DETERMINING SELECTION INDICES FOR IMPROVING YIELD OF GRAIN SORGHUM POPULATION USING PATH ANALYSIS

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Abstract

This investigation aimed ato determine the useful traits as selection criteria for improving yield using path analysis and to detect the realized gain by pedigree selection method. The breeding materials were F3, F4 and F5 progenies of grain sorghum population derived from the single cross (R-Line--93002 × MR812) .The field Experiments were carried out at Shandaweel Agric. Res. Station, ARC., Sohag, Egypt during 2009, 2010and 2011 summer growing seasons. Highly significant differences among F3 families (the base population), sufficient genotypic coefficient of variability and high broad sense heritability were obtained for all the studied traits, for instance grain yield/ plant (99.22%), 1000 – grain weight (93.14%) and plant height (95.95%). In the base population, grain yield/ plant showed positive correlations with all studied traits except with days to 50% flowering and panicle length where correlation was negative at both the phenotypic and genotypic correlations levels. Path coefficient analysis indicated that kernel no./plant and 1000 – grain weight play important roles in grain yield/plant. The results indicated that the use of kernel no./ plant, 1000 – grain weight, panicle length and panicle width in future selection programs depending on the correlated response would be more effective. Results indicated that path coefficient analysis could be successfully used to identify adequate selection criteria for improving grain yield of grain sorghum.

Key words: Path analysis, Grain sorghum, Pedigree selection, Yield components

INTRODUCTION

In Upper Egypt, grain sorghum (*Sorghum bicolor* L. Moench) is considered a major summer crop, since the cultivate area about 388,000 Feddan, which produces about 158 thousand tons of grains (FAO 2009). Most of this area is concentrated at Assiut and Sohag Governorates.

Success in a crop improvement program depends on the amount of genetic variability available and its utilization. Althought many sorghum breeders have used traditional breeding methods successfully, genetic potentials have not been fully utilized, and yield is still below the theoretical maximum values. One reason is the limited amount of genetic variability capitalized upon by traditional methods (Flores *et al.*1986).

The study of relationships among quantitative traits is important for assessing the feasibility of joint selection of two or more traits and hence for evaluating the effect of selection for secondary traits on genetic gain for the primary trait under study. A positive genetic correlation between two desirable traits makes the task of the plant breeder easy for improving both traits, simultaneously. Even the unassociation between two thaits does not complicate joint improvement of them. However, simple correlations do not give an insight into the true biological relationships of these traits with yield. Yield, being quantitative trait in nature, so it is a complex trait with low heritability and depends upon several other components with high heritability (Grafius, 1956).

Several investigators used the path analysis to partition phenotypic and genotypic correlations into direct and indirect effects. The correlation coefficient simply measured mutual association without regard to causation while path analysis specifies the causes and their relative importance. El-Nagouly *et al.* (1981), represented the genotypic and phenotypic variance and simple correlations that partioned to direct and indirect effects of four characters in a late maize population. Mahdy *et al.* (1982) reported that, grain yield/ plant showed positive significant genotypic and phenotypic correlations with each of 1000–kernel weight, number of kernels/ plant and plant height, and a negative correlation with days to 50% flowering in two years. Negative correlations were also found between number of kernels/ plant and 1000 – kernels weight.

Singh and Baghel (1977) reported that, both number of grains per panicle and 1000–grain weight were major components of grain yield as indicated by their large positive direct effects. This information was utilized by different plant breeders (Eckebil *et al.*(1977) and Patil and Thombre 1985).They stated that, the path analysis revealed that days to anthesis showed negligible direct effects on grain yield, but a positive and a negative indirect effect via grain yield, which agrees with the results reported by Sinha and Sharma (1979). Ehadie and Waines (1989) stated that, the study of correlations coupled with path analysis for many traits are of great importance for improving yield. Ezeaku et al.(2006) reported that, 1000-kernel weight show high direct effect on grain yield. El–Menshawi (2006) reported that, panicle traits showed slight direct and indirect effects on grain yield with panicle width having the greatest direct effect. Ali *et al.*(2006) reported that, a path coefficient analysis for genotypes indicated that kernel no./ plant and 1000 – kernel weight played an important role in grain yield.

The current investigation was conducted (i) - to determine phenotypic correlation coefficients among the studied agronomic traits of F3 population derived from a single grain sorghum cross, (ii) to determine direct and idirect effects on grain yield utilizing the path coefficient analysis, and (iii) - to compute the realized response to selection for two cycles of pedigree selection for grain yield/ plant.

MATERIALS AND METHODS

The breeding materials used in this study were 100 F3 families (base population) that were derivatives of a random sample of F2 plants of the grain sorghum single cross (R-Line 93002 × MR812).

The parental lines were :

1- ICSR-93002 is sn exotic restorer line from ICRISAT Center (International Crop Research Institute for Semi-Arid Tropics, India) and adapted to the Egyptian environment, blooms on the 70 days and its height is between 175 and 180 cm.

2- MR812 is a restorer line from Zambia, blooms on the 65 days from planting and its height is between 165-170 cm.

3 -The cultivar (Dorado) as an introduced from U.S.A., adapted to the Egyptian environment, branches less type and its height is between 135 and 145 cm was used as a check.

Field procedures

In 2009 summer growing season, the 100 F3 families along with their two parents and a random sample bulk (a mixture of equal number of grains from each head to represent the generation mean) were sown on July, 15th in a field experment at Shandaweel Res.Sta.,ARC, Egypt. A randomized complete block design with three replications was used. Each family was represented by one row in each replicate. The experimental plot was one ridge, four meter long, 60 cm apart. Planting was carried out in hills spaced 20 cm apart and seedlings were thinned to two plants per hill. During the growing season, ten random guarded plants in each plot were marked and the following traits were measured: days to 50%flowering, plant height, panicle Length, panicle width, grain yield/plant, 1000 – Kernel weight and kernel no./ plant).

The best 20 plants from the best 20 families in grain yield/plant were saved to give seeds of selected F4 families.

In 2010 growing summer season, the 20 selected F4 families, the parents, the bulk sample and the check cultivar were sown on 12th of July and evaluated in a randomized complete block design of three replications. The data were recorded as in the previous season. The best plant from each of the best 10 families were saved to give seeds of selected F5 families.

In 2011 season, the ten selected F5 families with the parents, the bulk sample and the check cultivar were evaluated in a randomized complete block design of three replications and similar data were recorded as in the first and second seasons.

Statistical analyses

1– The genotypic and phenotypic coefficients of variation and broad sense heritability were estimated from the expected mean squares of the variance selected families, as given by Federer (1963).

2-The phenotypic correlations coefficients were estimated among the studied traits as outlined by Walker(1960).

3- A path coefficient analysis was performed according to Wright(1934) and similar to that applied by Dewey and Lu(1959),)

4- The reakized gain from selection was estimated in percentage as a deviation of the mean selected families from the mean of the best parents, the bulk sample and the check cultivar.

RESULTS AND DISCUSSION

1- Base population

A. Performance

The analysis of variance (Table 1) of the base population (F3- families), displayed highly significant variability among families for all the studied traits, that due to the genetic diversity among the crossed parents. This was adequate for selection in the base population for improving grain yield. These genetic variability measured by the genotypic coefficient of variability, For instance, ICSR -93002 headed after 75 days while MR 812 headed after 68 days from sowing. Plant height varied from 160 for MR 812 to 175 cm for ICSR -93002. 1000 –grain weight ranged from 23.0 for MR 812 to 31.0 g for ICSR -93002. Grain yield/plant varied from 55.0 for MR 812 to 68.0 g., for ICSR -93002. kernel no. / plant ranged from 2194 for MR 812 to 2391 for ICSR -93002. The phenotypic and genotypic coefficient of variability caused high estimates of broad sense heritability for all studied traits except panicle width. Burton (1952) and Sanghi *et al.* (1964) reported that, a genetic coefficient of variation together with a heritability estimate only would seem to give the best picture for the amount of the expected genetic advance from selection. Ismail (2001) reported highly significant differences among F3 families (base population) for all studied traits. The magnitude of phenotypic and genotypic coefficient of variability of the base population indicated that, greater response to selection can be expected from selection. Large magnitude of heritability for all the studied traits was observed (Table 1).

Table 1. Mean performance, mean squares, genotypic(G.C.V%) and phenotypic (P.C.V%) coefficient of variability and broad sense heritability(Hb) of F3 – families, the parents, the bulk sample and the check cultivar.

Trait	Mean performance					Mean squares			GCV%	PCV %	Hb%
	F3	R line-93002	MR 812	Bulk sample	Check cultivar	Reps	Families	Error			
Days to 50% flowering	71.00	75.00	68.00	74.00	72.00	1.56	8.32**	1.55	2.12	2.35	81.59
Plant height, cm.	202.00	175.00	160.00	215.00	140.00	179.58**	608.52**	24.64	6.91	7.05	95.95
Panicle length(cm).	29.00	30.00	23.00	26.00	26.00	3.84	9.02**	1.37	5.51	5.98	84.72
Panicle width(cm)	6.00	6.25	5.00	5.33	6.00	0.04	2.86**	0.94	13.33	16.27	65.09
Grain yield/plant(g)	78.00	68.00	55.00	70.33	59.08	25.05**	319.06**	2.51	13.17	13.22	99.22
1000-grain weight(g)	25.00	31.00	23.00	23.33	27.80	2.69	27.39**	1.88	11.66	12.09	93.14
Kernel no./ plant	3120.0	2194.0	2391.0	3015.0	2125.0	36304.0	267550.9**	31412.54	8.74	9.57	88.26

** Significant at o.o1 level of probability.

b– Phenotypic correlations:-

Estimates of the phenotypic correlations among all possible pairs of the six traits studied in these population are shown in Table (2).

Table 2. Phenotypic correlation coefficients among pairs of traits in F3 generation(base population).

Trait	Days to 50% flowering	Plant height(cm)	Panicle length(cm)	Panicle width(cm)	1000-grain weight(g)	kernel no. / plant	Grain yield/plant(g)
Days to 50% flowering	-						
Plant height(cm)	-0.0901	-					
Panicle length(cm)	0.0298	0.0897	-				
Panicle width(cm)	0.0601	-0.1701	-0.0845	-			
1000-grain weight(g)	-0.0941	0.0486	-0.1547	0.2268*	-		
kernel no. / plant	0.1067	-0.0403	0.0279	0.1247	-0.3451**	-	
Grain yield/plant(g)	-0.0241	0.0234	-0.1361	0.3185**	0.7421**	0.3647**	-

(**)Significant at o.o1 level of probability.

Since the grain yield/plant is the essintial end product, its correlation with other studied traits were estimated as well as the interrelationships amon them. Generaly, the multiple regression and determination coefficients were 0.9942 and 0.9884, respectivily, indicating that these traits causing most variations of the grain yield. The corelation coefficients between grain yield with 100 kernel weight, kernel number / head and head width were highly significant. Potdukhe *et al.* (1994), indicated that, grain yield was positively and significantly correlated with panicle length, panicle weight and 1000–grain weight. However, Menkir *et al.* (1994) found weak correlations among yield, plant height, days to 50 % flowering and seed weight. They also stated that selection for yield alone resulted in lines with increased height and dayes to flowering. On the other hand, phenotypic correlation coefficients were negative between days to 50% flowering, grain yield/ plant, 1000- grain weight and panicle weight except plant height and panicle width. While grain yield /plant had positive phenotypic correlations with all studied traits except days to 50% flowering and panicle length. Therefore, selection for one trait may cause a corresponding increase in other correlated traits. These results are in the same line with Mahdy *et al.* (1999), Ismail (2001) and Ali *et al.* (2006).

c– Path coefficient analysis

The path coefficient analysis provides an effective means for detecting direct and indirect effects of associations between the influence of causal factors and the affected trait (for example, grain yield) and compare the forces acting to produce a given correlation and measures the relative importance of each casual factor. Dewey and Lu 1959, Bhullar and Nijjar 1984 and Bhulla and Chaudhary 1986.

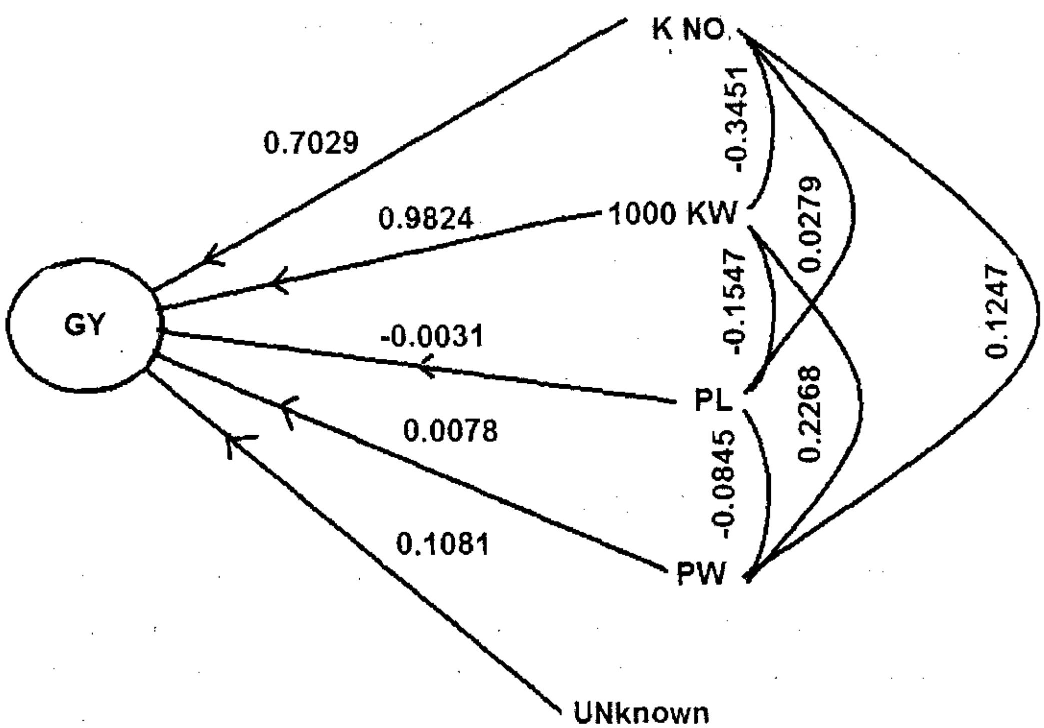

Fig. 1. Direct and indirect effects of yield components on grain yield/ plant (Arrow lines for path coefficeints, and un-arrow curves for correlation coefficeints, respectively) .

Table 3. Path coefficient analysis showing the direct and indirect effect of yield copmonents on grain yield / plant of grain sorghum .

Causal traits	Panicle length(cm)	Panicle width(cm)	1000-grain weight(g)	kernel no. / plant	Total
	correlation				
Panicle length(cm)	-0.0031	-0.0007	-0.1520	0.0196	-0.1361
Panicle width(cm)	0.0003	0.0078	0.2229	0.0876	0.3185
1000-grain weight(g)	0.0005	0.0018	0.9824	-0.2426	0.7421
kernel no. / plant	-0.0001	0.0010	-0.3391	0.7029	0.3647
	Determination				
Panicle length(cm)	0.0000	0.0000	0.0005	-0.0001	0.0004
Panicle width(cm)	0.0000	0.0001	0.0017	0.0007	0.0025
1000-grain weight(g)	0.0005	0.0017	0.9652	-0.2383	0.7291
kernel no. / plant	-0.0001	0.0007	-0.2383	0.4940	0.2563

Table 3 and Figure 1 showed the results of partitioning the effects of yield components and head charactristcs traits on grain yield into direct and indirect effects. the results revealed that 1000 kernel weight and kernel no./plant had the highest direct effect on grain yield/ plant (0.9824 and 0.7029, respectively) while both panicle length and width had trivial contribution about zero. The indirect effect of panicle trait on grain yield/ plant neggligible. Hawever, the share of the negative correlation between 1000 kernel weight and kernel number/plant cause also negative indirect effects on the correlation or determination of these traits on drain yield/ plant. Several others workers (Rao and Damodaran 1964, Singh and Govila 1989 reported similar results in pearl millet. This result confirms a true relationship between yield component traits and grain yield/ plant, so direct selection on those traits will be effective in improving soghum grain yield in this population via corresponding response. The path coefficient of non-descriped factors was 01081(residual fig.1)) and compareble to those obtained by Reddy et al. (1988). These results Indicated that, the use of yield components in any selection progarm would be more effective than the use of morphological traits. Budak and Yildirim (1999) reported that an increase in one component might result in increase yield if there is no reduction due to other components. These results are in agreement with those reported by El- Menshawi (2006) and Ezeaku and Mohammed (2006).

2. Pedigree selection for grain yield/plant

Phenotypic (PCV %) and genotypic (GCV %) coefficient of variability of cycles 1 and 2 (F4 and F5 progenies) for the studied traits (days to 50 % flowering, plant height, panicle length, panicle width, grain yield/ plant, 1000 – grain weight and kernel no./ plant) are presented in Table (4). The results indicated that pedigree selection had the most harmful effect on the genetic variability of the selected traits after two cycles of pedigree selection alongside the high selfing pollenation of sorghum.The GCV of grain yield / plant decreased from 13.33 in the base population (Table 1) to 3.87 after the second cycle of pedigree selection for these trait.

Table 4. Means, phenotypic (PCV%),genotypic (GCV%) coefficient of variability and heritability in broad sense (Hb) for all the studied traits in the two cycles(C1 andC2) of pedigree selection.

Item		Days to 50% flowering	Plant height(cm)	Panicle lenght(cm)	Panicle width(cm)	Grain yield/plant(g)	1000-grain weight(g)	kernel no./plant
	Cycle 1							
C1	F4 fam.	69.15	190.75	28.92	6.20	83.33	28.59	2915
	PCV%	2.61	7.13	5.42	15.25	4.11	10.86	9.22
	GCV%	2.45	6.96	4.68	13.24	3.87	10.34	8.81
	Hb	88.34	95.35	74.60	75.29	88.30	90.66	91.40
	Cycle 2							
C2	F5 fam.	67.40	185.00	32.00	6.50	88.40	32.01	2762
	PCV%	1.59	6.74	5.21	14.16	3.51	7.42	5.12
	GCV%	1.42	6.54	4.94	10.55	3.18	6.96	4.47
	Hb	79.77	94.23	89.29	55.30	82.32	88.04	76.22

Falconar (1989) indicated that selection reduces genotypic varaince of the following generation. Theoretically, heritability estimates of family means increase with the increase in homozygosity. However, heritability in Table 4 decreased from the F4 to the F5 generation after the second cycle of selection for studied traits. In a population subjected to selection, the reduction of variance and size of the population lead to less gcv causing reduced heritability estimaes. These results, are in agreement with Mahdy *et al.* (1999) and Ali *et al.* (2006).

The observed gains after two cycles of pedigree selection mesured as the percentage deviation of the overall mean of cycle 1 and cycle 2 from the best parent, the bulk sample and the check cultivar Dorado are presented in Table 5. With respect to pedigree selection for grain yield / plant, which is the main goal in most breeding programs, the results showed that observed gain in grain yield after two cycles of selection for grain yield / plant was 33.19 %, 22.27% and 47.26 from the best parents, the bulk sample and the check cultivar Dorado, respectively. In fact, such realized gains from one and two cycles are very high, but, could be due to some degrees of heterozygosity, dominance and epistatic effect that still exist in the early generation, and the breeder have to follow up the superior families through pedigree selection till complete homozygosity.

Table 5. Observed gain from pedigree selection for grain yield/ plant measured in percentage from the best parent, the bulk sample and the check cultivar Dorado.

Selectionn cycle	Genotypes	Days to 50% flowering	Plant height(cm)	Panicle lenght(cm)	Panicle width(cm)	Grain yield/plant(gm)	1000-grain weight(gm)	kernel no./plant
	Means of the best parent, bulk sample and the check cultivar							
C1	Best parent (R-93002)	71.67	180.00	29.00	5.00	68.50	28.33	2417
	Bulk	73.00	190.00	28.06	5.70	74.00	27.00	2741
	Check (Dorado)	70.33	140.33	24.00	5.33	62.50	28.00	2322
	F4	69.15	190.75	28.92	6.20	83.33	28.59	2915
C2	Best parent (R-93002)	71.70	175.33	29.30	5.00	66.37	28.00	2371
	Bulk	70.00	185.10	27.60	5.44	72.30	26.40	2739
	Check (Dorado)	69.10	145.00	25.00	6.00	60.03	28.40	2114
	F5	67.40	185.00	33.00	6.50	88.40	32.01	2762
	Observed gain for the cycle 1							
C1	F4 - Bp	-3.52	5.97**	-0.28	24.00	21.65*	0.92	20.56**
	F4 - bulk	-5.27**	0.39	3.07	8.77	12.61**	5.89**	63.48**
	F4 - check	-1.68	35.93**	20.50**	16.32	33.33**	2.11	30.60**
	Observed gain for the cycle 2							
C2	F5 - BP	-5.99**	5.52	12.63**	30.00**	33.19**	14.32**	16.49**
	F5 - Bulk	-3.71**	-0.05	19.57**	19.49	22.27**	21.25**	0.84**
	F5 - check	-2.46	27.59**	32.00**	8.33	47.26**	12.27**	23.46**

Unfavourable increase in plant height over the best parent, the bulk sample and the check cultivar in the cycle one and two, except cycle two which decreased from the bulk sample by -0.05% , accompanied pedigree selection for grain yield / plant. Correlated increases over the best parents, the bulk sample and the check cultivar were also observed for 1000- grain weight of 14.32 %, 21.25% and12.27 %, respectively. Igaruta *et al.* (1996) reported that, the increase of grain yield occured as a consequence of changes in different yield components for population. However, correlated decreases were observed for kernel no./ plant which reached from cycle one 20.56%,63.48% and 30.60% to 16.49 %, 0.84% and 23.46% in cycle two over the best parents, the bulk sample and the check cultivar Dorado, respectively. O 'Brien *et al.*(1978), Loffler and Busch(1982) and Mahdy *et al.*(1996) showed that, selection based on grain yield per seed was the most effective in improving such complex trait. Also, correlated decreases were observed for days to 50% flowering which reached -5.99 %, -3.71% and -2,46%, respectively . Finally, pedigree selection for grain yield / plant was accompained with favorable effects on the traits, days to 50 % flowering, panicle lenght, panicle width and 1000 grain weight and unfavuorable increase in plant height. Eckebil *et al.*(1977) found that, the predicted genetic gain for grain yield ranged from 15.2 to 28.8 %for three populations. The results of the presented study are in agreement with Jinks and Connolly (1973), Mahdy *et al.*(1999) and Ali *et al.* (2006).

Table 6 . mean grain yield/ plant of the ten selected families (F5) after the second cycle of pedigree selection .

Serial No.	Family No.	Days to 50% flowering	Plant height, cm.	Panicle lenght, cm.	Panicle width,cm.	Grain yield/plant, gm.	1000-grain weight, gm.	kernel no./plant
1	6	67.00	170.00	31.00	7.67	88.00	32.00	2750
2	12	68.00	175.00	30.90	6.00	80.67	28.00	2881
3	16	69.00	185.00	33.00	6.00	77.33	28.00	2762
4	22	67.00	165.00	35.00	6.00	105.00	34.44	3048
5	24	66.00	185.00	30.30	5.67	82.33	30.67	2684
6	37	67.00	195.00	29.90	7.00	90.33	33.00	2737
7	42	68.00	200.00	29.56	5.33	93.33	34.00	2745
8	43	66.00	180.00	29.13	7.33	85.33	33.67	2534
9	75	67.00	195.00	28.29	6.00	90.00	33.33	2700
10	81	69.00	200.00	33.00	8.00	91.67	33.00	2778
Mean		67.40	185.00	32.00	6.50	88.40	32.01	2762
Bulk		70.00	185.10	27.60	5.44	72.30	26.40	2739
$LSD_{0.05}$		1.56	9.60	2.o2	1.96	4.54	2.50	220.41
$LSD_{0.01}$		2.24	13.77	2.91	2.82	6.53	3.59	316.68

*' ** Significant at o.o5 and o.o1 probability levels, respectively.

Table (6) summarizes the rank of selected families based on high grain yield/ plant after two cycles of selection. It is noticed that family No. 22 could be considered the best selected one than the bulk sample family for grain yield / plant, it showed 45.23 % increase in yield, earlier by -4.29 % and had heavier grains by 30.46% .

It could be concluded that path analysis could be successfully used to determine selection traits that can be utilized to improve yield of grain sorghum under the conditions of the present study.

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تحديد الصفات الانتخابية لتحسين محصول النبات فى عشيرة من ذرةالحبوب الرفيعة باستخدام معامل المرور

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يهدف هذا البحث الى تحديد الصفات الانتخابية التى يمكن استخدامها فى تحسين محصول الحبوب/النبات باستخدام معامل المرور وكذلك تقدير الاستجابة للانتخاب بعد دورتين من الانتخاب المنسب . تم استخدام عشيرة انعزالية من ذرة الحبوب الرفيعة فى الجيل الثالث ناتجة من التهجين (R-line 930028*MR812) خلال ثلاث مواسم صيفية ٢٠٠٩الى ٢٠١١ م بمزرعة محطة بحوث شندويل – مركز البحوث الزراعية .

اوضح تحليل التباين ان هناك فروق عالية المعنوية بين الصفات الانتخابية للعشيرة القاعدية فى الجيل الثالث وايضا هناك اختلافات وراثية ومظهرية مناسبة للانتخاب بالاضافة الى مدى واسع من درجة التوريث بالمعنى العريض وذلك فى جميع الصفات المدروسة.

اظهر معامل المرور قيما عالية للتاثير المباشر لعدد حبوب / نبات و وزن الالف حبة كان ٠,٧٠٢٩ و ٠,٩٨٢٤ بالترتيب

وزن الالف حبة بعد دورتين من الانتخاب المنسب لصفة المحصول/النبات وصلت الزيادة فيها الى ١٤,٣٢ % ، ٢١,٢٥% و ١٢,٢٧% مقارنة بأحسن الاباء و العينة العشوائية و الصنف الاختبارى.

الخلاصة ان معامل المرور اعتبر مفيدا فى تحديد الصفات الانتخابية لتحسين محصول /النبات فى ذرة الحبوب الرفيعة.