Iran. J. Agric. Res. Vol. 5, No. 1, 1977, pp. 1–13. Pergamon Press. Printed in Great Britain.

VARIATION AND COVARIATION IN SEGREGATING WHEAT POPULATIONS GROWN UNDER RAINFED AND IRRIGATED CONDITIONS IN SEMI-ARID REGION OF THE MIDDLE EAST[1]

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ABSTRACT

F_3 and F_4 generations of two wheat crosses, Ciano x S10 B^3 as C1 and Siete Cerross 66-Nadadores 63 x (Ciano x Lerma Rojo 64^2 – Sonora 64) as C2 were examined for breeding behavior. The F_4 progeny lines were grown under two extreme water conditions, the rainfed and irrigated, to determine their degree of relationship between the two water conditions.

Variations among the F_3 plants and the F_4 progeny lines of each cross were significantly wide for yield, tillering capacity, kernel weight, and plant height. Also, the

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variation among the F_4 lines for days to heading was significant. The means of the F_4 lines of C2 grown in either of the water conditions were near the mid-parent value for grain yield, kernel weight, and days to heading. The means of tillering capacity and plant height were near the high parent value when the lines were grown under the rainfed condition, and near the mid-parent value when the lines were grown under the irrigated condition.

Heritability estimates measured by the variance component method were high for days to heading and intermediate for yield and the other characteristics measured. Estimates measured by the standard unit method (narrow sense) were generally lower than those measured by the variance component method. The values of predicted genetic advance were high for plant height and intermediate for grain yield indicating the effect of selection expected for these characteristics.

Phenotypic correlation coefficients were positive and significant between yield and tillering capacity, and yield and kernel weight. Plant height was not correlated with grain yield when the lines were grown under irrigated conditions and some short-statured lines were among the very high yielding ones. Under rainfed conditions, yield was highly associated with earliness.

Highly significant positive r values existed between the rainfed and irrigated conditions for yield as well as the other characteristics measured.

INTRODUCTION

High grain yield, short plants, heavy kernels and high tillering capacity are some desired characteristics for more efficient wheat production where high productivity conditions prevail. Simultaneous improvement of such characteristics has been a continuing objective of wheat breeders. Heritability estimates have been low for grain yield (2, 7), high for kernel weight (2, 5, 8) and high for plant height (2, 8). The degree of correlation was high for grain yield with plant height (5) and for grain yield

with kernel weight and with tillering capacity (6, 7).

The present study was undertaken to determine the degree of correlation between the performance of the same early generation progeny lines of two wheat crosses grown under (a) rainfed and (b) irrigated conditions. Also, the breeding behavior of the progeny lines was evaluated for grain yield and its components and the relationship between different agronomic characteristics was studied.

MATERIALS AND METHODS

The 1971-72 experimental materials of this study consisted of 81 F_3 plants of each of two wheat crosses, Ciano x S10 B^3 referred to hereafter as C1, and Siete Cerross 66-Nadadores 63 x (Ciano x Lerma Rojo 64^2 – Sonora 64) referred to hereafter as C2, and 24 plants of each of two cultivars, Inia 66 and Lundi. Due to the unavailability of the actual parental materials, Inia 66 and Lundi were used to facilitate the measurement of environmental variances for the measured characteristics. The plants were space planted in rows 25 cm apart and at 15 cm within row spacing and grown under rainfed conditions (450.2 mm). The F_3 plants were generated from F_3 seeds that were in turn generated at random from F_2 plants.

In the 1972-73 growing season, the experimental materials consisted of 81 F_4 progeny lines generated from the 81 F_3 plants (1971-72 materials) of each of the two wheat crosses, and the parental lines Ciano (P1C1), Lerma Rojo 64^2 – Sonora 64 (P2C2), and Siete Cerross 66 – Nadadores 63 (P1C2). Twelve F_4 seeds of each progeny line and parent were planted in one 60 cm row per replicate and per water condition. The rows were 25 cm apart. The experimental design was a randomized complete block with four replications. The two water conditions were (a) rainfed, receiving 277.7 mm of annual rainfall plus one sprinkler irrigation of about 70 mm applied in late March 1973, and (b) supplemental irrigation referred to hereafter as irrigated condition, receiving in addition to the rainfed condition, five surface irrigations of about 100 mm each, applied in the period April 17 to May 29, 1973. The sprinkler irrigation in case of the rainfed

condition was done to correct the rather very exceptionally poor rain distribution. The fertilizer rates applied were 80 kg N plus 60 kg P_2O_5 per ha for the rainfed condition and 180 kg N plus 120 kg P_2O_5 per ha for the irrigated condition.

Five agronomic characteristics were measured. These were grain yield in g per plant in the 1971-72 materials and g per 0.15 m^2 in the 1972-73 materials, tillering capacity as number of seed-bearing heads per plant in the 1971-72 materials, and number of seed-bearing heads per 0.15 m^2 in the 1972-73 materials, plant height in cm, kernel weight in mg and number of days from planting to heading.

The statistical analyses were as follows:

a. Analyses of variance appropriate to the randomized complete block design were done according to the procedures outlined by Cochran and Cox (3).

b. Heritability estimates were calculated by three methods:

   1. $H = \sigma^2_G / \sigma^2_G + \sigma^2_E$ as outlined by Allard (1), where the genotypic variance (σ^2_G) plus the environmental variance (σ^2_E) constitute the phenotypic variance, and the heritability estimate (broad sense) is the ratio of genotypic to phenotypic variance. The σ^2_E was estimated from non-heritable variance obtained from the genetically uniform populations. This method was applied to the F_3 populations grown in the 1971-72 season.

   2. Variance components method utilizing the standard (broad sense) formula, $H = \sigma^2_L / \sigma^2_{ph}$ where σ^2_L and σ^2_{ph} are the genotypic and phenotypic variances among lines, respectively. This method was applied to the F_4 populations grown in the 1972-73 season under both rainfed and irrigated conditions.

   3. Standard unit (narrow sense) method used by Frey and Horner (4).

c. Genetic advance was estimated according to the formula outlined by Allard (1). Since all F_3 plants were tested in the F_4 generation, selection for high and low was tested for all characteristics measured.

d. Correlation coefficients (r) were calculated for all character combinations and for the two water conditions.

RESULTS AND DISCUSSION

Variations among the F_4 progeny lines of each cross were significant for all characteristics measured and under both water conditions (Table 1). The variation among the F_3 plants of both crosses were also wide. This indicates the presence of significant genotypic variation among the progeny lines which is suggestive of possible effective selection.

The F_4 lines of both crosses and their parental materials yielded much more under the irrigated than under the rainfed. This was also true for the tillering capacity, plant height and kernel weight, but not for days to heading.

The means of the F_4 lines of C2, under both water conditions, were near the mid-parent values for grain yield, kernel weight and days to heading. The means of tillering capacity and plant height were near the high parent value when the lines were grown under the rainfed conditions and near the mid-parent value when grown under the irrigated conditions.

In C1, the 1972-73 means of the F_4 lines were higher than at least the one parent tested in grain yield, kernel weight, plant height and days to heading.

The broad sense heritability estimates (Table 2) in the F_3 populations (method 1) were high in both crosses for plant height (0.47 and 0.78 for C1 and C2, respectively) and in C1 for kernel weight (0.77) and in C2 for grain yield and tillering capacity 0.46 and 0.61, respectively). The broad sense estimates of the F_4 populations (method 2) were high in both crosses and under both the rainfed and irrigated conditions except in the case of the tillering capacity of C2 grown under the rainfed condi-

Table 1. Ranges and means of yield and its components of three parental lines and F_3 and F_4 generations of two wheat crosses grown under rainfed and supplemental irrigation conditions in 1971–72 and 1972–73 seasons in Beqa'a, Lebanon.

Crosses parents and generations+	No. of ent. †	Grain yields††		Tillering capacity π		Kernel weight, mg		Plant height, cm		Days to heading	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
C1 F_3 R	81 P	3.1– 10.3	5.7	3.0– 6.0	4.2	26–50	36.6	70–105	89.3	–	–
C1 F_4 R	81 L	8.5– 29.5**	18.3	17.5– 42.5*	30.3	17–29**	24.8	60– 75**	71.7	162–173**	165.7
C1 F_4 I	81 L	43.5–148.5**	85.8	47.5– 87.5**	66.3	32–50**	40.9	100–120**	108.1	162–173**	165.2
P1C1 R	24 r	8.5– 36.5	20.9	22.5– 67.5	41.4	17–29	23.0	55– 80	67.7	162–164	162.1
P1C1 I	24 r	36.5–113.5	80.7	62.5–112.5	85.3	32–47	39.6	85–105	97.3	162–164	162.4
C2 F_3 R	81 P	3.2– 10.8	5.6	2.0– 7.0	4.4	26–41	32.2	55–105	75.4	–	–
C2 F_4 R	81 L	8.5– 43.5**	24.9	12.5– 57.5**	37.5	17–26**	21.4	55– 80**	68.5	164–174**	170.1
C2 F_4 I	81 L	22.5–141.5**	90.6	37.5– 92.5**	66.9	29–41**	34.8	80–125**	101.7	163–176**	169.7
P1C2 R	24 r	8.5– 50.5	26.7	22.5– 62.5	33.8	14–29	22.1	60– 75	68.3	172–174	172.9
P1C2 I	24 r	85.5–148.5	113.1	52.5– 92.5	73.7	29–41	36.1	85–110	106.5	173–175	173.2
P2C2 R	24 r	8.5– 36.5	21.2	17.5– 42.5	33.5	14–32	20.7	55– 75	61.3	165–172	168.1
P2C2 I	24 r	57.5–134.5	84.0	47.5– 82.5	63.3	29–41	34.0	85– 95	90.8	165–170	167.6

*- Differences among entries are significant at the 5% level.

**- Differences among entries are significant at the 1% level.

+- C1 = Ciano x S10 B^3, P1C1 = Ciano, C2 = Siete Cerross 66 - Nadadores 63 x (Ciano x Lerma Rojo 64^2 - Sonora 64), P1C2 = Siete Cerross 66 - Nadadores 63, P2C2 = Lerma Rojo 64^2 - Sonora 64, R = rainfed, and I = irrigated.

†- Ent. = entries, P = plants, L = lines, and r = rows.

††- g per plant for F_3's and g per .15 m^2 for F_4's and parents.

π- Number of seed-bearing heads per plant for F_3's and number of seed-bearing heads per .15 m^2 for F_4's and parents.

Table 2. Heritability estimates of yield and other characteristics of F_3 and F_4 generations of two wheat crosses grown under rainfed and supplemental irrigation conditions in 1971-72 and 1972-73 seasons in Beqa'a, Lebanon.

Crosses* and generations	Grain yield+	Tillering capacity†	Kernel weight mg	Plant height cm	Days to heading
C1					
F_3 R b.s. Method 1	.22	.15	.77	.49	–
F_4 R b.s. Method 2	.53	.29	.64	.56	.92
F_4 I b.s. Method 2	.76	.52	.76	.70	.88
F_3 & F_4 n.s. Method 3	.20	.25	.37	.31	–
C2					
F_3 R b.s. method 1	.47	.61	.01	.72	–
F_4 R b.s. method 2	.62	.71	.49	.78	.92
F_4 I b.s. method 2	.74	.48	.69	.86	.94
F_3 & F_4 n.s. method 3	.25	.09	.29	.46	–

* C1 = Ciano x S10 B^3, C2 - Siete Cerross 66 - Nadadores 63 x (Ciano x Lerma Rojo 64^2 - Sonora 64), R = rainfed, and I = irrigated, b.s. = broad sense, and n.s. = narrow sense.

\+ g per plant for F3's and g per 0.15 m^2 for F4's and parents.

† Number of seed bearing heads per plant for F3's and number of seed bearing heads per 0.15 m^2 for F4's and parents.

tion where the estimate was only 0.29. The narrow sense estimates (method 3) which were generally lower than their corresponding broad sense ones, were low to intermediate for grain yield, tillering capacity, kernel weight and plant height indicating that some breeding progress can be made within these populations. Narrow sense estimates were not measured for days to heading for the lack of F_3 generation data.

The values of predicted genetic advance following the selection of the high and low 10% of each F_3 population for each of the characteristics measured were high for plant height and intermediate for grain yield in both crosses and high for tillering capacity and kernel weight in one of the two crosses (Table 3). As to the observed advance, in all cases, except the irrigated F_4 lines of C2 selected for low number of tillers, the F_4 high and low selection means were respectively higher and lower than the overall F_4 population mean. The percentage of improvement due to selection ranged from 4.3% increase in the tillering capacity of the F_4 population of C2 grown under irrigated conditions to 27.3% increase in grain yield in the same population when grown under rainfed conditions. Among the characters studied, grain yield and plant height exhibited the highest increases or decreases due to selection, which indicates the effectiveness of selection. Superior lines will be further tested in advanced generations to verify their performance.

Phenotypic correlation coefficients (Table 4) of grain yield with tillering capacity were highly significant and positive in both F_3 and F_4 generations of both crosses and under both water conditions. This reflects the importance of tillering capacity as a yield component. The association between grain yield and kernel weight was positive in most populations studied. Also grain yield was positively associated with plant height in three of the six cross-generation - water condition combinations. Under irrigated conditions, this association was not significant and some short statured lines were among the very high yielding ones. This combination is very desirable in areas where lodging conditions prevail and where growing conditions are favorable.

Table 3. Summary of predicted genetic advance and observed advance following selection, 8 high and 8 low, of 81 F_3 plants for yield and its components of two wheat crosses grown under rainfed and supplemental irrigation conditions.

Predicted and observed advance of F_3 and F_4 generations of C1 and C2*	Grain yield+		Tillering capacity†		Kernel weight, mg		Plant height, cm	
	C1	C2	C1	C2	C1	C2	C1	C2
F_3 generation - rainfed								
Overall mean	5.7	5.6	4.2	4.4	36.6	32.2	89.1	75.4
High selections mean	8.2	9.1	5.5	7.1	44.1	38.5	102.4	97.4
Low selections mean	3.9	3.5	3.0	2.8	28.9	25.1	75.6	58.1
Predicted genetic advance	±0.5	±1.4	±0.2	±1.4	±10.6	±0.1	±7.2	±14.1
F_4 generation - rainfed								
Overall mean	18.3	24.9	30.3	37.5	24.8	21.4	71.7	68.5
High selections mean	21.4	31.7	32.1	41.7	25.9	23.1	75.7	72.5
Low selections mean	13.7	18.6	28.6	35.3	23.5	20.3	70.8	63.7
Observed advance (High)	+3.1	+6.8	+1.8	+4.2	+1.1	+1.6	+4.0	+4.0
Percent increase above overall mean	16.9	27.3	5.9	11.2	4.4	7.5	5.6	5.8
Observed advance (Low)	–4.6	–6.3	–1.7	–2.2	–1.3	–1.1	–0.9	–4.8
Percent decrease from overall mean	25.1	25.3	5.6	5.9	5.3	5.1	1.3	7.0
F_4 generation - irrigated								
Overall mean	85.8	90.6	66.3	66.9	40.9	34.8	108.1	101.7
High selections mean	96.7	94.1	75.7	6'69	43.8	36.9	110.2	110.2
Low selections mean	81.7	83.2	64.4	68.8	38.3	33.3	105.6	92.8
Observed advance (High)	+10.9	+3.5	+9.4	+3.0	+2.9	+2.1	+2.1	+8.5
Percent increase above overall mean	12.7	3.9	14.2	4.5	7.1	6.0	1.9	8.4
Observed advance (Low)	–4.1	–7.2	–1.9	+1.9	–2.6	–1.1	–6.6	–8.9
Percent decrease from overall mean	4.8	8.0	2.9	–	6.4	3.2	6.1	8.8

* C1 = Ciano x S10 B^3, C2 = Siete Cerros 66 - Nadadores 63 x (Ciano x Lerma Rojo 64^2 - Sonora 64), observed advance = mean of F_4 selected lines less overall mean of F_4 generation.

\+ Gram per plant for F_3 generation and g per .15 m^2 for F_4 generation.

† Number of heads per plant for F_3 generation and number of heads per 0.15 m^2 for F_4 generation.

Table 4. Phenotypic coefficients correlation between yield and some agronomic characteristics in F_3 and F_4 generations of two wheat crosses grown under rainfed and supplemental irrigation conditions in 1971-72 and 1972-73 season in Beqa'a, Lebanon.

	Cross 1 = Ciano x S10 B^3			Cross 2 = Siete Cerross 66 _ Nadadores 63 x (Ciano x Lerma Rojo 64^2 _ Sonora 64)		
	F_3	F_4		F_3	F_4	
	Rainfed	Rainfed	Irrigated	Rainfed	Rainfed	Irrigated
Grain yield x tillering capacity	.71**	.67**	.47**	.57**	.86**	.70**
Grain yield x kernel weight	_.01	.36**	–.03	.63**	.43**	.51**
Grain yield x plant height	.48**	.28**	.19	.05	.34**	.13
Grain yield x days to heading	–	–.33**	.25*	–	–.56**	–.17

* = Significant at the 5% level, r = 0.22.

** = Significant at the 1% level, r = 0.28.

Grain yield was negatively associated with days to heading in both crosses when grown under rainfed conditions. Under limited rainfall conditions and when rain ceases about 10 weeks before the normal harvesting time, earliness becomes a very important yield determinant. Early maturing lines tend to escape drought. The same lines when grown under irrigated conditions showed no association between grain yield and earliness.

The correlation coefficients between the rainfed and irrigated conditions (Table 5)

Table 5. Correlation coefficients between rainfed and supplemental irrigated conditions for four agronomic characteristics of the F_4 lines of two wheat crosses grown in the 1972-73 season.

Agronomic characteristics	C1+	C2†
Grain yield	0.40**	0.43**
Tillering capacity	0.49**	0.50**
Kernel weight	0.49**	0.38**
Plant height	0.38**	0.69**

** = Significant at the 1% level, r = 0.28.

\+ Cross 1 = Ciano x S10 B^3

† Cross 2 = Siete Cerross 66 - Nadadores 63 x (Ciano x Lerma Rojo 64^2 – Sonora 64).

were positive and highly significant for all characteristics measured. These positive correlations indicate that selections made under one water condition may, to a certain extent, be superior also to the other water condition.

It can be concluded from this study that the significant variation and covariation and the intermediate to high levels of heritability estimates for all characters studied, indicated the presence of enough genetic differences for effective selection. This was also exhibited in the genetic and observed advance obtained. Also, several lines of each cross which exceeded the overall population mean for one or more characteristic are of potential for developing improved wheat cultivars adapted to the region.

Another conclusion which can be drawn is that selection under one water condition may to some extent serve for the other condition. This was shown by the highly significant r values obtained between the two water conditions for the characteristics studied. Such a relationship may save some unnecessary duplications of evaluating the same breeding materials in other locations.

LITERATURE CITED

1. Allard, R.W. 1960. Principles of Plant Breeding. John Wiley and Sons, Inc. N.Y.
2. Bhatt, G.M. 1972. Inheritance of heading date, plant height and kernel weight in two spring wheat crosses. Crop Sci. 12: 95-98.
3. Cochran, W.G. and G.M. Cox. 1964. Experimental Design. John Wiley and Sons, Inc. N.Y.
4. Frey, K.J. and T. Horner. 1957. Heritability in standard units. Agron. J. 49: 59-62.
5. Johnson, V.A., K.J. Biever, A. Honnolld and J.W. Schmidt. 1966. Inheritance of plant height, yield of grain and other plant and seed characteristics. Crop Sci. 6: 336-338.
6. Knott, D.R. and B. Talukdar. 1971. Increasing seed weight in wheat and its effect on yield, yield components and quality. Crop Sci. 11:280-283.

7. Lebsock, K.L. and A. Amaya. 1969. Variation and covariation of agronomic traits in durum wheat. Crop Sci. 9: 372-375.

8. Merkle, O.G. and I.M. Atkins. 1964. Inheritance of plant height and stem rust resistance in wheat, *Triticum aestivum* L. Crop Sci. 4: 453-454.