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Full Length Research Paper

Determination of the best cotton cultivars and selection criteria to improve yield in Gorgan climatic region

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The purpose of this research was to introduce cultivars of high products in Gorgan region climatic condition and study the interrelationships between the seed cotton yields and several traits of 8 cotton genotypes at Plant Institute, Gorgan, Iran. The experimental design was a randomized complete block design with four replications. A positive significant (P<1%) correlation was observed between yield and weight of seed cotton in first harvest. Stepwise regression and path analysis showed that the weight of seed cotton in first harvest, and the number of monopodial branches and weight of seed cotton in second harvest could explain the maximum variations of yield (R^2 = 0/963). The weight of seed cotton in first harvest had the highest direct effects on yield/plant (P = 1/087). Due to their high direct and/or indirect effects on yield, the weight of seed cotton in both the first and second harvest can be used as selection criteria to identify the high yielding genotypes. The result of lint quality showed that genotype Siokra from the view point of lint percentage, lint length, lint homogeneity, lint resistance and fiber strength has a better quality than Sahel cultivar.

Key words: Cotton, seed cotton yield, correlation, stepwise regression, path analysis, lint quality.

INTRODUCTION

The exclusive features of cotton's lint (*Gossypium hirsutum L.*) are caused to be most important fibrous plant in Iran and other countries. The amount of Iran's cotton production (lint and cotton seed) in 2009 was about 254,000 ton, which when compared with the amount of 5 years ago (the amount of production in 2004 was about 420,000 ton), it shows considerable decrease (Anonymous, 2011b). Also, in recent years, the level of cultivation of cotton strongly decreased in Golestan province, to the extent that this province which came first position in 1994 dropped to second position after Khorasan razavi provinces in 2009 (Anonymous, 2011b). Increase and stable production of cotton in Golestan province depends on the increase of producing power in cultivation and their competition with other crops such as soybean, oilseed rape, and wheat.

Despite the current development and artificial fibrous, the exclusive feature of cotton's lint has made it possible for it to allocate about 48% of fibrous world consumption to itself, and even in some cases, no product could be replaced with it (Hatamee and Latifi, 2004). Even if about 105000 ha of cultivable lands of country is dedicated to cotton cultivation in 2009 (Anonymous, 2011b), the amount of acre yield is still lower (Ghulam et al., 2011) and its production is not enough. However, a significant amount of oil and fibrous is still imported annually. Solution of this problem is through modification and introduction of productive cultivars. Hybrid Sahel cultivar plays an important role in the increment of cotton production in Iran and in the economy of the region. The area under cultivation of cotton seed in Golestan province is about 12500 ha in 2009 (Anonymous, 2011b). Finding productive cultivars from current cultivars can affect the production significantly. Yield is a complex trait that includes many components and it has polygenic inheritance (Brojervic, 1990). Although, the determination of relation between important traits with seed yield is significant, yet the calculation of correlation coefficient does not determine the nature of trait's relation (Moghaddam et al., 1996). Using path analysis, the chance of identification has indirect effects on different traits and their indirect effects are more than those of the yield's traits. Grafius (1964) offered a geometrical curve to show the relation of yield and its components. So, real yield is resulted by its components.

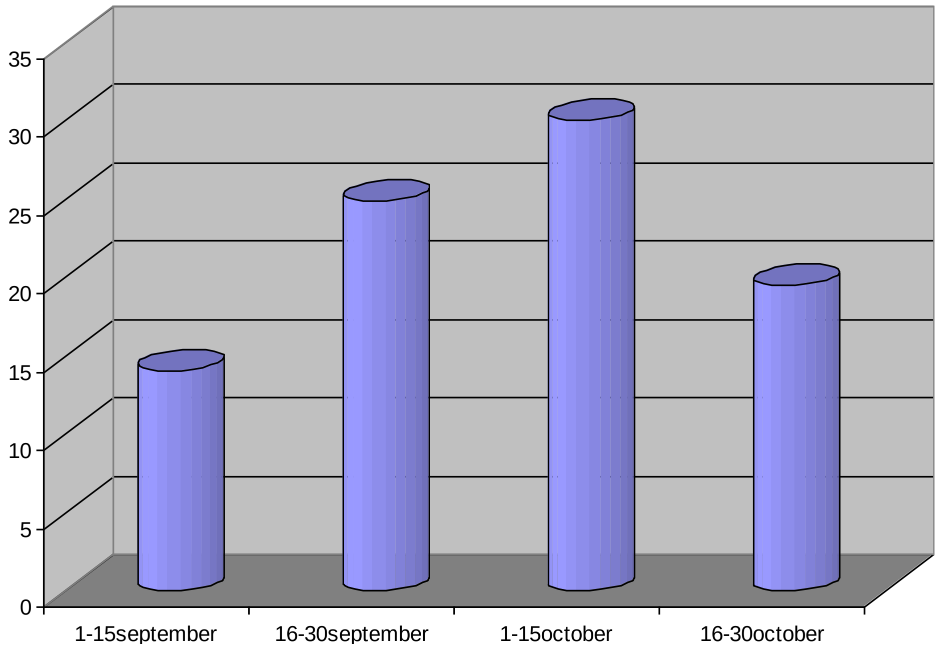

Figure 1. Average precipitation (mm) in Hashemabad, Gorgan weather station during 1984-2010 in September and October.

Modification of yield components is accompanied with yield improvement, although these components act as compensation, and increasing one of them can decrease another. Li (1956) introduced the first path analysis of yield's components. In early maturing cultivars, first harvest is at the middle of the first half of September and second harvest is at late September. In late maturing cultivars, first harvest is at early October and second harvest is at the middle of the second half of October. Interval of two harvests is 20 days. Average precipitation in Hashemabad, Gorgan weather station (Figure 1) during 1984-2010 at first half of September, second half of September, first half of October, and second half of October are 14.11, 24.93, 30.1 and 19.55 mm, respectively (Anonymous, 2011a). Sahel cultivar, which is a custom cultivar in Golestan province, has many harvests. However, harvests 3 and 4 have no value in weaving. Therefore, after the second harvest, the field is plowed. Meanwhile, using early maturing cultivars, cultivation can be done twice a year.

Since more than 85% of oil is imported in Iran, autumn soybean, oilseed rape can be used after cotton's cultivation. Unfortunately, today, most cultivable lands of Golestan province are cultivated at one time. It seems that the main problem is using late maturing cultivars that do not provide necessary time for second cultivation. Rauf et al. (2004) indicated that boll number per plant and sympodial branches had positive and highly significant correlation at genotypic and phenotypic level with seed cotton yield. Ahuja et al. (2006) found that number of sympodial branches per plant with seed cotton yield were not significantly positive in sets 2 and 3 and negative in set 1. From the results of path analysis and multiple regressions, Rauf et al. (2007) revealed that fibers per seed had the greatest direct effect on the lint yield. Karademir et al. (2009) showed that the number of sympodial branches, boll number per plant, boll weight and seed cotton weight per boll had positive and highly significant correlation with plant height. Path coefficient analysis reviews that bolls per square meter had the largest direct effect on lint yield, while boll weight and lint percentage had secondary direct effects on yield (Zeng et al., 2009). Major yield components (bolls plant-1, boll weight, seeds locule-1 and seeds boll-1) were also found to have positive correlation with seed cotton yield. However, plant height (due to lodging) was negatively correlated with yield (Makhdoomi et al., 2010). Sympodial branches, bolls per plant, boll weight, G.O.T (%) and lint index were found to be positively correlated with yield per plant in all the genotypes at 1.0% level of probability (Salahuddin et al., 2010a). The purpose of this research is to study the effect of the most important morphological and agronomic features on cotton's yield and choose the criteria for improvement of plant yield in the breeding program in regional condition. Also, this research introduced cultivars of high products in regional condition, instead of cultivars of products under cultivation, for the sole reason of creating the province's cotton.

MATERIALS AND METHODS

Plant materials

Specifications of some test genotypes are as follows:

Table 1. Comparison of mean of tested genotypes with Duncan's test.

Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cotton genotype	**Siokra**	**Sahel**	**Super okra**	**Frego-bract**	**Okra's red leaf**	**Smooth leaf**	**Deformed leaf**	**H.A.R**
Y(kg/ha)	A 2094/64	C 1555/18	AB 1980/36	BC 1631/25	BC 1702/68	BC 1720/18	BC 1718/39	ABC 1900

Different letters in each column show a significant difference with probability of 5%.

Siokra: This genotype was imported from Australia in 1989. Leaves of this plant have deep and narrow cuts, with dwarf and lots of long branches. It is close to Sahel by resistance against diseases (Nasrollanejad et al., 2006).

Sahel: This genotype is produced by a combination of Coker 100 wilt and Line 349 in Varamin Cotton Research Institute, and is introduced to farmers since 1968. Its fibrous is longer and stronger, with larger bolls, so its crop is easier. It is resistant against disease, so it is suitable for pollutant regions like Gorgan and Gonbad (Husseininejad, 1992).

Super okra: This produces 8.8% less fibrous than normal cotton. It has a better yield than normal cotton in humid regions and high precipitation.

Frego-bract: It is a mutation genotype in which bracts turned toward outside, so that bud and boll appeared. This is a recessive trait. It has good resistance against pests. Also, it is strong against *Helicoverpa zea*, but it increases sensation to *Lygus* spp*.*

Okra: It is a mutation genotype with narrow leaves. It is suitable for humid regions.

Smooth leaf: It has leaves without any trichoms.

H.A.R.: It was imported to Iran by France Research Institute of Cotton (IRCT) in 1965. This genotype is produced by combination of three species of *G. hirsutum, G. arboreum* and *G. raimondii*, and has open form and aerial trichom bodies. Genotypes with normal leaves, Siokra, Okra and Super okra have normal, semi deep, deep and very deep cuts on their leaves, respectively. Yield of fibrous and seed weight decrease with an increase in the number of leaves cuts (Meredith, 1984).

Experimental design and statistical analysis

Eight genotypes of cotton were examined in a randomized complete block design with four replications in Cotton Research Station of Hashemabad, Gorgan. Each replication was included in 8 plots. In each plot, one genotype was planted in 10 lines of 11 meters with a pattern of 20 * 80 cm, and the two ends were considered as a border with half meter. The following traits were measured: yield (Y), early maturing (EM), boll number in first harvest (BNFH), plant height (PH), highest length of monopodial branch (HLMB), length of fifth sympodial branch (LFSB), number of monopodial branch (NMB), number of sympodial branch (NSB), weight of seed cotton in first harvest (WSFH), mean weight of 20 bolls in first harvest (WBFH), weight of seed cotton in second harvest (WSSH) and boll number in second harvest (BNSH). Average weight of 20 bolls in each test unit was considered as boll weight.

Early maturing = WSFH / Total yield

Before each kind of analysis, the test of non-additivity and test of normality were performed. In the next step, mean comparison of Duncan's test for yield was used at 5% level of probability (Valizadeh and Moghaddam, 2001). Then, simple correlation coefficient of traits was estimated. So, for confidence of error freedom, the test of Durbin and Watson's binoculars was used for the experiment. In path analysis of yield, the result of Durbin and Watson test was 2/48. Path coefficients (direct effects of each variant on the dependent variant) were obtained as follow (Li, 1956):

$$R_{jj}^{-1} \times R_{jy} = p_{yj}$$

where R_{jj}^{-1}= inverted matrix of simple correlation coefficients among independent traits, R_{jy}= matrix of simple correlation coefficients of independent traits with dependent trait (yield), and P_{yj}= path coefficients (standard defective regression coefficient).

For obtaining of indirect effects, each variant was used through other dependent variants from $\mathbf{r_{ij}\ p_{yj}}$ (Dillon and Goldestein, 1984). The studied quality traits for Sahel and Siokra cultivars are shown subsequently: Lint percentage from fiber ratio to seed cotton is calculated as follows:

Lint percentage = the weight of the sample after separating from seed / weight of sample before separating from seed x 100

Lint length (calculated in millimeters as length of 2/5% of fiber with the HVI device).

Fiber strength (necessary force for rupture of fiber, this measurement is done with the HVI device and expressed in gr/tex).

Lint homogeneity (the ratio of mean of the length of 50% to the length of 2/5% of fiber calculated with HVI device and expressed in percentage).

Lint elongation (if a force is exerted to fiber, the lint length increases and reaches the rupture level, and the amount of increased length is calculated with the HVI device and expressed in percentage).

Lint resistance (the amount of resistance of a clump against the rupturing of fiber as shown by Pressley device).

Micron air index (put a fixed weight of fiber in a cylinder with a fixed bulk and conduct air with pressure through the cylinder. If fibers are more delicate, less air conducts through the cylinder and micron air index becomes smaller. This measurement is done with the HVI device and expressed in micrograms per inch square).

For analysis of data and figure preparations, MSTAT-C, SPSS, Excel and Microsoft Word softwares were used.

RESULTS AND DISCUSSION

Duncan's test (DMRT) for yield

Mean comparison (Table 1) identified 1, 3 and 8 as high yielding genotypes. Also, other genotypes are located in one group (Table 1). The plant of cotton is not able to tolerate big and heavy bolls, because in bad environmental condition, these small bolls with more numbers will have retrievable effect on yield. Therefore, the genotype of Sahel has the biggest boll, but produced least yield. Sahel late maturing genotype, with maximum number and heaviest boll in the first and second harvest, has a splotch of boll during rainfall at the end of the season and produced minimum yield.

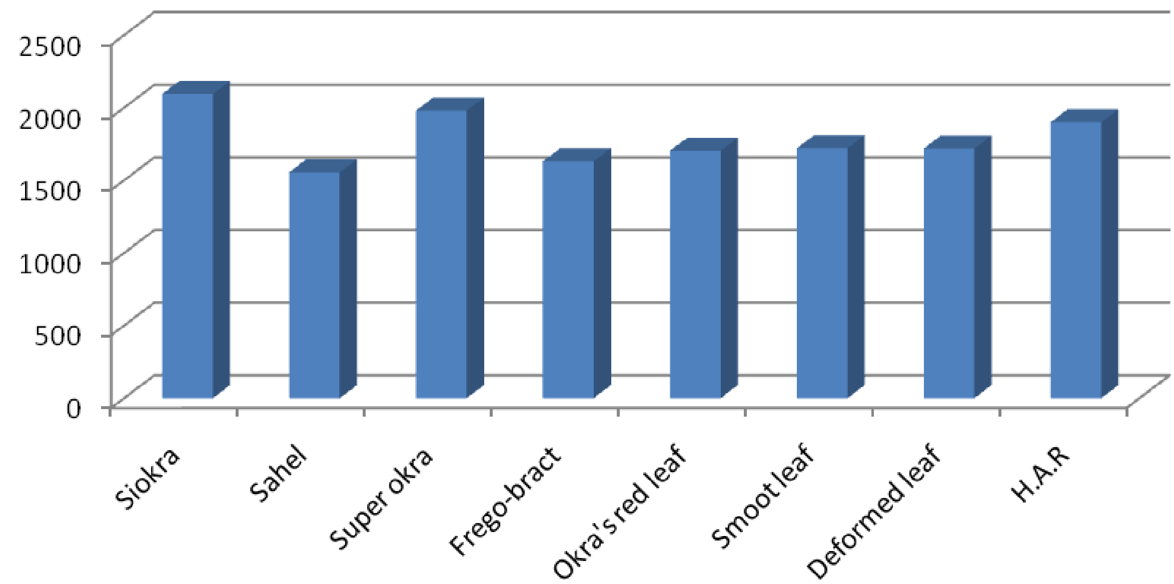

Figure 2. Weight of seed cotton in 8 cotton genotypes in Gorgan region (kg/ha).

Golestan province has two different climates. West of this province, beside Kordkuy and Bandar-Gaz towns, is proximate with Caspian Sea, so the problem of this area to cultivate cotton is humidity and disease. Therefore, upon results of this study, it is better to use Siokra, Frego-bract and Deformed leaf genotypes, although Sahel genotype is resistance to disease, and that is acceptable in this region, because of its lower yield. In fact, in regions that are proximate to sea, for example, in Kordkuy, Bandar-Gaz and Gorgan, early maturing genotypes are more suitable. Sahel genotype has severed downfall of boll because of precipitation although it has high boll number in harvests 1 and 2 and big boll. By study of yield of genotypes, the best genotype for humid regions is Siokra. Siokra produces 35% more than Sahel cultivar (Figure 2). At east of this province that Gonbad town is located, there is dry climate. The problem of this area to cultivate cotton is the hot weather condition of the cultivation season. Thus, the best time to cultivate cotton in this area is April 14. In fact, in early cultivation, they try to escape from the primer heat of the growth season. In this region, there is no late season precipitation or disease. Siokra, Super okra and H.A.R are suitable because it has high yield.

Correlation

Between yield and plant height, a negative significant (P<1%) correlation was observed. Negative relation in plant height with yield indicates that shorter variety must be more attended, and this shortens of plant is a characteristic of early maturing variety is as reported by Ehdai and Waines (1989). In lack of water, correlation between plant height and yield is positive. However, if there is enough water, this correlation is negative. There are different ideas about correlation between stem height and yield. Briggs and Aytenfisu (1980) reported a positive relation between plant height and seed production, while Walton (1971) obtained different results. As it pointed out before, stems does not only function as store of photosynthesis material before blossom, but also it's useful in stability and defiance for lodging and for existence of chlorophyll had portion in total of plant photosynthesis and causes to be more complex of its role in yield. Between yield and number of sympodial branch, there is a negative correlation at 1% level, which is in line with the findings of Ramezanpour et al. (2002). This is because, with increasing of number of sympodial branch, it causes to be increase boll number. It seems that yield should increase, but insomuch the boll size is smaller and the amount of seed cotton decrease, then the number of sympodial branch is desirable demanded but not more than enough. In Naseri (1995) said about yield, for boll component, specially its size, there are desirable amount and this desirable amount in various genotype or group of genotypes according to agricultural condition and yield amount is different. Arshad et al. (1993) suggested that there is a positive and significant correlation between yield of seed cotton and number of sympodial branches,

Table 2. Simple correlation coefficient between different traits in the tested cotton genotypes.

	Y	EM	BNFH	PH	HLMB	LFSB	NMB	NSB	WSFH	WBFH	WSSH	BNSH
Y	1**											
EM	0/244	1**										
BNFH	0/078	-0/224	1**									
PH	-0/534**	-0/66**	-0/081	1**								
HLMB	0/016	-0/381*	0/183	0/281	1**							
LFSB	-0/125	-0/463**	0/118	0/463**	0/522**	1**						
NMB	0/121	-0/035	0/198	-/026	0/714**	0/287	1**					
NSB	-0/521**	-0/49**	-0/187	0/895**	0/306	0/402*	-0/011	1**				
WSFH	0/886**	0/658**	-/03	-/717**	-/192	-/328	0/039	-/632**	1**			
WBFH	-0/226	-/027	/286	/077	/241	-/089	/05	/02	-/181	1**		
WSSH	-/028	-/943**	/274	/568**	/302	/376*	-/055	/388*	-/444*	-/002	1**	
BNSH	-0/166	-/271	/84**	/096	/035	/266	/017	/027	-/237	/12	/271	1**

ns, * and **, Nonsignificant and significant at 5 and 1% level of probability, respectively.

Table 3. Phenotype correlation analysis to determine direct and indirect effects of different traits on yield of cotton.

Independent variable	Direct effect on yield	Indirect effect on yield			Simple correlation
		WSFH	NMB	WSSH	
WSFH	1/087**	–	/004	-/204	/886**
NMB	ns/104	/042	–	-/025	ns/121
WSSH	/460**	-/483	-/006	–	ns-/028
R^2= 0/963					

ns, * and **, Nonsignificant and significant at 5 and 1% level of probability, respectively.

which is also in line with the findings of Kazerani (2006) and Salahudin et al. (2010b) confirmed this. Between height with number of sympodial branch, there is positive correlation at 1% level, but between height and number of monopodial branch, there is negative relation, which in agreement with the result of Hatamee and Latifi (2004). It can be construe, that sympodial branch in case of existence of photosynthesis materials have dominance for number of monopodial branch. Also with increasing plant height cause to increase node number in main stem and distance among inter nodes, the ability of plant increase for formation of sympodial branch. There is no correlation between yield and boll number per plant, which it contradicts with the findings of Kazerani (2007) and Arshad et al. (1993). It should be said that because boll number is measured in two different harvests, correlation of these two harvests cannot be studied (Table 2).

It must be mentioned that, correlation between two variant cannot be reason of existence of causality's relation among them. To indicate quantity relation between two traits, quadrate of correlation coefficient (R^2) was used. Existence of coefficient of determination (R^2) indicates that, the variations of these two traits were less according to environmental effects, and it's more dependent to genetic effects. It can be use in indirect choosing of traits in plant breeding.

Path analysis

Phenotype correlation analysis

Stepwise regression was used for identification of traits which must be entering in model. On the basis of this model, Table 3 indicate that, traits of weight of seed cotton in first harvest, number of monopodial branch, weight of seed cotton in second harvest, as independent traits, final model establish for yield as dependent variant.

Analysis of regression

In the analysis of regression (Table 4), regression's effect of traits on yield was significant at 1% level, so the model is accepted. With attention to the coefficient of determination (R^2= 0/963), about 0/96 numbers out of the many parts of the yield that are changing is related to the three aforementioned traits, and others do by factors that do not exist in the model. The remaining effect or error obtained is 0/19. About this matter, we can say that the remaining effect (0/19) shows a nonlinear relation among traits. The purpose of direct effects is the path coefficient or correlation coefficient of each trait with yield if other traits are stable. In Table 3, total direct and indirect effects in each row will be equal to the correlation coefficient of the yield. Among the three traits (the number of monopodial branch, the weight

Table 4. Yield analysis of regression.

S.V	SS	Df	MS	F
Regression	95565389/91	1	95565389/91	780/29**
Error	3674228/06	30	122474/27	
Total	99239617/97	31		

**Significant with probability 1%.

of seed cotton in the first harvest and the weight of seed cotton in the second harvest), most correlation coefficient on yield was related to weight of seed cotton in first harvest with 0/886. Least correlation coefficient on yield was related to weight of seed cotton in second harvest with -0/028. Most direct effect on yield was related to weight of seed cotton in first harvest with 1/087. Least direct effect on yield was related to number of monopodial branch with 0/104. Most indirect effect of seed cotton in first harvest is through number of monopodial branch and among number of monopodial branch with weight of seed cotton in first harvest exist positive relation. It means that, with increase in the number of monopodial branch, weight of seed cotton in first harvest is more and it causes increase in yield. But this relation is very less. This is in line with results of correlation coefficient, because correlation coefficient of seed cotton in first harvest and number of monopodial branch is 0/039. Most indirect effects of seed cotton in second harvest were obtained through number of monopodial branch.

In as much as the relation is negative, then with increase in the number of monopodial branch, the weight of seed cotton decrease in second harvest. In as much as the correlation coefficient of seed cotton in the second harvest and number of monopodial branch is -0/055, this matter is in agreement with results of correlation coefficient. Table 3 shows the correlation coefficient of traits in weight of seed cotton in first harvest and number of monopodial branch with yield almost close to the direct effect or path coefficient of this trait on yield. Therefore, correlation coefficient of this trait indicates the amount of their real relation with the defective variant yield means, and direct choosing can be useful through its trait. Explanation of the relation in number of monopodial branch with yield can indicate increase in photosynthesis area, increase in transpiration, and can cause an increase in yield. In studying the explanation traits, path analysis of defective yield in correlation coefficient of traits, number of monopodial branch and weight of seed cotton in second harvest is seen. In as much as these traits do not show significant correlation with yield, it can be said in the case of fixation of other traits that there is positive and significant relation among these traits with yield, but in the case of the change observed in other traits, the relation is not significant. This is because of the negative and significant effects observed in other traits rather than the two traits mentioned in the foregoing. Considerable point in this way is positive and direct effect of weight of seed cotton in second harvest on yield, but indirect effects of this trait through traits of weight of seed cotton in first harvest and number of monopodial branch cause to decrease the correlation coefficient and its non significant. So in traits choosing on the basis of weight of seed cotton in second harvest must decrease the limited effects in weight of seed cotton in first harvest and number of monopodial branch till can be used from the direct effect of this trait. It must be mentioned, main reason that cause to be differ path analysis of yield with various experiments and among organized components of yield exist positive and negative correlation, this is because of nature of relation among components was not genetic and change from environment to another environment (Adams, 1967), and for this reason in experiment are seen different results. In fact interaction of genotype and environment with effect in components of yield define amount of product and any one of yield's component isn’t lonely the factor of existent variety in yield. Correlation between seed yield and component of yield with fertile level, amount and date of implant and used cultivar is changing. The selection only one of components cause to breakage in increasing of product, this is because of negative relation in component. In addition of mentioned traits as main components of yield, also there are traits and structures in plant, that either their effect was less on seed yield or indirectly appeared through other traits, in the most references. Figure 3 show the obtained results from path analysis of yield’s components.

Final model

Table 5 shows the final model and step by step regression of yield. With regarding to importance of competition among formed components of yield and weight of seed cotton in first harvest as most important component on yield in this experiment and also, the formation of these traits determine at the beginning of period, therefore providing suitable growth in this period and choosing genotypes of high photosynthesis's coverage is recommended.

Quality traits

According to the results of the recent investigation, genotype Siokra showed a thirty five percent increase as compared to Sahel cultivar. As the economical value of

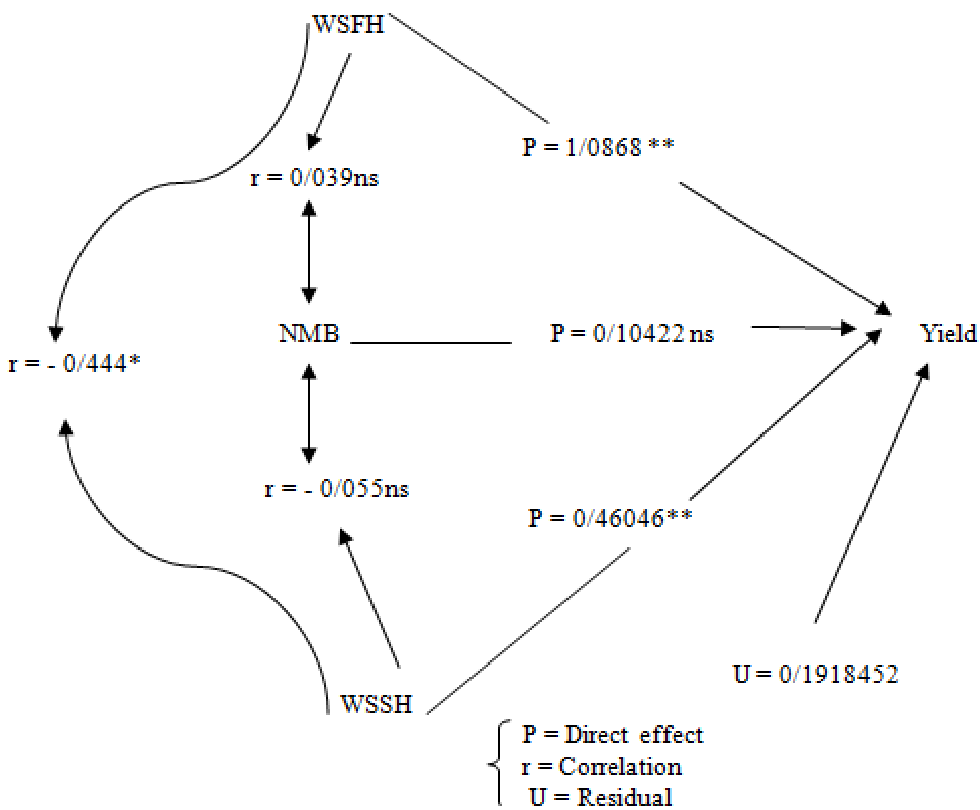

Figure 3. Cause and effect relation among effective traits on cotton's yield.

Table 5. Final model and Yield analysis of stepwise regression.

Variable	Regression coefficient	Standard error	T	Probability
NMB	0/034315	0/011992	2/861**	0/007
WSFH	0/017590	6/5701	26/774**	0/000
WSSH	0/0020426	0/018021	11/335**	0/000
Y = -12818/941891 + 0/034315a + 0/017590b + 0/0020426c				

ns, * and **, Nonsignificant and significant at 5 and 1% level of probability, respectively.

Table 6. Quality traits and fiber parameters.

Parameter	Siokra	Sahel
Lint percentage (%)	22/39	17/36
Micron air index (Mg/inch^2)	2/4	8/3
Lint length (millimeter)	9/27	27
Lint homogeneity (%)	5/48	8/46
Lint resistance (pressley)	82/6	68/6
Fiber strength (gr/tex)	93/20	83/20

Lint elongation (%)	27/7	4/7

cotton in trade is indicated by the quality of fiber, the fiber quality of these two genotypes were investigated (Table 6).

The result of fiber quality showed that genotype Siokra from the view point of lint percentage, lint length, lint homogeneity, lint resistance and fiber strength has a better quality than Sahel cultivar, but from the view point of micron air index and lint elongation, it has a poor quality.

As the micron air index is not a good item in indicating the economical value of cotton fiber in Iran trades, it is not as important as it was speculated to be. Because of the humidity of Gorgan, the resistance of diseases is important, but according to the findings of Nasrollanejad et al. (2006), from the view point of resistance of diseases, genotype Siokra is close to Sahel cultivar. Thus, according to high yield and high quality of Sahel cultivar, we can suggest the use of this cultivar to farmers.

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