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BIOMETRICAL APPROACHES FOR DETERMININIG STABILITY OF SOME EGYPTIAN LENTIL CULTIVARS

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ABSTRACT

Lentil cultivars suffer from several constraints that limit and fluctuate production in Egypt. Three field trials were conducted in this study at the Agricultural Experiment and Research Station, Faculty of Agriculture, Giza, during 2006/2007, 2007/2008 and 2008/2009 seasons. .Each trial was conducted in a spilt-spilt plot design in a randomized complete block arrangement with three replications. Main plots were assigned to two sowing dates (1st of November and 15th of November) while sub-plots were devoted to three planting seed rates (300, 450 and 600 seed m $^{-2}$***) and sub –sub plots to five lentil cultivars (Sinai 1, Giza 51, Giza 9, Giza 4 and Giza 370). Thus, this investigation included 18 environments (2 sowing dates X 3 planting seed rates X 3 seasons). The objective was to elucidate the stability of studied lentil cultivars under variable environmental conditions using four stability parameters (CV%, Wi, bi and*** S^2d***).The analysis of G x E interaction across 18 environments showed significance for all traits, indicating that tested cultivars ranked differently in various environments, except number of pods. Studied traits were classified into 3 categories, viz. environmentally sensitive traits of (CV > 15.0%,) environmentally tolerant traits (CV< 5.0%) and moderately affected traits of(CV around 10.0%) . Ecovalence (*** W_i***) seemed to be the most proper stability parameter for differentiating lentil genotypes rather than Eberhat and Russell's two parameters*** b_i ***and*** S^2d***. This may be due to data transformation which narrowed the variability among environments. This variation is an important factor for validating the regression analysis in stability studies.***

Key words**: *Lentil (Lens culinaris), Cultivars, Seeding rates, Sowing dates Transformation, Stability parameters, Ecovalence, Regression, Coefficient of variability.***

INTRODUCTION

Lentil (*Lens culinaris* Medik) is one of the most important food legume crops allover the world and ranked second in Egypt after faba bean due to its seed protein richness and for being used in preparing several popular dishes. However, lentil acreages have been declined drastically during the last two decades from 5885 to 801 ha, which reduced production from 12000 to 1480 tons of seeds. The current production fall short of demand (66364 tones) with self-insufficiency of about 98.3%.This may be attributed to several constraints that limit lentil production, which mainly referred to the sensitivity of cultivars to various biotic and abiotic stresses. These factors include weeds, fungal pathogens and other pests; in addition to drought and salinity (Saxena *et al* 1993, Hamdi *et al* 2004 and Sarker *et al* 2005).

To overcome or at least alleviate the effects of these factors, several efforts were conducted in Egypt to develop proper lentil cultivars. The cultivars recommended were selected and tested across variable environments (Hassan *et al* 1988, Hamdi and Rabeia 1991, Khattab 1992, Abd El-Gawad *et al* 1997, Selim 2000 and Hamdi *et al* 2002). Several local and exotic lentil accessions were evaluated under variable locations extended from Nubaria and Northen Sinai in the North to Abu-Simble in Upper Egypt (Hamdi *et al* 2003). The outcomes of these investigations were several cultivars, i.e. Giza 9, Sinai 1 (Precoz) and Giza 370 that were recommended due to resistance to root rots and wilt, rainfed cultivation and multi-locations stability (Hamdi *et al* 1995).

Different stability parameters were adopted to determine the most promising lentil genotypes (Abo-Elwafa 1999, Abo-Elwafa and Ismail 1999, Hamdi *et al* 2002 and Mehdi *et al* 2006).

Sowing date is considered one of the major factors influencing yield and yield components in lentil as reviewed by Sarker *et al* (2009). Sowing dates of lentil on the beginning and /or middle November were proper than planting during December according to Ezatt (1994) and Allam (2002).The suitable planting seed rates were 300 plants m^{-2} for cultivar Sinai1 and 400 plants m^{-2} for other cultivars as recommended by Ezzat *et al* (2005).

However, the harvested area and production of lentil are still declininGz This revealed the existence of wide gap between experimental results and farmers outcomes. This may attributes to the climate changes or seasonal variations, which may affect inversely the performance of lentil cultivars and the reliability of recommended cultural practices in the recent years. On the other hands, such conditions may disturb the regular assumptions followed in variety trials or statistical analyses techniques.

Therefore, the present investigation was planned to elucidate the validity of various stability parameters to differentiate among lentil cultivars for performance and yielding ability under variable environmental conditions.

MATERIALS AND METHODS

Experimental procedures

Three field trials were conducted at the Agricultural Experiment and Researche Station, Faculty of Agriculture, Cairo University, Giza, Egypt, during 2006/2007 , 2007/2008 and 2008/2009 seasons.

In each experiment, three factors, i.e. two sowing dates, three planting seed rates and five lentil cultivars were studied. The sowing dates were at the beginning of November (early) and 15th November (recommended). The planting seed rates were 300, 450 and 600 seed m^{-2} (low, medium and high seed rate, respectively). The five studied lentil cultivars were Sinai 1, (Gz) 51, (Gz) 9, (Gz) 4 and (Gz) 370. The seed were obtained from Food Legume Crops Section, Field Crops Research Institute, ARC, Giza.

Each trial was conducted as a spilt-spilt plot design in a randomized complete block (RCB) arrangement with three replications. The sowing dates occupied the main plots, planting seed rates were assigned to sub plots and lentil cultivars were in the sub –sub plots .The experimental plot comprised of four ridges, each was 4m long and 60 cm apart; with aplot size of 9.6 m^2. The given seed numbers of each ridge according to planting seed rates were drilled at both sides of the ridge.

Data collection

During the growth period of the plants, number of survived plants /plot after one month from sowing was detected. The survived plants % was estimated as the number of survived plants relative to the number of emerged seedlings (after one week from sowing). The dead plants were referred to the infection of vascular wilt and root rot diseases, as kindly diagnosed by Legume Diseases Section, ARC, Giza.

At maturity, a sample comprised of 10 guarded plants were harvested individually from the central two ridges of each plot to record the individual plant traits. These characters were number of pods/plant (Pods) , and weight of 1000 seed (S.I).The rest of plants/plot were counted and their dry weight and seed yield were recorded, as DWT and SY per plot, respectively.

Statistical analyses

Sequential statistical analyses were conducted on the obtained data. Separate R.C.B.D analyses were performed using data of each seed rate in each sowing date during the 3 seasons summed 18 environments to detect the error mean squares of environments. Such variances were used for testing homogeneity followed Bartlett's procedure as outlined by **Gomez and Gomez (1984)** as prerequisite to the combined analysis across environments. In case of heterogeneity, proper transformation of the actual data was tested prior statistical analyses to fit the data to normal distribution. **Gomez and Gomez (1984)** suggested three common transformations of abnormal data and /or non-uniform applications of treatments. The logarithmic transformation is the most appropriate approach for data that exhibited multiplicative effects (the standard deviation is proportional to the mean). On the contrary, square – root transformation is appropriate in case of small counting or these possessed proportional trends between variance and mean. The third type of transformation is arc sin or angular transformation that normally used for data expressed as a decimal fraction or percentages. According to the homogeneity test, the proper data as actual or transformed of each 18 environments were reanalyzed on separate RCB design and combined analysis across environments.

In case of significant G X E interaction, further stability analyses were performed. Three measurements of stability in performance were utilized. Parameters of Eberhart and Russell (1966) b_i and S^2d i.e. regression coefficients and mean squares of deviation from regression, respectively, W_i: ecovalence (Wricke1962) and the coefficient of variability: (CV %) (Francis and Kannenberg 1978) were calculated.

RESULTS AND DISCUSSION

Climatic description

The averages of maximum and minimum air temperature degrees (C°) and relative humidity (RH %) at the experimental location during 2006/2007 , 2007/2008 and 2008/2009 seasons in 2 weeks intervals from the beginning of Nov. to April of the next year are presented in Figs.1 and 2 , respectively.

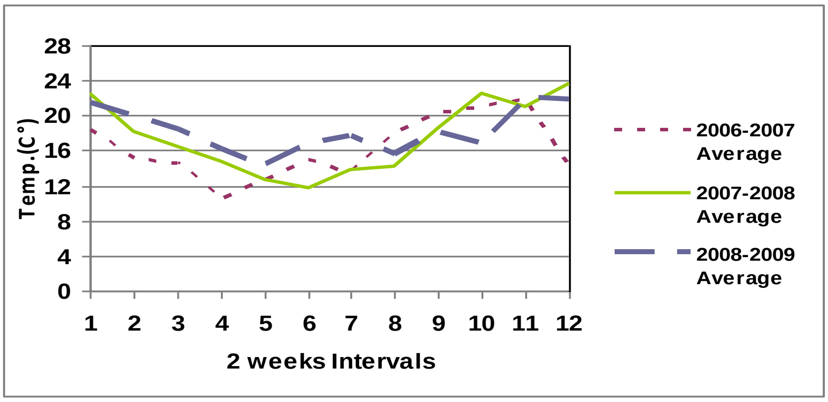

Fig. 1. Average air temperatures during the three seasons of experimentation .

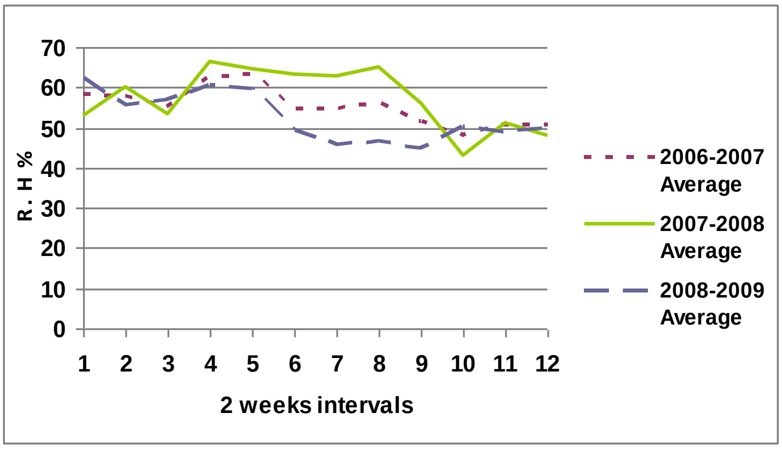

Fig. 2. Average relative humidity (RH % during the three seasons of experimentation.

During the first two months (1^{st} of Nov. to 31 Dec.), the temperatures were lower in the first season than the second one by about 2-4 C^o. However, the second season possessed lower temperature than the 3^{rd} season during the same period. The third season recorded similar higher temperatures than both first and second season by about 2-4 C^o until the Med. February. The relative humidities were generally, lower in the third season than both first ones. Third season exhibited warmer and dryer air than first two seasons. Regarding the max-min differences of temperature, slight differences were recorded among seasons, which varied from growth period to another.

Test of homogeneity

The significance of χ^2 of Bartlett test conducted to the different seasonal treatment combinations of RCBdesign for studied traits are presented in Table (1). Each season represented by six combinations (2 sowing dates and 3 planting seed rates). Thus, bi- seasonal combination included 12 environments and tri-seasonal one comprised 18 environments.

Table 1. Significance of Bartlett test (homogeneity test) of the error mean squares of different bi- and tri- seasonal alternatives of separate RCB design analyses for studied lentil traits.

Trait	Season 1 & 2 (2006-07) & (2007- 08)		Season 1 & 3 (2006-07) & (2008- 09)		Season 2 & 3 (2007-08) & (2008- 09)		3 Season (2006-2009)		Type of transformation
	Actual	Trans.	Actual	Trans.	Actual	Trans.	Actual	Trans.	
Survived plants % / plot	**	**ns**	**	**ns**	**	**ns**	**	ns	**Arc sin**
No. pods / plant	**	**ns**	**	**ns**	**	**ns**	**	ns	**Log**
Biological yield /plot (g)	**	**ns**	**	**ns**	**	**ns**	**	ns	**Log**
Seed yield / plot (g)	**	**ns**	**	**ns**	**	**ns**	**	ns	**Log**
Seed index (g)	**ns**	**----**	**ns**	**----**	**ns**	**----**	ns	----	----

n.s, ** indicate nonsignificant (homogeneous error variances) and significant at 1% level of probability of χ^2, respectively.

The actual data either bi-seasonal or tri-seasonal combinations exhibited heterogeneous error variances for all studied traits, except seed index. The alternative solutions for proper transformations were arc sin for survived plants % and log for other three traits (No. of pods/plant, biological yield/plot and seed yield/plot).

However, actual data of seed index showed insignificant χ^2, which indicate that the actual data of this trait is proper for statistical analysis. The aforementioned results of the first four traits may be due to the huge influence of environmental effects on lentil field yield attributes. These effects resulted in death of some plants and the survived ones were greatly negatively affected by such conditions. This situation is referred to infection of vascular wilt and root rot diseases. The homogeneity of fungus infestation distribution in the experimental fields was not guaranteed, which resulted in different influences on grown lentil plants. In other words, the effects ranged from complete death to slight reduction in yield attributes. However, seed index was determined using harvested seed, which may avoid direct effects of field conditions in spite of random samplinGz Thus, error mean squares of seed index were homogeneous.

Gomez and Gomez (1984) classified the heterogeneity of variances into two types: not normally distributed data and nonuniform application of distribution of the adopted treatments. The survived plants % belonged to the first type, which may be distributed as poisson ($S^2=\overline{X}$) or binomial distributions ($S^2=\overline{X}$ $(1-\overline{X})$). The data of these distributions describe one or two possible outcomes (alive or dead). However, nonuniform distribution of fungus infestation and or undetermined other factors may result in a higher variability among studied plots and consequently substantially higher or lower performance among experimental plots.

Stability analyses

The detected proper transformations for the studied traits were adopted prior performing combined analysis across 18 environments except seed index (actual data were used). The mean squares of combined analysis of variance across18 environments corresponded to the level of significance are presented in Table (2).

Table 2. Significance of mean squares of transformed data (except S.I.) of combined analysis across 18 environments (3 seasons x 2 sowing dates x 3 population seed rates)

S.O.V	d.f	Survived plants %(arc)	Pods (log)	Biological yield /plot (g) (log)	SY/plot (log)	S.I
Evironments (E)	17	1980.5**	0.402 **	0.234 **	0.684 **	14.9 **
Reps(E)	36	39.1	0.070	0.059	0.096	3.9
Cultivars (G)	4	23.8	1.528 **	0.844 **	0.225 **	2452.3 **
GxE	68	94.5 **	0.03	0.051 **	0.077 **	8.9 **
Error	144	45.1	0.029	0.017	0.018	2.4

**** indicated significantce at 1 % probability level.**

Environments were highly significant source of variation for all studied traits. This indicates that environmental conditions generated from the seasons, sowing dates and planting seed rates, affected significantly the lentil-studied traits.

The magnitudes of environmental and genotypic variances varied from trait to another. Environmental variances for survived plants % and SY/plot equal 83 and 3 fold as much as higher of respective genotypic one, respectively. Thus, environmental differences seemed to be the most important factors influencing the level of surviving and consequently the seed yield and to some extent the biological yield. On the other hand, mean squares due to cultivars were more than 3.5 fold for pods and BY/plot and 16.5 fold for S.I as of corresponding environmental variances.

On the other hand, lentil genotypes varied highly significantly for all traits, except survived plants percentage. Therefore, the studied lentil cultivars had pronounced variations for pods, BY /plot and S.I.

The performance of cultivars varied differently from one environment to another as proved by significant G x E variance for all traits except pods. Therefore, further stability analyses were performed for traits that recorded significant G x E.

The mean performance and the estimated stability measurements for studied traits are presented in Table (3).

All the investigated lentil cultivars possessed reliable resistance to root rot and vascular wilt as recorded more than 77% of survived plants. The number of pods per plant of Sinai 1 cultivar was significantly lower (13.6) than other four genotypes (more than 31). Sinai 1 recorded similar lower values of biological (1224.8 g) and seed (236.2 g) yields than other cultivars. However, 1000 seed weight (S.I.) of Sinai 1 was significantly higher (32.1 g) than other studied cultivars (about 17.0 g). It is worthy to mention that Sina 1 matured one month earlier than other cultivars. Both Sina 1 and Gz51 cultivars are considered as macrosperma seed type (Hamdi 1998). From obtained results, this was true only for Sina 1 rather than Gz 51.

Regarding the stability in performance of the investigated cultivars, CV%, Wi, bi and S^2d parameters were used as mentioned previously. According to the CV % estimates, a stable genotype is the one showing a small coefficient of variability (Becker and Léon 1988). The studied characters could be classified into 3 groups due to the magnitude of calculated CV.%. The first may be considered as environmentally highly affected traits, which showed somewhat higher percentages of coefficients of variability. This gap included survived plants% and pods (more than 15%). In contrast, biological yield recorded relatively lower CV % (about 5.0%), thus may described as environmentally tolerant trait. The rest of traits showed moderately influences of environments as about 10.0% of CV.% (seed yield and seed index). In spite of this general view, cultivars showed variable magnitudes of CV% that differed by traits. In this concern, lower CV.% was exhibited by Sina 1 for survived% (15.7%), Gz 51and Gz 9 for pods (11.8 & 11.4%), Gz9 for BY (3.9%), Gz 370 for SY (8.5%) and Sina 1 and Gz 51 for S.I (7.6 & 7.3%). However, higher CV.% were recorded by Gz 9 and Gz 370 for survived% (21.6 & 22.1%), Sina 1 for pods (16.9%), Sina 1 and Gz 9 for BY (6.9 and 6.1%), Gz 4 and Gz 9 for SY (12.0 and 12.2%) and Gz 4 for S.I (11.4%). These cultivars may be considered as moderately performed for corresponding traits. The tested genotypes exhibited different stability measured by CV.% for pods though lacking of G x E significance .Due insignificant G x E interaction for number of pods, this trait will be excluded from discussion for other stability parameters.

Regarding the ecovalence (W_i) as a parameter of stability proposed by Wricke(1962),which measures the contribution of each genotype to the G x E interaction. The significance (either at 5% or 1%) corresponding to Wi means unstable performance across environments. In other words, Wricke considered the stable genotype that possess high ecovalence or Wi= 0.0. Accordingly, cultivars Sini1 and Gz9 recorded significant. W_i i.e. instability for all four traits. However, the other three cultivars showed similar instability in performance (measured by Wi) commonly for BY and SY in addition to Gz4 for S.I and Gz370 for survived%. This means that all the recommended lentil varieties were unstable in performance across the studied environmental conditions for biological and seed yield. Moreover, three of these cultivars, i.e. Sinai 1, Gz 9 and Gz370 were unstable for surviving %, though lack of significance among genotypes for this trait. Sinai 1, Gz4 and Gz9 recorded similar instability for S.I. The investigated cultivars were recommended according to reliable production and stability as reported by Abo- Elwafa (1999) .

Eberhart and Russell's (1966) model considered (b) as a parameter of response and S^2d as a parameter of stability. Giza 4 and Gz370 seemed to be significantly responsive to favorable conditions than other cultivars for SY and SI, respectively. This is the outcome of significant positive b coefficients (more than unity) for these traits. However, Sinai1 recorded significant negative b (less than unity) for survived plants % , which is an indication of better performance under the environment with lower infestation of wilt diseases.

Table 3. Mean performance and stability parameters across 18 environments for studied lentil cultivars

traits	CVs	Sina 1	Giza 51	Giza4	Giza 9	Giza 370
Survuved plants / plot (Arc sin)	Mean[1)]	79.2	79.7	77.5	77.9	78.5
	CV %	15.7	17.7	19.1	21.6	22.1
	W_i [2)]	149.60**	76.18	47.43	95.12 *	104.12 **
	b[3)]	0.74 **	0.926	1.011	1.137	1.186
	S^2d[4)]	17.893**	5.775**	-1.62 ns	9.26**	9.62**
pods per plant (log)	mean[1)]	13.6[b]	34.0 [a]	31.6 [a]	32.1 [a]	31.5 [a]
	CV %	16.9	11.8	14.9	11.4	13.7
	W_i [2)]	0.064	0.015	0.028	0.026	0.015
	b[3)]	0.781	0.975	1.212	0.888	1.144
	S^2d[4)]	0.007	-0.006	-0.003	-0.003	-0.006
Biological yield (log)	mean[1)]	1224.8 [c]	2328.4 [a]	2251.9 [ab]	2072.6 [b]	2228.4 [a]
	CV %	6.9	3.9	4.8	6.1	4.7
	W_i [2)]	0.084 **	0.029 *	0.033 *	0.085 **	0.038 **
	b[3)]	1.2	0.81	1.033	0.997	0.96
	S^2d[4)]	0.017	0.002	0.003	0.015	0.005
Seed yield (log)	mean[1)]	236.2 [b]	352.9 [a]	365.2 [a]	362.7 [a]	324.1[a]
	CV %	10.5	9.8	12.0	12.2	8.5
	W_i [2)]	0.163 **	0.044 **	0.046 **	0.077 **	0.054 **
	b[3)]	0.658	1.011	1.308 **	1.212	0.812
	S^2d[4)]	0.035	0.007	0.003	0.014	0.008
Seed index	mean[1)]	32.1 [a]	17.1 [c]	16.5 [d]	16.7 [cd]	18.1 [b]
	CV %	7.6	7.3	11.4	10.0	9.4
	W_i [2)]	25.8**	3.3	6.3**	5.6 **	3.6
	b[3)]	0.1	0.84	1.4	1.16	1.5 *
	S^2d[4)]	5.57 **	0.11	0.79	0.75	-0.04

1)Actual data are presented , but transformed ones were analyzed except S.I . Means in the same row followed by the same letter/s are not statistically different at 0.05 level of probability.
2)* and ** = significant unstable at 5% and significant at 1%, probability level, respectively.
3)* and ** indicate significant at 5% and 1% of regression coefficient from unity, respectively.
4) = significant at 1% for deviation of regression from zero.**

Judging by the Eberhart and Russell's parameter of stability viz.S^2d, all cultivars showed stable in performance for BY and SY. Similar stability could be observed for seed index of all cultivars except Sina 1 as proved by insignificant and significant S^2d from zero, respectively. On the contrary, all cultivars except Gz4 recorded highly significant S^2d for survived % , which was reflected in instability for this character.

The above-mentioned results proved that most of studied lentil yield and yield components under the conditions of wilt diseases infestations need transformation to confirm the assumptions for statistical analysis. The ignorance of needed data transformation may reflect in misleading results and conclusions. Such precise of statistical procedures in lentil trials will contribute greatly to better performance of resultant promising genotypes and consequently lentil production.

According to the investigated stability measurements, variable conclusions were obtained. Regarding the CV.% as a measure of stability, a narrow range of CV values were detected. Thus this parameter is not very suitable for differentiating among genotypes, particularly with transformed data. The limitation of CV% is dependent upon the inverse relation to the average performance of the trait. Thus different genotypes had variable mean performance and similar standard deviation show variable CV.%.

The other three parameters, i.e. W_i, b and S^2d considered as dynamic or agronomic concept of stability (Becker and Léon 1988). In this concept, the stable genotype possesses a change or response which is not deviated from estimated level of each environment, and that is not necessary equal for all genotypes. However, the other concept of stability termed static or biological one, which describe the stable genotype that shows no deviation from the expected character level, which means that its variance among environments, is zero (Becker 1981).

From the obtained results the ecovalence seemed to be the most proper stability parameter for differentiating lentil genotypes rather than Eberhat and Russel's two parameters. This may be due to that the data transformation narrowed the variability among environments. This variation is an important factor for validating the regression analysis in stability studies (Pfahler and Linskens 1979). However, ecovalence represents the proportion of the entry x environment sum of squares attributed to each genotype. Thus such interaction greatly depends on the mode of genotype performance across different environments.

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طرق بيومترية لتقديرثبات اداء بعض اصناف العدس المصرية

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اجريت الدراسة لتقييم الثبات و القدرات الانتاجية لاصناف العدس المسجلة حديثا و المنزرعة في مصر تحت ظروف بيئية مختلفة باستخدام بعض مقاييس الثبات . حيث اقيمت ثلاث تجارب حقلية خلال ثلاثة مواسم زراعية متتالية هي 2006–2007 , 2007–2008 و 2008–2009 بمحطة التجارب و البحوث الزرعية بكلية الزراعة – جامعة القاهرة – الجيزة .باستخدم تصميم القطع المنشقة مرتين في توزيع القطاعات الكاملة العشوائية بوضع عوامل الدراسة الثلاثة لكل تجربة كالتالي:القطع الرئيسية ممثلة في 2 ميعاد للزراعة هما (اول و منتصف نوفمبر) , والقطع المنشقة في ثلاث معدلات للتقاوي (300–450–600 نبات/ المتر المربع) والقطع تحت المنشقة في خمسة

اصناف من العدس (سيناء 1-جيزة 51- جيزة 370- جيزة 9 -جيزة 4) في ثلاث مكررات. و بذلك تم عمل التوليفات الممكنة من 6بيئات (2 ميعاد زراعة X 3 معدلات تقاوي) لكل موسم بواقع 18 بيئة في الثلاث مواسم .

- بالرجوع الي بيانات الطقس المتمثلة في درجات الحرارة و الرطوبة النسبية خلال مواسم زراعة التجربة الثلاث نجد انخفاض في درجات الحرارة بمعدل 2-4 درجة خلال شهر من الزراعة (ديسمبر) عن مثيلتها في الموسم الثاني و الثالث, وفي الموسم الثالث سجلت ارتفاع في درجات الحرارة عن مثيلتها للمواسم الاخرى بمعدل 2-4 درجة ايضا وذلك خلال مرحلة التزهيرو بداية نضج المحصول في منتصف فبراير, في حين كانت الرطوبة النسبية اقل في السنة الثالثة عن الاولى و الثانية.
- تم تسجيل صفات المحصول و كانت ممثلة في غلة محصول البذور ووزن المادة الجافة الكلية للنباتات و وزن الالف بذرة و عدد البذور في النبات الفردي علاوة علي النسبة المئوية لعدد النباتات في القطعة التجريبية بعد شهر من الزراعة.
- اظهرت تحليل الاختلاف لكافة البيئات مع جميع الصفات أن هناك تباينات معنوية بين الاصناف تحت الدراسة عدا صفة النسبة المئوية لعدد النباتات بعد شهر من الزراعة بالاضافة الى ان التفاعل بين اداء الاصناف عبر البيئات المختلفة كان معنويا فيما عدا صفة عدد القرون الامر الذي ادى الي استخدام مقياس معامل الاختلاف النسبى والمكافىء البيئى وتحليل الانحدار كمقياس لثبات اداء الاصناف عبر البيئات المختلفة,حيث اظهرت النتائج ترجيح الثبات لاصناف في بعض الصفات عن غيرها من الاصناف اخرى علاوة على عدم الاعتماد بشكل تام على كلَ من الاختلاف النسبى وتحليل الانحدار كمقياس للثبات السبب الاولى ضيق قاعدة التباين لها نتيجة لاستخدام اسلوب تحوير البيانات للصفات و السبب الثاني لاتساع التباينات بين البيئات . كان المقياس الاكثر تفضيلا للثبات الية هو مقياس المكافىء البيئى .

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