EFFECT OF ENVIRONMENTAL CONDITIONS ON THE PRODUCTIVITY OF SOYBEAN IN EGYPT

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ABSTRACT

Two field experiments were conducted at the Agricultural Experiments and Researches Station, Faculty of Agriculture, Cairo University, Giza, Egypt during 2009 and 2010 seasons. The objectives were to investigate the response of some recent local soybean cultivars to seasonal changes, cropping systems and plant densities and the effects of these factors on soybean growth, grain yield and its components. Two systems as solid soybean and intercropping of 4 soybean ridges alternated with 2 corn ridges were adopted. Giza 21, Giza 35 and Giza 111 soybean Egyptian cultivars were used. The planting densities were 210 000, 175 000 and 140 000 seeds/ per Feddan (=4200 m2).

Out of ten studied soybean yield and yield component traits, 7 traits were significantly affected by seasonal variations. Air temperatures and relative humidity during the growing periods indicated that the 2010 season was characterized by higher temperatures and RH.

Cropping systems (CS) significantly affected soybean plant height (PlHt), seed yield / plant(SYP) and harvest index (HI). However, the (S x CS) interaction was insignificant for all traits. Plating densities (PD) significantly affected seed yield/ plot (SY /plot) and seed index (SI). The interaction of PD with other studied factors, recorded significant variances due to CS x PD interaction for days to onset flowering (DF) and seed index (SI). Mean squares due to soybean cultivars varied significantly for DF, Days to maturity (DMAT), HI, and SI. Such cultivars performed differently from season to another for DF, DMAT, pods and seed yield / plant (SYP). The studied soybean cultivars varied for stability in performance only for environmentally tolerant and moderately affected traits. It may be concluded that performance of soybean traits is differently influenced by the environmental conditions and could be classified in this respect to sensitive, moderate and tolerant to environmental conditions. This variation in performance of soybean traits should be taken into considerations in soybean yield trials in attempting to improve the level of stability of soybeans.

Key Words: ***Soybean, Glycine max, Cultivars, Climatic changes, Seasonal variation, Cropping systems, Planting densities, Stability.***

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] is the leading oilseed in the world (Wilcox, 2004). According to FAO Statistics, 98.8 million hectares of soybean were harvested in the world in 2009, of which 30.9 million hectares were harvested in the USA. The world's soybean production in 2009/10 is projected at 247.2 million tons.

In Egypt, soybean acreages had declined drastically during the last twenty years, from about 42 thousand ha in 1991 to about 7.2 thousand ha in 2009 due to several biotic and abiotic factors negatively affecting soybean production. During 2008 Egypt imported 1,192,400 tons of soybean seed and 228,865 tons of soybean oil costing to $ 450 and $ 446 million, respectively.

Climatic changes greatly affect soybean yield and yield components (Jin and Liu , 2004 and Biabani *et al* 2008). Such changes may by generated from seasonal variation, cropping systems and cultural practices (Mathew *et al* 2000). Cropping systems as solid or intercropping with maize create various environmental conditions, which depend upon the system of intercropping and plant population density. Intercropping soybean with corn reduces light intensity and temperature around soybean plants due to shading.

Different intercropping patterns were suggested to maximize yields of both soybean and corn grown in the same plot. These patterns differ in the number of alternating ridges of corn and soybean from 2x2, 2x3 to 2x4 or 4x2 ridges (Metwally *et al* 2007 and 2009). Such patterns exhibit variable shading effects, light intensities and compatibility with other resources. The wider pattern (2x4 ridges) increases soybean yield and yield components compared to other patterns (Badr 1998 and Metwally *et al* 2007 and 2009). Thus intercropping may help increase crop production and farmers income through more efficient utilization of solar radiation (Yang *et al* 2009).

Adeniyan and Ayoola (2007) found that Soybean plant height at harvest, number of days to 50 percent flowering; number of pods per plant, weight of 100 seeds and seed yield were significantly affected by intercropping systems.

Metwally *et al* (2007) reported that the interaction between cropping patterns and soybean varieties was statistically significant for plant height, number of pods/plant, number of seeds/plant, seed yield and harvest index, while, number of branches/plant and seed index were not affected.

Proper planting density is an important tool to optimize crop growth and the time required for canopy closure, and to achieve maximum biomass and grain yield. However, increased plant density reduces the number of branches, node length, No. of pods, grain yield per plant and per branch and grain weight. In contrast, the seed protein and oil contents, harvest index, 100grain weight and the number of grains per pod on the main and sub branch are not affected by plant density (Shamsi and Kobraee 2009).

Earlier research also shows that cropping system and distributions of both corn and soybean plants may have a large positive impact on the amount of sunlight radiation intercepted by maize plants which affected yield per plant of both crops.

The objectives of the present studies were to investigate the response of some recent local soybean cultivars to different seasonal changes, cropping systems and plant densities and the effects of these factors on soybean growth, grain yield and its components.

MATERIALS AND METHODS

Two field experiments were conducted at the Agricultural Experiments and Station Researches of the Faculty of Agriculture, Cairo University, at Giza, Egypt during 2009 and 2010 seasons.

The following factors were investigated:

1-Soybean cultivars (CVS.): three Egyptian cultivars: Giza 21, Giza 35 and Giza 111 were used.

2- Planting densities (P.D): three levels as high (H.D), medium (M.D) and low (L.D) planting densities were evaluated. These levels were tested using 480, 400 and 320 seeds per plot of 4 ridges (=9.6m^2), respectively. The densities correspond to 210, 175 and 140 thousand seeds per feddan (4200m^2), in the same order.

3-Cropping systems (C.S): two systems were tested: solid soybean and intercropping (4 soybean ridges alternated with 2 corn ridges).

Each experiment was conducted as randomized complete blocks design (RCBD) in split-split plot arrangement with four replications. Cropping systems were allocated in the main plots and seed densities were assigned to the sub-plots, and tested cultivars were laid in the sub- sub plots.

Experimental plots were consisted of 4 ridges; was 4m long and 60 cm wide (9.6m^2). The direction of ridges was from North to South, and soybean seed was drilled on the Eastern and Western sides of each ridges and maize on the western side of the ridges. Corn ridges were planted with SC. 10 variety on one side in hills distanced 30 cm apart, which were thinned later to two plants per hill. Soybean seeds were sown by the " Hearti " method (dry seeds in wet soil or pre irrigated soil). Maize ridges were sown by the Afir method (dry seeds in dry soil). Maize ridges were sown about one week prior to soybean. Planting date was May 22 in both seasons. The preceding crop was faba bean in both seasons. Irrigation was scheduled every two weeks. All the other agronomic practices were applied according to recommendations.

Studied characters

During growth period the date of onset of flowering (DF) and data of the maturity of 90% (DMAT) of soybean plants were recorded. Light intensity was measured three times per day: early (6^{00}-7^{00} am), med- day (11^{00}-12^{00} am) and late (18^{00}-19^{00} pm) at day 90 from sowing using three plants per plot by a Lux-meter on the upper leaves (top) and the lower leaves (bottom) of plants.

At maturity a sample of five guarded plants of each plot were used for recording the individual plant characters. Seed and bundle dry weight were determined for the remaining soybean plants plus those included in the individual samples per plot ($9.6m^2$). Seed index (SI) and harvest index (H I) were determined as the weight of 100 seeds in gms and the percent of seed yield to the bundle dry weight / plot, respectively.

Statistical analysis

Regular analysis of variance of the split- split plot design for the recorded data of each season and a combined analysis over seasons was performed for each trait using the MSTAT-C Statistical Package (Freed 1991). Treatment means were compared by the least significant differences (L.S.D) test at 5% level of probability to compare differences between the means. To assess the stability in performance of soybean cultivars, twelve environments were considered as the combinations of studied treatments during both seasons. For this purpose, combined analysis over environments was conducted and the coefficients of variability (C.V. %) were estimated as a measure of stability.

RESULTS AND DISCUSSION

Significance of variance due to different sources of combined analysis over seasons

Table (1) presents the magnitudes of variances and significance of combined analysis over seasons for different traits.

Seasons (S) were a significant source of variation for all studied soybean traits except days to onset flowering (DF), branches / plant and seed index (SI). Cropping systems (CS) significantly affected soybean plant height (PlHt), seed yield / plant(SYP) and harvest index (HI). However, the (S x CS) interaction was insignificant for all traits.

This indicates that out of ten studied soybean yield and yield component traits, 7 traits were significantly affected by seasonal variations.

Meteorological data viz., air temperatures and relative humidity during the growing seasons indicated that the 2010 growing season was characterized by temperatures higher by about 2-5c^0, particularly the minimum temperatures (Fig1.). Warmer air temperature dominated the second season were accompanier by generally higher relative humidity (RH). On the contrary, minimum RHs were lower than 2009 season (Fig.2). However, the climatic features showed some exceptions during various growth periods. These inter-seasonal and intra- seasonal fluctuation in both climatic parameters greatly affected the studied soybean traits. The effects of climatic changes on soybean yield and yield components were stressed by Jin and Liu (2004) and Biabani (*et al* 2008). Moreover, Mathew *et al* (2000) pointed out that cropping systems and cultural practices along with seasonal variations affect soybean growth and yield components.

The investigated CS (solid vs. intercropping) did not significantly affect most of the soybean traits. This may be due to the fact that the intercropping system included 4 ridges (2.6m) wide alternating with 2 corn ridges (1.3m) wide. This wider spacing did not expose the soybean plants to substantial stress from intercropping. The direction of ridging was from North to South, which presumably shaded the soybean plants only during a short period after sunrise and before sunset. Otherwise, the soybean plants were exposed to sunshine for more than 10 hours per day similar to solid- planted soybean. This is supported by the measured light intensities at day 90 from sowing. The data in Table (2) present the percent of sun light that penetrated through the canopy to the bottom of soybean plants relative to light intensity at the top leaves in the day 90 from sowing.

In spite of differences between seasons in light intensity that penetrated the soybean canopy, S x CS interactions were insignificant for all traits. This means that the effects of CS were consistent between both seasons. Lack of significant S x CS interactions may also be ascribed to the higher air or soil temperatures (by about 12-22c^0) during the second season.

Plating densities (PD) significantly affected seed yield/ plot (SY /plot) and seed index (SI). The interaction of PD with other studied factors, recorded significant variances due to CS x PD interaction for days to onset flowering (DF) and seed index (SI).The second order interaction (S x CS x PD) significantly affected only days to soybean maturity (DMAT).

These findings proved that the most of studied factors affected soybean independently from factors. This may be due to the fact that narrow ranges of levels of each factor were investigated and/ or to the great effects of seasonal variation on the studied other factors.

Mean performance and variation among soybean cultivars

Mean squares due to soybean cultivars varied significantly for DF, DMAT, HI, and SI (Table1).

The studied cultivars performed differently among seasons for DF, DMAT, number of pods and seed yield/ plant (Syp) judging by the significant S x CVS interaction for these traits. Thus, the studied soybean cultivars were sensitive to seasonal variation in air and soil temperature and RH, which varied among seasons and fluctuated within seasons.

Other interactions of studied factors with CVS, were significant for few traits viz,. CS x CVS (for HI and SI), PD x CVS (for SI) and S x CS x PD x CVS (for DMAT).

Stability of soybean cultivars across environments

The investigated treatment combinations, i.e. 2 CS x 3 PD across both seasons summed 12 environments, were considered in combined analysis of variance over environments. This is conducted to simplify cultivars performance across the given environments.

Table 1. Significance of mean squares due to various sources of the variation of combined analysis of variance over seasons for flowering and maturity dates, and soybean yield and yield components

S.V.		DF		DMAT		Pl HT,cm		Branches		Pods	
	d.f	M S	Sig	M S	Sig	M S	Sig	M S	Sig	M S	Sig
Seasons	1	23.4	ns	1094.5	**	149189.1	**	19.5	ns	32610.3	**
CS	1	5.4	ns	43.3	ns	4042.8	*	1.6	ns	175.6	ns
CS x S	2	6.3	ns	19.5	ns	357.8	ns	2.5	ns	807.5	ns
PD	2	28.0	ns	18.4	ns	751.5	ns	0.8	ns	94.1	ns
PD x S	2	6.2	ns	6.0	ns	71.5	ns	1.9	ns	536.4	ns
PD x C S	2	45.1	*	29.7	ns	270.9	ns	2.1	ns	63.0	ns
PD x S x Cs	2	0.3	ns	320.4	**	586.6	ns	2.7	ns	403.4	ns
Cvs	2	370.4	**	511.0	**	769.0	ns	6.8	ns	408.9	ns
Cvs x S	2	109.2	**	675.5	**	138.6	ns	3.3	ns	1550.5	*
Cvs x CS	2	0.4	ns	12.6	ns	438.9	ns	0.1	ns	615.4	ns
Cvs x S x CS	2	7.6	ns	40.5	ns	348.9	ns	1.8	ns	118.8	ns
Cvs x PD	4	8.6	ns	130.1	ns	1651.4	ns	0.5	ns	32.6	ns
Cvs x S x PD	4	2.1	ns	30.2	ns	1906.6	*	2.4	ns	96.6	ns
Cvs xCSx PDx	4	16.1	ns	80.2	ns	612.3	ns	2.1	ns	33.4	ns
CvsxSxCsx PD	4	3.9	ns	210.8	**	110.0	ns	0.8	ns	1157.2	ns

S.V.		SYP		SY/plot,g		Dwt/plot,g		HI		SI	
	d.f	M S	Sig	M S	Sig	M S	Sig	M S	Sig	M S	Sig
Seasons	1	290.2	*	55785961.0	**	919929120.1	**	167.1	*	42.5	ns
CS	1	15.5	ns	1907161.0	**	290161.8	ns	715.1	**	12.1	ns
CS x S	2	0.6	ns	275625.0	ns	1099701.8	ns	2.1	ns	0.014	ns
PD	2	22	ns	411883.6	*	5026928.9	ns	0.4	ns	53.9	**
PD x S	2	88	ns	292601.6	ns	3779973.9	ns	0.1	ns	0.245	ns
PD x C S	2	142.8	ns	156602.3	ns	1911916.4	ns	1.8	ns	21.3	**
PD x S x Cs	2	22.1	ns	13284.3	ns	153186.4	ns	9.4	ns	0.014	ns
Cvs	2	79.1	ns	90935.6	ns	2623364.0	ns	36.7	*	184.7	**
Cvs x S	2	235.2	*	56017.6	ns	965214.7	ns	29.9	ns	0.479	ns
Cvs x CS	2	41.9	ns	54110.6	ns	3516179.7	ns	59.9	**	15.3	*
Cvs x S x CS	2	136.4	ns	161075.3	ns	886573.0	ns	5.2	ns	0.0	ns
Cvs x PD	4	25.1	ns	185471.4	ns	2981160.7	ns	1.0	ns	62.5	**
Cvs x S x PD	4	77.4	ns	136315.9	ns	1874900.3	ns	6.9	ns	0.041	ns
Cvs xCSx PDx	4	19.6	ns	42186.3	ns	516372.4	ns	4.4	ns	7.4	ns
CvsxSxCsx PD	4	80.5	ns	63591.5	ns	2283397.0	ns	17.0	ns	0.019	ns

ns, * and ** indicate insignificant, significant at 5% and significant at 1% level of probability, respectively

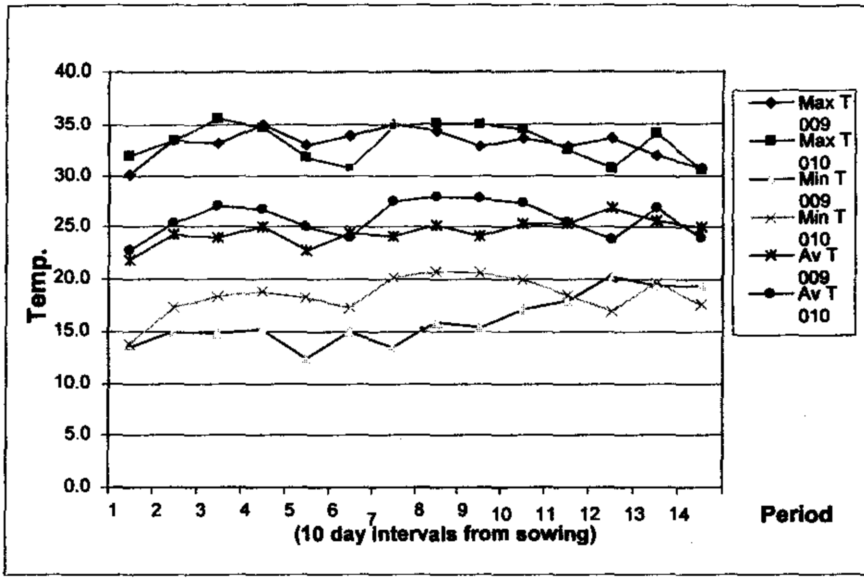

Fig.1. Air temperature during 2009 and 2010.

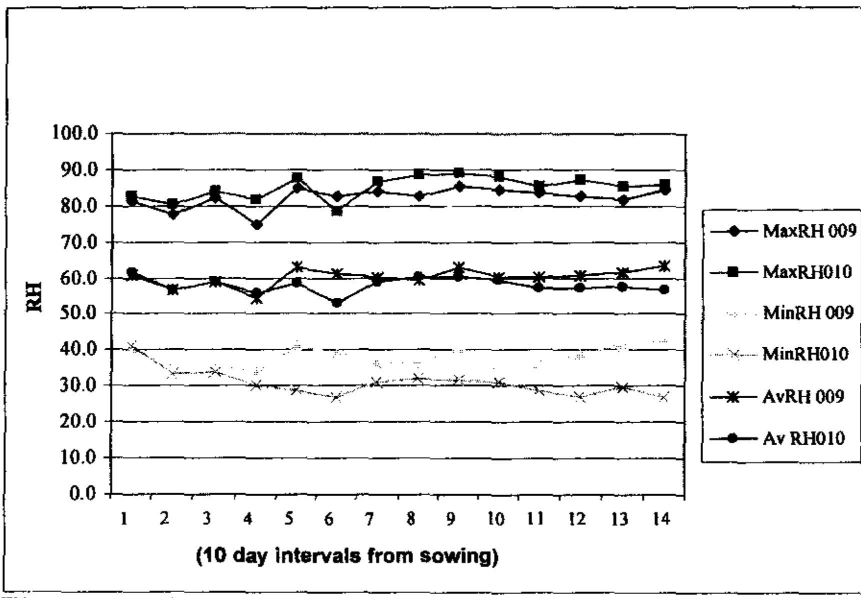

Fig.2. Relative humidity during growth periods of 2009 and 2010.

Table 2. Relative light intensity (Lux) penetrated the soybean canopy at early, mid-day and late- afternoon of day 90 from sowing of intercropping and solid systems in 2009 and 2010 seasons.

Period of day	Solid		Inter-cropping	
	2009	2010	2009	2010
Early	14.8	2.0	13.2	2.3
Mid-day	10.3	0.7	9.2	0.7
Late-afternoon	24.2	3.2	26.4	3.6

Table (3) presents the significance of combined analysis over 12 environments.

Table 3. Significance of mean squares from combined analysis of variance over 12 environments for soybean genotypes.

S.V.	d f	DF	DMAT	PLHt, cm	Bran ches	Pods	SYP, g	SY/plot, g	Dwt/plant	Hi	SI
Env.(E)	11	17.7ns	173.3**	14268.3**	3.5ns	3253.3**	77.8ns	5428862.8**	8573299.5**	82.5**	18.6**
Genotypes (G)	2	370.4**	511.0**	769.0ns	6.8ns	408.8ns	79.0ns	90935.6ns	2623368.1ns	36.7*	184.7**
G x E	22	16.2*	148.3*	862.5ns	1.5ns	447.7ns	74.5ns	102394.0ns	1879966.2ns	14.0ns	14.1**
E	72	8.9ns	48.0ns	715.6ns	2.9ns	454.6ns	44.4ns	117507.6ns	254451.7ns	10.6ns	4.1ns

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

Differences due to environments were significant for all studied traits except DF, branches and SYP. However, genotypes varied significantly in DF, HI and SI. The G x E interaction was significantly for DF, DMAT, SYP, and SI. Therefore, seasonal (unpredictable) effects as will as cultural practices changes (predictable environmental effects) greatly affected the soybean traits. However, genotypic differences were significant for DF, HI and SI. This proved that the investigated soybean cultivars varied only for flowering date, harvest index and seed weight. But cultivar performance was affected by environmental variations for DF, DMAT, SYP and SI as evidenced by the significant G x E for these traits. This variable performance from one environment to another indicates the need to study the degree of stability of soybean genotypes. The coefficient of variability (C.V. %) was used as an agronomic measure of stability of performance of cultivars as shown in Table 4.The high magnitudes of C.V.% indicate low stability in performance and vice versa.

Table 4. Mean performance of soybean cultivars and coefficients of variability across treatment combinations.

CVs	G.21		G.35		G.111	
Traits	Mean	C.V.%	Mean	C.V.%	Mean	C.V.%
DF	50.4	4.0	44.9	5.4	48.5	3.3
DMAT	139.2	3.2	132.8	6.4	135.0	3.8
PHt,cm	153.6	23.7	149.9	25.4	145.6	24.0
Branches	6.8	12.8	6.6	12.9	6.1	6.4
Pods	90.9	22.3	94.0	13.2	88.1	24.6
SYP,g	22.0	12.2	24.6	21.8	22.9	19.9
SY/Plot,g	1377.3	51.3	1453.5	49.4	1451.9	43.2
DWt/plot,g	5229.9	54.9	5550.2	49.8	5685.0	44.8
HI	27.9	15.4	26.7	6.6	26.2	9.4
SI	28.9	3.7	30.0	3.2	26.2	11.9

For mean performance, cultivar G.35 was significantly earlier in flowering and maturity than the other cultivars by about 5 days. G.35 also beared the highest number of pods and significantly heavier seed (30.0g).

The studied soybean characters could be classified into 3 groups according to the magnitudes of C.V. %. The first group is the environmentally sensitive group of traits (with more than 40 % C.V.), includes SY/ plot and DWt / plot. The second group that may described as environmentally tolerant traits (with C.V of about 10 %) comprised DF, DMAT, branches, HI, and SI. The third group, moderately environmentally influenced traits included the remainder of traits viz., PLHt, pods, and SYP showing about (20.0 % C.V). This classificati is suggested regardless of the level of significance of G x E interaction.

The investigated soybean genotypes exhibited variable C.V. % across environments. The G.35 cultivar showed lower C.V. % for DF (5.4%), DMAT (6.4%), pods (13.2%) and H I (6.6%). Therefore, it may be considered the stable cultivar for flowering and maturity dates and number of pods and H.I. However, the other two cultivars shared G.35 in stability measured by C.V. % for some traits. G.111 had somewhat lower C.V. % (9.4%) like G.35 (6.6%) for HI, G. 21 shared G.35 similar low C.V.% (3.5) for SI. Moreover, G.21 cultivar had unique lower C.V. % (12.2%) than other two cultivars for SYP.

The three investigated cultivars recorded high C.V. % for the rest two yield traits (SY and Dry wt. per plot). This may be due to the fact that both seed yield and dry weight are complex traits governed by several genes and are highly affected by environmental conditions.

Thus, the studied soybean cultivars varied for stability in performance only for environmentally tolerant and moderately affected traits. It may be concluded that performance of soybean traits is differently influenced by the environmental conditions and could be classified in this respect to sensitive, moderate and tolerant to environmental conditions. This variation in performance of soybean traits should be taken into considerations in soybean yield trials as will as the stability of traits among various cultivars in attempting to improve the level of stability of soybean flowering, maturity and yield components.

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تأثير الظروف البيئية على إنتاجية
فول الصويا فى مصر

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أجريت تجربتان حقليتان بمحطة التجارب والبحوث الزراعية – كلية الزراعة جامعة القاهرة – جيزة – مصر فى موسمي ٢٠٠٩ ، ٢٠١٠ ما يلى :ـ

١. نظامين للزراعة هما زراعة منفردة ، وزراعة تحميل (٤ خطوط فول صويا ، ٢ خط ذرة شامية)
٢. ثلاثة أصناف من فول الصويا هى جيزة ٢١ ، جيزة ٣٥ و جيزة ١١١
٣. ثلاثة كثافات للزراعة هى ٢١٠٠٠٠ ، ١٧٥٠٠٠ و ١٤٠٠٠٠ نبات / فدان

ويمكن تلخيص أهم النتائج المتحصل عليها فيما يلى :ـ

١. كان تأثير المواسم معنويا على كل الصفات المدروسة عدا عدد الأيام من الزراعة الى التزهير ، عدد الأفرع / نبات ودليل البذرة
٢. كان لنظم الزراعة تأثيرا معنويا على طول النبات ، محصول البذور / نبات ودليل الحصاد وكان تأثير التفاعل بين نظم الزراعة والمواسم معنويا على جميع الصفات ودلت النتائج ان سبعة صفات من الصفات العشر المدروسة تأثرت معنويا بالاختلاف بين المواسم
٣. كان هناك تأثيرا معنويا للأصناف على الأيام للتزهير ، دليل الحصاد ، دليل البذرة وعدد الأيام من الزراعة للنضج . وقد كان هناك فروق معنوية بين الأصناف من موسم لأخر لصفات عدد الأيام من الزراعة للتزهير ، عدد الأيام من الزراعة للنضج ، عدد القرون / نبات ومحصول البذور / نبات و كان التفاعل بين المواسم والأصناف معنويا لهذه الصفات .
٤. اختلفت الأصناف فى مقدار ثباتها عبر البيئات المستخدمة وكانت الاختلافات جلية للصفات الأكثر تحملا للاختلافات الظروف البيئية وتلك متوسطة التحمل لها مما يعضد ضرورة اخذ ذلك فى الاعتبار فى تجارب مقارنة الاصناف و عند تحسين اداء اصناف فول الصويا.