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Original scientific paper

YIELD COMPONENTS ANALYSES IN COTTON: *G. hirsutum* CULTIVARS WITH MULTIVARIATE STATISTICAL METHODS

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Cotton is the first and the main fibrous plant that it plays an important role in the creation of careers for individuals and development of textile industries in all over the world. Selection of a suitable cultivar for the West Azerbaijan region is important, since West Azerbaijan is the origin of cotton in Iran. This research conducted in order to evaluate of quantitative and qualitative traits of hopeful cotton cultivars under cold conditions in Urmia region. In this study eight cultivars evaluated with Varamin and Sahel as check cultivars in form of randomized complete block design with four replications in 2014 and 2015 (two cropping seasons) at Saatlou station of west Azerbaijan agricultural research, education, and extension organization. Results showed that K8802 cultivar is earliness cultivar and also is one of the best cultivars according to the traits such as the number of bolls per plant, sympodia per plant, final yield, seed cotton yield (yield of per plant), and qualitative traits. According to the combination analysis results, the interaction effect between treatment and year (treatment*year) for seed cotton yield, yield, and the number of bolls per plant at probability level (α=0.01) were significant. Stepwise multiple liner regression analysis revealed entrance of three variables, the number of bolls per plant, boll weight, and plant

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height entered in the model. Path analysis showed that direct effect of the number of bolls per plant with yield, indirect effect of the number of bolls per plant and boll weight with yield are the most in among all effects. Principal components analysis for two main components with the high value for variables showed that there is the number of bolls per plant in both components and this trait is one of the main traits in cotton studies. Therefore, the cotton breeders must work on the number of bolls per plant trait. Due to the results of this study in two years, K8802 cultivar suggests for cultivation in Urmia weather conditions.

Keywords: Cultivar suggestion, Fiber quality, Quantitative Properties, Yield

INTRODUCTION

Cotton (*Gossypium hirsutum* L.), is part of the Malvaceae family and cultivates almost all over the world since very old time. It is one of the most important cash crops in many countries and cultivates in warm regions. In addition to the lint, cottonseed is a main source for oil extraction, which makes about 80 percent of the national oil production. Cotton cultivated usually for fiber that cotton is an economic unit and it plays a basic role for raising countries economy (RIAZ *et al*., 2013). A great population of the countries as agricultures in the fields, cotton companies, textile factories and relevant businesses are involved with cotton (IMRAN *et al.*, 2011). *Gossypium* has the most widely species in the world and it is the leading of fiber crops in more than eighty countries (SHAKEEL *et al*., 2011). Cotton known as “White gold” is a premier cash, fiber crop and It is a major contributor in order to financial stability for more than eighty countries with production of more than twenty million tons every year (FARASAT *et al*., 2014). Characterization, protection of genetic material in form of genotypes, best cultivation lines and the masses of wild lines have matter value in evolutionary breeding and genetic process (HAIDAR *et al*., 2012; JANKOVIC *et al.,* 2018). Utilization of genetic diversity based on different morphological and agronomic characters have been done for victorious hybridization programs which it needs perfect selection since environment effects on these characters and selection process, therefore significant attention should be given to develop highly producing of cotton cultivars (AHMAD *et al*., 2012). Cotton production in the future will depend on the development of cotton varieties with higher yield potential and quality of seed cotton, and as well as better tolerance to biotic and abiotic stresses. A breeder usually records data based on selection of favorable economic characters for which positive or negative correlation may exist. The understanding of the correlation of factors effecting yield is a pre-requisite for designing an effective plant-breeding program. Different statistical techniques used in modeling crop yield including correlation, regression, path coefficient analysis, factors analysis, and cluster analyses to estimate yield and yield units for breeding programs in cotton and other plants (MASSART *et al*., 1997; IKIZ *et al*., 2012). The correlation, regression analysis of seed cotton yield, and its contributing units are too important in determination of appropriate selection indicator for the improvement of seed cotton yield. Complete studies about the nature, mean yield, range of relationship and correlation of yield with various agronomic characters are necessary for breeder to face up to the problems of increasing of yield successfully. Information on the strength and direction of unit characters with seed yield and inter correlation among them can be very useful in formulating an effective selection indicator for improvement of yield. Determination of correlation factors between various characters helps to obtain best mixtures of traits in cotton crop for getting higher return per unit area a simple measure of correlation of characters with yield is not enough, as it will not return the straight effect of component characters on the yield. Therefore, it is a necessary to divide the correlation factors into direct and indirect effects (DEWEY *et al*., 1959). Determination of correlation factors between various characters can help to identify with certainty the factors traits during selection to develop seed yield. Multivariate statistics are relevant to understand the different aims background and describe how different variables are associated with each other. The practical implementation of multivariate statistics to a specific difficult can inclusive several types of univariate and multivariate analyses in order to realize the relationships among variables and their relevance to the real problems being studied. Many different multivariate analyses such as path coefficient, stepwise multiple linear regression, factor analyses, etc. are accessible. Keeping these points were done in order to determine the dependence relationship between seed cotton yield and yield component traits of cotton genotype by using five statistical procedures including; simple correlation and regression, path analysis, stepwise multiple linear regression (JOHNSON *et al*., 1996). Path analysis lets to plant researcher that can select specific traits that those help in the realization of contribution of several characters in total variation by division the total correlation into direct and indirect effects (SHAHRIARI *et al*., 2014). Breeders to evaluate genetic diversity have used multivariate statistical techniques like principal component analysis (PCA). Results will be useful as diversified genotype for cotton hybridization program keeping in view the above facts about diversity in cotton, the present evaluation was to explore genetic diversity, notify extraordinary genotype, direct and indirect effects of important related traits on yield (REHMAN *et al*., 2015). This research conducted in cold conditions of Urmia region in order to evaluate of quantitative and qualitative traits of hopeful cotton cultivars and suggestion a suitable cultivar(s) for region.

MATERIALS AND METHODS

Plant material and plant establishment

Plant material and experiment place

Ten different cultivars with named as: *NSK-847, GKTB-113, SKN2-739, Varamin, K8801, BC-244, SKT-133, K8802, SKSH-249*, and *Sahel* (*Varamin* and *Sahel* as check cultivars) were evaluated in the lab of cotton research, institute of Varamin. This research carried on at the Saatlou station of agricultural and natural resources research and education center, West Azerbaijan province, Iran, duration two cropping years (2014 and 2015). The geographical location of the the Saatlou station is longitude 45 degrees 10 minutes 95 seconds east, latitude 37 degrees 44 minutes 18 seconds north and its height from sea level is 1338 meters.

Experiment design, plot size

A randomized complete block design (RCBD) with four replications applied to evaluate treatments in two years. For each cultivar a plot in the blocks with length and width of 6×4 meters was created, number of rows were four rows that distance of between rows and plants on blocks were eighty and twenty centimeters (80×20).

Traits measurement

Data collected after removing border effects from whole plots. The quantitative and qualitative traits measured from five plants randomly. Quantitative and qualitative traits include as follows: monopodia per plant (MPP) and sympodia per plant (SPP), plant height, number of nodes, the number of bolls per plant, and the number of bolls per plant. Mean of bolls weight of each plant recorded as the boll weight of each plant with gram unit, final yield in form of kg/ha calculated from seed cotton yield (yield per plant). Quality traits were measured include percent of elongation fibers (EF), fiber strength (FS), fiber fineness (Micronaire), length and uniformity of fiber.

Statistical Analysis

In first step, means of five data for quantitative traits were calculated and in second step, the averages analyzed. Analysis of variance (ANOVA), Tukey's test (α=0.05) used for mean comparisons, combined analysis, stepwise multiple liner regression, path analysis, and principal components analysis (PCA) performed by SAS (9.2), Excel (2013), SPSS (22.0), and Minitab (16.0). The qualitative trait analyzed by HVI machine.

RESULTS AND DISCUSSION

Descriptive analysis

The analyses of basic statistical parameters like minimum value, maximum value, mean value, coefficient of variation (CV%), analysis of variance, and the best treatment in comparisons of mean (Tukey's test) for ten cotton cultivars under investigation of all studied traits are presented in Table 1. The CV for the traits varied from 6.83% (yield) to 20.02% (sympodia per plant). The coefficient of variation is a good variable for the measurement of variation and experimental accuracy and will be effective in comparing of the studied traits. Analysis of variance of two years for all traits showed that all traits were significant at the one percent level (α=0.01). The results showed that K8802 cultivar is the best according to number of bolls per plant, seed cotton yield, yield, and sympodia per plant. Considerable range of variations can provide good opportunities in order to selection of traits for crops improvement in plants breeding and selection for seed cotton yield can only be effective if desired genetic variability be in the genetic store (EL-KADY *et al*., 2015). According to studies on Egyptian cotton cultivars, they reported high variability for seed cotton yield and its components (AHUJA *et al*., 2006; ALISHAH *et al*., 2008). Results of this study are in accordance with their researches.

Table 1. The analyses of basic statistical parameters for yield and yield components in cultivars

Traits	Min	Max	Mean	CV%	Analysis of Variance	Tukey's test (α=0.05)
Number of bolls per plant	3	22	12.8	8.81	39.22^{**}	*K8802*
Boll weight (g)	3.95	6.3	4.89	10.19	0.57^{**}	*NSK-847*
Seed cotton yield (g)	10	94	62.43	7.43	1284.45^{**}	*K8802*
Yield (kg/h)	625	5875	3902.34	6.83	5017415.36^{**}	*K8802*
Monopodia per plant	2	6.6	3.98	19.51	1.17^{**}	*GKTB-113*
Sympodia per plant	1.4	5.8	3.40	20.02	1.85^{**}	*K8802*
Plant height (cm)	28.2	77.2	58.58	9.29	513.74^{**}	*BC-244*
Number of nodes	3.8	11	7.82	17.10	7.80^{**}	*Varamin*
Number of flowers	0	16	5.21	16.07	11.13^{**}	*GKTB-113*

CV: Coefficient of variation (%), **: Significant in probability level of one percent, Min: minimum values, Max: maximum values, Mean: means of cultivars, analysis of variance and best treatment in comparisons of mean of two years

Cotton fiber characteristics

Fibers of cotton after harvesting and packing sent to Varamin research center in order to qualitative analysis by HVI machine (Table 2). According to the results and based on uniformity traits of fibers, fiber length, fiber fineness, fiber strength, and fiber elasticity percent, respectively the cultivars K8802, K8801 and SKT-133 have the highest amounts of fiber and elegance so they are better for textile applications. The production of cotton fiber is the most important, first purpose and cottonseed oil is the second purpose. Due to the strong competition of synthetic fibers with cotton nature fiber in the world, attention to the quality of cotton fibers is first aim in cotton breeding. In favorable conditions, cotton fibers are creamy white and have good coloring. ZHENG *et al*. (2015), for fiber strength reported that effects of year and place are not significant, but interaction effects of year × place are significant at one level (α=0.01). According to CLEMENT *et al*. (2015), in the study over two years for the effects of year, genotype and genotype × year for the percent of fiber stretching are significant (α=0.01). Based on the results of quality analysis of this research, K8802 cultivar has good quality and it is the best cultivar according to the quality traits, therefore K8802 cultivar suggests for Urmia weather conditions.

Table 2. Analysis of fiber quality traits

Cultivar	UI (%)	UHML (mm)	MI	STR	EL (%)
NSK-847	86.8	28.2	5	25.5	6.5
GKTB-113	87.1	23.6	5.2	32	6.6
SKN2-739	86.8	29.4	4.8	31.2	6.6
Varamin	85/7	29.8	5.2	28.3	6.2
K8801	89.5	30.9	6	32.9	6.8
BC244	83.7	27.7	5.5	28.7	6.6
SKT-133	89.2	30.4	5.2	32.1	6.7
K8802	89.8	31.5	6	33.2	6.8
SKSH-249	88.6	26.1	5	28.1	6.1
Sahel	84.8	27.2	5	27.3	6.6

Combined analysis of variance for yield and yield components traits

In first step, the data tested for normality and uniformity of variance, and then analysis of variance based on randomized complete block design (RCBD) carried out. Combined analysis of variance for quantitative characteristics (Table 3) showed that the effect of year for the number of bolls per plant, seed cotton yield, yield, and sympodia per plant were significant at the one percent level (α=0.01). Plant height significant at the five percent level (α=0.05), also the interaction effect between year and treatment (year × treatment) for the number of bolls per plant, seed cotton yield, and yield significant at the probability of one percent (α=0.01). Number of bolls per plant, seed cotton yield, and yield in first year were better than second year. The second year was better than the first year for sympodia per plant also for plant height statistical difference did not observe between the two years. In the second year, the project began two weeks early than first year and we expected that we will have a lot of bolls opening and high yield in the second year but the results showed that the first year is better than the second year and from its reasons can refer to occur heavy and early rains of autumn. One of the main problems of cotton cultivation in Urmia is early rainfalls and early cold in the autumn, which will cause less open bolls and low quality of fibers. K8802 cultivar was an early maturity cultivar and did not show these problems. According to MOHSEN and AMEIN

(2016), mean squares from combined analysis of variance showed greatly significant (p<0.01) differences between twenty Egyptian cotton genotypes for six characters. They reported highly significant differences between years for lint percentage (%) and seed cotton yield per plant (g). Reports of SOOMRO *et al*. (2005); COPUR (2006), contrasted the yield and yield units of cotton cultivars and demonstrated significant differences for these traits. According to SUINAGA *et al*. (2006); MEENA *et al*. (2007), they evaluated the *Gossypium hirsutum* cultivars and hybrids they observed variation values for seed cotton yield and number of bolls plant.

Table 3. Combined analysis of quantitative of traits

SOV	df	Number of bolls per plant	boll weight (g)	Seed cotton yield (g)	Yield (kg/h)
Years	1	884.0222**	0.0040 ns	23480.8163**	9363330.80**
Replication/years	6	22.8964	0.6934	482.5013	1876936.85
Cultivars	9	56.9527**	1.1979**	1289.7906**	5264350.04**
Cultivars × Years	9	21.8174**	0.2976 ns	611.8799**	2566216.36**
Error	54	6.3372	0.6934	195.8427	779316.80
CV (%)	-	19.61	10.55	22.39	22.62

Table 3. Continued

SOV	df	Monopodia per plant	Sympodia per plant	Plant height	Number of nodes	Number of flowers
Years	1	0.3251ns	2.4154**	119.5606*	2.1451 ns	10.9520 ns
Replication/years	6	0.1091	0.1319	35.0772	3.5264	94.7500
Cultivars	9	3.0055 **	2.8768**	939.0086**	14.3174**	31.4691**
Cultivars × Years	9	0.5661 ns	0.0829 ns	3.5477ns	0.0762 ns	1.5886 ns
Error	54	0.4883	0.3438	25.0725	1.6181	3.3257
CV (%)	-	17.54	17.23	8.69	16.25	24.96

ns - non-significant, *- significant at P ≤ 0.05, and ** - significant at P ≤ 0.01

Analysis of stepwise multiple liner regression, correlation, and path analysis

In this research, stepwise multiple liner regression used in order to remove effects of non-effective characteristics in regression model on seed cotton yield (Table 4). Stepwise multiple liner regression analysis revealed the number of bolls per plant entered in the regression model with a high coefficient of determination (89%) and significance of model in one percent (α=0.01). In the second step, boll weight with a low coefficient of determination (8%) and significance of model in one percent (α=0.01) like of first step entered. In the third step, plant height with a very low coefficient of determination (0.1%) and significance of model in five percent (α=0.05) entered in the regression model. Stepwise multiple liner regression equation established as $Y= -56.53897+5/17822(X_7) +11.86481(X_6)–0.09351(X_4)$. The correlation between three variables with yield (Table 5) showed that the correlation between yield and the number of bolls per plant was very high and positive ($r=0.944^{**}$). Path analysis (Figure 1) shows that there were three direct paths for arriving to yield, the number of bolls per plant, boll weight, and plant height. Number of bolls per plant direct path was highest coefficient of yield (1.0046) also there were six indirect paths between the three variables entered in the regression model and yield (Table 6).

Table 4. Relative contribution (partial and model R_2), regression coefficient (b), F-value, and probability value (P-value) in predicting seed cotton yield by the stepwise procedure analysis

Step	Variable Entered	Partial R-square	Model R-square	B	F	P-value
1	X_7	0.8910	0.8910	5.17822	3690.85	0.0001
2	X_6	0.0878	0.9788	11.86481	240.25	0.0001
3	X_4	0.0013	0.9800	-0.09351	4.88	0.0303

(x_7) - Number of bolls plant, (x_6) - Boll weight (g), (x_4) - Plant height

Table 5. Simple correlation analysis between variables entered in the regression model

Parameters	Yield	Number of bolls per plant	Boll weight	Plant height
Yield	1			
Number of bolls per plant	0.944**	1		
Boll weight	0.104	-0.198	1	
Plant height	-0.061	0.105	-0.445**	1

** Correlation is significant at the 0.01 level (2-tailed)

Table 6. Estimation of path coefficient analysis for some studied traits on the total yield

Rate of scale	Path coefficient values	Traits and Indirect paths
Low	- 0.05665	The number of bolls and boll weight with yield
Negligible	-0.00415	The number of bolls and plant height with yield
High	-0.1989197	Boll weight and the number of bolls with yield
Low	0.017582	Boll weight and plant height with yield
Negligible	0.0024101	Plant height and the number of bolls with yield
Low	0.0299604	Plant height and boll weight with yield

The path of boll weight with the number of bolls per plant had the highest amount and was very important. The number of bolls per plant was the most important factor and variable for increasing yield. Because, with increasing it, the number of flowers and flowers that change to bolls will be high, so the bolls per plant are great. Based on the results of two years of this research, K8802 cultivar has high number of bolls per plant and the results of two years showed that it has the highest yield among cultivars. According to MOHSEN and AMEIN (2016), the number of bolls per plant, boll weight and lint percentage with R-square of 96.51% was responsible for the maximum changes in yield. High value of the adjusted coefficient of determination (R_2=95.78%) showed that the traits chosen for this study described almost all seed cotton yield variation. Taking into account that the number of bolls per plant was (x_1), boll weight (x_2), and lint percentage (x_4), by using multiple linear regression models, as the results of this analysis, they evaluated regression equation and defined regression coefficients. FAROOQ *et al*. (2015) indicated that positive correlation and positive direct effects of sympodia per plant, bolls per plant and plant height with seed cotton yield was indicative and selection for these traits perhaps used to increase seed cotton yield.

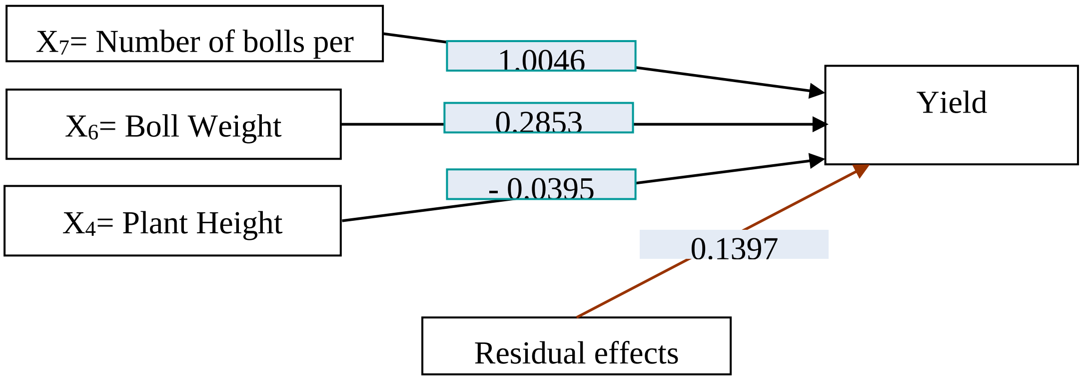

Fig 1. Path diagram showing the relationship between yield and some yield components entered in the stepwise multiple liner regression models

Principal component analysis (PCA)

According to table 7, in the first component, the number of bolls per plant, boll weight, plant height, seed cotton yield, and monopodia per plant have the positive and the high effects, also in this component sympodia per plant has a negative effect. In the second component, the number of bolls per plant has the highest and positive effect, number of nodes and monopodia per plant have the highest and negative effects. Comparison of two components reveals that the number of bolls per plant exists in both components has a positive and the highest effect. The number of bolls per plant in cotton is an important component of yield that it directly affects on yield. Comparisons in contribution of each variable in the table shows that number of bolls per plant with 83%, boll weight and plant height respectively with 14% and 1%, totally are responsible for up 99 percent of the total variance and changes. Cultivars distribution based on the characteristics come in Figure 2, according to this figure, cultivars SKSH-249 and NSK-847 are different with the rest of treatments. Cultivars K8802, K8801, SKT-133 are nearly similar t00 each other and have the highest yield in two years. Varamin cultivar is better than the Sahel for Urmia region as a check cultivar. Figure Biplot shows that the number of bolls per plant, plant height, and seed cotton yield (x_1, x_3, and x_4), boll weight and monopodia per plant (x_2 and x_8), number of nodes and number of flowers (x_5 and x_6) are close together but the sympodia per plant (x_7) is different from the rest (fig 3). According to the report of MOHSEN and AMEIN (2016), two components could describe approximately 73.96% of the total variation. The first component, which accounted for about 53.21% of the variation, was strongly associated with number of bolls plant, boll weight, seed index and lint percentage, the second component was strongly associated and positive effects on earliness index only, which accounts for about 20.75% of the variation. BILAL *et al* (2015), reported that the correlation analysis, path coefficient analysis and principle component analysis together offered that these attributes and genotypes should be give prime emphasis in effective selection to make a better cottonseed yield.

Table 7. Principal component analysis

Traits	First component	Second component	Eigenvalue	Proportion	Cumulative
No. of bolls per plant	0.379	0.381	728.96	0.8302	0.8302
Boll weight (g)	0.356	-0.126	130.32	0.1484	0.9786
Plant height	0.440	0.205	13.62	0.0155	0.9941
Yield per plant	0.397	0.204	2.35	0.0027	0.9968
No. of flowers	0.142	-0.281	1.97	0.0022	0.9990
No. of nodes	0.212	-0.747	0.43	0.0005	0.9950
Sympodia per plant	-0.389	-0.141	0.36	0.0004	0.9999
Monopodia per plant	0.403	-0.314	0.06	0.0001	1.0000

The numbers have been underlined; they have more value in the two components

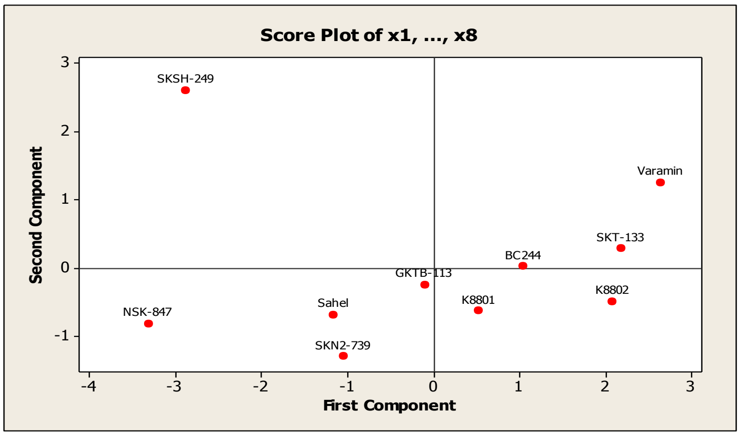

Fig 2. Diagram of distribution of ten cultivars based on the first and second components

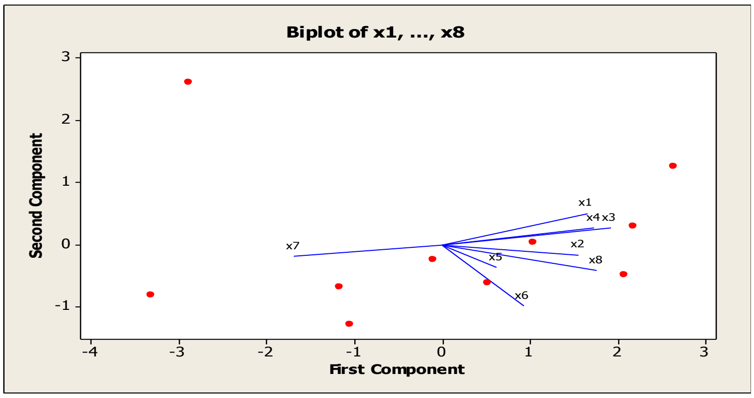

Fig 3. Biplot between PC-1 and PC-2 showing contribution of various traits in variability among different cultivars. The number of bolls per plant (x_1), boll weight (x_2), Plant height (x_3), Seed cotton yield (x_4), Number of flowers (x_5), Number of nodes (x_6), Sympodia per plant (x_7), and Monopodia per plant (x_8)

CONCLUSION

Places like Urmia, which cultivates cotton later than other part of cotton production areas, having cold weather with rain until middle of spring, fall rains and early cold in autumn, need to a cultivar or cultivars with high yield and earliness. The results of two years of this research showed that K8802 cultivar is the best variety for the cultivation in Urmia region. This cultivar (K8802) has a highest yield in per hectare and it is an early maturity variety.

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ANALIZE KOMPONENTI PRINOSA KOD KULTIVARA PAMUKA (*G. hirsutum*) MULTIVARIJATNIM STATISTIČKIM METODAMA

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Izvod

Pamuk je vodeća i najvažnija vlaknasta biljka koja igra važnu ulogu u životu pojedinaca i za razvoj tekstilne industrije u celom svetu. Izbor pogodne sorte za region Zapadnog Azerbejdžana je važan, jer je zapadni Azerbejdžan izvor pamuka za Iran. Istraživanje je sprovedeno u cilju procene kvantitativnih i kvalitativnih osobina kultivara pamuka u hladnijim delovima u regionu Urmije. U ovoj studiji, ocenjivano je osam sorata (Varamin i Sahel su korišćene kao standardi) u randomiziranom kompletnom blok dizajnu sa četiri ponavljanja u 2014. i 2015. godini (dve vegetacione sezone) u Saatlou stanici zapadnog Azerbejdžana za poljoprivredna istraživanja, obrazovanje i savetodavne usluge. Rezultati su pokazali da je kultivar K8802 rana sorta, jedna od najboljih prema karakteristikama, kao što su broj simpodija i plodova po biljci, konačni prinos, prinos semena pamuka (prinos po biljci) i kvalitativne osobine. Prema rezultatima kombinovane analize, efekat interakcije između tretmana i godine (tretman x godina) za prinos semena, prinos i broj plodova pamuka po biljci na nivou verovatnoće (α = 0,01) bili su značajni. Stepenasta višestruka linearna regresiona analiza otkrila je ulaz tri varijable, broj zrna po biljci, težinu ploda i visinu biljke unetu u model. *Path* analiza pokazala je da je direktan efekat broja plodova po biljci sa prinosom, indirektni efekat broja zrna po biljci i težine ploda sa prinosom najviši među svim efektima. Analiza glavnih komponenti za dve glavne komponente sa visokom vrednošću za varijable pokazala je da je broj semenki po biljci u obe komponente i ta osobina je jedna od glavnih osobina u izučavanjima pamuka. Prema tome, oplemenjivači pamuka moraju da rade na osobini broj plodova po biljci. Zahvaljujući rezultatima ovog dvogodišnjeg istraživanja, K8802 kultivar se preporučuje za gajenje u Urmiji.

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