Electronic Journal of Plant Breeding, 8(4): 1046-1052 (Dec 2017)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00155.7

Research Article

Combining ability estimates for seed cotton yield and quality characters of parents and crosses based on genetic male sterility in Asiatic cotton (*Gossypium arboreum* L.)

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(Received: 27 Jan 2017; Revised: 9 Nov 2017; Accepted: 28 Dec 2017)

Abstract
Fourteen parents and 40 F1 crosses (genetic male sterility based) were evaluated in a line x tester fashion in Asiatic cotton (*Gossypium arboreum*). The statistical analysis was performed using the method developed by Kempthorne (1957) with the help of OPSTAT computer program (developed by CCS Haryana Agricultural University, Hisar. Sufficient variability among hybrids and their parents was found as the mean squares of genotypes for all the traits including fibre quality were significant. The variance due to GCA was lower than SCA for boll number per plant, boll weight and GOT. For other traits like seed cotton yield, fibre length, micronaire value and strength, the SCA was higher which reflected the role of both additive and non-additive types of gene action (dominant or epistatic). GCA was significant for male parents CISA-6-165, CISA-6-187, CISA-6-209, CISA-6-295, CISA-6-350, CISA 7, CISA 8 and female parents CISA 2, DS 5, GAK 413A for seed cotton yield. Parents CISA-6-123, CISA-6-165, CISA-6-350, CISA 8, CISA 9, GAK 413A, CISG 20 showed significant GCA for fibre length and CISA-6-123, CISA-6-350, CISA 8 for micronaire value. Among 40 cross combinations, SCA was positively significant for seed cotton yield in 5 crosses, for boll number in 16 crosses, for boll weight in 9 crosses and for fibre length and micronaire in 16 crosses.

Key words
Cotton, Combining ability, Seed cotton yield, Genetic male sterility, Fibre quality

Introduction

Cotton is an important oil and fibre crop and is considered a vital cash crop in many countries such as USA, China, India, Pakistan, Uzbekistan, Australia and Africa as it influences their economies. In India, all the four species of cotton namely *Gossypium hirsutum*, *G. brabadense*, *G. arboreum* and *G. herbaceum* are grown. *G. hirsutum* covers more than 90% of acreage while the diploid the least, however, the diploids are relatively tolerant to insect-pest and diseases and require less inputs as compared to *G. hirsutum*. The cotton leaf curl disease is prevalent in *G. hirsutum* and no genotype is immune to this disease, however, diploid cotton *G. arboreum* is observed to be immune to this dreaded disease. The diploid cotton provides an alternative to such situation if it gives remuneration equal to or higher than *G. hirsutum*.

For any breeder, the primary objective is to enhance the fibre yield per unit area and its quality. This can be achieved through hybridization. The first step in a successful breeding program is to select appropriate parents which should be genetically divers. Earlier findings revealed that variation in seed cotton yield and its components were controlled by genes acting additively and non-additively. Line x Tester analysis provides a systematic approach for detection of appropriate parents and crosses in terms of estimation of general and specific combining abilities in both self and cross pollinated plants (Kempthorne, 1957). This method has been used by many workers for analysis and identification of potential combiners in early generation (Ashok kumar *et al*. 2010, Verma *et al.* 2005 and Tuteja and Verma 2011). Therefore, considering the importance of combining ability of parents for various characters in cotton, a line x tester experiment of 14 parents involving four genetic male sterile lines and ten male parents of Asiatic cotton (*G.arboreum*) was studied for gene action and combining ability estimates.

Materials and methods

The experimental material utilized for the present study, consisted of 10 male parents CISA-6-123, CISA-6-165, CISA-6-187, CISA-6-209, CISA-6-256, CISA-6-295, CISA-6-350, CISA 7, CISA 8,CISA 9 and 4 female GMS lines, *viz,* CISA 2, DS 5, GAK 413A and CISG 20 crossed in a line x tester fashion at the Central Institute for Cotton Research, Regional Station, Sirsa in 2010-11. Fourteen parents and 40 crosses were grown in a Randomized Block Design (RBD) with three replications and crop geometry of 67.5x45cm during 2011-12 crop season. Five random plants were selected to record the data on number of bolls/plant and boll weight. The data on seed cotton yield was recorded on per plot of 10.8m^2 basis and converted to kg/ha. All the seed cotton samples were cleaned and ginned carefully in the laboratory for estimation of GOT % (ginning outturn

DOI: 10.5958/0975-928X.2017.00155.7

percentage) and analyzed for fibre quality parameters, *viz.* fibre length, micronaire value and fibre strength on High Volume Instrument (HVI) as per the standard methods. The data were used for statistical analysis using the method developed by Kempthorne (1957) with the help of OPSTAT computer program which was developed by Chaudhary Charan Singh Haryana Agricultural University, Hisar.

Results and discussion

The analysis of variance (Table 1) indicated that the mean squares of genotypes for all the traits including fibre quality were significant indicating the presence of sufficient variability among hybrids and their parents. Hence, further analysis for combining ability was possible. The total genetic variability was partitioned to general combining ability (GCA) and specific combining ability (SCA). The variance due to GCA was lower than SCA for boll number per plant, boll weight and GOT. For other traits like seed cotton yield, fibre length, micronaire value and fibre strength, the SCA was higher which reflected the role of both additive and non-additive types of gene action (dominant or epistatic), which is in accordance with previous results of Ahuja & Dhayal (2007), Cetin Karademir *et al.* (2009), Verma *et al.* (2004), Tuteja and Verma (2011), Tuteja and Banga (2013). However, the general combining ability variance was higher than SCA variance for seed cotton yield and GOT which reflected the role of additive type of gene action (Table 1). The results are similar with the findings of Rauf *et al*. (2006), Cetin Karademir *et al*. (2009), Tuteja *et al.*(2005) and Tuteja *et al.* (2011) who studied the conventional cross combinations.

The GCA effects of parents are presented in Table 2. For seed cotton yield, the male parents CISA-6-209, CISA-6-295, CISA 7 and female parents CISA 2, GAK 413A showed significant positive GCA effects, and other parents CISA-6-165, CISA-6-187, CISA-6-350 and DS 5 showed significant negative GCA effects. Among them CISA-6-209, CISA-6-295, CISA 7 and female parent CISA 2 appeared to be good general combiners. For number of bolls/plant, the male parent CISA-6-165, CISA-6-350, CISA 7, CISA 9 and female parents CISA 2, DS 5 were general good combiners. For boll weight, male parents CISA-6-165, CISA 8, CISA 9 and female parent CISA 2 showed significant positive GCA effects whereas the parents CISA-6-123, CISA-6-350 exhibited significant negative GCA effects. For fibre length, the male parents CISA-6-123, CISA-6-165, CISA-6-350, CISA 8, CISA 9 and female parents GAK 413A, CISG 20 recorded significant positive GCA effects can be used to improve this trait. For mirconaire value the male parents CISA-6-165, CISA-6-209, CISA-6-256, CISA-6-350, CISA 7 and female parents CISA 2, DS 5 showed significant positive GCA effects whereas male parents CISA-6-187, CISA 8, CISA 9 and female parent GAK 413A exhibited significant negative GCA effects and observed to be good general combiner as lower micronaire value increases the fineness of cotton fibre. For fibre strength, the male parents CISA-6-123, CISA-6-350 and female parents GAK 413A, CISG 20 recorded significant positive GCA effects and appeared to be good general combiners. The positive significant specific combining ability effects for seed cotton yield were observed in crosses CISA 2 x CISA-6-165, DS 5 x CISA 9, GAK 413A x CISA-6-209, CISG 20 x CISA-6-123 CISG 20 x CISA-6-295 while negative significant SCA effects were observed in crosses CISA 2 x CISA 9, DS 5 x CISA 8, CISG 20 x CISA-6-123, CISG 20 x CISA 9. For boll number, CISA 2 x CISA-6-256, CISA 2 x CISA-6-295, CISA 2 x CISA 7, CISA 2 x CISA 9, DS 5 x CISA-6-187, DS 5 x CISA-6-209, DS 5 x CISA-6-256, DS 5 x CISA-6-295, GAK 413A x CISA-6-123, GAK 413A x CISA-6-165, GAK 413A x CISA-6-209, GAK 413A x CISA 8, GAK413A x CISA 9, CISG 20 x CISA-6-256, CISG 20 x CISA-6-350, CISG 20 x CISA 8 crosses had positive and significant estimates for SCA effects, the maximum being in case of DS 5 x CISA-6-187. In case of GOT no cross combination recorded significant positive SCA effects indicating that more number of diverse parents may be included to have high GOT while negative and significant SCA effects were shown by CISG 20 x CISA-6-123 cross combination. For boll weight, positive and significant estimates for SCA effects were observed in crosses CISA 2 x CISA-6-165, CISA 2 x CISA 8, DS 5 x CISA-6-295, DS 5 x CISA 7, DS 5 x CISA 9, GAK 413A x CISA-6-123, CISG 20 x CISA-6-256, CISG 20 x CISA-6-350, CISG 20 x CISA 7 while negative and significant SCA effects were observed in crosses CISA 2 x CISA-6-123, CISA 2 x CISA-6-256, CISA 2 x CISA 7, DS 5 x CISA-6-165, GAK 413A x CISA-6-295, CISG 20 x CISA-6-123, CISG 20 x CISA 8, CISG 20 x CISA 9. The cross combinations CISA 2 x CISA-6-165, CISA 2 x CISA-6-256, CISA 2 x CISA-6-350, CISA 2 x CISA 9, DS 5 x CISA-6-295, DS 5 x CISA 7, GAK 413A x CISA-6-123, GAK 413A x CISA-6-187, GAK 413A x CISA-6-209, GAK 413A x CISA-6-295, CISG 20 x CISA-6-209, CISG 20 x CISA-6-295, CISG 20 x CISA 7, CISG 20 x CISA 8, CISG 20 x CISA 9 showed positive and significant SCA effects for fibre length, while CISA 2 x CISA-6-123, CISA 2 x CISA-6-209, CISA 2 x CISA 7, CISA 2 x CISA 8, DS 5 x CISA-6-165, DS 5 x CISA-6-187, DS 5 x CISA-6-295, DS 5 x CISA 9, GAK 413A x CISA-6-256, GAK 413A x CISA 8, GAK 413A x CISA 9, CISG 20 x

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CISA-6-165, CISG 20 x CISA-6-187, CISG 20 x CISA-6-256, CISG 20 x CISA-6-350 showed negative and significant SCA effects.

For cotton fibre fineness (micronaire value), negative SCA effects are desirable as lower the micronaire value finer will be the cotton fibre. Negative and significant SCA effects were obtained from CISA 2 x CISA-6-187, CISA 2 x CISA-6-209, CISA 2 x CISA-6-256, CISA 2 x CISA-6-350, DS 5 x CISA-6-165, DS 5 x CISA-6-209, DS 5 x CISA-6-256, DS 5 x CISA-6-350, DS 5 x CISA 7, GAK 413A x CISA-6-123, GAK 413A x CISA-6-187, GAK 413A x CISA8, GAK 413A x CISA 9, CISG 20 x CISA-6-123, CISG 20 x CISA-6-295, CISG 20 x CISA 8 cross combinations while undesirable positive and significant estimates for SCA effects were seen in crosses CISA 2 x CISA-6-123, CISA 2 x CISA-6-295, CISA 2 x CISA 8, CISA 2 x CISA 8, DS 5 x CISA-6-187, DS 5 x CISA 8, GAK 413A x CISA-6-165, GAK 413A x CISA-6-209, GAK 413A x CISA-6-256, GAK 413A x CISA-6-295, GAK 413A x CISA-6-350, CISG 20 x CISA-6-187, CISG 20 x CISA-6-350, CISG 20 x CISA 9. The crosses CISA 2 x CISA 7, DS 5 x CISA-6-256, GAK 413A x CISA-6-123, GAK 413A x CISA-6-209, CISG 20 x CISA-6-350, CISG 20 x CISA 7, CISG 20 x CISA 8 had positive and significant SCA effects for strength while crosses CISA 2 x CISA-6-123, CISA 2 x CISA 8, DS 5 x CISA-6-209, DS 5 x CISA-6-295, DS 5 x CISA 8, GAK 413A x CISA-6-165, GAK 413A x CISA-6-350, GAK 413A x CISA 7, CISG 20 x CISA-6-256 showed negative GCA effects.

The present study based on genetic male sterility in cotton revealed that additive variances were significant for fibre fineness while, non-additive as well as additive gene effects were significant for seed cotton yield, boll number, boll weight, ginning percentage, fibre length and fibre strength. The CISA-6-123 and CISA-6-350 were observed as general good combiner for fibre properties as higher MIC value is not desired for spinning. Genotypes CISA 7 and CISA-6-209 were observed good general combiner for seed cotton yield. Specific cross combinations for seed cotton yield (CISA2 x CISA 6-165, DS 5 x CISA 9, GAK 413A x CISA 6-209 CISG 20 x CISA 6-295), fibre length (CISA2 x CISA 6-165, CISA2 x CISA 6-256, CISA2 x CISA 6-350, CISA2 x CISA 9, DS 5 x CISA 6-123, DS 5 x CISA 8, GAK 413A x CISA 6-187, GAK 413A x CISA 6-209, GAK 413A x CISA 6-295, CISG 20 x CISA 6-209, CISG 20 x CISA 6-295, CISG 20 x CISA 7, CISG 20 x CISA 8 and CISG 20 x CISA 9), MIC value (CISA2 x CISA 6-187, CISA2 x CISA 6-209, CISA2 x CISA 6-256, DS 5 x CISA 6-165, DS 5 x CISA 6-350, GAK 413A x CISA 6-123, GAK 413A x CISA 6-187, GAK 413A x CISA 8, GAK 413A x CISA 9, CISG 20 x CISA 6-123, CISG 20 x CISA 6-295 and CISG 20 x CISA 8) and fibre strength (CISA2 x CISA 7, DS 5 x CISA 6-256, GAK 413A x CISA 6-123, CISG 20 x CISA 6-350 and CISG 20 x CISA 8) may further be utilized for developing GMS based hybrids for higher seed cotton yield and better fibre qualities.

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DOI: 10.5958/0975-928X.2017.00155.7

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Electronic Journal of Plant Breeding, 8(4): 1046-1052 (Dec 2017)
ISSN 0975-928X
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Table 1. Analysis of variance for line x tester and combining ability for yield and quality characters in Asiatic cotton (*G. arboreum*)

Source	df	Seed cotton yield (kg/ha)	Boll No	Boll wt.	GOT (%)	2.5% span length (mm)	Mic. value	Fibre strength (g/tex)
Replication	2	189911.67**	33.07**	0.06**	19.52**	0.90**	0.13*	0.82**
Genotypes	53	394364.93**	153.43**	0.09**	3.69	6.68**	1.22**	1.43
Parents	13	1094282.19**	145.46**	0.10**	4.70	12.07**	1.59**	2.17
Parents vs Hybrids	1	2100230.39**	29.75*	0.10**	48.53**	0.75	0.24	0.02
Hybrids	39	117319.03**	159.26**	0.07	2.20	5.03	2.14*	1.22
GCA (Lines)	3	465451.37**	90.64	0.09**	1.45	33.81**	1.75**	5.24**
GCA (Testers)	9	193048.64**	194.79**	0.14**	3.53**	3.20**	1.58	1.44*
SCA (Line x Tester)	27	53394.45**	155.04**	0.04	1.85	2.45**	0.90**	0.70**
Error	53	22752.61	6.58	0.008	1.73	0.07	0.04	0.11
σ^2GCA		13135.98	-0.59	0.004	0.031	0.77	0.04	0.13
σ^2SCA		9524.35	50.8.	0.010	-0.069	0.81	0.29	0.20
σ^2GCA/σ^2SCA		1.38	-0.01	0.40	-0.45	0.95	0.14	0.65

**P*=0.05, ***P*=0.01 respectively

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Table 2. Mean performance and general combining ability effects of parents for yield and fibre quality characters in Asiatic cotton (*G. arboreum*)

Parents	Seed Cotton Yield (kg/ha)		Boll No.		GOT (%)		Boll wt (g)		Fibre length (mm)		MIC value		Fibre strength (g/tex)	
	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA
CISA-6-123	977.4	36.262	47.0	-5.832**	33.7	-1.293**	2.2	-0.090**	25.4	0.268**	5.2	-0.554**	18.7	0.589**
CISA-6-165	1714.7	-109.288*	49.7	1.102*	37.8	0.548	1.6	0.110**	26.0	0.368**	5.6	0.346**	18.6	-0.278**
CISA-6-187	1025.6	-104.405*	40.2	-6.482**	37.3	-0.443	2.0	-0.132**	25.3	-0.532**	7.2	-0.463**	17.0	-0.444**
CISA-6-209	2103.3	229.362**	53.7	-0.698	35.7	0.04	2.1	0.002	22.4	-0.707**	7.2	0.287**	17.1	0.031
CISA-6-256	2171.9	8.278	52.7	-1.232**	38.7	0.398	2.0	-0.023	22.6	-0.333**	7.1	0.396**	16.8	-0.253**
CISA-6-295	1051.7	145.612**	41.5	-1.165**	36.3	0.398	2.0	0.002	25.7	-0.157**	7.2	0.021	18.6	-0.236*
CISA-6-350	1013.3	-158.78**	48.2	3.927**	37.0	-0.177*	2.0	-0.107**	25.6	0.618**	7.1	0.229**	17.5	0.481**
CISA 7	2032.5	93.803*	61.5	5.252**	38.5	0.198	1.6	-0.073**	23.5	-0.557**	7.1	0.287**	18.4	-0.136
CISA 8	2720.6	-107.963*	50.4	0.402	36.8	0.032	1.8	0.110**	20.6	0.368**	7.3	-0.363**	16.9	0.298**
CISA 9	925.9	-32.88	42.8	4.727**	36.7	0.298	1.8	0.202**	23.6	0.667**	5.7	-0.188*	17.4	-0.052
CD at 5% (kg/ha)	210.7		6.4		0.7		0.2		0.7		0.0		0.5	
S. E.±		43.146		0.444		0.393		0.02		0.038		0.054		0.092
CISA 2	910.3	174.598**	36.6	0.637*	37.2	0.012	2.0	0.057**	21.5	-0.078**	7.2	0.167**	16.9	0.017
DS 5	837.6	-66.158**	42.7	1.95**	36.2	-0.048	2.2	0.020	20.8	-1.428**	7.1	0.238*	16.3	-0.563**
GAK 413A	1369.3	-108.088**	55.7	-2.163**	36.8	0.285	2.0	-0.007	22.5	1.073**	7.2	-0.266**	17.3	0.444**
CISG 20	1176.6	-0.352	54.2	-0.423	35.8	-0.248	2.0	-0.070**	20.8	0.433**	7.2	-0.139**	16.2	0.101*
CD at 5% (kg/ha)	108.1		3.5		0.5		0.1		0.7		0.1		0.5	
S. E±.		24.911		0.256		0.227		0.011		0.022		0.031		0.053

**P*=0.05, ***P*=0.01respectively

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Table 3. Crosses with high sca effects for seed cotton yield and fibre quality characters in Asiatic cotton (*G. arboreum*)

Hybrid/cross	Seed Cotton Yield (kg/ha)	Boll No	GOT (%)	Boll wt (g)	Fibre length (mm)	MIC value	Fibre strength (g/tex)
CISA2 x CISA 6-123	-54.932	-4.412**	0.863	-0.073*	-1.547**	0.791**	-0.793**
CISA2 x CISA 6-165	158.418*	-1.078	-0.712	0.193**	0.653**	-0.176	0.208
CISA2 x CISA 6-187	-23.698	-6.862**	-0.487	0.002	0.053	-0.901**	-0.126
CISA2 x CISA 6-209	-72.432	-5.078**	-1.07	-0.065	-0.673**	-0.251**	0.166
CISA2 x CISA 6-256	78.918	4.988**	-0.195	-0.073*	0.953**	-0.226**	0.283
CISA2 x CISA 6-295	-64.082	1.922**	0.338	-0.032	-0.122	0.249**	0.133
CISA2 x CISA 6-350	141.943	-2.403**	0.78	0.01	0.203**	-0.192*	0.016
CISA2 x CISA 7	-78.64	8.038**	0.172	-0.157**	-0.323**	-0.151	0.399*
CISA2 x CISA 8	83.893	0.288	0.238	0.160**	-0.747**	0.599**	-0.468**
CISA2 x CISA 9	-169.39*	4.597**	0.072	0.035	1.553**	0.258**	0.182
DS 5 x CISA 6-123	4.325	-6.692**	1.223	0.063	1.202**	-0.146	0.054
DS 5 x CISA 6-165	43.442	0.342	0.948	-0.270**	-0.398*	-0.279**	0.154
DS 5 x CISA 6-187	-52.742	11.025**	0.573	-0.028	-0.198**	0.529**	0.154
DS 5 x CISA 6-209	47.158	2.408**	0.457	0.005	-0.123	-0.221*	-0.321*
DS 5 x CISA 6-256	-81.258	6.442**	-0.535	-0.037	1.303*	-0.196*	0.796**
DS 5 x CISA 6-295	-62.258*	3.308**	-0.668	0.105**	-0.972**	0.146	-0.454**
DS 5 x CISA 6-350	-112.667	1.35	-0.993	-0.053	0.052	-0.363**	0.063
DS 5 x CISA 7	56.117	0.958	-0.068	0.113**	0.027	-0.221*	0.179
DS 5 x CISA 8	-156.183*	-11.358**	-0.768	0.03	0.302**	0.662**	-0.321*
DS 5 x CISA 9	314.067**	-7.783**	-0.168	0.072*	-1.198**	0.087	-0.304
GAK 413A x CISA 6-123	-99.579	14.822**	0.157	0.090**	0.402**	-0.242**	0.914**
GAK 413A x CISA 6-165	-3.162	5.355**	-0.652	0.023	0.102	0.358*	-0.352*
GAK 413A x CISA 6-187	39.521	-1.395	0.173	-0.035	0.702**	-0.467**	0.114
GAK 413A x CISA 6-209	151.555*	3.788**	0.323	0.032	0.577**	0.316**	0.339*
GAK 413A x CISA 6-256	60.971	-15.578**	-0.235	0.023	-0.498**	0.374**	-0.277
GAK 413A x CISA 6-295	-68.595	-5.345**	-0.268	-0.102**	0.327**	0.582**	0.306
GAK 413A x CISA 6-350	2.263	-1.97**	0.173	-0.027	-0.048	0.341**	-0.477**
GAK 413A x CISA 7	-40.087	-8.595**	0.232	-0.027	0.127	0.249**	-0.894**
GAK 413A x CISA 8	-60.287	4.788**	-0.002	-0.043	-0.798**	-0.668**	0.072
GAK 413A x CISA 9	17.396	4.13**	0.098	0.065	-0.898**	-0.843**	0.256
CISG 20 x CISA 6-123	150.185*	-3.718**	-2.243**	-0.080*	-0.058	-0.402**	-0.176
CISG 20 x CISA 6-165	-198.698**	-4.618**	0.415	0.053	-0.358**	0.097	-0.009
CISG 20 x CISA 6-187	36.918	-2.768**	-0.26	0.062	-0.558**	0.839**	-0.142
CISG 20 x CISA 6-209	-126.282	-1.118	0.29	0.028	0.217**	0.156	-0.184
CISG 20 x CISA 6-256	-58.632	4.148**	0.965	0.087*	-1.758**	0.047	-0.801**
CISG 20 x CISA 6-295	194.935**	0.115	0.598	0.028	0.767**	-0.978**	0.016
CISG 20 x CISA 6-350	-31.54	3.023**	0.04	0.070*	-0.208**	0.214*	0.399**
CISG 20 x CISA 7	62.61	-0.402	-0.335	0.070*	0.167*	0.123	0.316*
CISG 20 x CISA 8	132.577	6.282**	0.532	-0.147**	1.242**	-0.594**	0.716**
CISG 20 x CISA 9	-162.074*	-0.943	-0.002	-0.172**	0.543**	0.498**	-0.134
S. E. ±	74.732	0.768	0.68	0.034	0.066	0.094	0.16

**P*=0.05, ***P*=0.01respectively