of sesame cultivars.

MATERIALS AND METHODS

The genetic materials used in this study were composed of 16 genotypes, including: local populations of Dezful, Jiroft and Moghan; nine cultivars and lines named as: Darab 14, Varamin 27, Varamin 3822, Moghan 11, Moghan 17, Non-branching Naz, Branching Naz, Karj 1 and Yekta and finally exotic genotypes as Palestinian, Panama, Indian and Chinese. The materials were grown in a randomized complete block design with three replications, at Seed and Plant Improvement Institute, Karaj, Iran during 2005-6. Plots were composed of four meters with 60*15 cm inter and intra-row spacing. Five plants per plot were selected randomly for each genotype and tagged for recording detailed observations of characters such as: capsule per node (X1), branch per plant (X2), capsule length (X3), capsule per plant (X4), plant height (X5), height of first capsule (X6), height of branching (X7), and yield per plant (Y).
Simple bi-variate correlation, stepwise regression and path analysis were carried out using SPSS and path software's but the sequential path analysis was done by hand calculations.

RESULTS

Simple correlation

Phenotypic association of yield and its comps (Table 1) indicated that yield displays positive significant correlation with capsule per plant (r=0.811), plant height (r=0.476) and capsule length (r=0.3). Height at first capsule shows a positive significant correlation with plant height (r=0.432). Branch per plant has a negative significant correlation with those of Avila and Montilla [10] and Padmavathi and Thangavelu [11].

Stepwise regression:

Stepwise regression analysis, considering plant yield as dependent variable showed that only two characters, plant height (X5) and capsule per plant (X4) remained in the model. Accordingly, it could be written: Y= -14.382 + 0.16 X4 + 0.105 X5 (R=0.85). The equation emphasizes that in spite of a significant simple correlation between a yield component and yield *e.g.* capsule length, it wasn't included in the stepwise regression equation, a result arisen from inter-correlation of the yield components. This shortcoming will be eliminated using path analysis.

Ordinary path analysis:

Correlation analysis only provides the inter _relationships between yield and yield components, and does not reveals the causes and effects of the components on the yield, as the path coefficient analysis does. The cause _effect between the analyzed variables suggested that yield (Y) is affected by: capsule per plant (X4). Plant height (X5), and branching height (X7). The relationship is shown in figure 1. The path coefficient results are shown in Table 2.
The greatest direct and positive effect on the yield was caused by capsule per plant, followed by plant height (0.701 and 0.295, respectively) and the highest positive indirect effect was caused by plant height through capsule per plant (0.185), followed by capsule per node through capsule per plant (0.168). Earlier workers reported the direct positive effect of capsule per plant on plant yield [12, 13]. Also, as reported by Avila and mantilla [10] and Murali et al. [12], plant height had a great direct and positive effect on plant yield. Finally, branching height had a medium and direct negative effect on plant yield (-0.146).

Sequential path analysis:

Bi-directional arrows considered in Figure 1 denote all kinds of indirect of yield components. But considering the sequential nature of the formation of the yield components, e g. formation of height at first capsule, plant height and capsule per plant respectively, the indirect effect of capsule per plant as well plant height through height at first capsule don't have biological concept. Entering the effects in path relation causes biases on estimation of other effect. In sequential path analysis only meaningful relationships are considered. Accordingly, sequential and nearly real diagram for the measured characters is shown in Figure 2. The results of the sequential path analysis are furnished in Table 3.

Table 1. Simple correlation coefficients between the evaluated sesame parameters.

	X1	X2	X3	X4	X5	X6	X7	Y
X1 (Capsule/ node)	-	- 0.55**	-0.03	0.24	- 0.299**	- 0.21	-0.391**	0.021
X2 (Branch / plant)	-	-	- 0.05	0.187	0.229	0.457**	0.544**	0.209
X3 (Capsule length)	-	-	-	0.193	0.203	-0.073	-0.11	0.3*
X4 (Capsule / plant)	-	-	-	-	0.265	-0.035	-0.102	0.811**
X5 (Plant height)	-	-	-	-	-	0.432**	0.187	0.476**
X6 (Height of first capsule)	-	-	-	-	-	-	0.256	0.024
X7 (Branching height)	-	-	-	-	-	-	-	-0.113

* and ** stand for significant at 0.05, 0.01, respectively

Table 2. Direct and Indirect yield component effects on plant yield in sesame.

Character	**Direct effect**	**Indirect effect**						
		X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**
X1 (Capsule/ node)	-0.083	-	-0.051	-0.003	0.168	-0.089	0.019	0.056
X2 (Branch / plant)	0.091	0.045	-	-0.005	0.131	0.067	0.044	-0.08
X3 (Capsule length)	0.083	0.002	-0.005	-	0.135	0.06	0.006	0.015
X4 (Capsule / plant)	0.701	-0.02	0.017	0.016	-	0.078	0.003	0.014
X5 (Plant height)	0.295	0.024	0.02	0.017	0.185	-	-0.042	-0.028
X6 (Height of first capsule)	-0.. 95	0.017	0.041	-0.007	-0.025	0.127	-	-0.038
X7 (Branching height)	-0.146	0.032	0.049	-0.01	-0.072	0.055	-0.025	-
Residual effect: 0.483								

Table 3. Direct and sequential Indirect Yield component effects on plant yield in sesame

Character	Direct effect	Sequential Indirect effect						
		X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**
X1 (Capsule/ node)	-0.098	-	-	-0.0059	0.125	-	-	-
X2 (Branch / plant)	0.102	-	-	-	0.1	-	-	-
X3 (Capsule length)	0.197	0.003	-	-	0.1	-	-	-
X4 (Capsule / plant)	0.519	-	-	0.038	-	-	-	-
X5 (Plant height)	0.315	-	0.023	-	-0.137	-	-	-
X6 (Height of first capsule)	0.042	-	-	-	-0.0182	-	-	-
X7(Branching height)	0.077	-	0.055	-	-0.053	-	0.01	-

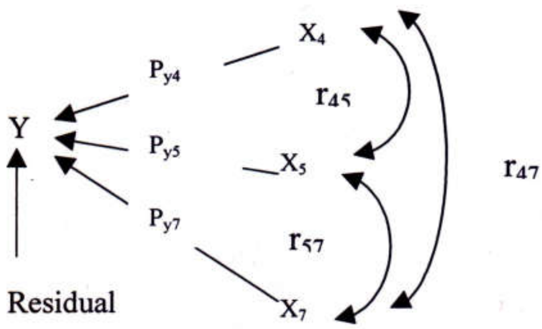

Figure 1. Ordinary path diagram for yield and three important characters in sesame, where P y_i stands for direct effect of i^{th} character (i =4, 5, or 7) and r_{ij} (i=4, 5 or 7 and i ≠ j) for simple correlation coefficients between i^{th} and j^{th} characters.

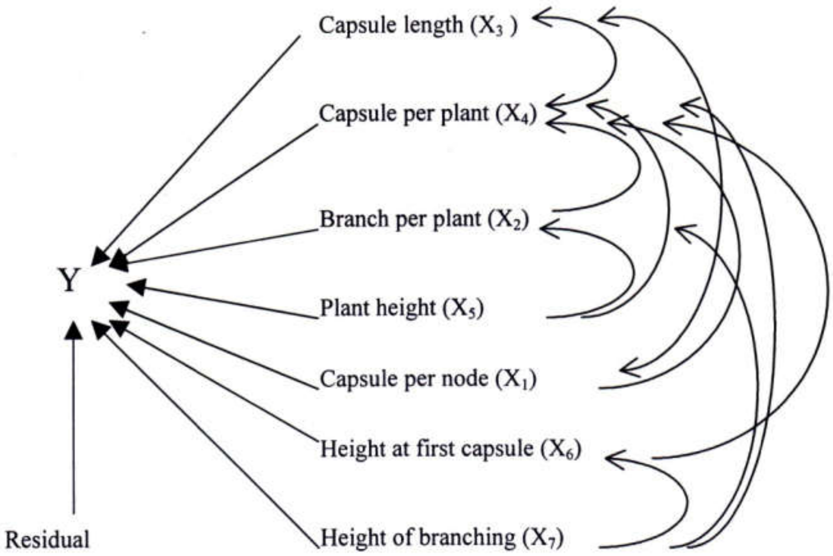

Figure 2. Sequential path diagram for yield and some characters in sesame. The unidirectional arrows between the variables in indicate the sequential nature of indirect effect.

DISCUSSION

Simple correlation

Avila and Mantilla [10] and Padmavathi and Thangavely [11] earlier denoted existence of positive significant correlation between the yield with capsule per plant, plant height, and capsule length. Capsule per plant and plant height had been considered as two important components of the yield [14], and our result is in agreeing with the fact.

Significant positive correlations between height at first capsule and plant height is an agree with the result of Sakila *et al* [15]. It may be concluded that for producing the yield potential of each individual plant, with considering capsule per plant as the most efficient yield component, an increase in the height at first capsule could be accompanied by increase in plant height (in order to compensate total number of capsule per main stem). Although the increase in the branch per plant is followed by the source (leaf number), but each branch, in turn, bears some capsule, therefore for compensating of assimilates, capsule per node must be decreased.

Stepwise Regression

X4 (capsule per plant) was the first variable entered into the model, followed by X5 (plant height), indicating the major role of capsule per plant in yield formation. The result of stepwise regression analysis to those of path analysis, with superiority of dividing the effect of each character into direct and indirect effects in the later ones.

Path analysis

Comparing Table 2 with 3, it is confirmed that in sequential method, the direct effect of X2, X3 and X5 has been increased while that of X4 decreased. The results of the sequential method indicated that capsule per node affects on the yield only via capsule per plant, and branch per plant has an equal effect on the yield either directly or indirectly through capsule par plant. Capsule length has a medium effect on the yield. Plant height has a nearly high effect on the yield and a medium through capsule per plant, as well.

Capsule per plant individually determines the magnitude of the yield, hence the character applied its effect only directly, but some other characters such as capsule per node, branch per plant, capsule length, and plant height effect on plant yield through capsule per plant. Worth noting that plant height has both direct and indirect effects (through capsule per plant) on the yield. It may be possible by considering some other attribute related to plant height, the contribution of indirect effects of plant height will increase in the expense of its direct effects.

Capsule per node, branch per plant, and plant height have indirect effects on the yield via capsule per plant, in fact the letter characters are the nearest factor in determining seed per plant. But it must be noted that regardless of formation of the capsule on branch per plant, and plant height has indirect effects on the yield via capsule per plant, in fact the letter characters is the nearest factor in determining seed per plant. But it must be noted that regardless of formation of the capsule on branches and plant main stem (which in turn are contributed in the indirect effects of X2 of and X5), branches and the main stem are involved in assimilate production, due to bearing leaves. On the other hand, branch patterns help plant for intercepting, more light efficiently. This consideration may explain some part of the indirect effect of the two variables. If some characters related to photosynthesis will be involved in the path model, it could be possible the indirect effect of X2 and X5 increased in the expense of diminishing their direct effects. It is possible that by inserting some other variables, such as 1000-seed weight, seed per capsule, leaf area per main stem and branches, etc., more precise results could be obtained, in addition to reducing residual effect.

CONCLUSION

According to the obtained results of this study, a very complex trait like yield is divided into three similar characters, *e.g.* capsule per plant, plant height and branch per plant. Therefore, these three characters could be used as selection criteria for improving the yield. On the other hand, changing and manipulating processes involving information the three characters with oligo-genic nature, comparing to yield, as a very complex trait and polygenic inherent, could improve the yield potential of the crop, efficiently.

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