Genetic variability and interrelationships of grain yield and its components of irrigated rice in Gezira

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ABSTRACT

Nineteen genotypes of irrigated rice were evaluated at the Gezira Research Station Farm, Wad Medani, Sudan, for two consecutive seasons (2004 and 2005) in a randomized complete block design with three replicates. This study was conducted to estimate the genotypic and phenotypic variability, broad sense heritability and traits correlation with grain yield. The highest genotypic coefficient of variation and genetic advance were recorded for plant height and number of panicles/m^2, and the lowest for number of tillers/plant, days to 50% flowering, days to 50% maturity and panicle length, in both seasons. High heritability estimates (>80%) were recorded for plant height, days to 50% flowering, days to 50% maturity and 1000-grain weight. The highest estimate of heritability combined with the highest genetic advance as percentage of the mean was shown by plant height and 1000-grain weight, in both seasons. The high yielding genotypes were WITA5 (TOX 3255-82-1-3-2), IRI 3240-108-2-2-3(SAHEL.108)(FKR44) and TOX 3081-36-2-2-3-1. Their grain yields were 4.9, 4.9 and 4.6 t/ha, respectively. Grain yield/ha was significantly and negatively correlated with the percentage of unfilled grains/panicle, plant height and days to 50% flowering. How-ever, it was significantly and positively correlated with number of tillers/ plant, number of panicles/m^2, number of filled grains/panicle and 1000-grain weight, in both seasons. Path coefficient analysis indicated that number of filled grains/panicle, 1000-grain weight and number of panicles / m^2 were the most directly related traits to grain yield/ha.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop in the world, feeding more than half of the world population. It is estimated that 48% of the world's population use rice as a major source of energy (Longping and Jiming, 2005).World rice production is about 608 million tones, from 153 million hectares. Asian farmers produce about 90% of the total production (FAO, 2005). In the Sudan, rice has been grown since 1905. It is grown on 5.5 thousand hectares producing 8 thousand tones. Sudan produces an average of 1.5 t/ha (AOAD, 2001).

Rice yield potential has almost leveled off at 10 t ha^{-1} for current high-yielding inbred cultivars, while the theoretical potential has been estimated at 15.9 t ha^{-1} in tropical environments (Morgan *et al*., 2002). In order to break through this apparent yield barrier, several researchers advocated more breeding work to be targeted at those characteristics of the rice plant that contribute to final grain yield. The relationship betw-een rice yield and its components has been studied extensively at the phenotypic level (Gravois and Helms, 1992).

Yield per hectare is the most important consideration in rice breeding program, but yield is a complex character in inheritance and may involve several related components. Rice yield is a product of number of panicles per unit area, number of spikelets per panicle, percent-age of filled grains per panicle and 1000-grain weight (Yoshida, 1981). The process of breeding is primarily conditioned by the magnitude and nature of intera-ctions of genotypic and environmental variations in plant characters. It becomes necessary to partition the observed variability into its heritable and non-heritable components and to have an understanding of parameters such as genotypic coefficient of variation, heritability and genetic advance.

Accordingly, this study was conducted to estimate heritability and genetic advance of yield and yield components and establish suitable selection criteria to provide basis for selection and yield improvement irrigated rice in Sudan.

MATERIALS AND METHODS

The present research work was conducted over two consecutive rainy seasons (2004 and 2005) at the Gezira Research Station Farm (GRSF) (latitude $14^0$24′N and longitude $33^0$29′E) of the Agricultural Research Corporation (ARC), Wad Medani, Sudan. The soil of the experimental plots is classified as vertisol with high clay content (40-65%), less than 1% organic carbon, low in available nitrogen (0.03% total nitrogen) and medium in available P_2O_5(406 to 700 ppm total phosphorus), and has pH values ranging from 7 to 8.6. The climate is semi-arid.

The plant material used in the study was 19 irrigated rice genotypes imported from West Africa Rice Development Association (WARDA), namely, ITA 252, IR 2042-178-1, BW 293-2 (SAHEL.201), BG 400-1 (BG400-1-SLR)(KOK 31),WITA 7 (TOX 3440-171-1-1-1), TOX 3880-38-1-1-2, TOX 3772-94-1-1-1, RF8 5 C-C 1-32-1-2-2-3, IRI 3240-108-2-2-3(SAHEL.108)(FKR44), ITA 230 (FARO50), TOX 3081-36-2-2-3-1, TOX 3052-39-1-2-1, WITA 4 (TOX 3100-44-1-2-3-3), TOX 3154-17-1-3-2-2, WITA 5 (TOX 3255-82-1-3-2) ITA 222 (FARO 36),ITA 222 (FARO 36), TOX 3248-76-3-1-2, GAMBIAKA CL and TOX 3883-58-2-2-2-1-3.

The experimental plots were laid out in a randomized complete block design with three replications. The plot size was 5 x 3 m and consisted of 14 rows spaced 20 cm apart. The sowing date were the 12th and 2nd of July in 2004 and 2005 seasons using a seed rate of 120 kg/ha.

Fertilizers were applied at the rate of 86 and 43 kg/ha of nitrogen and P_2O_5, respectively, in the form of urea and triple super phosphate. $P_2O_5$was applied as basal dose during final land preparation. Nitrogen was top dressed in two equal split doses one at 21days after sowing and the other before panicle initiation. Hand weeding was performed three times per season. All plots were irrigated at sowing and then at weekly intervals until it reached maturity.

Data were collected on days to 50% flowering and days to 50% maturity. At harvest, a random sample of five plants in each experimental unit was taken to measure the following parameters: Plant height (cm), panicle length (cm), number of tillers/plant, number of grains/panicle, number of filled grains/panicle, percentage of unfilled grains/panicle, 1000-grain wei-ght (g) and grain yield (t/ha) based on grain yield/m^2 and then converted to grain yield/ha,

Analysis of variance was used to test for significant differences among the 19 genotypes. The combined analysis of variance was done for the traits in which the error mean squares were homogenous. The phenotypic and genotypic variances and their coefficients, heritability in the broad sense and genetic advance were computed according to the formula described by Singh and Chaudhary (1985). Means for each season were used to compute simple linear correlation coefficients. Path coefficient analysis was used to partition the simple linear correlation coefficients, combined over seasons, between grain yields/ha and four other traits; namely, 1000-grain weight, number of tillers/plant, number of filled grains/panicle and panicle length, into the direct and indirect effects.

RESULTS AND DISCUSSION

The results showed a wide range of variability among the genotypes for most of the eleven traits, in both seasons (Table 1). The range and analysis of variance indicated potential genetic variability and diversity in the material under consideration. These results indicated the possibility of genetic improvement through conventional selection methods. Many rese-arch workers indicated genetic variability in the rice material they studied (Gonzales and Ramirez., 1998; Rasheed *et al*., 2002; Bose *et al*., 2005).

High heritability estimates in broad sense (h^2_B) (>80%) were exhibited by plant height, days to 50% flowering, days to 50% maturity and 1000-grain weight, in both seasons. Sarma *et al.,* (1996) and Nuruzzaman *et al.*, (2002) reported similar results. This indicated that selection of these traits would be more effective as compared to others. Moderate heritability estimate was shown by grain yield and low heritability estimate were exhib-ited by number of tillers/plant and number of grains/panicle.

The excepted genetic advance expressed as percentage of mean, varied from 3.22% to 33.41% in the first season and from 5.9% to 65.32% in the second season. Traits that exhibited high genotypic coefficient of variation like plant height and number of panicles/m^2, also gave high genetic advance as percentage of mean (GA %), in both seasons (Table1).This indicated the possibility of their use as selection criteria for high grain yield.

Table 1. Estimates of phenotypic variability, heritability in broad sense (h^2B), genotypic (GCV) and phenotypic (PCV) coefficients of variation, genetic advance as percentage of the mean for 11 traits in 19 rice genotypes, grown at the Gezira Research Station Farm, seasons 2004 and 2005.

Trait	Season	Range	General mean	F value	h^2B (%)	GCV (%)	PCV (%)	GA as % of mean
Plant height (cm)	2004	52-88	62.3	7.8***	87.3	13.4	14.3	25.7
	2005	55-94	72.4	8.6***	89.4	12.7	13.5	24.5
Number of tillers/plant	2004	3-5	4.4	1.2	20.9	3.4	7.5	3.2
	2005	3-4	3.6	1.8	43.6	6.2	9.4	8.5
Days to 50% flowering	2004	111-130	119.1	35.5***	97.2	3.9	4.0	7.6
	2005	107-135	117.3	5.6***	82.1	6.5	7.2	12.1
Days to 50% maturity	2004	130-142	136.6	16.7***	94.0	3.0	3.1	6.0
	2005	129-153	140.4	5.3***	81.3	4.4	4.8	8.1
Panicle length (cm)	2004	19-22	20.0	1.9*	45.7	3.2	4.8	4.5
	2005	19-23	21.0	2.1*	51.9	4.0	5.5	5.9
Number of panicles/m^2	2004	299-637	481.7	3.8***	73.8	16.1	18.8	28.6
	2005	227-548	434.0	3.1**	67.5	13.3	16.2	22.5
Number of grains/panicl	2004	54-81	68.4	0.8	24.4	5.5	11.1	5.6
	2005	52-84	70.6	2.7**	62.5	9.0	11.4	14.7
Number of fillec	2004	38-64	48.5	2.8**	64.3	13.9	17.3	22.9
grains/panicle	2005	27-57	44.0	2.8**	64.6	16.2	20.2	26.8
Unfilled grains/panicle	2004	16-40	28.7	2.2**	64.7	20.0	24.7	33.4
(%)	2005	20-55	37.6	2.2**	65.6	20.6	25.5	34.4
1000-grain weight (g)	2004	17-28	22.3	15.8***	93.6	12.6	13.1	25.2
	2005	17-25	20.7	6.4***	84.3	9.0	9.8	17.0
Grain yield (t/ha)	2004	2.3-5.5	4.1	3.3**	69.8	17.3	20.8	29.6
	2005	1.2-4.5	2.5	6.4***	85.1	34.4	37.3	65.3

*,**, *** Significant at 0.05 ,0.01, and 0.001 probability levels, respectively.

The range for plant height was 55-91 cm with genotype GAMBIAKA CL as the tallest and genotypes TOX 3883-58-2-2-2-1-3 and IR I3240-108-2-2-3(SAHEL.108)(FKR44) as the shortest (Table 2).The late flow-ering and maturing genotypes were ITA 252 and TOX 3880-38-1-1-2, and the early flowering and maturing genotypes were ITA 230 (FARO50) and IR 2042-178-1. A range of 55-78 in the number of grains /panicle was shown by genotypes TOX 3772-94-1-1-1 and IRI 3240-108-2-2-3 (SAHEL.108)(FKR44), respectively, while the geno-types TOX 3880-38-1-1-2 and TOX 3081-36-2-2-3-1, gave respectively a range of 33-60 in the number of filled grains per panicle.

The lowest percentage of unfilled grains/panicle (18) was shown by TOX 3081-36-2-2-3-1 and the highest (45) by GAMBIAKA CL. Adequate number of fertile grains/panicle and heavy grains are import-ant traits, which should be considered in selection for high yield (Prasad *et al.*, 2001; Sürek *et al.*, 2003).Increasing the number of spikelets/panicle does not always result in higher grain yield, but with increased filled grains percentage it increases yield. The highest yielding genotypes were WITA5 (TOX3255-82-1-3-2), IRI 3240-108-2-2-3(SAHEL.108) (FKR 44) and TOX 3081-36-2-2-3-1 giving, over two seasons, an average of 4.9, 4.9 and 4.6 t/ha, respectively.

Grain yield was positively and significantly ($P \leq 0.05$) correlated with number of panicles/m^2, number of grains/panicle, number of filled grains/ panicle and 1000-grain weight, in both seasons (Table3), indica-ting the importance of these components in rice yield. The result agreed with that of Luzikihupi (1998) and Süerk and Beser (2003). Grain yield was significantly and negatively correlated with percent of unfilled grains/ panicle. This was expected since filled grains/panicle has a high signific-ant correlation with grain yield (Luzikihupi, 1998). There was a negative relationship between number of filled grains/panicle and number of unfilled grains/panicle. Days to 50% maturity was positively and signi-ficantly correlated with days to 50% flowering, panicle length and number of grains/panicle. Similar results were reported by (Mehetre *et al.*, 1996).

Table 2. Mean performance of 19 rice genotypes grown at the Gezira Research Station Farm (combined over two seasons, 2004 and 2005)

Genotype	PH(cm)	NTPP	DFPF	DFPM	PL(cm)	NPPM
ITA 252.	82.3 B	4.3 AB	131.7 A	147.5 A	22.5 A	491.7ABCD
IR2042-178-1.	65.0 EFGH	4.3 AB	112.5 HIJ	131.3 GH	20.3 BCD	404.2 DE
BW 293-2 (SAHEL.201).	63.2 FGHI	3.7 BC	115.8 EFGHI	140.0 BCD	20.5 BCD	448.7 CDE
BG 400-1 (BG400-1-SLR)(KOK 31).	76.8 BC	3.4 ABC	111.0 IJ	134.7 EFGH	20.0 CDE	564.0 AB
WITA7 (TOX 3440-171-1-1-1).	62.2 FGHI	4.0 ABC	114.2 GHIJ	136.8 CDEF	19.7 CDE	512.7 ABC
TOX 3880-38-1-1-2.	71.7 CDE	4.0 ABC	128.5 AB	147.3 A	21.2 ABC	392.3 DE
TOX 3772-94-1-1-1	58.7 HI	4.5 A	114.7 FGHIJ	136.3 CDEF	18.6 E	478.7 BCD
RF8 5 C-C 1-32-1-2-2-3.	72.7 CD	4.0 ABC	119.5 CDEFG	137.2 CDEF	20.5 BCD	452.9 CDE
IRI3240-108-2-2-3 (SAHEL.108)(FKR44).	55.9 I	4.0 ABC	118.2 DEFGH	136.7 CDEF	20.8 ABC	585.7 A
ITA 230 (FARO50).	61.2 GHI	4.5 A	109.2 J	132.5 EFG	20.9 ABC	396.3 DE
TOX 3081-36-2-2-3-1.	63.2 FGHI	4.0 ABC	117.8 DEFGH	136.6 CDEF	21.4 ABC	537.8 ABC
TOX 3052-39-1-2-1	65.2 EFGH	4.0 ABC	120.8 CDE	141.2 BC	20.6 BCD	355.5 E
WITA 4 (TOX 3100-44-1-2-3-3).	68.9 DEF	4.0 ABC	111.3 IJ	130.2 H	20.6 BCD	495.2 ABC
TOX 3154-17-1-3-2-2.	64.1 FGH	3.8 ABC	122.7 CD	140.3 BCD	20.9 ABC	467.2 BCD
WITA 5 (TOX 3255-82-1-3-2)	66.7 DEFG	4.3 AB	119.5 CDEFG	138.2 CDE	20.8 ABC	522.2 ABC
ITA 222 (FARO 36).	63.0 FGHI	3.8 ABC	116.2 EFGHI	135.7 DEFG	20.1BCDE	470.2 BCD
TOX 3248-76-3-1-2.	71.9 CDE	3.8 ABC	120.5 CDEF	143.8 AB	21.8 AB	452.3 CDE
GAMBIAKA CL	91.1 A	3.3 C	124.8 BC	139.0 BCDE	19.7 CDE	263.0 F
TOX 3883-58-2-2-2-1-3.	55.8 I	4.5 A	116.5 EFGHI	145.8 A	19.0 DE	409.5 DE

Table 2. (cont.).

Genotype	NGPP	NFGPP	PUGPP	T GW	GY(t/ha)
ITA 252.	78.5 A	54.2 ABC	30.3 BCDE	23.1 CDE	3.6 BC
IR2042-178-1.	67.0 AB	44.0 CDE	33.5 ABCD	20.9 FG	3.6 BC
BW 293-2 (SAHEL.201).	67.0 AB	43.8 CDE	38.2 ABCD	22.1 DEF	3.2 BCD
BG 400-1 (BG400-1-SLR)(KOK 31).	67.0 AB	43.5 CDE	34.3 ADCB	21.1 FG	3.1 CD
WITA7 (TOX 3440-171-1-1-1).	63.0 AB	43.8 CDE	30.5 BCDE	22.0 DEF	3.4 BCD
TOX 3880-38-1-1-2.	65.5 AB	42.8 CDE	33.2 ABCD	18.8 HIJ	1.9 E
TOX 3772-94-1-1-1	65.5 AB	45.3 CDE	30.3 BCDE	21.3 FG	3.1 CD
RF8 5 C-C 1-32-1-2-2-3.	75.0 A	48.5 ABCD	35.7 ABCD	17.2 J	3.3 BCD
IRI 3240-108-2-2-3 (SAHEL.108) (FKR44).	78.8 A	58.3 AB	25.9 DEF	24.1 ABC	4.9 A
ITA 230 (FARO50).	66.2 AB	43.0 E	33.8 ABCD	23.6 BCD	3.0 CD
TOX 3081-36-2-2-3-1.	73.0 A	50.0 A	17.8 F	24.8 AB	4.6 A
TOX 3052-39-1-2-1	74.2 A	43.3 CDE	40.7 AB	21.9 DEF	2.9 CD
WITA 4 (TOX 3100-44-1-2-3-3).	71.7 A	53.0 ABC	27.0 CDEF	22.3 DEF	4.2 AB
TOX 3154-17-1-3-2-2.	76.7 A	47.5 BCD	38.8 ABC	19.7 HG	3.3 BCD
WITA 5 (TOX 3255-82-1-3-2)	66.3 AB	52.8 ABC	20.5 EF	25.6 A	4.9 A
ITA 222 (FARO 36).	65.3 AB	36.3 DE	43.8 A	22.3 DEF	2.6 CDE
TOX 3248-76-3-1-2.	76.0 A	47.8 BCD	36.3 ABCD	21.4 EF	3.0 CD
GAMBIAKA CL	68.8 AB	37.2 DE	44.5 A	17.9 J	2.0 E
TOX 3883-58-2-2-2-1-3.	55.0 B	33.2 E	38.3 ABC	19.2 HI	2.5 DE

Means followed by the same letter(s) within a column are not significantly different at 0.05 probability level according to Duncan's Multiple Range Test.

PHT: Plant height, NTPP: Number of tillers/plant, DFPF: Days to 50% flowering, DFPM: days to 50% maturity, PL: Panicle length, NPPM: Number of panicles/m^2, NGPP: Number of grains/panicle, NFGPP: Number of filled grains/panicle, PUGPP: percent of unfilled grains/panicle, TGW: 1000-grain weight and GY: grain yield

Table 3. Simple linear correlation coefficients between 11 pairs of traits in rice using season 2004

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
X_1	-	-.534*	.074	-.127	.202	-.127	.124	.015	.105	-.199	-.298
X_2	-.402	-	.116	.250	.158	.006	-.068	.117	-.303	.358	.202
X_3	.672**	-.373	-	.830**	.502*	.077	.496*	.442	-.172	.094	.156
X_4	.373	-.139	.742**	-	.328	.037	.261	.135	.064	-.041	.057
X_5	.293	-.394	.441	.286	-	.232	.589**	.640**	-.447	.417	.436
X_6	-.548*	.341	-.495*	-.429	-.002	-	.444	.579**	-.464*	.572*	.683**
X_7	.463*	-.524*	.496*	-.009	.633**	-.069	-	.799**	-.273	.433	.622**
X_8	.041	-.132	.053	-.338	.460*	.483*	.630**	-	-.792**	.634**	.771**
X_9	.265	-.226	.245	.392	-.124	-.639**	-.060	-.810**	-	-.615**	-.593**
X_{10}	-.400	.028	-.247	-.351	.274	.393	-.013	.307	-.393	-	.678**
X_{11}	-.260	.193	-.244	-.521*	.094	.634**	.195	.688**	-.726**	.596**	-

(above the diagonal) and season 2005 (below the diagonal).

*, ** Significant at 0.05 and 0.01 probability levels, respectively. N = 57.

X_1: Plant height (cm)
X_2: No. of tillers/plant
X_3: Days to 50% flowering
X_4: Days to 50 % maturity
X_5: Panicle length (cm)
X_6: No. of panicles/m^2
X_7: No. of grains/panicle
X_8: No. of filled grains/panicle
X_9: Unfilled grains/panicle (%)
X_{10}: 1000 grain weight (g)
X_{11}: Grain yield (t/ha)

The result of the path coefficient analysis, based on combined data is presented in Table 4. Number of filled grains/panicle had the highest direct positive contribution (0.577) to the grain yield/ha and also had positive indirect effect on grain yield/ha through 1000-grain weight (0.148) and number of tillers/plant (0.054), while had negative indirect effect on grain yield/ha through panicle length (-0.096). High positive correlation of the number of filled grains/panicle with grain yield/ha resulted in a positive direct effect. Many research workers reported similar findings (Prasad *et al.*, 2001; Iftekharuddaula *et al*., 2002 and Sürek and Beser., 2003).

Table 4. Path coefficient analysis of the direct and indirect effects of the different yield components and their simple correlation coefficients with grain yield /ha.

Trait	Effect via				Simple correlation with grain yield/ha
	TGW	NTPP	NFGPP	PL	
TGW	0.286	0.102	0.300	- 0.043	0.645**
NTPP	0.104	0.282	0.111	0.114	0.611**
NFGPP	0.148	0.054	0.577	- 0.096	0.683**
PL	0.045	- 0.120	0.205	- 0.270	- 0.140

** Significant at 0.01 probability levels. The direct effects are underlined.

TGW: 1000 grains weight, NTPP: Number of tillers/plant, NFGPP: Number of filled grains/panicle, PL: Panicle length

The direct effect of 1000-grain weight on grain yield/ha was the second largest (0.286), indicating that the significant positive correlation between 1000-grain weight and grain yield/ha resulted mainly from the direct effect of 1000-grain weight.

The direct effect of number of tillers/plant on grain yield/ha was the third largest (0.282). It had positive indirect effect on grain yield through 1000-grain weight (0.104), number of filled grains/panicle (0.111) and panicle length. This result is in agreement with the finding of Prasad *et al.* (2001) and disagreed with that reported by Rao *et al.*, (1997). This result indicates that for increasing the effective tillers/plant, other causal factors must be simultaneously considered.

The panicle length had negative direct effect on grain yield/ha (-0.270) and negative indirect effect on grain yield/ha through number of tillers/ plant (-0.120) and had positive indirect effect on grain yield/ha through 1000-grain weight (0.045) and number of filled grains/panicle (0.205).

The number of filled grains/panicle, 1000-grain weight and number of tillers/plant were the most important traits that directly contributed to the grain yield/ha. Similar results were reported by (Gravois and Helms, 1992; Luzikihupi, 1998).

The path coefficient analysis showed that number of filled grains /panicle, 1000-grain weight and number of tillers/plant were the most important traits related to grain yield. These results were also supported by correlation analysis in identifying number of filled grains/panicle, 1000 -grain weight and number of tillers/plant as important grain yield traits. These traits will be given high consideration in the development and selection of high yielding irrigated rice genotypes.

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التباين الوراثي والعلاقات المرتبطه بالأنتاجيه ومكوناتها في الأرز المروي في الجزيرة

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الخلاصة

تم تقييم تسعة عشر طرازاً وراثياً من الأرز المروي لموسمين (2004 و2005) بمزرعة محطة بحوث الجزيرة، واد مدني،السودان. أستخدم تصميم القطاعات العشوائية الكاملة بثلاثة مكررات وذلك لدراسة كل من التباين الوراثي، والمظهري، ودرجة التوريث، والتقدم الوراثي ، ومعامل الارتباط بين الصفات. سجل طول النبات و عدد السنابل في المتر المربع أعلى معامل للتباين الوراثي والتقدم الوراثي ، بينما سجل عدد الاشطاء في النبات وعدد الأيام حتى 50% ازهار وعدد الأيام حتى 50% نضج ، وطول السنبله، اقلها في الموسمين . سجل طول النبات , و عدد الأيام حتى 50% ازهار وعدد الأيام حتى 50% نضج ، ووزن الـ 1000 حبة ، أعلى نسبة درجة توريث على النطاق العريض (<80%) في الموسمين , بينما سجل طول النبات ، ووزن الـــ 1000 حبة، أعلى نسبة درجة توريث على النطاق العريض والتقدم الوراثي في الموسمين . اعطت الطرز الوراثيه التاليه:
WITA5 (TOX3255-82-1-3-2), IRI3240-108-2-2-3 (SAHEL.108) (FRK44), TOX 3081-36-2-2-3-1 أعلى انتاجيه من الحبوب (4.9 , 4.9 و 4.6 طن للهكتارعلى التوالي). و كما أظهرت الدراسة أن إنتاجية الحبوب للهكتار لها إرتباطاً سالبا ومعنوياً مع نسبة الحبوب الفارغة في السنبلة ، وطول النبات، و عدد الأيام حتى 50% أزهار بينما أظهرت إرتباطاً بسيطاً موجباً ومعنوياً مع عدد الاشطاء في النبات ، وعدد السنابل في المتر المربع ، وعدد الحبوب المليئة في السنبلة ، ووزن الـــ 1000 حبه ، في الموسمين. دل تحليل معامل المسار أن عدد الحبوب المليئة في السنبلة وعدد السنابل في المتر المربع ووزن الـــ 1000 حبه هي أهم الصفات ذات العلاقة المباشرة مع الإنتاجية للهكتار.