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Stability analysis by TAI method for some genotypes in Flax (Linum usitatissimum L.)

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ABSTRACT

This research was conducted to estimating the stability of eight new genotypes of flax, which are Sakha 1, Sakha 2, Sakha 3, Sakha 5, Sakha 6, Giza 8, Syrian and Poloni . The genotypes were planted in the research station of the Field Crops Department, College of Agriculture - University of Tikrit during the season (2019/2020), It included six agriculture environments, which are the combination of two planting distances (5 and 10 cm) and three planting dates, and it was applied according to the split-plot system in the Randomized Complete Block Design (RCBD) with three replicates. Plants were distributed in separate plots by four lines for each genotype in each environment, were the length of the line was (2 m) and the distance between the lines was (0.40 m). The main plots contained agricultural environments and the sub plot contained the genotypes. The study included thirteen traits, the duration to 50% flowering and plant height, the number of vegetative branches, and the number of capsules per plant , Number of seeds per capsule, seed yield per plant, The 1000 seed weight, average leaf weight, biological yield, leaf percentage, seed yield, and harvest index. The results showed that the genotypes that occurred in the α area , which were of moderate stability, were (Sakha 2) in the traits of plant height, (Syrian and Sakha 3) in the number of vegetative branches, (Sakha 2 and Sakha 5) in the number of seeds per capsule and (Sakha 1 ,Giza 8) in average the leaves weight and (Sakha 3 and Sakha 1) in the percentage of leaves and (Sakha 5 and Poloni) in the harvest index, The genotypes that are adapted to environments with high productivity were shown as (Sakha 5 and Poloni) in duration to 50% flowering, (Syrian) in plant height, (Giza 8) in the period to maturity, (Sakha 3, Giza 8) in the number of capsules and (Syrian and Sakha 3 and Sakha 1) in The number of seeds per capsule, (Syrian and Sakha 3) in the seed yield of the plant, (Sakha 6) in the weight of 1000 seeds, (Poloni) in the average leaf weight, (Sakha 3) in the biological yield, (Giza 8) in the leaf percentage, and (Syrian and Sakha 6) in the seed yield and (Syrian) in the Harvest index.

INTRODUCTION

Flax or Linseed is one of the oldest plant crops known to Human and has been cultivated since ancient times to take advantage of oil or fiber or both. Which consists of 13 genera and 300 species (Raddy et al., 2013), its scientific name is (Linum usitatissimum L.).Flaxseeds are classified among the important functional foods for their abundance of many nutrients compared to other vegetable oils, such as unsaturated fatty acids, protein and lignans. Therefore, it is unique among oilseeds due to its high content of fixed oils for the fatty acid (Alpha-Linolenic Acid ALA) and its percentage ranges from (30 45)% of the oil, which makes up about 57% of the total fatty acids (Simmons et al., 2011) . Plant breeders are interested in introducing genotypes that perform well under variance environmental conditions, and that the ability to develop stable, high-yield

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cultivars is the main focus of most breeding programs, and in the end, it is more important than identifying unstable cultivars. This is achieved by working on the development of cultivars that are characterized by high productivity and the continuous development and introduction of new genotypes that can be adopted in agriculture with the aim of any of them being an alternative to the cultivars that may deteriorate due to continuing to cultivate it for several seasons. Where the phenotypic differences resulting from genetic differences between cultivars or between genotypes may decrease or increase significantly under the influence of environmental factors. However, the response of genotypes to changes in environmental conditions and the consequent instability of their traits under different environmental conditions causes difficulties for plant breeders in determining the excelled ones, and accordingly, estimating stability is one of the important criteria that plant breeders must take into account .In this regard, Yadav et al. (2000) investigated the phenotypic stability of the yield traits of ten genotypes of flax seed in three locations and determine the stability, T397, Garima, and ES44 showed stability of seed yield by the plant and the stability in yield was related to stability in the crop components such as early growth trait, days to 50% of flowering, vegetative branches of the plant, days to maturity, number of seeds per capsule. In this study, El Mohsen and Amein (2016) confirmed their analysis to estimate the interaction between the genotype and environmental , and determine the stability of genotypes. It was found that the cultivar Sakha 1, Sakha 3 and Giza 9 was stable for all the studied traits. When estimating the phenotypic and genetic stability values according to the Russell and Eberhart method (1966) and the Tai method (1971), El-Hosary et al. (2016) showed sixteen genotypes of flax (13 strains and 3 commercial cultivars were used as control cultivars), Whereas, the estimated variation to the environments and genotypes and the interaction between them were significant in all the studied traits. E1 gave the highest seed yield for the plant, the highest oil yield, and E2 the highest value for oil percentage and the highest seed yield value. Nine strains gave high significant values of seed yield and seed yield, While there was no significant interaction between genotypes and environments or a deviation from the regression line with respect to the seed yield trait of the individual plant and the seed yield. The aim of the current study is to know the stability of eight genotypes of Flax in six different environments that included three planting dates and two planting distances. According to the model (Tai1971), which uses alpha α and λ to evaluate thirteen genotypes and choose the genotypes that combine high yield and stability to determine the best cultivars that can be used as useful genetic resources in the flax breeding program and to clarify them with detailed graphs.

Materials and methods

In this study, 8 Flax genotypes were used, six genotypes of which were introduced and sourced from the Arab Republic of Egypt, Cairo University, College of Agriculture, Department of Field Crops, and two cultivars from Iraqi Kurdistan, College of Agriculture, Salah Al-Din University. The details are shown in Table (1), It was planted in six environments, which is the combination between three planting dates (November 10, November 25 and December 10) and two planting distances (5 and 10) cm. The experiment was conducted according to the arrangement of split plots with a randomized complete block design (R.C.B.D.).The main plots included the agricultural environments and the subplots of genotypes and with three replicates after preparing the experiment land by plowing it perpendicularly tillage , smoothing , leveling and dividing it into replicates by four lines in each experimental unit, where the length of the line was (2 m) and the distance between the lines was (0.40 m),The experiment land was fertilized with phosphate fertilizer at an average of (80 P_2O_5 kg.ha^{-1}) with a form of triple superphosphate (P_2O_5% 45) at a level of 80 kg.ha^{-1} (Grant et al., 2010), It was added in one batch with tillage , and nitrogen fertilizer was added at an average of (200 N kg.ha^{-1}) using urea fertilizer (with nitrogen content of N46%) and in two batches (Hassan and Shaker, 2013),and Table (1) shows the eight genotypes. The study was conducted on (10). Plants were taken randomly from the two middle lines for each experimental unit and the study included the following traits:

1- Plant height (cm.$Plant^{-1}$): The height was measured in centimeters from the base to the end of the main stem (the plant top) in the stage of maturity and its average was recorded.

2- Duration to 50% flowering (day): The number of days was recorded from the date of the first irrigation until 50% of the plants of the experimental unit flowered.
3- Duration to maturity (day): The number of days was recorded from the first irrigation until the physiological maturity of the plants of the experimental unit.
4- Number of vegetative branches (branch. plant^{-1}): The number of branches was counted from the base of the main stem of each plant and their average was recorded.
5- Number of capsules (capsule. plant^{-1}): The total number of capsules was calculated from ten randomly selected plants for each experimental unit and the average value was obtained.
6- The number of seeds (seed.Capsule $^{-1}$): The total number of seeds was calculated in ten randomly selected capsules for each of the ten plants that were randomly assigned from each experimental unit and their average was calculated.
7- Seed yield (g.Plant^{-1}): The individual plant yield was recorded by weighing the seeds of each plant from ten randomly selected plants after the lesson and calculating their average.
8- Weight 1000 seeds (g): 1000 seeds were weighed in grams using a sensitive scale after seeds were taken randomly from each plant.
9- Average leaf weight (g): The weight of the dry leaves, after sun drying, was recorded for ten plants that were randomly taken in the stage of physiological maturity, and then the average value was calculated.
10- Biological yield (g): represents (weight of dry matter). Ten dried plants were weighed randomly on the sun, and then the average weight of each plant was calculated (g).
11- Leaf percentage (%): It was measured from the dry leaf weight / dry matter weight at harvest to obtain the average value as a percentage.
12-Seed yield (kg.ha^{-1}): The yield per hectare of seeds was estimated according to the following equation:

$$\textbf{Seed yield (Kg.ha}^{-1}\textbf{)} = \frac{\textit{Individual plant yield} * 10\text{g}}{\textit{The area occupied by the plant}}$$

13-Harvest index = seed yield per plant (g) / biological yield (g) x 100

Table (1) The items used in the study have their source and lineages

Lineages	Source	Origin	Cultivars Name	Cultivars number
I.1485 x Bombay	College of Agriculture - Cairo University	Egyptian	Sakha 1	1
Hera × 1.123	College of Agriculture - Cairo University	Egyptian	Sakha 2	2
Belinka (2E) × 1.2096	College of Agriculture - Cairo University	Egyptian	Sakha 3	3
Belinka (R3) ×1.2569	College of Agriculture - Cairo University	Egyptian	Sakha 5	4
S.420 x bombay (I. USA)	College of Agriculture - Cairo University	Egyptian	Sakha 6	5
Giza6 × Senta Catalina	College of Agriculture - Cairo University	Egyptian	Giza 8	6
Imported	College of Agriculture - University of Salahaddin	Syrian	Syrian local	7
Imported	College of Agriculture - University of Salahaddin	Polonian	Thorshansity72	8

Stability analysis by Tai (1971)

The stability model of Tai (1971), which evaluates the interaction between genetics and environment to effects of the genotype, which depends on two components, namely the linear response to environmental influences (α), and the deviation from the linear response from the proportions of the variance size and describes (λ) lambda. Genotypes over Alpha-Lambda distances in different locations and are an indication of their stability. The horizontal axis is λ while the vertical is for α, and the curves are the limits for predicting α = 0 at probability levels 0.90, 0.95, and 0.99 respectively, so the genotypes that fall in the region (α) are not significantly different from zero (0 = α) and (λ) It does not differ significantly from the unit (λ =1) It has moderate stability. Whereas if the genotypes have values of α> 0 and λ =1, meaning that -1 = α and λ =1, then these cultivars have above-average stability and their stability is certain and respond even in poor environments, As for where the stability parameters are 0 <α and λ =1, meaning that the values of α are significantly higher than zero and the values of 1 =, their stability is less than the average of the genotypes included in the study, but if the values of differing significantly from the one + 1 > λ and that α = 0. These genotypes are adapted to high productivity environments.

Results and discussion

The stability of the genotype was measured, which computes the most extreme stability statistics for the traits under study according to the model (Tai1971) that uses alpha α and lambda λ that were evidenced by the graphs and according to the sequence of genotypes in the study shown in Table (1).

Duration to 50% flowering (day)

The graphical analysis in Fig. 1 showed that genotypes No. 1 and 6 are less stable than the average with a probability of 95%, and genotypes no. 2 has the lowest average stability with a probability of 99% among the average genotypes stability , and this means that these genotypes are less stability than the average the genotypes included in the study, While genotypes 4 and 5 had values of α <0 and λ = 1, this means that these genotypes are stable above average and their stability is confirmed and responsive even in poor environments, and genotypes 3 and 8 were unstable according to (Tai 1971) because A value of λ ≠ 1, this finding is in agrees with (Abo-Kaied et al., 2015).

Plant height (cm)

The results indicated in Fig. (2) that the genotype No. (1) showed the average stability, i.e. α does not differ significantly from zero 0 = α and the extent of is not significantly different from one = 1, and this means that this genotype has moderate stability, Genotypes 3, 4 and 5 showed that they have a stability degree above the mean 0> α and λ=1, which means that these genotypes are above average stability and their stability is confirmed and respond even to poor environments, While the genotypes 6, 7, and 8 were less stability than the mean 0 <α and 1 = λ that the values of α were significantly higher than zero and λ=1, this means that these genotypes are less stability than the average of the genotypes included in the study. As for the genotype (2), it was not stable according to (Tai, 1971) because the value of λ =1, this result agreed with what was stated by (Yadav et al., 2014).

Duration to maturity (day)

Figure (3) gives a graphical summary useful in determining genetically stable genotypes, where the results indicated that genotypes 3, 5 and 8 were stable above the mean α <0 and λ = 1, and this means that these genotypes are stable and respond until for poor environments, While genotypes 1, 2 and 4 were less stability than the average genotypes included in the study, where for genotype (7), its results indicate that it is an unstable cultivar, and this result is in line with its findings (Abo-Kaied et al., 2015).

Number of vegetative branches (branch. Plant^{-1})

Regarding this trait, Figure (4) shows that the two genotypes 2 and 4 showed moderate stability, which means that α does not differ significantly from α =0 and λ = 1and that they are of moderate stability. 90%,As for each of the genotypes 5, 7 and 8, they had higher stability than average as they had a value of 0> α and λ = 1. Therefore, these combinations are above average stability where their stability is certain and respond even to poor environments, while genotypes 1 and 6 and gave stability less than the mean stability because the value of significant α is higher than zero α> 0. According to the Tai method (1971).

Number of capsules (capsule.plant^{-1})

The graphical analysis of Figure (5) showed that all the genotypes under study were divided into groups. The first group took the genotypes No. 4 and 7 with a value of λ ≠1. Therefore, these genotypes can be classified as unstable and adapted to environments with high yield of capsules according to the Tai method. , 1971) and the second group includes the genotype (3), which showed stability above the average α <0 and λ = 1. This means that this genotype has a certain stability and responds even in poor environments, while the third group included the genotypes 1, 2, 6 and 8, as shown in the figure. It had less stability than the average of the genotypes included in the study, meaning that the value of α> 0 and λ = 1.

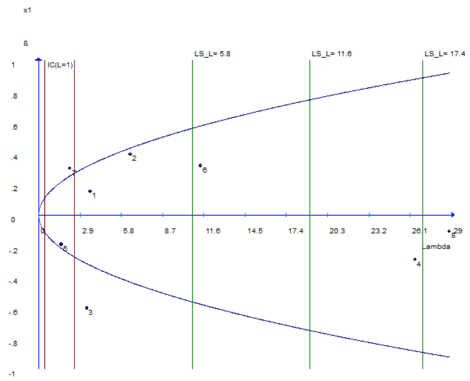

Figure (1): Distribution of genetic stability statistics for the duration trait to 50% flowering of flax genotypes.

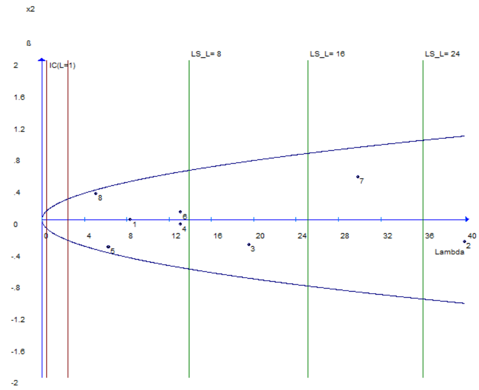

Figure (2): Distribution of genetic stability statistics for plant height characteristic of flax genotypes.

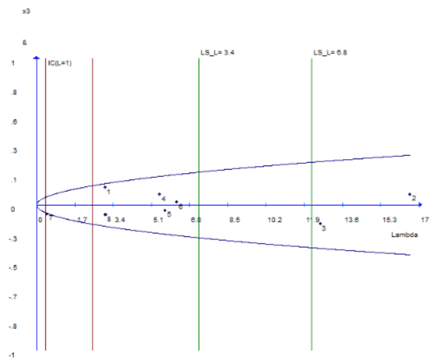

Figure (3): Distribution of genetic stability statistics for the duration to maturity trait of linen genotypes.

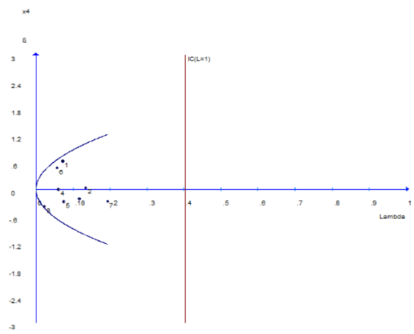

Figure (4): Distribution of genetic stability statistics for the number of vegetative branches characteristic of linen genotypes.

Number of seeds (seed. capsule^{-1})

Figure (6) shows the relationship between α and λ according to (Tai, 1971). Thus, it becomes clear that the two genotypes 1 and 3 were located in the average region of stability and that (α) did not differ significantly α=0 and (λ) did not differ significantly from the one λ=1, and composition No.8 has the lowest average stability with a probability of 99% of the mean stability of the compositions which indicates their moderate genetic stability compared to other genotypes, and it was found that genotype (5) was more stable than average stability and with a value of α <0 and λ =

1, so this pattern responds even to poor environments, while genotype (7) was recorded less than the average stability that contains values of α> 0 and λ = 1,While the genotypes 2, 4, and 6 gave a mean that differed significantly from the one ((λ 1), indicating that these genotype are instability and only adapt to high-productivity environments. This result is partially consistent with the results reached by (El-Hosary et al., 2016).

Seed yield (plant.g^{-1})

The graph in Fig. 7 indicates that the genotypes 2 and 4 were unstable because the value of λ ≠ 1, and the genotypes 3 and 5 showed a degree of stability above the mean α> 0 and λ = 1,This means that these genotypes respond even in poor settings. While genotypes No. 1, 6 and 8 recorded the lowest value of the mean of stability than the mean of the genotypes included in the study, and that the value of α was higher than zero and the significance of α> 0 and λ = 1. This results agrees with (Yadav et al., 2014).

The 1000 seeds weight (g)

The graphic analysis of Figure (8) showed that all the genotypes under study were divided into three groups. The first group took the genotypes 1, 2, 7 and 8 that were less stability than the average genotypes in the study, meaning that the value of α> 0 and λ = 1,While the second group showed genotypes 3 and 4, which showed stability above the average, α <0 and λ = 1.This means that these genotypes are stable and respond even in poor environments. The group included genotypes 5 and 6 which were unstable because the value of λ ≠ 1, so these genotypes can be classified as unstable and adapted to high productivity environments according to the method (Tai, 1971).

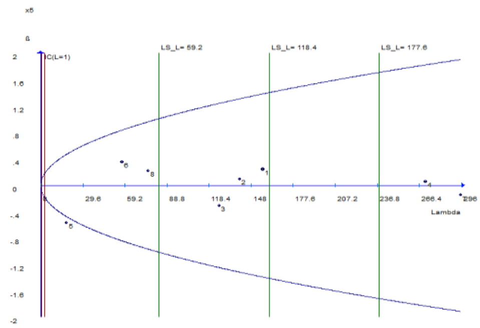

Figure (5): Distribution of genetic stability statistics for the number of capsules per plant for flax genotypes.

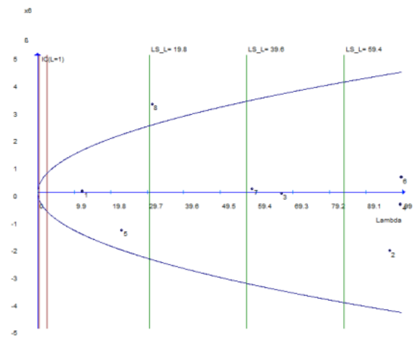

Figure (6): Distribution of genetic stability statistics for the number of seeds per capsule for flax genotypes.

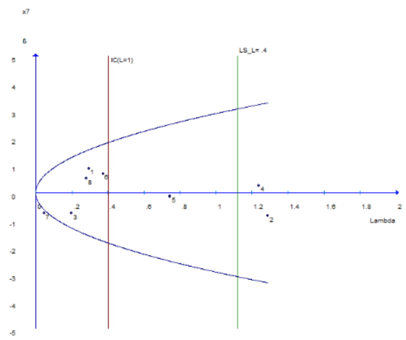

Figure (7): Distribution of the genetic stability statistics of the seed yield trait of the plant for flax genotypes.

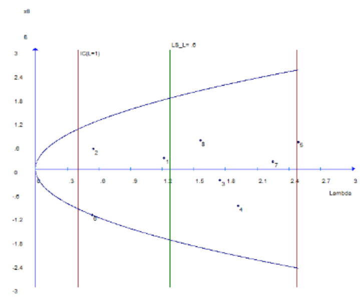

Figure (8): Distribution of genetic stability statistics for a 1000-seed weight trait for linen genotypes.

Average leaf weight (gm)

Figure (9) shows that genotype 6 and 7 showed average stability between α = 0, which does not differ significantly from zero and for λ= 1, and this means that these two genotypes have moderate stability, while genotypes 3 and 4 were stable above the average α <0 and λ = 1, which responds even in poor environments, While the genotypes No. 1, 2 and 5 showed less stability than the average genotypes in the study, and genotype No. (8) recorded a mean value of λ ≠ 1, which indicates that it is genetically unstable and adapts to high productivity environments according to (Tai, 1971).

Biological yield (g)

The graph in Fig. 10 showed that the genotypes No. 2, 3, 5, 6 and 7 had higher stability than the mean α <0 and λ = 1 and that these genotypes are stable above average and their stability is certain and respond even to poor environments, and genotypes No. 1 and 8 were less than average stability because the value of α is significant and higher than zero (α> 0),Therefore, these genotypes have stability less than the average of the genotypes included in the study, and the genotype (4) record a value of λ ≠ 1 and can be classified as genetically unstable and adapted only to environments that are characterized by high productivity. These results agrees with (El-Hosary et al., 2016).

Percentage of leaves (%)

The results in the graph in Fig. (11) indicate that the two genotypes No. 4 and 6 showed moderate stability, which means that α does not differ significantly from zero and for the λ = 1, which means that these aforementioned genotypes are of moderate stability. Genotypes No. 3 and 5 have a degree of stability above the mean α <0 and λ = 1 with a probability of 90%, and genotype number 2 is higher than the average stability with a probability of 99%, so their stability is confirmed and responds even to poor environments. While genotypes No. 1 and 8 were less stable than the average with a probability of 90%, and genotype 7 was genetically unstable due to the difference from the one λ ≠ 1, which adapts to high production environments according to (Tai, 1971).

Seed yield ($kg.ha^{-1}$)

Figure (12) shows each of the genotypes No. 3, 4, 7 and 8 had above average stability, so their stability is certain and responds even in poor environments because the value of α is below zero (α <0). As for the genotypes No. 1 and 6, they had a degree of stability less than the average stability because the α value was higher than zero and the significance of α> 0 and λ =1.While both genotypes No. 2 and 5 are genetically unstable, because the value of λ differs significantly from one λ ≠ 1 and that α= 0. This means that genotypes 2 and 5 are adapted in high-productivity environments. This results agrees with (El-Hosary et al., 2016).

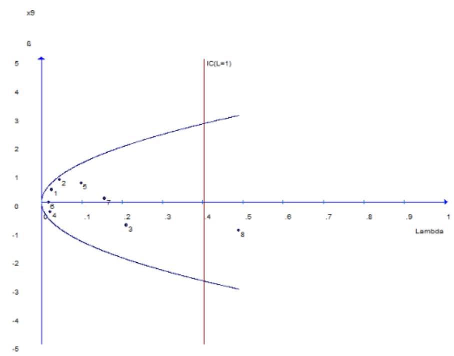

Figure (9): Distribution of genetic stability statistics for average leaf weight trait for linen genotypes.

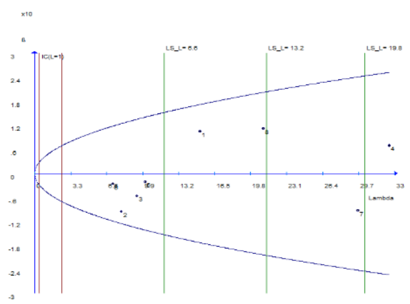

Figure (10): Distribution of genetic stability statistics for the biological yield characteristic of linen genotypes.

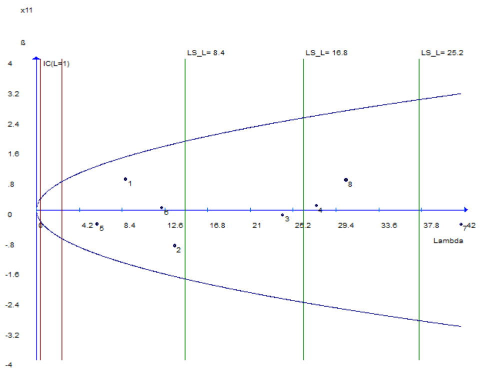

Figure (11): Distribution of genetic stability statistics for the leaf ratio characteristic of linen genotypes.

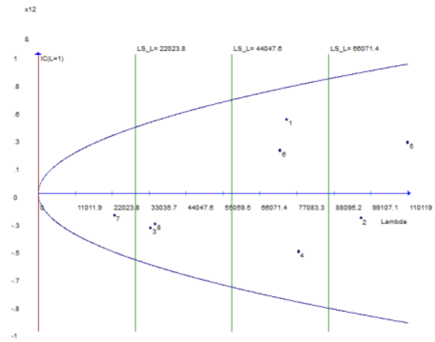

Figure (12): Distribution of genetic stability statistics for the seed yield trait of flax genotypes.

Harvest index (%)

The two genotypes in the graph showed (Fig. 13) No. 3 and 8 have moderate stability for their location in the α area, which does not differ significantly from zero, and this means that these two genotypes are of moderate stability as these types contain values of α = 0 and λ = 0,While genotype 1 and 6 gave less stability than the mean, where the values of α are significantly higher than zero, and significantly α> 0, and the values of λ= 1, their stability is less than the average of the genotypes included in the study. And that genotype No. 2 was unstable λ ≠ 1, so this genotype is adapted to environments with high productivity in this trait. This finding is consistent with his findings (Abo-Kaied et al., 2015). This information about the set of genotypes that was adopted in the study can be used in breeding programs to improve crop traits and develop new cultivars with outstanding performance in a wide range of environmental conditions in Iraq.

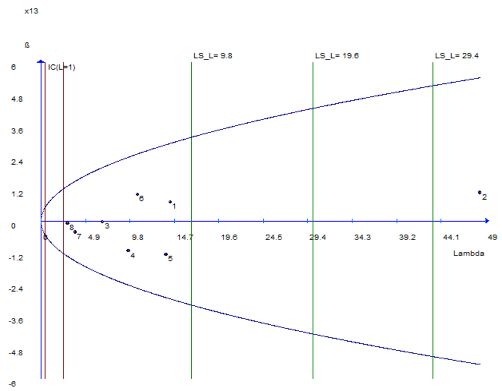

Figure (13): Distribution of the genetic stability statistics for the harvest index trait for linen genotypes.

We conclude from the foregoing that the genotypes that occurred in the α region, which were of moderate stability, were (Sakha 2) in the trait of plant height, (Syrian and Sakha 3) in the number of vegetative branches, (Sakha 2 and Sakha 5) in the number of seeds per capsule and (Sakha 1 Giza 8) in average weight leaves and (Sakha 3 and Sakha 1) in the percentage of leaves and (Sakha 5 and Poloni) in the Harvest Index, and genotypes that are adapted to environments of high productivity, they are (Sakha 5 and Poloni) in duration to 50% flowering, (Syrian) in plant height, (Giza 8) in period to maturity, (Sakha 3 and Giza 8) in the number of capsules, and (Syrian ,Sakha 3 and Sakha 1) in the number of seeds per capsule and (Syrian and Sakha 3),In the seed yield of the plant, (Sakha 6) in the weight of 1000 seeds, (Poloni) in the average weight of leaves, (Sakha 3) in the biological yield, (Giza 8) in the percentage of leaves, (Syrian and Sakha 6) in the seed yield, and (Syrian) in the harvest index. All these results are in line with the findings of (Yadav et al., 2014), (Abo-Kaied et al., 2015) and (El-Hosary et al., 2016) according to the method of Tai (1971).

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تحليل الأستقرارية بطريقة TAI لبعض التراكيب الوراثية في الكتان

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الخلاصة

الكلمات المفتاحية: الكتان ، الأستقرارية الوراثية ، التراكيب الوراثية .

نفذ هذا البحث لتقدير الأستقرارية في ثمانية تراكيب وراثية جديدة من الكتان هي سخا1 و سخا2 و سخا3 و سخا5 و سخا6 و جيزة8 و سوري و بولوني ، زُرعت التراكيب الوراثية في المحطة البحثية التابعة لقسم المحاصيل الحقلية كلية الزراعة - جامعة تكريت خلال الموسم (2019 / 2020) ، شملت ست بيئات زراعية وهي التوليفة لمسافتين زراعية (5 و10) سم وثلاثة مواعيد زراعة وتم تطبيقها وفقاً لنظام الالواح المنشقة في تصميم القطاعات العشوائية الكاملة (R.C.B.D.)وبثلاثة مكررات ، وزعت النباتات في الواح

منفصلة بواقع أربعة خطوط لكل تركيب وراثي في كل بيئة حيث كان طول الخط (2 م) والمسافة بين الخطوط (0.40 م) احتوت القطع الرئيسية البيئات الزراعية والقطع الثانوية التراكيب الوراثية وتضمنت الدراسة ثلاثة عشر صفة هي المدة الى ازهار 50% وارتفاع النبات وعدد الافرع الخضرية وعدد الكبسولات بالنبات وعدد البذور بالكبسولة وحاصل البذور بالنبات ووزن 1000 بذرة ومعدل وزن الاوراق والحاصل البيولوجي ونسبة الاوراق وحاصل البذور ودليل الحصاد. أظهرت النتائج أن التراكيب الوراثية التي وقعت في منطقة α والذي كانت ذو استقرارية معتدلة هي (سخا2) في صفة ارتفاع النبات و(سوري و سخا3) في عدد الافرع الخضرية و (سخا2 وسخا5) في عدد البذور بالكبسولة و(سخا1 وجيزة8) في معدل وزن الاوراق و(سخا3 وسخا1) في نسبة الاوراق و(سخا5 وبولوني) في دليل الحصاد ، وأظهرت التراكيب الوراثية التي تتأقلم للبيئات ذات الانتاجية العالية فهي (سخا5 وبولوني) في المدة الى ازهار50% و(سوري) في ارتفاع النبات و(جيزة8) في المدة الى النضج و(سخا3 وجيزة8) في عدد الكبسولات و(سوري وسخا3 وسخا1) في عدد البذور بالكبسولة و(سوري وسخا3) في حاصل البذور بالنبات و(سخا6) في وزن 1000 بذرة و(بولوني) في معدل وزن الاوراق و(سخا3) في الحاصل البيولوجي و(جيزة8) في نسبة الاوراق و(سوري وسخا6) في حاصل البذور و(سوري) في دليل الحصاد .