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SELECTION FOR GRAIN YIELD AND ITS COMPONENTS IN EARLY GENERATIONS IN RICE (*Oryza sativa* L.)

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Abstract: The aims of this study were to determine the response to selection for high and low grain yield and yield components, to estimate the heritability of these traits, and to compute the correlations of grain yield with yield components in the different segregating generations of rice (*Oryza sativa L.*). The research was conducted at Thrace Agricultural Research Institute in 1995 and 1996. Two segregating populations for each generation were used in F3, F4, and F5 in this study. The results indicated that selections for grain weight and the number of grains per panicle were effective in early generations. There were positive and significant associations between grain yield and the number of grains per panicle in all populations in both years. High heritabilities estimated for 1000 grain weight. The estimated narrowsense and realized heritabilities were similar in terms of magnitude. The selection for grain weight was effective as much as direct grain yield selection and the number of grains per panicle followed it.
The results of selection conducted for low and high values of the yield components, correlations between grain yield and yield components and heritability values revealed that the number of grains per panicle could be used as selection criteria in early generations. Also, selection for desired grain size may be done in early generations.

Key words: Correlation, heritability, rice (*Oryza sativa L.*),

Çeltikte (*Oryza sativa L.*) Erken Generasyonlarda Dane Verimi ve Verim Komponentleri İçin Seleksiyon

Özet: Bu araştırmanın amacı, çeltikte (*Oryza sativa L.*) farklı generasyonlardaki açılan materyalde, yüksek ve düşük tane verimi ile verim komponentleri için yapılan seleksiyonda, seleksiyona cevabın belirlenmesidir. Bunun yanında, bu karakterlerin kalıtım dereceleri ve tane verimi ile olan ilişkileri de tespit edilmiştir. Araştırma, 1995 ve 1996 yıllarında Trakya Tarımsal Araştırma Enstitüsünde gerçekleştirilmiştir. Bu araştırmada, F_3, F_4 ve F_5 generasyonlarında, ikişer adet açılan populasyon kullanılmıştır. Sonuçlar, dane ağırlığı ve salkımda dane sayısının erken generasyonlardaki seleksiyonda etkili olduğunu göstermiştir. Her iki yılda, bütün generasyonlarda, tane verimi ile salkımdaki dane sayısı arasında pozitif ve önemli ilişkiler tespit edilmiştir. 1000 dane ağırlığı için yüksek kalıtım dereceleri tahmin edilmiştir. Dar anlamda ve gerçekleştirilmiş kalıtım derecesi değerleri büyüklük bakımından benzerlikler göstermiştir. Dane ağırlığı için yapılan seleksiyon, doğrudan tane verimi için yapılan seleksiyon kadar etkili olmuştur. Onu salkımdaki dane sayısı izlemiştir.
Düşük ve yüksek verim komponent değerleri için yapılan seleksiyon sonuçları, tane verimi ile verim komponentleri arasındaki ilişkiler ve kalıtım derecesi değerleri, salkımdaki tane sayısının erken generasyonlarda, bir seleksiyon kriteri olarak kullanılabileceğini gösterdi. Aynı zamanda, arzu edilen dane ağırlığı için erken generasyonlarda seleksiyon yapılabilir.

Anahtar kelimeler: Çeltik (*Oryza sativa L*), kalıtım derecesi, korelasyon.

Introduction

Rice breeders are interested in developing high yielding cultivars with improved yield and other desirable agronomic characters. To achieve this goal, the breeder has the option of selecting desirable genotypes in early generations or delaying intense selection until advanced generations, when progenies are nearly homozygous. In early stages of breeding programs, direct estimates of yield are quite difficult. Plant breeders are commonly selecting for yield components which indirectly increase yield. Yield component breeding to increase grain yield would be most effective, if the components involved were highly heritable and genetically independent or positively correlated.

The selection criteria for production may be yield, one or more of the morphological components of yield; number of panicles per unit area, the number of grains per panicle, or grain weight.

Woodworth (1931) suggested that yield might be increased in small grains by selecting for the component of yield and that parental varieties should be selected on the basis of component attributes. Whereas, Frankel (1935) and Adams (1967) reported that the components of yield are influenced greatly by environment and that negative correlations among them are common. Thus, selection for one of the components may fail in increasing yield, because of negative associations among the components. In contrary, Grafius (1960) suggested that individual yield components may contribute valuable information in breeding for yield. McNeal (1960) determined correlations between six plant characteristics and grain yield per plant in the F_2 and F_3 generations of a "Lemhi/Thather" wheat cross and observed that only kernels per plant was highly associated with yield in both generations. Knott and Talukdar (1971) suggested that wheat yield could be increased by selecting for increased kernel weight.

Rasmusson and Cannell (1970) selected lines for low and high yield and yield components in F_4 generation in barley (*Hordeum vulagre L.*). They observed that selection for number of heads resulted in changes in yield that were similar to those when selection was for yield itself. Selection for kernel weight was highly effective in alterning yield. They postulated that the optimum genotypic level for kernels per head and number of heads would vary depending on environment, but that the optimum for kernel weight would be near its genetic maximum.

Strokopf and Reinbegs (1966) reported that grains per spike accounted for 50.4%, tiller per plant 28.3% and grain weight 21.3% of the variation observed for yield in barley. In oats, grains per panicle was even greater importance than in barley, accounting for a mean of 76.6% of the total variability, while tillers per plant accounted per a mean of only 2.9%.

Selection index for grain yield and its contributing characters in rice (*Oryza sativa L*) was studied by Talwar (1976). It was concluded that the selection pressure concentrated on grain yield, total tillers and grain per panicle could be advantageous in the breeding programme.

Venkateswarlu et al., (1986) examined the effect of the high density grain on grain yield. They suggest that increasing the proportion of high density grains would enhance potential yield. An estimated 30% increase in grain yield is possible by increasing the number of grains per panicle. On the other hand, Kato (1990) reported that selection for grain size of rice was effective even early segregation after crossing.

Gravais and McNew (1993) suggested that the selection for increased yield via selection for either panicle weight or panicle number alone would be ineffective. However, a selection index that included selection for both increased panicle weight and panicle number to increase yield was estimated to be 91% as effective as selecting for yield directly. Contrary, Feil (1992) reported that among the components of grain yield of a cereal crop, the number of spikelets per panicle appeared to be a predominant key characters in the development of high-yielding cultivars. Morales (1986) suggested that number of grains/panicle and 1000 grain weight might be considered important criteria for increasing yield/unit area. On the other hand, Moeljopawiro (1989) and Reuben and Katuli (1989) reported that grains/panicle was the yield determing component with the greatest effect. On the contrary, İbrahim et al., (1990) found out that productive tillers was the most reliable character tn selecting genotypes of rice and Mehetre et al., (1994) reported that the filled grains/panicle was important yield-contributing characters.

The relationship between rice yield and yield components has been studied extensively at phenotypic level; Sharma and Choubey (1985) and Dhanraj and Jagadish (1987) reported that yield/plant was positively correlated with the number of productive tillers, panicles and spikelets/plant and 1000 grain weight while Prasad et al., (1988) observed positive correlations between grain yield/plant and yield components; total spikelets/panicle, fertile grains/panicle and 1000 grain weight. Bai et al., (1992) reported positive correlation of grain yield with number of productive tillers, and number of grains/panicle. Sürek et al., (1998) reported that grain yield/plant was significantly correlated with the number of panicles per plant and 1000 grain weight.

Heritability (h^2) of a trait is important in determining its response to selection. Grain yield is known to have low heritability and it is highly influenced by the environment. Rasmusson and Cannel (1970) reported that the estimates of realized heritabilities in barley for yield ranged from 0.18 to 0.26, no of heads 0.12 to 0.22, kernels per head 0.09 to 0.57, and kernel weight 0.43 to 0.68, respectively. Gravais and McNew (1993) estimated 0.45 realized heritability in rice for panicle number and 0.31 for panicle weight. Takeda and Saito (1983) reported high realized heritability for grain weight. Their heritability estimates ranged from 0.63 to 0.90. On the other hand, Kato (1997) estimated 0.16 realized heritability for number of panicles per plant and 0.20 to 0.33 for number of spikelet per panicle. Sürek and Korkut (1998) estimated high narrow sense heritability for grain weight, moderate for the number of spikelets per panicle and low for the number of panicles per plant.

The objectives of this study were to determine the response to selection for high and low yield and yield components, to estimate the heritability of yield and yield components, and to compute the correlation of grain yield with yield components in segrigating different generations of rice (*Oryza sativa L.*)

Materials and Method

Two different crossing populations were used for each generation in F_3, F_4, and F_5 for this study. The cross combinations and the number of lines used in the experiment were given in Table 1.

Table 1. The cross combinations and the number of lines used in the experiment.

No	Cross	Generation	The number of lines
1	Trakya x Lido	F_3	51
2	Trakya x M-102	F_3	52
3	İpsala x N1-41T-1T-0T	F_4	52
4	Altınyazı x Titanio	F_4	52
5	Krasnodarsky-424 x Europa	F_5	52
6	Baldo x Balilla-28	F_5	45
	Total		304

Within each population, the lines shown in Table-1 were randomly selected by taking one panicle from each plant in 1994, in F_2, F_3, and F_4 generations. They were grown together with parents in 2 m long single plant rows spaced 25 cm. The rice was drill-seeded on 27 May 1995. When the seedlings reached the four or five-leaf stage, the plant were thinned to an uniform density. Harvested area was 1.5 x 0.25= 0.37 m^2, to avoid side effect, excluded 25 cm distance from both side in each row. After harvest and evaluation of data, the lines had 10 high and 10 low values for the traits¸ grain yield, the number of productive tiller, the number of filled grains and 1000 grain weight were selected for each generation. In addition, 10 lines were randomly selected from each population to represent a random sample. These selected lines in each population grown together with their parents in a randomised complete block experiment design with three replications. Each entry was drilled in a plot which consisted of two 2m rows spaced 25 cm apart on 30 May 1996. Four hundred seed /m^2 were used in planting. When the seedling reached the four or five-leaf stage, the plant were thinned to an uniform density. Harvesting area was 0.5 x 1.8 =0.9 m^2. In both years, fertilizers was applied at rate 150 kg N and 80 P ha^{-1}. All phosphorus and 1/3 part of N applied at pre planting, 1/3 at tillering and remaining at panicle initiation.

Data were recorded for grain yield, the number of productive panicle per square meter, the number of filled grains per panicle, and 1000 grain weight.

Analysis of variance was carried out to study the variation among the lines for examined traits. Phenotypic correlations were computed by the procedures described by Steel and Torrie (1960), to study the associations of yield components with grain yield. Heriatbility of grain yield and yield components in the narrow sense was estimated from the regression (r^2) of Fg_2 on F g_1 values (g_1 : initial generation and g_2 : the following generation). Realized heritability (h^2) estimated according to Falconer (1960) and Sharnma and Smith (1986). Using the means of high and low progenies, this formula was utilised to calculate realized heritabilty = High-Low Fg_2/High-Low g_1 . The paired t-test was used to compare the mean differences of the traits for the lines selected for high and low values. The selection gain from selection for high yield components and grain yield were computed as the difference between the mean of the high lines and the mean of random selected lines for these traits (Bhatt, 1977).

Results and Discussion

The results of variance analysis showed that there were significant differences among the lines for examined traits, except the productive tiller per square meter, there was no significant differences for this trait in two generations, one in F4 (Trakya x Lido cross) and one in F5 (İpsala x N1-41T-1T-0T cross). As it seen in table 2, 3, and 4, there were significant differences between the lines selected for high and low values of the traits, grain yield, the number of productive panicles per square meter, the number of grains per panicle and 1000 grain weight. These differences continued following generations for 1000 grain weight in all generations, F_4, F_5, and F_6. Also, the differences continued for the number of grains per panicle, except in one F_4 generation (Trakya x Lido cross). These results indicated that selections for grain weight and the number of grains per panicle were effective in early generations (table-5, 6, 7, 8, 9, and 10). On the other hand, the selection for high and low progenies of the number of productive panicles per square meter was not effective in all generation of the crosses. The reason for this is taht the optimum genotypic level for this component varies depending on environment, so that selection was not effective. Rasmusson and Cannall (1970) observed similar results in barley. On the contrary, Benbelkacem et al., (1984) reported significant difference between high and low progeny groups for tiller number in barley.

Table 2. Mean performance of the selected lines, the ten highest and the ten lowest, in the F_3 generation for each character.

Character	Cross					
	Trakya x Lido			Trakya x M-102		
	High	Low	Difference	High	Low	Difference
Grain yield g/ m^2	877	583	294**	827	485	332**
No. productive panicles per m^2	430	268	162**	446	286	160**
No. of grains per panicle	86	49	37**	77	38	39**
1000 grain weight (g)	36	28	8**	36	29	7**

**: Significant at 0.01

Table 3. Mean performance of the selected lines, the ten highest and the ten lowest, in the F_4 generation for each character.

Character	Cross					
	Altınyazı x Titanio			İpsala x N1-41T-1T-0T		
	High	Low	Difference	High	Low	Difference
Grain yield g/ m^2	873	494	379**	1072	591	481**
No. productive panicles per m^2	454	283	171**	457	285	172**
No. of grains per panicle	77	40	37**	79	42	37**
1000 grain weight (g)	36	30	6**	44	34	7**

**: Significant at 0.01 level.

Table 4. Mean performance of the selected lines, the ten highest and the ten lowest, in the F_5 generation for each character.

Character	Cross					
	Krasnodarsky-424 x Europa			Baldo x Balilla-28		
	High	Low	Difference	High	Low	Difference
Grain yield g/ m^2	765	256	509**	850	454	395**
No. productive panicles per m^2	440	271	169**	376	236	140**
No. of grains per panicle	72	23	50**	74	39	38**
1000 grain weight (g)	38	28	10**	44	32	12**

**: Significant at 0.01 level.

Table 5. Mean performance of the parental varieties, the selected and random lines , and selection gain in F_4 generation of Trakya x Lido cross.

Character	Parent		Response to selection			Selection gain %	Random lines
	Trakya	Lido	High	Low	Differ.		
Grain yield g/ m^2	926.8	666.0	675.2	660.7	14.5	-0.3	677.5
No. productive panicles per m^2	362.0	415.0	369.7	357.3	16.4	0.8	366.6
No. of grains per panicle	72.0	70.0	66.9	60.3	6.6	0.7	66.4
1000 grain weight (g)	35.5	25.3	33.6	27.4	6.2**	12.3	29.9

**: Significant at 0.01 level.

Table 6. Mean performance of the parental varieties, the selected and random lines , and selection gain in F_4 generation of Trakya x M-102 cross.

Character	Parent		Response to selection			Selection-gain %	Random lines
	Trakya	M-102	High	Low	Differ.		
Grain yield g/ m^2	926.8	599.4	607.8	563.5	44.3	1.4	590.7
No. productive panicles per m^2	362.0	407.0	350.6	326.6	24.0	1.7	344.5
No. of grains per panicle	72.0	53.0	62.3	50.7	11.6**	4.1	54.6
1000 grain weight (g)	35.5	28.0	34.2	28.6	5.6**	7.2	31.9

**: Significant at 0.01 level.

Table 7. Mean performance of the parental varieties, the selected and random lines , and selection gain in F_5 generation of Altınyazı x Titanio cross.

Character	Parent		Response to selection			Selection-gain %	Random lines
	Altınyazı	Titanio	High	Low	Differ.		
Grain yield g/ m^2	644.3	634.8	678.4	632.4	46.0	5.2	644.5
No. productive panicles per m^2	363.0	353.0	347.4	321.0	26.2	1.4	342.5
No. of grains per panicle	50.0	63.0	61.1	52.4	8.7**	3.5	59.0
1000 grain weight (g)	33.1	32.1	33.5	30.5	3.0**	6.3	31.5

**: Significant at 0.01 level.

Table 8. Mean performance of the parental varieties, the selected and random lines , and selection gain in F_5 generation of İpsala x Nı-41T-1T-0T cross.

Character	Parent		Response to selection			Selection-gain %	Random lines
	İpsala	N1-41T-1T-0T	High	Low	Differ.		
Grain yield g/ m^2	727.1	750.4	756.0	669.7	86.3	6.8	707.4
No. productive panicles per m^2	332.0	320.0	352.9	329.5	23.4	7.2	329.3
No. of grains per panicle	50.0	65.0	59.4	50.9	8.5**	1.0	60.0
1000 grain weight (g)	40.1	29.2	39.1	33.2	5.9**	2.8	35.6

**: Significant at 0.01 level.

Table 9. Mean performance of the parental varieties, the selected and random lines , and selection gain in F_6 generation of Krasnodarsky-424 x Europa cross.

Character	Parent		Response to selection			Selection-gain %	Random lines
	Krasno-424	Europa	High	Low	Differ.		
Grain yield g/ m^2	940.2	576.8	609.2	571.9	37.6*	1.8	596.6
No. productive panicles per m^2	352.0	324.0	348.5	323.1	25.4	3.0	338.i
No. of grains per panicle	90.0	51.0	68.8	53.7	15.1**	16.0	59.3
1000 grain weight (g)	29.7	25.2	34.3	27.3	7.0**	11.0	30.9

*, **: Significant at 0.05 and 0.01 level, respectively.

Table 10. Mean performance of the parental varieties, the selected and random lines , and selection gain in F_6 generation of Baldo x Balilla-28 cross.

Character	Parent		Response to selection			Selection-gain %	Random lines
	Baldo	Balilla-28	High	Low	Differ.		
Grain yield g/ m^2	800.6	545.6	720.7	630.4	90.0**	22.8	586.9
No. productive panicles per m^2	365.0	320.0	331.4	313.4	18.1	3.8	319.1
No. of grains per panicle	72.0	68.2	63.8	54.3	9.5*	5.2	67.3
1000 grain weight (g)	39.0	25.0	36.7	30.2	6.5**	7.3	34.2

*, **: Significant at 0.05 and 0.01 level, respectively.

Selections for high and low grain groups were not effective in early generations, however, it was effective in F_5 generation in two populations (Baldo xBalilla-28 and Krasnodarsky-424 x Europa).

In general, the values of random selected lines were between low and high progeny groups for all characters.

The selection gains for 1000 grain weight was high in all generations it followed by the number of grains per panicles. High selection gain obtained for grain yield in one generation of two F_6 crosses.

Increasing Yield by Selecting for Components of Yield

Selecting for the number of grains per panicle resulted in a positive response in yield except one population in F_4 (Trakya x Lido cross) (table- 11, 12 and 13). The mean yield of the progenies of lines selected for high number of grains per panicle exceeded the mean yield of the prognies selected for low number of grains per panicle, except one population of F_4 (Trakya x Lido cross).

The yield response obtained by selecting for grain weight was very large. This was larger than the gain from selection for yield itself, except one population in F_5 (Altınyazı x Titanio cross). These results in agreement of the findings observed by Rasmusson and Carnell (1970) in barley.

Table 11. Mean yield (g/m^2) of lines selected for high and low grain yield, number of panicle, number of grains per panicle and 1000 grain weight in F4 generation.

Character selected	Cross					
	Trakya x Lido			Trakya x M-102		
	High	Low	Difference	High	Low	Difference
Grain yield g/ m^2	675.0	660.7	14.5	607.8	563.5	44.3
No. productive panicles per m^2	738.8	677.7	61.1	476.2	628.1	-151.9**
No. of grains per panicle	694.4	700.1	-5.7	622.8	555.5	67.3
1000 grain weight (g)	747.7	678.8	68.9	570.5	451.7	118.8

**: Significant at 0.01 level.

Table 12. Mean yield (g/m^2) of lines selected for high and low grain yield, number of panicle, number of grains per panicle and 1000 grain weight in F5 generation.

Character selected	Cross					
	Altınyazı x Titanio			İpsala x N1-41T-1T-0T		
	High	Low	Difference	High	Low	Difference
Grain yield g/ m^2	678.4	632.4	46.0	756.0	669.7	86.3
No. productive panicles per m^2	579.4	634.6	-55.2	743.7	701.7	42.2
No. of grains per panicle	651.2	577.6	73.2**	690.1	659.0	31.1
1000 grain weight (g)	613.8	621.8	-7.7	746.4	686.0	60.4

**: Significant at 0.01 level.

Table 13. Mean yield (g/m^2) of lines selected for high and low grain yield, number of panicle, number of grains per panicle and 1000 grain weight in F6 generation.

Character selected	Cross					
	Krasnodarsky-424 x Europa			Baldo x Balilla-28		
	High	Low	Difference	High	Low	Difference
Grain yield g/ m^2	609.7	572.5	37.2*	720.7	630.4	90.3**
No. productive panicles per m^2	564.6	613.2	-48.6	643.3	651.5	-8.0
No. of grains per panicle	591.0	575.1	15.9	648.6	622.3	26.3
1000 grain weight (g)	626.8	569.0	57.8	714.4	494.7	219.7**

*, **: Significant at 0.05 and 0.01 level, respectivly

There were negative yield response to selection for the number of productive panicles per square meter in four populations. Positive yield differences were observed only in two populations between low and high number of productive panicle progenies.

The selection for grain weight was effective as much as direct grain yield selection in the most of populations used. The number of grains panicle followed it.

There were positive and significant associations between grain yield and grains per panicle in all populations in both years (table-14). Similar results were reported by Prasad et al., (1988) and Baia et al., (1992).

The correlations between grain yield and the number of productive panicle per square meter were not important in all populations in both years. In contrary, Sharma and Choubey (1985), Dhanraj and Jagadish (1987) observed positive correlation with grain yield of this trait. The correlations with grain weight were positive and significant in three of the six populations in different generations in both years. However, Sharma and Coubey (1985), Dhanraj and Jagadish (1987), and Prasad et al., (1988) observed positive and significant associations between grain yield and 1000 grain weight.

Table 14. Correlations between grain yield and yield components in the different generations.

Character	Crosses									
		Trakya x Lido	Trakya x Titanio		Altınyazı x Titanio	İpsala x Europa		Krasno-424 x Europa	Baldo x Balilla-28
No. productive panicles per m^2	F3	0.272	0.006	F4	0.245	0.298*	F5	0.201	0.065
	F4	0.132	0.302*	F5	-0.068	-0.007	F6	0.333*	0.066
No. of grains per panicle	F3	0.465**	0.702**	F4	0.603**	0.516**	F5	0.780**	0.591**
	F4	0.608**	0.809**	F5	0.773**	0.602**	F6	0.538**	0.796**
1000 grain weight	F3	-0.029	0.062	F4	0.190	0.149	F5	-0.085	0.438**
	F4	0.063	0.353**	F5	0.135	0.204	F6	0.264	0.541**

*, **: Significant at 0.05 and 0.01 level, respectively.

Narrow sense and realized heritabilities were estimated in all populations (table-15). High heritabilities estimated for 1000 grain weight, it was medium to low for grain yield. The lowest heritabilities were estimated for the number of productive panicles per square meter. Similar results for realized heritabilities observed for yield components by Rasmusson and Cannell (1970) in barley and for number of panicles per plant and number of spikelets per panicle by Kato (1997) in rice. Also, Tekada and Saito (1983) reported high realized heritability for grain weight.

There were similarity between narrow sense and realized heritability in terms of magnitude in all populations.

Table 15. The estimated narrowness (h^2) and realized (r^2) heritabilities for the traits in the different generations.

Character	Crosses											
	Trakya x Lido		Trakya x Titanio		Altınyazı x Titanio		İpsala x Europa		Krasno-424 x Europa		Baldo x Balilla-28	
	h^2	r^2	h^2	r^2	h^2	r^2	h^2	r^2	h^2	r^2	h^2	r^2
Grain yield g/ m^2	36	37	43	13	18	34	28	51	17	21	77	68
No. productive panicles per m^2	20	15	10	10	8	17	13	13	15	12	11	18
No. of grains per panicle	14	29	3	17	24	26	18	23	27	30	25	22
1000 grain weight	78	76	75	88	41	50	84	81	69	66	54	51

The selection results for low and high progenies of the yield components, correlations between yield and yield components, and heritability values showed that the grains per panicle could be used as selection criteria in early generations. On the other hand, selection for grain weight should be considered in early generations.

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