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INHERITANCE AND GENE ACTION FOR YIELD AND ITS ATTRIBUTES IN THREE BREAD WHEAT CROSSES (*Triticum aestivum* L.).

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ABSTRACT

The present investigation was carried out at El-Gemmeiza Agricultural Research station, Agricultural Research Center (ARC), Egypt during four successive seasons from 2007/2008 through 2010/2011. Three crosses were used among five parental varieties, namely P_1xP_2 (1), P_3xP_4 (2) and P_4xP_5 (3) five populations (P_1, P_2, F_1, F_2 and F_3) for each cross were used in this investigation. Highly significant heterotic values in positive direction were found for all charcters except for plant height and 1000-grain yield in the first cross, spike length in the second cross, and plant height, No. of grains/spike and No. of spikes/plant in the third cross. Over domenance for all characters except plant height and 1000-grain weight in the first cross, spike length in the second cross and No.of grains /spike in the third cross was detected. Inbreeding depression was obtained in two out of three crosses for spike length, No.of grains/spike, No.of spikes/plant, 1000-grain weight and grain yield/plant and in one out of the three crosses for plant height. The important roles of both additive and non-additive gene actionwere found in certain studied traits. Significant positive F_2 deviation (E_1) were indicated for plant height in the third cross, No.of spikes/pant and grain yield/plant in the second and third crosses and 1000-grain weight in the first and third crosses. High to medium values of heritability estimates were found to be associated with high and moderate expected and actual gain in most traits. These obtained results indicated that, these traits could be used in the early generations, but would be more effective if postponed to late generations.

Keywords: Wheat, Heterosis, GCA, SCA, Heterosis, Heritability, Inbreeding depression, Gene action.

INTRODUCTION

Increasing grain yield of cereal crops is an important national goal to face the increasing food needs of Egyptian population. Wheat production in Egypt increased from 6.75 million ton in 2009/2010 to 9 million ton in 2010/2011 season, 33 % increase (statistical Data, 2011, ARC, Giza). This increase was achieved both by increasing wheat area and the continuous rise in grain yield ha^{-1} as a result of cultivating high yield genotypes and improved cultural practices at newly reclaimed areas. Wheat breeders are always looking for means and sources of genetic improvements in grain yield and its components. Genetic diversity is the main tool for breeders to have better recombinants by creating heritable variability upon which selection can be practiced. Knowledge of genetic relationship among individuals or populations is essential to breeders for planning crosses to gain better selections for high yield and developing new promising lines.

Information regarding nature and magnitude of genetic effects prevailing in the breeding material is necessary to decide the kind of breeding procedure to be chosen for better exploitation of the genetic potential of different plant traits in a crop. Elhosary *et al* (2000) found that grain yield and its components in daillel cross among 8 parenrs, were controlled by both additive and non-additive gene effects. Akhtar and Chowdhry (2006) reported that most of the plant traits exhibited simple inheritance with additive dominance model. The additive or additive x additive gene effects were important for plant height to improve grain yield in both crosses as well as their reciprocals. Manal (2009) reported that The traits which had high heritability and also showed high expected genetic advance could be substantially considered or making selections as these traits were mainly influenced by the major effects of additive gene action.

This work was conducted to study genetic variance, gene action, heritability and comparison between actual and expected genetic gain of three bread crosses derived from five parental bread wheat genotypes using five populations of each cross. The ultimate goal of this study is to elucidate the breeding value of crosses that could be utilized in breeding programs to improve wheat yield.

MATERIALS AND METHODS

The present investigation was carried out at El-Gemmeiza Agricultural Research Station, Agricultural Research Center (ARC), Egypt during four successive seasons from 2007/2008 through 2010/2011. The names and pedigree of the six parental varieties and three crosses are presented in Table 1.

Table (1): The names and pedigree of varieties and / or lines evaluated

No	Variety of cross and pedigree	Origin
P1	Chil/2*Star.CM//2793-otopy-22M-020Y-010-4Y-010M-0AP	Syria
P2	Giza168 MRL/BUC//SERI CM93046-8M-OY-OM-2Y-OB-OGZ	Egypt
P3	Mayon-1. CM58924-2Ap-1Ap-2Ap-2Ap-OAp	CIMMYT
P4	Cs/E.GIG//2*CNO79/3/Ald(46)/4/BUC/BJY.CIGM86-Y54-1Y-1B-3Y-1B-1Y-0Y-3P-0Y.	CIMMYT
P5	Gemmeiza 7 CMH74A.630/SX//SERI 82/AGENT CGM4611-2GM-3GM-1GM-0GM	Egypt

In the first season (2007/08), the parental genotypes were crossed to obtain F_1 seeds, in the second season (2008/09), the hybrid seed of the three crosses were sown to give the F_1 plants. These plants were selfed to produce F_2 seeds. Moreover, the same parents were crossed to have enough F_1 seeds. The new hybrid seed and part of seeds obtained from F_1 selfed plants (F_2 seeds) were kept in refrigerator to the final experiment. In the third season (2009/10) three F_1 seeds were sown to produce F_1 plants, which were selfed to produce F_2 seeds. In addition, the F_1 and F_2 plants were selfed to produce F_2 and F_3 seeds, respectively. In the fourth seasons (2010/11) the obtained seeds of the five populations P_1, P_2, F_1, F_2 and F_3 of the three crosses were evaluated using a randomized complete block design with three replications. Rows were 4 m long; spaces between rows were 20 cm. The plants within rows were 10 cm apart. Two rows were devoted for each parent and F_1 progenies, ten rows for F_2 generation and 20 rows for F_3 families for each cross. Data were recorded on individual guarded plants for plant height, spike length, No. of grains/spike, No. of spikes/plant, 1000-grain weight (g) and grain yield/plant (g).

Various biometrical parameters in this study would only be calculated if the F_2 genetic variance was found to be significant. Heterosis was expressed as the percentage deviation of F_1 mean performance from better parent values (heterobeltiosis). Inbreeding depression was measured as the average percent decrease of the F_2 from the F_1. The T-test was used to determine the significance of these deviations where the standard error (S.E) was calculated as follows:

S.E for better parent heterosis

$\overline{F_1} - \overline{BP} = (\overline{VF_1} + \overline{VBP})^{1/2}$ and S.E for inbreeding depression

$\overline{F_1} - \overline{F_2} = (\overline{VF_1}+\overline{VF_2})^{1/2}$

Potence ratio (P) was also calculated according to Peter and Frey (1966). In addition, F_2 deviation (E1) and F_3 deviation (E2) were measured as suggested by Mather and Jinks (1971).

Type of gene effects was estimated according to Hayman model in 1958 as described by Singh and Chaudhary (1985) as follows:

The standard error of additive-additive x dominance(d), dominance (h), dominance x dominance (l) and additive x additive (i) is obtained by taking the squares root of respective 'T' test values are calculated upon dividing the effects of d, h, l and i by their respective standard error.

$$m = \overline{F_2}$$

$$d = 1/2\ \overline{P_1} - 1/2\ \overline{P_2}$$

$$h = 1/6(4\ \overline{F_1} + 12\ \overline{F_2} - 16\ \overline{F_3})$$

$$l = 1/3(16\overline{F_3} - 24\ \overline{F_2} + 8\overline{F_1})$$

$$i = \overline{P_1} - \overline{F_2} + 1/2(\overline{P_1} - \overline{P_2} + h) - 1/4\ l$$

The variances of these estimates were computed as follows:

$$Vm = \overline{VF_2}$$

$$Vd = 1/4(\overline{VP_1} + \overline{VP_2})$$

$$Vh = 1/36(16\overline{VF_1} + 144\overline{VF_2} + 256\overline{VF_3})$$

$$Vl = 1/9(256\overline{VF_3} + 576\overline{VF_2} + 64\overline{VF_1})$$

$$VI = \overline{VP_1} + \overline{VF_2} + 1/4(\overline{VP_1} + \overline{VP_2} + Vh) + 1/16\ Vl$$

Heritability was calculated in both broad and narrow sense according to Mather (1949) and parent off-spring regression according to Sakai (1960). Furthermore, the expected and actual genetic advance (Δg) was computed according to Johanson *et al.* (1955).

Likewise, the genetic gain represented as percentage of the F_2 and F_3 mean performance (Δg %) and was estimated using the method of Miller *et al*. (1958).

RESULTS AND DISCUSSION

Parental defferences in response to their genetic background were found to be significant in most characters under investigation. The F_2 genetic variances were also significant for all studied characters in three crosses. Means and variances of the five populations (P_1, P_2, F_1, F_2 and F_3) for the studied characters in the three crosses are presented in Table 2. The results showed that for the first cross (P_1xP_2); P_2 variety recorded higher mean values for spike length, No.of grains/spike, No.of spikes/plant and grain yield/plant than P_1. While P_1 variety revealed higher values for plant height and 1000-grain weight than $P_{2.}$ Similarly F_1 was higher than parents, F_2 and F_3 for spike length, No.of grains/spike, No.of spikes/plant and grain yield/plant. The F_2 was higher value than their parents, F_1 and F_3 for 1000-grain weight, while the F_3 exceeded all population in plant height.

With regard to two crosses (P_3xP_4) and (P_4xP_5); the mean performance of P_2 variety recorded higher values for plant height, spike length, No.of spikes/plant, 1000-grain weight and grain yield/plant than P_1 variety for cross (P_3xP_4), plant height, No.of grains/spike, 1000-grain weight and grain yield/plant than P_1 variety for cross (P_4xP_5). The $F_{1.}$ Was hiegher value than their parents, F_2 and F_3 for plant height, No.of grains/spike, 1000-grain weight and grain yield/plant for cross (P_3xP_4), spike length, No.of spikes/plant and 1000-grain weight for cross (P_4xP_5). The F_2 was higher than F3 in plant height, spike length and No.of spikes/plant and exceeded all populations in No.of spikes/plant and 1000-grain weight for cross (P_3xP_4). While F_3 was higher than F_2 in No.of grains/plant and exceeded all population in plant height for cross (P_4xP_5). Therefor selection could be effective in the improvement of the characters spike length, No.of grains/spike, No.of spikes/plant and grain yield/plant in the next generation. The data also revealed that the variance of F_2 and F_3 respectivly was larger for all characters than P_1, P_2 and $F_{1.}$ This indicates that the environmental fluctuation have marked effects on the expression of these characters. These results are in harmony with those obtained by Abdel-Nour, Nadya and Moshref (2006).

Heterosis, potence ratio (P), inbreeding depression percentage, E_1, E_2 and different gene actions for the six characters are given in Table 3. It could be observed from the data that highly significant heterotic values in positive direction were found for all charcters except for plant height and 1000-grain weight in the first cross, spike length in the second cross, and plant height and No.of grains/spike in the third cross. Similar trends were reported by Abdel-Nour, Nadya *et al.* (2005).

Table 2 : Number, means and variance for some studied characters using the five population (P1, P2, F1, F2 and bulked F3 crosses. families) for three bread wheat

Character	n	P1xP2				
		P1	**P2**	**F1**	**F2**	**F3 bulk**
Plant height	x̄	115.57	104.22	108.45	109.79	121.55
	S2	21.79	35.23	5.96	182.69	140.89
Spike length	x̄	14.43	14.57	18.57	11.28	12.87
	S2	0.69	0.89	0.79	2.14	1.85
No. of grains/spike	x̄	97.51	98.67	123.60	79.95	75.71
	S2	32.57	50.69	48.24	331.25	210.11
No. of spikes/plant	x̄	7.13	9.40	13.50	11.16	8.73
	S2	2.20	3.21	2.11	11.60	7.62
1000-grain weight	x̄	48.40	45.95	46.24	50.85	46.71
	S2	4.20	3.50	4.00	20.97	18.09
Grain yield/plant	x̄	32.74	55.57	60.00	49.05	43.04
	S2	9.66	20.37	23.26	358.70	276.80
		P3xP4				
Plant height	x̄	103.87	129.67	135.27	117.91	105.94
	S2	1.36	33.26	31.45	395.97	165.87
Spike length	x̄	14.20	16.27	15.63	13.83	12.23
	S2	1.06	1.31	2.10	4.35	2.85
No. of grain/spike	x̄	99.59	98.60	121.08	75.84	73.03
	S2	80.40	75.89	97.59	362.08	344.87
No. of spikes/plant	x̄	7.13	9.40	9.96	11.31	11.25
	S2	2.20	3.21	2.11	11.98	7.10
1000-grains weight	x̄	40.22	41.76	49.53	45.92	46.61
	S2	3.75	9.01	6.33	22.37	12.65
Grain yield/plant	x̄	26.63	36.75	58.91	48.14	48.78
	S2	15.80	14.59	22.57	320.49	314.30
		P4xP5				
Plant height	x̄	112.86	114.53	108.16	121.19	125.56
	S2	1.28	2.23	1.21	251.74	133.57
Spike length	x̄	17.90	17.73	19.26	12.80	11.98
	S2	1.00	0.89	1.00	3.73	2.99
No. of grain/spike	x̄	87.38	99.60	92.60	63.11	70.48
	S2	98.46	50.37	39.68	242.15	201.02
No. of spikes/plant	x̄	9.40	7.30	13.26	12.42	11.01
	S2	0.71	0.41	1.37	12.06	11.17
1000-grains weight	x̄	41.64	45.10	50.26	48.11	46.07
	S2	1.45	1.73	1.02	22.73	10.67
Grain yield/plant	x̄	34.67	40.21	42.60	45.75	44.95
	S2	4.63	11.65	11.68	243.45	147.73

No.of spikes/plant, No.of grainss/spike and 1000-grain weight are the main components of grains yield/plant. Hence, heterotic increase, if found, in one or more of these attributes with others being constant would lead to favorable yield increase in a hybrid. The lack of significance in heterosis of No.of grainss/spike in the third cross and 1000-grain weight in the first cross could be due to the lower magnitude of the non-additive gene action. These results are in agreement with those obtained by Abdel-Nour, Nadya and Moshref (2006).

3

Concerning potence ratio, Table 3 revealed that over domenance for all characters except plant height and 1000-grain weight in the first cross, spike length in the second cross and No.of grains /spike in the third cross which their potence ratio were less than unity indicating partial domenance effect. These results are in agreement with those obtained by Hendawy (2003).

Inbreeding depression were obtained in two out of three crosses for spike length, No.of grains/spike, No.of spikes/plant, 1000-grain weight and grain yield/plant and in one out of the three crosses for plant height. This is a valid result, since the expression of heterosis in the F_1 may be followed by reduction in F_2 performance. The obtained results for most crosses were in harmony with those obtained by Abdel-Nour, Nadya and Moshref (2006). Morever, significant positive heterosis and significant negative inbreeding depression for these traits in one/two crosses were detected. The contradiction between heterosis and inbreeding depression estimates could be due to the presence of linkage between genes in these materials (Van der Veen, 1959).

Nature of gene action was determined using the five parametars Table 3. The estimated mean effect of F_2 (m) which reflects the contribution due to the over all mean plus the locus effects and ineractions of the fixed loci, was found to be highly significant. The additive gene effect (d) was significantly positive for plant height and 1000-grain weight in the first cross and for No.of spikes/plant in the third cross. Meanwhile, (d) was significantly negative for all the other traits in all crosses. These results suggest the potential for obtaining further improvement for the former traits by using pedigree selection program. Similar trend were obtained by Hendawy (2003).

Dominance gene effect (h) was positive significant for all traits except for plant height in the first and third crosses, spike length in the fisrt cross, No.of grains/spike and grain yield/plant in third cross and No.of spikes/plant and 1000-grain weight in the second cross. The significant in these components indicated that both additive and dominance gene effects are important in the inheritance of these traits. Therfore, selection of desired traits could be practiced in the early generation but would be more effective in the late ones. These results are in agreement with those obtained by Abdel-Nour, Nadya and Moshref (2006).

Dominance x dominance (I) type of gene was significant for No.of grains/spike in all three crosses, spike length in the first and second crosses, plant height in the first cross and 1000-grain weight in the second one. These indicates that dominance genetic effects were more important in the inheritance of these traits.

A significant additive x additive type of epistasis (i) was detected for spike length in the second and third crosses, No.of grains/spike in the first and second crosses and 1000-garin weight in the first one.

The important roles of both additive and non-additive gene action in certain studied traits indicated that selection procedures based on the accumulation of additive effects would be very successful in improving these traits. Similar approaches were reported by Moustafa (2002) and Hendawy (2003).

Significant positive F_2 deviation (E_1) were indicated for plant height in the third cross, No.of spikes/plant in the second and third crosses and 1000-grain weight in the first and third crosses. Meanwhile, significant negative values were obtained for spike length and No.of grains/spike in all crosses, plant height in the second cross and grain yield in the first one. These results may refer to the contribution of epistatic gene effects in the performance of these traits.

With regard to F_3 deviation (E_2) was revealed to be significantly positive for plant height in the first and third crosses, No.of spikes/plant and 1000-grain weight in the second one and grain yield in the second and third crosses. Morever, significant negative values were indicated for all traits of all crosses except for No.of spikes/plant in the third cross and 1000-grain weight in the first one. These results would ascertain the presence of epistasis in such large magnitude as to warrant great deal of attention in breeding programs.

Hertabilty in both broad and narrow senses, and between generations (parent off-spring regression) are presented in Table 4. High hertability values in broad sense were deetected for all the studied traits except for spike length in all crosses, No.of grains/spike in the second and third crosses, No.of spikes/plant in the first and second crosses and 1000-grain weight in the first and second crosses. Heritability estimates have been found to be useful in indicating the relative value of selection based on phenotypic expression of different characters, Kahrizi *et al.* (2010).

Table 4: Heritability and expected versus actual gain for all studied characters in three cross of bread wheat.

Characters	Crosses	Heritability %		Parent off spring	Expected gain		Actual gain	
		Broad sense	Narrow sense	regression	Delta g	% of F2	Delta g	% of F3
Plant height	1	88.508	45.76	52.10	12.74	10.60	12.74	10.48
	2	94.44	73.28	31.61	30.04	25.48	10.31	28.36
	3	99.375	93.88	58.20	30.69	25.32	13.86	24.44
Spike length	1	63.106	27.66	51.69	0.83	7.39	1.45	6.48
	2	65.716	68.79	34.84	2.95	21.37	1.21	24.15
	3	74.256	39.78	29.18	1.58	12.37	1.04	13.22
No. of grains/spike	1	86.768	73.14	24.70	27.42	34.30	7.38	36.22
	2	76.628	9.51	55.77	3.73	4.92	21.34	5.10
	3	74.050	33.98	49.05	10.89	17.26	14.33	15.45
No. of spikes/plant	1	78.371	68.69	42.37	4.82	43.20	2.41	55.12
	2	79.066	81.46	28.40	5.81	51.36	1.56	51.12
	3	93.097	14.81	76.73	1.06	8.53	5.28	9.63
1000-grains weight	1	81.398	27.39	28.26	2.58	5.08	2.48	5.53
	2	71.562	86.89	29.59	8.47	14.44	2.17	18.16
	3	93.84	62.13	23.42	6.10	12.68	1.91	13.24
Grain yield/plant	1	95.048	45.66	61.30	17.82	36.32	21.01	41.40
	2	94.492	3.87	66.44	1.43	2.96	24.27	2.92
	3	96.171	78.64	48.97	25.28	55.24	12.26	56.23

High to moderate estimates of narrow sense heritabilty and parent off-spring regression was found for all studied traits except for spike length and 1000-grain weight in the first cross, No.of grains/spike and grain yield/plant in the second cross and No.of spikes/plant in the third one. The differences in magnitude of both narrow sense and parent off-spring regression heritabilty estimates for all the studied traits would ascertain the presence of both additive and non-additive gene effects in the inheritance of these traits. Similar conclusions were also reported by Abdel-Nour, Nadya *et al.* (2005).

The expected versus actual genetic gain for all traits were estimated. The expected genetic advance (Δg % of F_2) ranged from 0.83 for spike length in the first cross to 30.69 for plant height in the third cross and actual genetic advance (Δg % of F_3) ranged from 1.04 for spike length in the third cross to 24.27 for grain yield/plant in the second cross. The results of expected genetic advance upon selection were higher for plant height in the second and third crosses, No.of grains/spike in the first one and grain yield/plant in the first and third crosses. Also, the results of actual genetic advance were higher for No.of grains/spike in the second cross and grain yield/plant in the first and third crosses. These results indicated the possibilty of practicing selection in early generations to enhance these traits and hence selection high yielding genotypes. Dixit *et al.* (1970) pointed out that high heritabilty is not always associated with high genetic advance, but in order to make effective selection, high heritabilty should be associated with high genetic gain. Manal (2009) pointed out that the traits which had high heritability and also showed high expected genetic advance could be substantially considered or making selections as these traits were mainly influenced by the major effects of additive gene action.

Generally, the most biometrical parameters resulted from the all crosses had high values for most traits . Consecquently it could be concluded that these crosses would be of interest in a breeding program for genetic improvement of wheat.

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طبيعة التوارث والفعل الجينى للمحصول ومكوناته لثلاثة هجن من قمح الخبز

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الهدف من إجراء هذا البحث هو دراسة التباين الوراثى ، والفعل الجينى ، ودرجة التوريث ، والتنبؤ بدرجة التحسين الوراثى وقيمة التربية للهجن الثلاثة والتى يمكن استخدامها فى برامج التربية لتحسين محصول القمح.

أجرى هذا البحث فى محطة بحوث الجميزة فى أربعة مواسم متتالية من 2008/2007 الى 2011/2010 ، على ثلاثة هجن من قمح الخبز بين خمسة أباء وهى الهجين (1) P_1xP_2 ، والهجين (2) P_3xP_4 ، والهجين (3) P_4xP_5 .

واشتملت الدراسة على كل من الأبوين والجيل الأول ، والثانى ، والثالث

وكانت أهم النتائج التى تم التوصل اليها كما يلى:-

١ - كانت قوة الهجين فى الجيل الأول عالية المعنوية وموجبة بالنسبة لكل الصفات ما عدا صفة ارتفاع النبات ووزن الألف حبة فى الهجين الأول وطول السنبلة فى الهجين الثانى ، وارتفاع النبات وعدد الحبوب للسنبلة وعدد السنابل/النبات فى الهجين الثالث.

٢ - أوضحت الدراسة ان درجة السيادة كانت سيادة فائقة تجاه الأب الأعلى فى كل الصفات ما عدا ارتفاع النبات ، ووزن الألف حبة فى الهجين الأول، وطول السنبلة فى الهجين الثانى ، وعدد الحبوب فى السنبلة للهجين الثالث.

٣ - تأثير التربية الداخلية كان موجبا ومعنويالصفات طول السنبلة وعدد الحبوب فى السبلة ووزن الالف حبة ومحصول الحبوب/النبات فى هجينان من ثلاثة، ولهجين واحد فقط لصفة ارتفاع النبات.

٤ - أظهرت التأثيرات الوراثية المضيفة وكذلك الفعل الجينى غير المضيف دورا هاما فى وراثة معظم الصفات المدروسة.

٥ - كانت انحرافات الجيل الثانى (E_1) وانحرافات الجيل الثالث (E_2) معنوية لمعظم الصفات فى الهجن تحت الدراسة مما يوضح أهمية الفعل الجينى التفوقى فى وراثة الصفات.

٦ - اظهرت درجة التوريث بمعناها الواسع قيما عالية الى متوسطة لمعظم الصفات المدروسة ، كما أظهرت درجة التوريث بمعناها الضيق قيما عالية الى متوسطة وكذلك الكفاءة الوراثية من الانحدار بين الاجيال لمعظم الصفات مرتبطة بنسبة تحسين وراثى

٧ - النتائج المتحصل عليها تدل على أن الانتخاب فى الاجيال الانعزالية المبكرة قد يكون مفيدا ولكن سوف يكون أكثر كفاءة اذا تم تأجيلة للأجيال الانعزالية المتأخرة.

قام بتحكيم البحث

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Table 3: Heterosis, potence ratio, inbreeding depression and gene action parameters for the three bread wheat crosses

Characters	Crosses	Heterosis M.P	potence ratio (P)	Inbreeding depression %	Gene action parameters						
					m	d	h	l	i	E1	E2
Plant height	1	-1.31	-0.25	-1.23	109.79**	5.67**	-32.25**	59.15**	-19.46**	0.62	24.76**
	2	15.84**	1.43	12.83**	117.91**	-12.90**	43.49**	-17.54**	-0.81	-8.11**	-40.16**
	3	-4.87	-6.64	-12.04**	121.19**	-0.83**	-20.35**	-11.41	-16.48**	10.26**	29.27**
Spike length	1	28.07**	58.99	39.25**	11.28**	-0.07	0.63	27.89**	-3.58**	-5.25**	-7.34**
	2	2.63	0.39	11.57	13.83**	-1.03**	5.46**	-3.68*	2.99**	-1.61**	-6.41**
	3	8.08**	17.32	33.56**	12.80**	0.08	6.49**	12.86**	5.22**	-5.74**	-13.12**
No. of grains/spike	1	26.01**	44.27	35.32**	79.95**	-0.58	40.42**	93.77**	13.76**	-30.90**	-70.28**
	2	22.19**	44.54	37.36**	75.84**	0.49	37.65**	105.66**	16.65**	-34.25**	-74.11**
	3	-0.95	-0.15	31.85	63.11**	-6.11**	0.00	117.96**	-11.33**	-29.94**	-45.13**
No. of spikes/plant	1	63.34**	4.61	17.36**	11.16**	-1.14**	8.03**	-6.69**	0.53	0.27	-4.31**
	2	20.53**	1.49	-13.54**	11.31**	-1.14**	-0.74	-3.92	-4.71**	2.20**	4.27**
	3	58.76**	4.67	6.31**	12.42**	1.05**	4.33**	-5.32*	1.52	1.62**	0.40
1000-grain weight	1	-1.98	-0.76	-9.98	50.85**	1.22**	7.97**	-34.39**	11.34**	4.15**	0.01
	2	20.83**	11.09	7.29**	45.92**	-0.77*	0.57	13.29**	-9.51**	0.66	2.70**
	3	15.88**	3.98	4.27**	48.11**	-1.73**	6.88**	-5.17	-3.47**	1.30**	-1.49**
Grain yield/plant	1	35.88**	1.39	18.25**	49.05**	-11.41**	23.33**	-2.87**	-15.34**	-3.03*	-18.08**
	2	85.88**	5.38	18.27**	48.14**	-5.06**	5.47*	32.11	-31.87**	2.85*	6.97**
	3	13.77**	1.86	-7.41**	45.75**	-2.77**	0.03	-12.70	-10.66**	5.74**	9.87**