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Evaluation of Greenmass Yield of Some Soybean Varieties by Ammi Analysis Method

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Abstract
This study was carried out with 4 soybean varieties in four different locations (Adana, Antalya, Manisa, Samsun) according to the Randomized Complete Block Design with six replications. In the study, the variation of greenmass yield of genotypes according to locations was evaluated with AMMI (Additive Main Effects and Multiplicative Interactions) analysis model. According to the analysis of variance genotype, environment, genotype×interaction and PC1 were found to be statistically significant. The greenmass yield for locations varied between 3064-5482 kg da^{-1}, the highest yield was obtained from Adana location, and the lowest yield was obtained from Samsun location. The greenmass yield of the varieties varied between 3918-4520 kg da^{-1}, the highest yield was obtained from 1530 (Yemsoy) variety and the lowest yield was obtained from Türksoy variety. In the AMMI analysis, PC1 accounted for 77.11% of the variation. According to the results obtained with the AMMI analysis, it was determined that the variety 1530 (Yemsoy) had the highest yield in the average of all four locations, while the Nazlıcan variety was above the average (vertical) curve and had high values. The variety 1530 (Yemsoy) was the most stable and the varieties 517 (Yeşilsoy) and Türksoy were far from the stability (horizontal) curve. Three locations, except Manisa location, are located in the same Mega-environment.

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1. Introduction

Soybean is an annual warm climate plant belonging to the legume family. Soybean is one of the plants with the highest production (61%) among oilseed plants and is among the 5-6 most important plants in the world in terms of plant food source (Lopes da Silva et al., 2017; Yaşar and Sezgin, 2022a). It is the world's leading source of high-quality protein and edible oil for both human food and animal feed. Due to the ability of soybean as a legume plant to benefit from nitrogen in the air, it can increase soil fertility for the plants to be planted after it by adding nitrogen to the soil (Morsy et al., 2015; Yaşar and Sezgin, 2022b).

Soybean is used as hay, silage, grazing, cover crop and green manure. The pulp remaining after the oil is taken from the seeds is very valuable in terms of adding it to animal nutrition and feed rations. Soybean pulp is an important protein source in the nutrition of cattle and small animals, the poultry industry and pet animals. In addition to its grains, greenmass is also used as animal feed. Late maturing and abundant leafy soybean varieties are loved and consumed by animals. Lactating dairy cows and growing heifers show similar performance when soybean hay or alfalfa is given. As a silage plant, it can be ensiled with maize and sorghum. Pure soybean silage is not very tasty for cows (Tayyar and Gül, 2007; Ayaşan, 2011; Kökten et al., 2013; Özer, 2021).

Soybean plant, which started to be grown in the Black Sea region for the first time in the early 1930s in our country, has now become widespread in the Mediterranean region in general and especially in the Çukurova region (Kökten et al., 2013). Soybean can be grown as the main crop in the Mediterranean Region. In addition, it has a special importance in our country due to the possibilities of being grown as a second product after the grain harvest in the Aegean, Mediterranean and Southeastern Anatolia regions. In the Mediterranean climate, forage soybean can provide an alternative to annual grass or perennial forage crops as a high yielding annual broadleaf plant. According to the data of the TÜİK, soybean cultivation was carried out in an area of 380.090 decares in Turkey in 2022 (TUIK, 2022).

Global warming forces working on alternative products. While there is a wide variety of products in terms of winter fodder plants in our country, there are not many alternatives for summer fodder plants. In recent years, especially in summer, temperature increases have emerged significantly due to climate change. However, irregularities also occur in precipitation regimes. Especially summer drought emerges as a serious problem. Soybean is one of the alternative plants that can be grown at increasing temperatures due to its adaptation to high temperatures. It is preferred to be grown in rainy conditions or by irrigating due to its high moisture demand. However, due to the drought problem we are facing, it is important to adapt the plant without irrigation (Özer, 2021).

More complex statistical models are needed every day to determine the varieties that are stable in terms of yield under stress conditions and to reveal the effect of GE (genotype×enviroment) interaction (Yaşar and Sezgin, 2022c). Recently, many researchers have been evaluating studies conducted in many environments using the AMMI Biplot technique on different plants. Varieties that adapt more easily to climatic conditions and have higher yield performance are preferred more by producers in different regions (Yaşar et al., 2023). It is also very important for environmental studies to be carried out, especially with less cost. It also gives very satisfactory results for detecting the most stable or highest varieties visually.

Therefore, it is a preferred method to identify stable varieties (Sousa et al., 2015; Dallo et al., 2019). In this study; In the study carried out in different locations, our main aim was to visually determine the genotype x environment effect by evaluating soybean varieties in terms of greenmass yield with the AMMI biplot technique and to evaluate the genotypes accordingly.

2. Materials and Methods

2.1. Materials

The research was carried out in Adana, Antalya, Manisa and Samsun locations during the 2007 growing season. In the study, 2 candidate varieties and 2 registered varieties in our country were used as material in the study (Table 1). The coordinates of the locations are given in Table 2 and the climatic data of the locations are given in Table 3. The experiment was carried out according to the Randomized Complete Blocks Design with six replications.

Table 1. Some information about the varieties

Varieties	Variety Owner Organization	Registration Year	Reclamation place	Plant Height (cm)	First Pod Height (cm)	Days to green maturity	Protein Ratio (%)	ADF (%)	NDF (%)	Relative Feed Value
1530 (Yemsoy)	Eastern Mediterranean Agricultural Research Institute	2008	Türkiye	106-156	4-27	112-117	11.6-14.3	37.3	49.8	112.6
517 (Yeşilsoy)	Eastern Mediterranean Agricultural Research Institute	2008	Türkiye	100-168	6-18	109-120	14.7-15.2	34.2	44.8	129.9
Türksoy	Eastern Mediterranean Agricultural Research Institute	2002	Türkiye	94-160	7-15	113-115	13.9-14.5	37.6	46.7	120.0
Nazlıcan	Eastern Mediterranean Agricultural Research Institute	2002	Türkiye	85-126	5-20	108-117	12.1-14.0	37.6	46.7	120.0

Source: *Variety Registration and Seed Certification Center, Ankara,-2022*

Table 2. Information about the location

	Location Coordinates		
Location	**Altitude (m)**	**Latitude**	**Longitude**
Adana/Yüregir	12	36°51'13.10"K	35°21'12.96"D
Antalya/Aksu	34	36°52'35.89"K	30°43'31.19"D
Manisa/Beydere	32	38°43'57.17"K	27°31'38.55"D
Samsun/Tekkeköy	3	41°13'40.66"K	36°30'10.20"D

Table 3. Climate data of locations

	Climate Factors					
	Total Precipitation (mm)		**Average temperature (°C)**		**Average Humidity (%)**	
Locations	**Years**		**Years**		**Years**	
	2010-2022	**2007**	**2010-2022**	**2007**	**2010-2021**	**2007**
Adana/Yüreğir	188.5	173.9	24.3	24.6	71.4	66.3
Antalya/Aksu	112.3	28.2	24.3	25.2	67.7	58.6
Manisa/Beydere	49.2	33.2	24.1	24.3	47.7	39.5
Samsun/Tekkeköy	332.5	302.8	20.5	20.1	77.2	67.8

Source: *General Directorate of Meteorology-Ankara (Average data from April to September)*

2.2. Methods

This study was carried out in 6 repetitions according to the Randomized Complete Block Design. Trial plantings; Adana 01 May 2007, Samsun 11 May 2007, Manisa 25 April 2007 and Antalya 03 May 2007. In the experiments, the planting depth was determined as 3-5 cm, the row spacing was 60 cm, the row spacing was 5 cm, the plot length was 5 m and 6 rows, and only the middle 4 rows were harvested in the trials. The seeds used in the experiment were 25 cc per 8 kg seed. Treated with $1x10^9$ *Bradyrhizobium japonicum* nitrogen bacteria. In the trials, 3.6 kg da^{-1} N and 9.2 kg da^{-1} P_2O_5 fertilizer were used. In the research; Greenmass Yield (kg da^{-1}) (For the measurement of soybean agricultural values, the plants harvested from 4 meters are tied with a rope and weighed with a hand scale and converted to yield per decare) Investigations were carried out in accordance with the directive of the Variety Registration and Seed Certification Center. Harvesting was done in the R-6 period at the full grain filling period just before the onset of light yellowing of the leaves and bean bark. Harvest dates of the experiment; Adana 21 September 2007, Samsun 14 September 2007, Manisa 19 September 2007 and Antalya 22 August 2007.

2.3. Statistical analysis

In the research; The greenmass yield obtained from four different locations was evaluated. The variance analysis of the data obtained from the greenmass yield in the study was performed in the Randomized Complete Block Design by using the J.M.P 7.0 (Copyright © 2007 SAS Institute Inc.) package program, and the averages of the important factors were determined by LSD grouped by test. In addition, AMMI analysis was made using the Genstat 12 package program, graphics were created and interpreted.

3. Results and Discussion

The data obtained from the study carried out with 4 soybean varieties for silage in four different locations were evaluated with the AMMI (Additive Main Effects and Multiplicative Interactions) analysis method. According to the analysis of variance; variety, location, variety location interaction and PC1 were statistically significant (P<0.01, P<0.05) in terms of greenmass yield (Table 4). According to the AMMI analysis, 92.0% of the average square footage is affected by the environment, 5.84% by the environment and 2.14% by the interaction, respectively. According to the results of the main effects and multiplicative interactions (AMMI) analysis, it has been shown that there are significant differences between the varieties in terms of hectoliter weight and the environment affects the variation more than other sources of variation. Differences in greenmass yield in soybean silage were grouped according to LSD test. The data obtained from each location in the study were grouped independently (Table 6).

Table 4. Variance analysis table (AMMI)

Variation Sources	Degrees of Freedom	Sum of Squares	Mean Squares	F Value	Impact Rate (%)
Total	95	155867839	1640714	*	
Applications	15	132380578	8825372	29.12	
Genotypes	3	7425452	2475151	8.17**	5.84
Locations	3	116785471	38928490	146.8**	92.00
Blok	20	5303751	265188	0.88	
GEI(İnteraksiyon)	9	8169654	907739	3**	2.14
IPCA	5	6024972	1204994	3.98**	65.0
IPCA	3	1941649	647216	2.14ns	35.0
Error	60	18183510	303059		

**:P<0.01,*;P<0.05 significant, ns: not significant

The genotype×environment interaction demonstrated by the AMMI analysis model has been reported by many researchers, especially when the interaction is split between two principal component axes (IPCA 1 and IPCA 2) (Kendal and Tekdal, 2018; Yan and Hunt, 2001). This model of AMMI analysis calculates genotype environmental effects in two ways. According to the results of the mean squares error, the PCA 1 (Principal component axis) axis was found to be significant compared to 1.0% (Table 4).

The AMMI model evaluated the greenmass yield values obtained from four environments and belonging to five varieties over two principal component axes, and the effect of each component axis on the interaction was found. According to the results of the analysis, it was determined that TBE 1 had an effect on the interaction in the total variation at the rate of 65.0% of the mean squares and 35.0% of the TBA2, and only TBE 1 was significant for 1% and TBE 2 was insignificant (Table 4). Gauch and Zobel (1996) report that the AMMI model is a very accurate model that can evaluate both principal component axes or more together and reveal how much each of them affects the genotype-environment interaction. From the principal component axis values of the genotypes (IPÇOpen[1], high value "+" positive value, IPÇÇÇ[2] low positive value, these genotypes are stable in all environments; likewise, environments (IPÇOpen[1], high "+" value) positive value and IPCAç[2] with a low positive value indicates that it is very favorable (Table 4, Table 5). The multidimensional analysis model is generally evaluated with the AMMI analysis model (Carbonell et al., 2004).

Table 5. Averages and scores of circles according to AMMI analysis results

Locations	Average Greenmass yield (kg da^{-1})	Variance	IPCAç[1]	IPCAç[2]
Adana	3186	5482	-1.827.983	1.465.551
Antalya	5482	5152	-1.184.943	-1.423.439
Manisa	5152	3186	2.113.223	848.930
Samsun	3064	3064	899.703	-891.042

When the greenmass yield was evaluated over the average of the locations, the data varied between 3186-5486 kg da^{-1}, while the highest greenmass yield was obtained from Adana location (Table 6). It can be said that the greenmass yield in the season in which the research was conducted is generally a little higher in Adana location compared to other locations. They confirmed our study by stating that this may be due to the environmental conditions in the Adana location during the growing season and that greenmass yield is a kind of feature in their previous studies on this subject, but there may be some changes according to the years and climate (Özer, 2001). According to the average of the genotypes, the greenmass yield varied between 3918-4520 kg da^{-1}, the highest greenmass yield was obtained from 1530 (Yemsoy) variety, and the lowest greenmass yield was obtained from Türksoy variety. Kökten et al., (2014) in their study with 12 different soybean varieties in Bingöl conditions, determined that the greenmass yield was between 1204 – 1652 kg da^{-1}, Şenbek and Açıkgöz (2019) with 12 lines and 4 soybean varieties in Bursa ecological conditions. Greenmass yield was between 2200 – 7687 kg da^{-1}, Altinok et al. (2004) determined that the greenmass yield was between 1912-2819 kg da^{-1} in 2000, between 1160 and 2252 kg da^{-1} in 2001, Özer (2021), in a study conducted with 5 different soybean varieties in Edirne, in the first year. They reported that it varies between 1103–1450 kg da^{-1}, and in the second year between 480–603 kg da^{-1}.

Table 6. Values and groups of greenmass yield traits in the study

Varieties	Adana	Antalya	Manisa	Samsun	Average	IPCAg[1]	IPCAg[2]
1530	6310 a	5676 a	2956 bc	3138	4520 A	-2.550.4	368.559
517	4849 c	5140 b	2859 c	3034	3971 B	449.588	-2.037.4
Türksoy	5001 c	4458 c	3297 ab	2913	3918 B	1.794.58	903.629
Nazlıcan	5764 b	5336 ab	3633 a	3172	4476 A	306.203	765.164
Average	**5481 A**	**5152 B**	**3186 C**	**3064 C**	**4221**		Variety :317.9**
LSD (0.05)	415.3**	485.5**	376.7**	668.1ns		LSD (0.05)	Locations:310.1**
CV(%)	6.15	7.65	8.86	17.7			G×E :635.7**

*LSD: Low significant difference, CV: coefficient of variation, **:P<0.01,*;P<0.05 significant, ns: not significant*

Greenmass yield may vary depending on environmental factors as well as genetic characteristics of genotypes. Greenmass yield in genotype-environment interaction changed between 5001-6310 kg da^{-1} in Adana location, the highest greenmass yield was obtained from 1530 (Yemsoy) variety and the lowest greenmass yield was obtained from Türksoy variety. In Antalya location, the highest greenmass yield, which changed between 4458-5676 kg da^{-1}, was obtained from 1530 (Yemsoy) variety and the lowest greenmass yield was obtained from Türksoy variety. The highest greenmass yield was obtained from Nazlıcan variety, and the lowest greenmass yield was obtained from 517 (Yeşilsoy) variety in Manisa location, varying between 2859-3633 kg da^{-1}. In Samsun location, the highest greenmass yield was obtained from 1530 (Yemsoy) variety, and the lowest greenmass yield was obtained from Türksoy variety, varying between 2913-3138 kg da^{-1}. It shows that the genetic characteristics of the genotypes are effective in the same varieties having the highest and lowest greenmass yield in the other three locations, except Samsun, and the fact that different varieties have the highest and lowest values in the Samsun location shows that the greenmass yield may partially change depending on the effect of the environment.

Visually in AMMI analysis, the x-axis on the figure explains the main effect of the varieties and the environment, and the y-axis explains the interaction (Asfaw et al., 2009). (Figure 1).

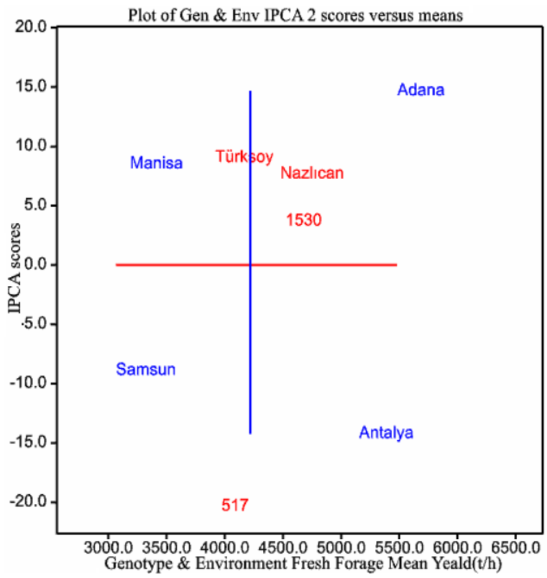

Figure 1. AMMI Chart Constructed from Data of Four Environments

Environment and varieties varied a lot in terms of both basic effect and interaction. In the AMMI visualy; According to the results obtained with the AMMI analysis technique, in the evaluation made on the average greenmass yield of all environments, 1530 (Yemsoy) variety had the highest greenmass yield in the average of all four locations, while the Nazlıcan variety was above the average (vertical) curve and showed high performance. It was determined that 1530 (Yemsoy) varieties were the most stable in terms of greenmass yield, while Türksoy and 517 (Yeşilsoy) varieties were far from the stability (horizontal) curve. Among the locations, Adana and Antalya locations were above the average curve in terms of greenmass yield, while the other two locations were below the average curve. In this analysis, it was visually revealed that the green herb yield from Adana and Antalya locations was higher than the other locations, 1530 (Yemsoy) was superior to other varieties and was stable, and Nazlıcan had a high performance (Figure 1). According to Mirosavlievic et al., (2014), varieties with low PCA 2 values are more stable, while according to Becker and Leon (1988), the basic statistical concept of stability shows minimal variation of stable varieties in all environments. High yielding genotypes represent dynamic stability and are used in commercial plant breeding (Flores et al., 1998). Similar results; It was also identified by Kendal and Tekdal (2016). In addition, with the sector analysis, the locations were grouped and the most suitable genotypes were determined for each sector and trait group (Figure 2).

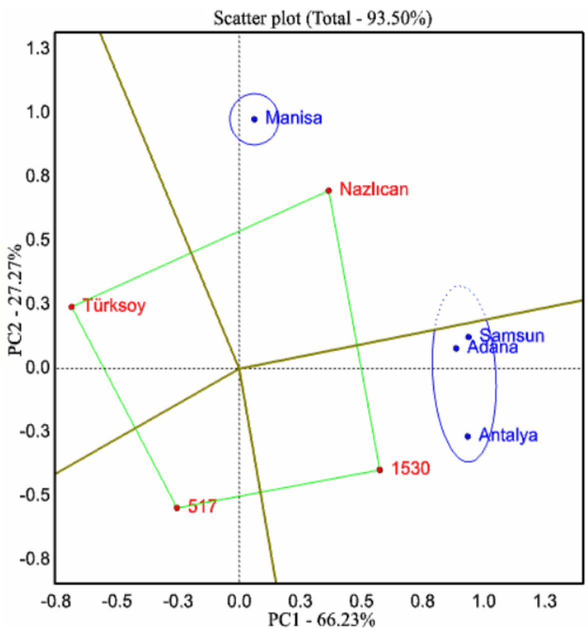

Figure 2. Sector analysis in AMMI biplot technique

As seen in Figure 2, a total of 4 different sectors have been formed in terms of varieties and locations. Considering only their locations, all three of the other locations, except for the Manisa location, formed the same group and took place in the same sector (1st sector). Thus, the use of only one of the locations in the same group of studies to be carried out with these varieties in terms of greenmass yield will reduce the cost. Therefore, it shows that the environments in the same group are ecologically similar. Along with these locations, 1530 (Yemsoy) varieties are also in the same sector, showing that they perform well in these locations. The Manisa location alone has created a separate mega-environment and, together with the Nazlıcan variety, has taken place in a different (2nd sector) sector. It can be said that there is a correlation between the varieties and locations located in the same sector. Türksoy and 517 (Yeşilsoy) varieties show that they show low performance in terms of locations by taking place in the sector where there is no independent location and no location. The GGE biplot technique makes it easy for us to visually interpret relationships (Sousa et al., 2015). The ranking biplot method, which is based on the greenmass yield data obtained from the locations and ranks the varieties according to their stability, is given in Figure 3. It is a model that ranks the varieties in terms of stability (horizontal) and mean (vertical) baseline curves for all locations in multi-location studies. This model has been used in many studies and by many researchers (Yan and Rajcan, 2002; Kılıç et al., 2018; Yaşar et al., 2023). In line with these explanations, in Figure 3, 1530 (Yemsoy) varieties were found to be the most stable in terms of all four locations, while Türksoy and 517 (Yeşilsoy) varieties were unstable. In addition, it can be said that the Nazlıcan variety used in the study is a suitable variety candidate as it is located both above the average and close to the stability curve. It was concluded that stable varieties should be preferred in a study to be carried out in terms of greenmass yield or to determine varieties.

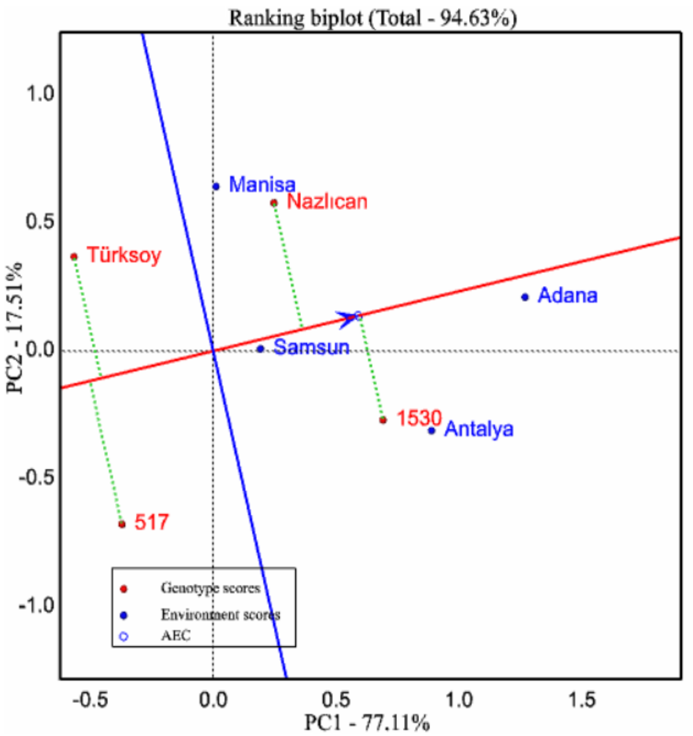

Figure 3. Stability of varieties in the Ranking biplot model

In addition, in the comparison model, an ideal center can be created according to the average of all locations and genotypes can be ranked according to this center (Figure 4).

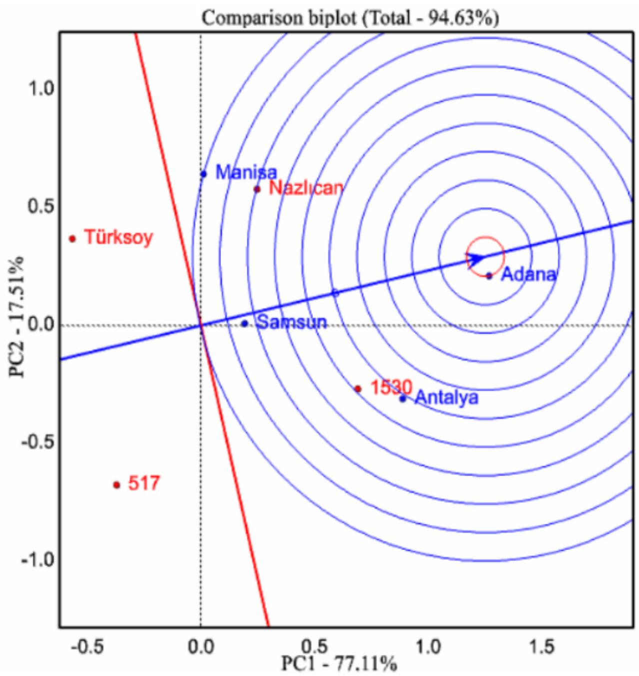

Figure 4. Determination of the most ideal varieties with the Comparison method

Accordingly, 1530 (Yemsoy) variety was determined to be the most ideal variety since it is the closest variety to the ideal center. In addition, Nazlıcan variety was found to be preferable in terms of greenmass yield since they are located close to the ideal center and above the average curve in terms of all locations. In addition, Türksoy and 517 (Yeşilsoy) varieties are both below the average and far from the ideal center. Determining the most ideal variety in terms of locations is very important for aquaculture and will pave the way for increasing yield. According to the results of the AMMI analysis, the ranking of the first four varieties that can be recommended for each environment, respectively, is given in Table 7.

Table 7. Top four preferable varieties for every environment according to AMMI analysis

Locations	Average Greenmass yield (kg da^{-1})	Scores of locations	Varieties to be Preferred First			
			1. çeşit	2. çeşit	3. çeşit	4. çeşit
Manisa	3186	21.13	Nazlıcan	Türksoy	1530	517
Adana	5482	-18.28	1530	Nazlıcan	Türksoy	517
Antalya	5152	-11.85	1530	Nazlıcan	517	Türksoy
Samsun	3064	9.00	Nazlıcan	1530	517	Türksoy

As a result of this analysis, it is seen in the order that the genotypes that can be preferred or selected in the first and second place for almost all environments are 1530 (Yemsoy) and Nazlıcan varieties, and the genotypes that should be preferred in the 3rd and 4th place are 517 (Yeşilsoy) and Türksoy varieties (Table 7). In addition, by looking at the results of the AMMI analysis in Table 7, it seems possible to select stable varieties with high primary or secondary grass yields for each environment or for more than one environment. Kendal and Doğan (2015) reported that AMMI analysis has the trait of conveying extremely important results in terms of seeing the most suitable genotypes or variety candidates that should be preferred in the first two places in studies conducted in more than one environment and supports our study.

4. Conclusions

In the study carried out in different locations, the results showed that 1530 (Yemsoy) variety was superior to the other 3 varieties in terms of greenmass yield and 1530 (Yemsoy) variety was the most stable. Three locations, except Manisa location, are located in the same Mega-environment.

Declaration of Author Contributions

The authors declare that they have contributed equally to the article. All authors declare that they have seen/read and approved the final version of the article ready for publication.

Declaration of Conflicts of Interest

All authors declare that there is no conflict of interest related to this article.

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