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Correlations and Path Coefficient Analysis in Exotic Safflower (*Carthamus tinctorious* L.) Genotypes Tested in the Arid and Semi Arid Lands (Asals) of Kenya

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Abstract: The objective of this study was to analyze the simple correlation coefficients in order to understand the pair-relations and carry out a path analysis to determine direct effects. Character associations between yield components can be used as the best guide for successful yield improvement by indirect selection. Thirty-six safflower accessions were evaluated for phenotypic traits at 4 locations namely Katumani, Kinamba, Lanet and Naivasha for two long rain seasons in two years. The experimental design was a Partially Balanced Lattice design with 3 replications. Path analysis of yield components revealed that components with the highest correlation to yield also had the highest direct effect to yield i.e., primary branches, capitula/plant, effective capitula, seeds/capitula and 100 seed weight. Two approaches can be suggested in selecting genotypes for specific traits to improve seed yield in safflower: Select genotypes with high number of seeds/capitulum, which is directly responsible for seed weight of capitulum as is evident from the high positive correlation between the two. Alternatively select genotypes with high 100 seed weight as this has a high significant ($p \leq 0.05$) positive association with seed yield. Generally simple correlations differed at the same location every year. The high correlation and direct effects of number of capitula/plant, effective capitula/plant and seeds/capitulum on seed yield suggests selection for these components will improve seed yield in safflower.

Key words: Safflower, quantitative character, selection, correlation coefficients, capitula, direct effects

INTRODUCTION

Safflower is a thistle-like plant with a strong central branched stem and varying number of branches. It is an annual drought tolerant crop requiring 350 to 650 mm of rain and adapted to a wide range of climatic conditions (Knowles, 1969). Safflower is a multipurpose crop used as a source of oil, dye, meal, medicine and birdseed. The seed contains 28-50% oil depending on the variety (Knowles, 1989; Nimbkar, 2002). The oil is of very high quality used both as food and in industry (Berglund *et al*., 1998). Due to its deep taproot (2-3 m), safflower can access and utilize moisture and nutrients from below the root zone of cereal crops and may be very useful in drying water profiles. It can also improve the soil structure when grown in rotation with other crops. The ability to prevent expansion of saline seeps, the need for dry conditions during flowering and maturation and vulnerability to few insect pests makes it an deal crop for sustainable cropping systems.

Seed yield is a quantitative character, which is largely influenced by the environment and hence has a low heritability (Johnson, 1989). The highest seed yields are expected when all components of seed yield are maximized. However, compensation for yield components may prevent large changes in seed yield because of negative correlations that exist among components of yield (Graf and Rowland, 1987). Such negative association may occur due to competition of two developing structures of the plant for limited resources like nutrients and water supply. Character associations between yield components can be used as the best guide for successful yield improvement by indirect selection (Sharaan and Ghallab, 1997). Thus, estimation of simple correlation coefficients gives a general idea about the pair-relations irrespective of the magnitude of heritable and non-heritable influences.

Selection is one of the important tools in crop improvement. The importance of selection for a particular trait depends upon the extent of direct or indirect effect of the trait on seed yield. Therefore before initiating selection in a crop improvement program, it becomes necessary to know the relative importance of different traits in influencing the trait of economic importance in a desired direction (Singh *et al*., 2004).

MATERIALS AND METHODS

Thirty-six safflower accessions were evaluated for phenotypic traits at 4 locations namely Katumani, Kinamba, Lanet and Naivasha for two long rain seasons in 2002 and 2003. The experimental design was a Partially

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Balanced Lattice design (6×6) with 3 replications. There were 6 blocks in each replication and each block had 6 accessions. Each plot had 4 rows of 6 m with a spacing of 40 and 30 cm between plants. Recommended crop management practices were followed at all sites. Plots were kept weed, pest and disease free until harvest. From a sample of 5 plants/plot, plant height was measured at physiological maturity, number of primary and secondary branches/plant, capitula/plant, effective capitula/plant, seeds/capitulum, head diameter, mean weight of 100 seeds and seed yield/plant. The seed yield/plot g m^{-2} was obtained from the total weight of two middle rows plus the weight of the sample.

The combined two-way analysis of variance for all the traits recorded was computed using Statistical Analysis System (SAS 6.12, 1996 software). Replications and locations were considered as random effects whereas genotypes were considered as fixed effects. Simple correlation coefficients were conducted to detect associations between traits. Quantitative data was standardized (mean zero and variance one) prior to cluster and principal component analysis, to give each descriptor an equal weighting in analysis.

RESULTS AND DISCUSSION

The yield/plot was positively ($p \leq 0.05$) associated with number of primary branches, secondary branches, capitula/plant, effective capitula/plant and seeds/capitulum in both years (Table 1) and only significant with yield/plant and 100 seed weight in the second year (2003). Seed weight recorded the highest positive correlation with yield/plant in 2003 while the number of capitula/plant and effective capitula/plant had a high positive effect on yield/plot in 2003. This suggests that breeding for higher yield through increased number of these components would be effective in safflower and these can be considered to be the most important traits for yield improvement in safflower. Singh *et al*. (2004) have observed similar results. Generally, the 100 seed weight was negatively and significant ($p \leq 0.05$) for most components in 2002. But in combined analysis it was negatively and significantly correlated with seeds/capitulum. Hence selection for high number of seeds/capitulum would reduce the yield/plant.

These results also reveal that the association between characters depended on the environment. Seed yield in safflower can be improved indirectly by selecting the genotypes producing more seeds/capitulum coupled with high seed weight.

The association in both years and environments revealed that there was a significant negative correlation between the yield/plot and the secondary branches (Table 2). This suggests indirect selection through increased number of secondary branches would be ineffective. Other yield contributing factors like primary branches, capitula and yield/plant were negatively but not significantly correlated with yield (Table 2). Considering yield to be a dependable complex inherited character, overall yield is determined by several contributing factors, which may be related or unrelated. The intercorrelation for yield/plant was negative and significant with the number of seeds/capsule. Except for the number of seeds/capitulum, the 100 seed weight showed a negative and significant correlation with all the other components. Such a negative association may occur due to the competition of two developing structures of the plant for limited resources like nutrients and water supply (Adams, 1967). The number of primary, secondary and capitula/plant had a very high and positive correlation (R^2 $p \leq 0.01$) with the number of effective capitula/plant. Hence, seed yield in safflower can be improved indirectly by selecting genotypes producing a large number of seeds/capitulum. Generally seed yield was positively and significantly influenced by all the seven components under study (Table 1).

Table 1: Correlations coefficients between yield components of 36 safflower accessions at 4 sites in 2002 and 2003

Variable	Year	1° branches	2° branches	No. capitula	Effective capitula	Yield/plant	Seeds/capitulum	Seed wt.	Yield/plot
1° branches		1							
2° branches	2002	0.83**	1						
	2003	0.80**							
No. capitula	2002	0.81**	0.94**	1					
	2003	0.63**	0.54**						
Effective capitula	2002	0.80**	0.90**	0.96**	1				
	2003	0.58**	0.45**	0.95**					
Yield/plant	2002	0.11*	0.04	0.05	0.04	1			
	2003	-0.11*	-0.16**	-0.04	0.04				
Seeds/capitulum	2002	0.15**	0.11*	0.10*	0.11*	-0.10*	1		
	2003	0.50**	0.43**	0.51**	0.52**	-0.10*			
100 Seed wt.	2002	-0.14**	-0.19**	-0.19**	-0.16**	-0.03	0.11*	1	
	2003	0.11*	-0.03	0.15*	0.23**	0.40**	0.14*		
Yield/plot	2002	0.12*	0.16*	0.13*	0.11*	-0.03	0.12*	0.05	1
	2003	0.51**	0.40**	0.63**	0.69**	0.21**	0.56**	0.38**	

*, **, Significant at 5% and 1% level of probability, respectively

Yield is a complex polygenic quantitative character greatly influenced by the environment. A correlation study provides information on the magnitude and direction of correlation between yield components with yield. It is difficult to exercise simultaneous selection for characters, which show negative association with each other because an increase in one causes a reduction in the other. An optimum combination of all these components would constitute the most desirable plant type. The importance of selection for a particular trait depends on the extent of direct or indirect effect of the trait on yield. In order to get a clear picture of the interrelationships between different traits, the direct and indirect effects of different characters were worked out using path coefficient analysis in respect to seed yield.

Primary, secondary and number of capitula/plant, had a very high and positive correlation between them (Table 1) hence the negligible direct effects (Table 3). In the combined correlations (Table 2), yield/plant had a negligible negative non-significant effect on seed yield and this can be attributed to interaction. The correlation coefficient between effective capitula, seeds/capitulum, yield/plant was negative but the direct effects were positive. Under the circumstances, restricted simultaneous selection where indirect effects are nullified is followed.

The correlations between primary and number of capitula/plant were almost equal to their direct effects. Hence correlation explains the true relationship and direct selection through the two would be effective.

Environment effects are important in the understanding of plant growth. Path analysis of yield components revealed that components with the highest correlation to yield also had the highest direct effect to yield i.e., primary branches, capitula/plant, effective capitula, seeds/capitula and 100 seed weight. The most important agronomic traits determining seed yield in the path coefficient analyses were: number of capitula/plant, effective capitula/plant and seeds/capitulum. Two approaches can be suggested in selecting genotypes for specific traits to improve seed yield in safflower:

- Select genotypes with high number of seeds/capitulum, which is directly responsible for seed weight as is evident from the high positive correlation between the two (Table 1).
- Alternatively select genotypes with high 100 seed weight as this has a high significant positive association with seed yield. Generally simple correlations differed at the same location every year (Table 2).

CONCLUSIONS

The high correlation and direct effects of number of capitula/plant, effective capitula/plant and seeds/capitulum on seed yield suggests selection for these components will improve seed yield in safflower.

Seed weight recorded the highest positive correlation with yield/plant in the 2003 while the number of capitula/plant and effective capitula/plant had a high positive effect on yield/plot. These can be considered to be the most important traits for yield improvement in safflower. Seed yield can also be improved indirectly by selecting genotypes producing a large number of seeds/capitulum coupled with high seed weight. Generally seed yield was positively and significantly influenced by all the seven components

Table 2: Combined simple correlations between yield components at 4 sites in 2 years

	Primary branches	Secondary branches	No. capitula	Effective capitula	Yield/plant	Seeds/capitulum	Seed wt.	Yield/plot
Primary branches	1							
Secondary branches	0.59**	1						
No. capitula	0.41*	0.78**	1					
Effective capitula	0.37*	0.73**	0.89**	1				
Yield/plant	0.29	0.24	0.14	0.12	1			
Seeds/capitulum	-0.05	-0.39*	-0.34*	-0.22	-0.04	1		
100 Seed wt.	0.05	0.02	0.11	-0.02	-0.07	-0.41*	1	
Yield/plot	-0.26	-0.33*	-0.16	0.09	-0.05	0.17	0.25	1

*, **, Significant at 5% and 1% level of probability, respectively

Table 3: Direct (diagonal and bolded) and indirect effects of seven yield components of safflower upon seed yield tested in 2002 and 2003

Parameters	Primary branches	Secondary branches	No. Capitula	Effective capitula	Yield/plant	Seeds/capitulum	100 seed wt.
Primary branches	**-0.2143**	-0.1264	-0.0879	-0.0793	-0.0621	0.0107	-0.0107
Secondary branches	-0.1264	**-0.1812**	-0.1413	-0.1323	-0.0430	0.0707	-0.0036
No. capitula	-0.0879	-0.1413	**-0.1780**	-0.1584	-0.0249	0.0605	-0.0196
Effective capitula	-0.0793	-0.1323	-0.1584	**0.3558**	0.0427	-0.0783	-0.0071
Yield/plant	-0.0621	-0.0430	-0.0249	0.0427	**0.1260**	-0.0050	-0.0088
Seeds/capitulum	0.0107	0.0707	0.0605	-0.0783	-0.0050	**0.2944**	-0.1207
100 Seed wt.	-0.0107	-0.0036	-0.0196	-0.0071	-0.0088	-0.1207	**0.9855**

under study. For traits showing a significant negative correlation between them, indirect selection through increased number of one would be ineffective. Seed yield in safflower can be improved indirectly by selecting genotypes retaining a large number of effective capitula/plant. Effective capitula and seeds/capitula had the highest correlation to yield and also the highest direct effect to yield.

Path analysis of yield components revealed that components with the highest correlation to yield also had the highest direct effect to yield. Hence selection should target components with the highest direct effect.

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