HELIA, **16**, Nr. 19, p.p. 11-18 (1993)

SELECTION INDICES FOR SEVERAL SEEDLING TRAITS IN A RANDOM MATED POPULATION OF SUNFLOWER

Hamid Ali Naeem[1] and Sadagat Mehdi[2]

1 Wheat Research Institute, Faisalabad.
2 Dept. of Plant Breeding and Genetics, Univ. Agr., Faisalabad.

SUMMARY

Fifty S_1 families of sunflower were evaluated for several seedling traits using three types of selection indices i.e., Smith-Hazel index, desired gain index and restricted selection index. Six seedling traits namely emergence percentage, emergence index, fresh shoot length, fresh root length, fresh root weight, shoot weight and dry shoot weight were included in all the indices as secondary traits. The efficiency of three types of selection indices was compared in terms of expected gains expressed in genetic standard deviations. It was observed that desired gain index with IS4 selection strategy including emergence percentage, emergence index, and fresh root length was more efficient than Smith-Hazel and restricted selection index as it predicted desirable correlated responses in all the seedling traits.

Key words: S_1 families, seedling traits, broad sense heritability, selection indices, predicted gains, aggregate genotype.

INTRODUCTION

Population improvement of a crop is the basic goal of all plant breeding programmes. A population improved for one trait may be deficient in one or more other traits. Consequently, a number of traits must be considered during the selection process. Smith (1936) was the first to explain the criteria of an efficient multiple trait selection in plants. He estimated the relative genetic worth of plants by the use of a discriminate function. Later on Hazel (1943) explained the theoretical aspects for the construction of indices and emphasized that only additive effects should be included in the genotypic value.

Due to linear combination of characters, undesirable responses are observed in individual characters with large variances within the aggregate genotype. To overcome this drawback, Kempthorne and Nordskog (1959) devised an index with restrictions. This index maximizes economic gain in a desired set of traits while having a correlation of zero with the function of traits which are not to be changed. Responses in individual characters can also be controlled using desired gain index (Pesek and Baker 1969). Expected response in each character will be a constant proportion of those given in the desired gain vector. The present study was conducted with the objectives of evaluating the possibility of using seedling characters as selection criteria for seedling vigour in sunflower, and comparing the efficiency of three types of index selection in order to evaluate the best selection strategy.

MATERIALS AND METHODS

Fifty S_1 families developed from a local random mated population of sunflower were evaluated for seedling characteristics in the laboratory of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. S_0 seeds of individual families were sown in polyethylene bags (23x8cm) each containing about 500 grams of sun-dried river sand in a randomized complete block design with three replicates. Each replicate comprised 20 seeds of each S_0 family and each polyethylene bag consisted of a single plant. Sunflower seeds were planted at a depth of 3cm. Adequate moisture levels were maintained by watering the seedlings with regular tap water. Laboratory temperature was maintained at 25±2C° during the whole experiment. After 13 days of seedling age, ten randomly selected plants were washed free of sand and blotted dried. These plants were divided at cotyledonary node into the respective root and shoot portions and data were collected for fresh shoot and root length (cm), fresh and dried weight of shoot and root (mg). The emergence index was calculated as suggested by Smith and Millet (1964).

Genotypic and phenotypic variances, covariances and correlations among seedling traits were calculated using the method described by Robinson *et al.* (1951). The estimates of variance of genetic correlations were computed as explained by Reeve (1955) and Robertson (1959). The estimates of broad sense heritability on a family mean basis were computed as a ratio of genetic variance to phenotypic variance. The standard error of heritability was also calculated by using the procedure of Lothrop *et al.* (1985). The estimates of genotypic correlation coefficient and heritability were considered significant if their absolute value exceeded twice their respective standard errors.

A series of indices were constructed to evaluate the most efficient selection index with best selection strategy. Six seedling characteristics, i.e., emergence percentage, emergence index, shoot length, root length, fresh root weight, and dry root weight were included in separate indices. Fresh shoot weight and dry shoot weight were included in all the indices as secondary traits. 'b' values for the Smith-Hazel index were computed by using the equation, $b=p^{-1}Ga$, where p^{-1} is the inverse of phenotypic variance-covariance matrix, 'G' is the genotypic variance-covariance matrix and 'a' is the vector of economic weights (Table 1).

Restricted selection indices were computed as outlined by Kempthorne and Nordskog (1959). Fresh shoot weight and dry shoot weight were restricted. The index coefficients were estimated by solving the equation

$$b=(I-P^{-1}\,GC\,(C'\,GP^{-1}\,GC)^{-1}\,CG)\,P^{-1}\,Ga$$

where I is identity matrix, C is coefficient of vector matrix, and C' is the transpose of C. P^{-1}, G and a, as previously defined. The vector of index weights (b) for the desired gain indices were estimated as proposed Pesek and Baker (1969).

$$b=Vg_g^{-1}g^h$$

where Vg^{-1} is the inverse of genotypic variance-covariance matrix and 'h' is the vector of desired gains (Table 1).

These three indices were compared in terms of the expected gains calculated using the formula given by Finney (1962)

$$K(Gb)_i/\sqrt{(b'\,P.b)}$$

where K is the standardized selection differential, i.e., 1.554 at 15% selection intensity, G= the genotypic variance-covariance matrix an b' is transpose of b.

The expected gains for all indices were expressed in genetic standard deviation units to facilitate comparison.

Table 1: Relative economic values and desired gains used in constructing selection indices for seedling traits of sunflower.

Trait	Relative economic value	Desired gains
Emergence percentage	1	11.647
Emergence index	-1	-1.118
Fresh shoot length (cm)	1	4.513
Fresh root length (cm)	2	1.727
Fresh shoot weight (mg)	0	0.0
Fresh root weight (mg)	2	15.214
Dry shoot weight (mg)	0	0.0
Dry root weight (mg)	1	9.524

RESULTS AND DISCUSSION

The estimates of genotypic and phenotypic variances pertain to a plant population from which the experimental material is a sample. Hence the estimates of one population are not applicable to another. Estimates of genotypic variances were smaller than phenotypic variances for all the seedling traits studied (Table 2). However, these differences were not too large. Highest estimates of genotypic and phenotypic variances were observed for fresh shoot weight followed by fresh root weight and emergence percentage. These statistics revealed that significant genetic variation existed among S_1 families of sunflower. Crosbie *et al.* (1980) also observed high estimates of genotypic variance for emergence percentage. Small differences observed among genotypic and phenotypic variances resulted in high estimates of broad sense heritability. Broad sense heritability estimates were computed on family mean basis for all the seedling traits which are useful for predicting direct and correlated responses in S_1 family evaluation. A perusal of the table indicates that highest estimates of heritability were observed for emergence percentage while lowest but still significant for fresh root length. High estimates of heritability have also been reported for emergence percentage, emergence index, and seedling weight, by Mock and Eberhart (1972), Mock and Mc Neil (1979), Crosbie *et al.* (1980).

Genotypic and phenotypic correlations among the seedling traits were calculated (Table 3). The estimates of genotypic correlation coefficients were higher than phenotypic correlation coefficients for their respective pairs of traits except between fresh shoot length and fresh root weight and dry root weight; and between emergence index and fresh root length. The tendency of genotypic correlations to be higher was because genotypic variances were smaller than their respective phenotypic variances.

Genotypic and phenotypic correlation coefficients differed in magnitude but had the same direction in their signs except between fresh shoot length and fresh root weight and between fresh shoot weight and dry shoot weight. A negative genotypic correlation existed between emergence percentage and emergence index. Crosbie *et al.* (1980) also reported similar results. The negative value indicated that fast emerging families will have a small value as evident from the formula of emergence index (Smith and Millet, 1964).

This association indicates the feasibility of indirect selection among S_1 families of sunflower.

Table 2: Genotypic variances, phenotypic variances and broad sense heritability among S_1 families of sunflower for seedling traits.

Trait	Genotypic variance	Phenotypic variance	Heritability
Emergence percentage	376.605**	410.960**	0.916*
Emergence index	1.251**	1.421**	0.880
Fresh shoot length (cm)	9.047**	9.998**	0.905*
Fresh root length (cm)	2.982**	4.415**	0.675*
Fresh shoot weight (mg)	29556.189**	34671.481**	0.853*
Fresh root weight (mg)	642.959**	767.762**	0.937*
Dry shoot weight (mg)	423.318**	583.366**	0.726*
Dry root weight (mg)	185.107**	226.164**	0.819*
*, ** indicates significant and highly significant respectively			

Predicted gains from selection using six selection strategies with three types of index selection are presented in Table 4. The economic values and desired gains for different traits were set such as to maximize predicted gain in seedling traits.

Table 3: Estimates of genetic (above diagonal) and phenotypic (below diagonal) correlation coefficients among seedling traits of S_1 families of sunflower.

Traits	E%	EI	FSHL	FRTL	FSWT	FRWT	DSWT	DRWT
E%		-0.715	0.101	-0.804$	-0.491	-0.256	-0.539	-0.294
EI	-0.634**		-0.767	0.089	0.239	0.427	0.193	0.427
FSHL	0.092	-0.349**		0.075	0.462	-0.002	-0.195	0.012
FRTL	-0.520**	0.110	0.043		0.327	0.549	0.244	0.558
FSWT	-0.421**	0.189	0.419**	0.250*		0.498	-0.081	0.455
FRWT	-0.232*	0.338**	0.033	0.386**	0.468**		0.002	0.985
DSWT	-0.406**	0.138	-0.165	0.164	0.051	0.000		-0.143
DRWT	-0.259**	0.415**	0.027	0.396**	0.425**	0.967**	-0.075	

E% = Percentage emergence, EI = Emergence index, FSHL = Fresh shoot length, FRTL = Fresh root length, FSWT = Fresh shoot weight, FRTW = Fresh root weight, DSWT = Dry shoot weight (mg), DRWT = Dry root weight

$ Correlation coefficients differ significantly from zero as its magnitude exeeded twice its standard error.

*, ** Significant at 0.05 and 0.01 probability levels respectively

When selection was for all six (IS1) and five seedling traits (IS2), the predicted gains were greatest using Smith-Hazel index. This is evident from the aggregate genotypic values. But selection for six traits at a time is not justifiable in any way since it would require much of effort and time which a breeder always lacks. Another major drawback using the Smith-Hazel index with IS1 and IS2 selection strategies include reduced emergence percentage which is almost equivalent to zero. Moreover, the predicted gain by using the Smith-Hazel index with IS1 and IS2 selection strategies is positive for emergence index which is undesirable. However, the desired gain index predicted reasonable responses in all the seedling traits for IS1 and IS2 selection stratgies. This index was most efficient in improving emergence percentage but the aggregate genotype is very low.

Table 4. Predicted gains (genetic standard deviation) and the aggregate genotypes for eight seedling traits of S_1 families of a random mating sunflower population using six selection strategies and three types of selection indices.

Selection strategy	Index[1]	Primary traits[2]						Secondary traits		Aggregate genotypes[3]	
		E%	EI	FSHL	FRTL	FRWT	DRWT	FSWT	DSWT		
IS1	SHI	-0.056	0.342	0.098	0.476	1.392	1.377	0.562	0.273	2.945	(3.780)
	RSI	0.091	0.258	-0.306	0.383	1.223	1.188	0.00	0.000	2.321	
	DGI	0.309	-0.515	0.773	0.515	0.309	0.360	0.000	0.000	2.781	
IS2	SHI	-0.063	0.371	0.023	0.474	1.396	1.381	0.528	-0.256	2.840	(3.112)
	RSI	0.074	0.293	-0.358	0.385	1.231	1.196	0.000	0.000	2.235	
	DGI	0.296	-0.494	0.000	0.494	0.296	0.345	0.000	0.000	1.925	
IS3	SHI	0.082	0.248	0.035	0.407	1.350	1.316	0.472	-0.286	2.942	(3.128)
	RSI	0.187	0.178	-0.324	0.337	1.341	1.135	0.000	0.000	2.498	
	DGI	0.221	-0.368	0.000	0.368	0.221	0.000	0.000	0.000	1.178	
IS4	SHI	1.551	-1.051	0.166	-0.670	-0.438	-0.491	-0.696	-0.743	1.169	(-0.270)
	RSI	1.138	-0.975	0.322	-0.291	-0.171	-0.350	0.000	0.000	1.623	
	DGI	0.412	-0.686	0.000	0.686	0.000	0.000	0.000	0.000	1.784	
IS5	SHI	1.104	-1.000	0.139	-0.672	-0.418	-0.465	-0.700	-0.757	0.688	(-0.769)
	RSI	1.140	-0.910	0.279	-0.290	-0.144	-0.319	0.000	0.000	1.576	
	DGI	0.479	0.000	0.000	0.798	0.000	0.000	0.000	0.000	1.277	
IS6	SHI	-0.592	-0.071	0.204	1.719	0.371	0.358	0.390	0.321	2.131	(2.842)
	RSI	-0.245	-0.251	0.116	1.564	0.206	0.230	0.000	0.000	2.122	
	DGI	0.000	-0.798	0.000	0.798	0.000	0.000	0.000	0.000	1.596	

[1] SHI = Smith-Hazel index, RSI = Restricted selection index and DGI = Desired gain index

[2] E% = Percent emergence, EI = Emergence index, FSHL = Fresh shoot length (cm), FRTL = Fresh root length (cm), FSWT = Fresh shoot weight (mg), FRWT = Fresh root weight (mg), DSWT = Dry shoot weight (mg), and DRWT = Dry root weight (mg)

[3] Aggregate genotype in parenthesis were summed from primary traits only

While summing up the aggregate genotype, negative sign of emergence index was considered positive

When selection was focused to four traits simultaneously (IS3), the aggregate genotype was greatest for seedling traits using Smith-Hazel and restricted selection indices. Both indices were useful in improving fresh and dry root weight. However, predicted gains for emergence percentage in the Smith-Hazel index were small when compared with the restricted selection index. The gains for fresh shoot length were negative using the restricted selection index. The desired gain index was efficient in improving emergence percentage and emergence index using IS3 selection strategy but aggregate genotype was small. When selection was for three traits simultaneously (IS4), the predicted gains for seedling traits were maximum using the desired gain index. The Smith-Hazel and restricted selection indices maximized predicted gain in emergence percentage and emergence index but undesirable responses in the other traits. However, the desired gain index using IS4 selection strategy predicted desirable correlated response in all the three seedling traits under consideration, i.e., emergence percentage, emergence index, and fresh root length. When selection was for two traits simultaneously (IS5&IS6), the Smith-Hazel index proved to be more efficient than any other index in improving emergence percentage and the emergence index using IS5 selection strategy and fresh root length using IS6 strategy. Eissa *et al.* (1983) observed that plants with long roots and high relative root weight would possess increased levels of resistance to seedling diseases. But the Smith-Hazel index with IS6 selection strategy cannot be used since undesirable responses are observed in the other seedling traits. Mock and Bakri (1976) observed difficulty in assigning meaningful economic values to corn seedling traits and suggested the use of the desired gain index. Crosbie *et al.* (1980) suggested the use of the restricted selection index for improving cold tolerance traits in maize. Our results indicated that the desired gain index is more appropriate and more efficient than the Smith-Hazel and restricted selection indices using IS4 selection strategy, as it predicted desirable correlated responses in all individual seedling traits. The Smith-Hazel index and restricted selection indices placed more emphasis on those traits with larger variance.

The superiority of selection indices over other methods of selection and of one index over another, mainly depends upon the accurate estimates of genotypic and phenotypic variances and covariances and economic values or desired gains specified for different traits. Their successful application to complex multiple-trait improvement also depends upon the judgement of the breeder himself as indicated by Mehdi (1986). The genotypic and phenotypic variances and covariances may differ greatly when different populations are considered. Therefore, indices reported in this paper pertain only to the population under study.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. Javed Ahmad for his help in preparing this paper.

REFERENCES

Crosbie, T.M., J.J. Mock and O.S. Smith. (1980). Comparison of gains predicted by several selection methods for cold tolerance traits of two maize populations. Crop Sci. 20:649-655.

Eissa, A.M., J.N. Jenkins and C.E. Vaughan. 1983. Inheritance of seedling root length and relative root weight in cotton. Crop Sci. 23: 1107-1111.

Kaufmann, K.D., and J.W. Dudley. 1979. Selection indices for grain yield, percent protein and kernel weight. Crop Sci. 19: 583-588.
Kempthorne, O., and A.W. Nordskog. 1959. Restricted selection indices. Biometrics 15:18-19.
Finney, F.J. 1962. Genetic gains under three methods of selection. Genet. Res. (Camb.) 3: 417-423.
Hazel, L.N. 1943. The genetic basis for constructing selection indices. Genetics 28:476-490.
Lothrop, J.E., R.E. Atkins and O.S. Smith. 1985. Variability for yield and yield components in IAPIR grain sorghum random mating population. I. Mean variance components and heritabilities. Crop Sci. 25:235-240.
Mehdi, S.S. 1986. Predicted response to S_1 selection for agronomic and disease resistance traits in two sunflower families. Ph.D. Thesis, South Dakota State Univ., Brookings, SD, USA.
Mock, J.J., and S.A. Eberhart. 1972. Cold tolerance in adapted maize population. Crop Sci. 12:466-469.
Pesek, J. and R.J. Baker. 1969. Desired improvement in relation to selection indices. Can. J. Plant Sci. 49:803-804.
Reeve, E.C.R. 1955. The variance of genetic correlation coefficient. Biometrics 11: 357-374.
Robertson, A. 1959. The sampling variance of genetic correlation coefficient. Biometrics 15: 469-485.
Smith, H.F. 1936. A discriminant function for plant selection. Ann. Eugen. 7:33-47.
Robinson, H.F., R.E. Comstock and P.H. Harvey. 1951. Genotypic and phenotypic correlations in corn and their implications in selection. Agron. J. 43:283-287.
Smith, P.G., and A.H. Millet. 1964. Germinating and sprouting responses of tomato at low tempratures. J. Amer. Soc. Hort. Sci. 84:480-484.
Wells, W.C. and K.D. Kofoid. 1986. Selection indices to improve an intermating population of spring wheat. Crop Sci. 26:1104-1109.

INDICES DE SELECCION PARA VARIOS CARACTERES DE LAS PLANTULAS DE GIRASOL EN UNA POBLACION DE POLINIZACION AL AZAR

RESUMEN

Cincuenta familias S1 de girasol fueron evaluadas para varios caracteres de las plántulas utilizando tres tipos de indices de seleción, el indice de Smith-Hazel, el indice de la gananacia deseada y el indice de selección restringido. Seis caracteres de plántulas, porcentaje de emergencia, indice de tallo y de la raiz fueron incluidos en todos los indices como caracteres secundarios. La eficiencia de los tres tipos de indices de selección fue comparada en terminos de ganancia esperada expresada en desviación standar. Se observó que el indice de ganancias deseada con la estrategia de selección IS4 incluyendo porcentaje de emergencia, indice de emergencia y longitud del tallo y raiz frescos fue más eficiente que los indices de Smith-Hazel e indice de seleciòn restringida de acuerdo con las predicciones de las respuestas correlacionadas deseadas en todos los caracteres de las plántulas.

INDICE DE SÉLECTION CONCERNANT DES CARACTÉRES RELATIFS AU STADE PLANTULE DANS UNE POPULATION DE TOURNESOL EN PANMIXIE

RÉSUMÉ

Plusieurs caractères relatifs au stade plantule utilisant trois types d'indice de sélection (l'indice de Smith-Hazel, l'indice de gain espéré et l'indice "restreint" de sélection) ont été utilisés pour évaluer cinquante famille S1 de tournesol. Les six caractères suivants ont été appliqués aux différents indices de sélection: pourcentage d'émergeance, indice d'émergeance, longuer des racines fraiches, poids frais des racines et poids sec des racines. Les poids frais et secs des racines ont été appliqués à tous les indices en tant que caractères secondaires. L'efficacité des trois indices a été comparée en terme de gain espéré exprimé par l'écart type génétique. Nous avons conclu que l'indice de gain espéré associé à la stratégie de sélection IS4 comprenant le pourcentage de levée, l'indice de levée et la longueur des racines fraiches était plus efficace que les indice de Smith-Hazel et l'indice de sélection "restreinte". En effet il prédisait des réponses recherchées et corrélées pour les caractéres relatifs aux plantules.