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Estimations on Trait Stability of Maize Genotypes

Vasileios Greveniotis [1,2,3,*], Elisavet Bouloumpasi [4], Stylianos Zotis [3,†], Athanasios Korkovelos [5] and Constantinos G. Ipsilandis [6]

1 Hellenic Agricultural Organization Demeter, Institute of Industrial and Forage Crops, 41335 Larissa, Greece
2 Department of Agricultural Development, Democritus University of Thrace, 68200 Orestiada, Greece
3 Department of Agricultural Technology, Technological Educational Institute of Western Macedonia, 53100 Florina, Greece; dzotis19@gmail.com
4 Department of Agricultural Biotechnology and Oenology, International Hellenic University, 66100 Drama, Greece; elisboul@abo.ihu.gr
5 Directorate of Water Management of Thessaly, Decentralized Administration of Thessaly—Central Greece, 41335 Larissa, Greece; athanasios.korkovelos@apdthest.gov.gr
6 Regional Administration of Central Macedonia, Department of Agriculture, 54622 Thessaloniki, Greece; ipsigene@gmail.com
* Correspondence: vgreveni@mail.com; Tel.: +30-241-067-1285
† Deceased.

Abstract: The purposes of this study were to define the kind of trait inheritance through stability estimations of various traits in maize, to define the relationship between different environments and maize hybrids, and to propose the best environments and hybrids for farmers. Field experiments were conducted in two years (2011 and 2012) at four different locations in Greece: Florina, Trikala, Kalambaka and Giannitsa which were selected as they represent different environments. The genetic materials tested in a Randomized Complete Block (RCB) design, were 15 F1 commercial maize hybrids and 15 open-pollination lines developed from 4-cycle Honeycomb evaluation. Materials were sown and harvested by hand at different dates according to local conditions. Trait stability index $(\overline{x}/s)^2$ across environments was computed for each maize trait studied: yield, specific weight, 1000-kernel weight, axis (spindle) weight, spike weight, number of kernels per spike, spike length and diameter, number of kernel rows, spindle diameter, main spike and plant height, prolificacy and number of kernels per row. The findings showed great differences in stability index between traits and also for the same trait across environments or between maize genotypes. GGE biplot for yield distributed genotypes in a different way for Florina on the basis of one main factor and managed to depict Trikala's differential response on the basis of two factors. Almost the same trend was found for 1000-kernel weight and specific weight, where there was a wide core for similar responding genotypes. Basic conclusions of this research are summarized in great differences of various traits, indicating qualitative, medium or quantitative inheritance. Estimations for trait stability can be easily performed in a multi-genotype experiment using trait stability index. The most stable hybrids were proved to be 31Y43, COSTANZA and FACTOR. The environment favouring a general stable performance proved to be Florina.

Keywords: trait stability index; G × E; indirect breeding

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1. Introduction

Stability across environments is the companion of realized yield for commercial cultivars or hybrids, meaning that a stable genotype shows minimum interaction with the environments where it is cultivated and in parallel responding positively in favourable environments [1]. Low variance across locations is the characteristic of a stable genotype aiming to enter in commercial use [2,3]. That is the reason Fasoulas [4] proposed the ratio between mean and standard deviation for stability estimations and, later, Fasoula [5] used the same ratio in its squared form as a better stability criterion for plant breeders. The criteria of stability across environments are of great consideration for maize breeders and breeders of other plants, while reliable criteria must undergo extensive research because of their relationship to genetic background [6]. Especially, Genotype × Environment (G × E) interactions are of great consideration for maize breeders, because they affect successful entrance of commercial hybrids in the market. Nevertheless, in maize breeding programs the trait of interest in most cases is grain yield. Grain yield is a complex trait because it depends on many loci and thus exhibits low heritability, so that many plant breeders use other correlated traits for improvement of grain yield [7]. Greveniotis et al. [8], established a new approach on stability and homeostasis, regarding seed yield in maize, based on Fasoula's [9,10] approach for selection by combining high yields with stability. Later, Greveniotis et al. [11–13] set the basis of analyzing stability by Fasoula's [9,10] stability index in common vetch (*Vicia sativa* L.) and peas (*Pisum sativum* L.), exploring various traits and using the AMMI (additive main effects and multiplicative interaction) and GGE (genotype plus genotype by environment interaction) biplot analyses.as tools Especially for yield, there were proposed some cultivars to be used in certain Greek environments, focusing on low-input cultivations that describe better farmers' fields.

G × E interaction is also the final result from differences in the sensitivity of genotypes to the conditions in the target environment to be cultivated [14], in other words to their tolerance to various biotic and abiotic stresses [15]. Those stresses affect individual genotypes (cultivars or hybrids) on a different level, leading often to an unstable yielding performance and confusing farmers on what they may choose to cultivate in their farms in a certain region [16]. Extensive experiments on maize performance across locations in China showed significant location, cultivar and interaction effects, concluding on basic stability parameters and their grouping as main factors [17]. They also located proper genotypes for favourable and unfavourable environments.

The purposes of this study were: (a) to define the kind of trait inheritance through stability estimations of various traits (i.e., the qualitative or quantitative character of the traits studied) in order to choose and apply the proper breeding method, (b) multi-location and multi-genotype evaluation in order to define the relationship between those factors (the different environments and maize hybrids), and (c) to propose the best environments and hybrids to farmers.

2. Materials and Methods

2.1. Crop Establishment and Experimental Procedures

Field experiments were conducted during two successive growing seasons growing seasons (2011 and 2012) in four different locations. Two locations in Northern Greece and two locations in Central Greece were selected, varying in soil type and altitude. Coordinates according to the WGS 1984 geographic coordinate system are provided.

(A) In the farm of Technological Education Institute of Florina, Greece (40°46′ N, 21°22′ E, 705 m a.s.l.). The soil type was Sandy Loam (SL): Sand 61.2%, Silt 27.6%, Clay 11.2% with pH 6.25, and organic matter content 1.29%

(B) In Trikala, Greece (39°55′ N, 21°64′ E, 120 m a.s.l.). The soil type was Sandy Clay Loam (SCL): Sand 49.0%, Silt 19.0%, Clay 32.0% with pH 8.0, and organic matter content 2.40%

(C) In Kalambaka, Greece (39°64′ N, 21°65′ E, 190 m a.s.l.). The soil type was Silty Clay (SiC): Sand 1.6%, Silt 49.1%, Clay 49.3% with pH 8.18, and organic matter content 2.14%

(D) In Giannitsa, Greece (40°77′ N, 22°39′ E, 10 m a.s.l.). The soil type was Clay (C): Sand 8.9%, Silt 37.4%, Clay 53.7% with pH 8.18, and organic matter content 3.50%.

These locations were selected on purpose because of their different environments. Environmental data (mean monthly temperatures in °C and rainfall in mm) based on daily records are presented in Figure 1.

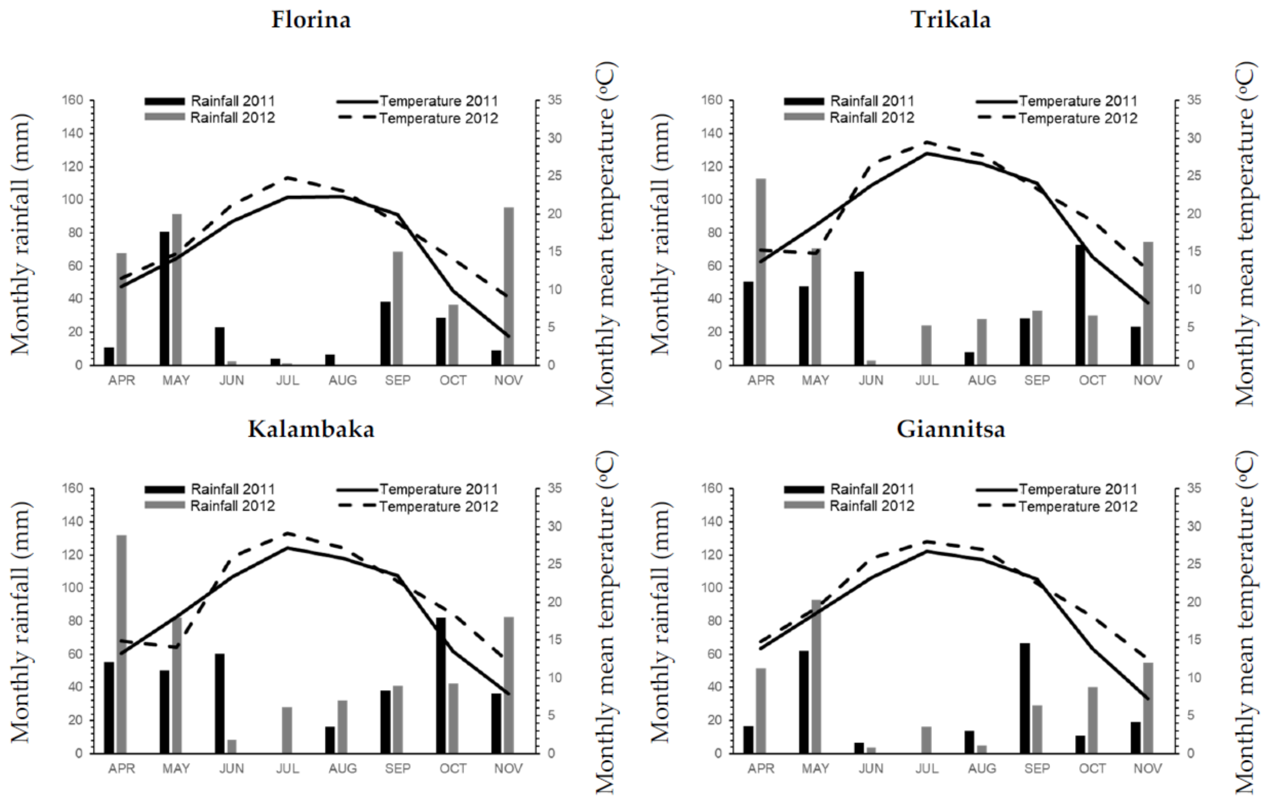


Figure 1. Basic weather data (mean monthly temperature in °C and rainfall in mm) based on daily records, through two growing seasons.

The genetic materials tested were 15 F1 commercial maize hybrids: G1: PR31Y43, G2: FACTOR, G3: COSTANZA, G4: ARMA, G5: PR31A34, G6: ELEONORA, G7: FAMOSO, G8: DKC6818, G9: MITIC, G10: DKC6040, G11: KERMESS, G12: PR31G98, G13: LG3535, G14: PR33A46, G15: PR31P41, and 15 open-pollination lines developed from 4-cycle Honeycomb evaluation with selection intensity near 1%, in years 2007–2010: G16: 1T, G17: 2T, G18: 3T, G19: 4T, G20: 5T, G21: 1F, G22: 2F, G23: 3F, G24: 4F, G25: 5F, G26: 6F, G27: 7F, G28: 8F, G29: 9F, G30: 10F. The starting material for open-pollinated lines was the F2 (C0) generation of the F1 commercial maize hybrid Costanza. Despite the use of open-pollination, the pedigree selection scheme was conducted for all years of experimentation on the half-sib progenies.

The final experiments were conducted on a Randomized Complete Block Designs (RCB) with four replications [18]. The plots consisted of two single rows with 75 cm row-to-row spacing. Each row consisted of 25 plants with plant-to-plant spacing at 18 cm. Maize seeds were sown on 5 May 2011 and 11 May 2012 for Florina, 5 April 2011 and 4 April 2012 for Trikala, 4 April 2011 and 5 April 2012 for Kalambaka and 11 April 2011 and 13 April 2012 for Giannitsa. Hills were over-seeded at a double rate and then thinned by hand at the two-leaf stage of maize to achieve the desired plant densities. Nitrogen and P fertilizer (element level) were applied at the same rate of 150 and 75 kg ha^{-1}, respectively, at sowing, while additional N (135 kg ha^{-1}) was applied when the plants reached 50 cm in height (boot stage). Weed control was ensured using post-emergence herbicides. Irrigation was conducted regularly (usually within a 10-day interval) in order to avoid any water stress level at any growth stage. The fields were harvested by hand on 16 December 2011 and 1 November 2012 for Florina, 3 October 2011 and 1 October 2012 for Trikala, 4 October 2011 and 30 September 2012 for Kalambaka, and 28 September 2011 and 25 September 2012 for Giannitsa.

2.2. Measurements

Ten plants were selected randomly from each plot at harvest (phenological stage R6 —physiological maturity) and axis (spindle) weight (in g), spike weight (in g), number of kernels per spike, spike length (in cm) and diameter (in mm), number of kernel rows, spindle diameter (in mm), main spike and plant height (in cm), prolificacy and number of kernels per row, were measured. Additionally, grain yield of each plot (in g) was measured and field yield estimated (in kg ha^{-1}), while 1000-kernel weight (in g), and specific weight (in g L^{-1}) were calculated. Each plant was separately weighted in an electronic balance.

2.3. Data Analysis

Data primarily were analyzed via ANOVA over environments to evaluate if there are significant differences for all traits investigated in this study. For the ANOVA table to be more informative the combination of each year and location was assigned as the environment. In this way, we have fewer interactions in the ANOVA table and do not affect the variance of Genotypes and the G $\times$ E interaction which is crucial for proceeding in the stability analysis.

Stability index calculation $(\overline{x}/s)^2$, where $\overline{x}$ and s are the entry mean yield and standard deviation, respectively, was employed for stability estimations [9,10]. Pearson coefficient according to Steel et al. [18] was applied for trait correlations, and statistical significance of all data was checked at $p < 0.05$ with SPSS ver. 25 statistical software. For the computation of AMMI and GGE biplot analyses for interactions used the free version of PB Tools v1.4 (International Rice Research Institute, Laguna, Philippines).

3. Results and Discussion

Good field performance must be accompanied by satisfactory stability of a commercial cultivar or hybrid and breeders have to develop such genotypes improved for stability. Primary stability estimations may define the kind of heritability and the type of trait inheritance (many or a few loci) of a specific trait and thus help breeders to choose the proper procedure [3]. Oliveira et al. [6] tried to apply a stability index in maize with encouraging results. In our data set we applied a simple criterion for assessing stability and trait inheritance.

Regarding the ANOVA table, the main effects for the genotypes for all traits expressed significant differences. Furthermore, the G $\times$ E interaction showed significant differences only for yield and number of kernels per row (Table 1).

Specific weight, spike diameter and number of kernel rows showed maximum mean values (200, 180 and 120, respectively) (Table 2). Medium values showed 1000-kernel weight, spike length, spindle diameter, height of main spike, prolificacy and number of kernels per row (close to or over 50 and below 100) (Table 2). Yield and spindle weight showed the lowest values (13 and 13.5) (Table 2). According to Fasoulas [3,4], low stability index values indicate unstable behaviour of the genotypes, due to quantitative inheritance and multi-gene action. Medium values show a gene action based on a few genes and high values show a qualitative inheritance based on one main gene or a limited number of genes. Yield and spindle weight exhibiting the lowest values proved once again to be complex traits controlled in their final expression by many loci [4,7]. Multi-location and multi-genotype experiments revealed the same for the stability expression of traits and genotypes.

Table 1. Mean squares (m.s.) from analysis of variance over environments for tested traits: yield (kg ha^{-1}), specific weight (g L^{-1}), 1000-kernel weight (g), axis (spindle) weight (g), spike weight (g), number of kernels per spike, spike length (cm) and diameter (mm), number of kernel rows, spindle diameter (mm), main spike and plant height (cm), prolificacy, and number of kernels per row.

Source of Variation	Yield (kg ha^{-1})	Specific Weight (g L^{-1})	1000-Kernel Weight (g)	Axis (Spindle) Weight (g)	Spike Weight (g)	Number of Kernels per Spike	Spike Length (cm)	Spike Diameter (mm)	Number of Kernel Rows	Spindle Diameter (mm)	Height of Main Spike (cm)	Plant Height (cm)	Prolificacy	Number of Kernels per Row
Environments (E)	209,261 **	5.9 ns	373.6 ns	90.3 ns	603.8 ns	5026.6 ns	6.60 ns	0.193 ns	2.39 ns	0.213 *	238.3 ns	683.2 ns	0.012 ns	71.3 **
REPS/Environments	145,749 **	29.6 ns	2808.4 ns	96.2 ns	1593.5 ns	15,489.7 ns	7.05 ns	0.158 ns	1.52 ns	0.076 ns	146.1 ns	1635.0 ns	0.019 *	7.8 ns
Genotypes (G)	2123,917 **	79.5 **	5804.4 **	271.5 **	2790.2 **	17,476.7 **	5.64 ns	0.162 ns	2.89 *	0.128 ns	632.3 **	6719.9 **	0.012 ns	46.2 **
Genotypes × Environments (G × E)	97,727 **	21.8 ns	2507.1 ns	73.6 ns	1504.9 ns	12,823.6 ns	5.95 ns	0.134 ns	2.30 ns	0.108 ns	239.9 ns	1752.8 ns	0.014 ns	36.0 **
Error	34,838	24.6	2629.5	76.3	1518.6	13,878.5	5.22	0.122	2.07	0.109	274.2	1825.8	0.013	16.7

Probability values: * $p \leq 0.05$; ** $p \leq 0.01$; ns = not significant.

Table 2. Trait stability index $(\bar{x}/s)^2$ across environments for tested traits: yield (kg ha^{-1}), specific weight (g L^{-1}), 1000-kernel weight (g), axis (spindle) weight (g), spike weight (g), number of kernels per spike, spike length (cm) and diameter (mm), number of kernel rows, spindle diameter (mm), main spike and plant height (cm), prolificacy, and number of kernels per row.

Environments	Yield (kg ha^{-1})	Specific Weight (g L^{-1})	1000-Kernel Weight (g)	Axis (Spindle) Weight (g)	Spike Weight (g)	Number of Kernels per Spike	Spike Length (cm)	Spike Diameter (mm)	Number of Kernel Rows	Spindle Diameter (mm)	Height of Main Spike (cm)	Plant Height (cm)	Prolificacy	Number of Kernels per Row
Giannitsa	12.5	185.8	42.3	13.8	24.8	25.1	77.6	176.9	108.9	47.4	55.6	33.3	115.1	40.5
Florina	16.1	212.8	46.1	12.1	25.2	20.8	61.7	188.0	120.2	47.8	58.9	35.3	70.4	50.4
Trikala	11.7	213.7	48.0	13.3	22.4	25.8	82.1	169.8	136.7	54.2	66.8	31.3	85.1	64.2
Kalambaka	11.6	186.1	48.5	13.2	27.0	23.8	63.6	183.0	113.1	56.3	56.0	34.1	114.9	58.7
Real Mean	13	200	47	13.5	25	24	71	180	120	51.5	59	33.5	93	53.5

Additionally, as occurs from Tables 3–6, there was a considerable fluctuation in stability index values for all traits within each location and across genotypes, indicating some kind of G × E interaction. Additionally, the environment (different locations) affected the expression of each trait, as shown in Table 2. Finally, each genotype revealed a different level of stability and inheritance as occurs from Table 7. In general, as show in Table 7, hybrids showed better stability than open-pollinated lines for various traits, especially for yield. Yielding performance of hybrids was much more stable than open-pollinated lines exhibiting values of index stability sometimes close or over 100. Specific weight showed somewhat confusing results, but open-pollinated lines exhibited in many cases very high values of stability index (2 genotypes over 400 and 3 over 300). In 1000-kernel weight, hybrids had more stable performance according to stability index. Spindle and spike weight showed, in general, low values for both open-pollinated lines and hybrids, while sometimes open-pollinated lines exhibited higher index values in comparison to hybrids. For the number of kernels per spike or per row, hybrids were somewhat more stable than open-pollinated lines, with stability index values up to 130.2 and 115.6, respectively, for the two characteristics. For spike length, hybrids were also more stable and, in many cases, showed values over 100, while only one open-pollinated line 100. For spike and spindle diameter, both open-pollinated lines and hybrids showed almost the same stability. For the number of kernel rows, hybrids proved to be more stable than open-pollinated lines. For plant and main spike height, open-pollinated lines were somewhat more stable than hybrids. Prolificacy revealed that open-pollinated lines were much more stable than hybrids, exhibiting values even over 400 and up to 577.4.

Fasoulas [3] proposed prolificacy as a means for improving indirectly maize yield and high values of stability index, which according to the same researcher, are an indication of a quality trait, controlled by a few loci, exhibiting high heritability. Unfortunately, correlations between stability coefficients of the traits studied were poor and generally not significant and thus slightly useful for indirect selection (Table 8).

Yield was correlated positively to 1000-kernel weight (r = 0.51), number of kernels per spike (r = 0.61), spike length (r = 0.51), number of kernel rows (r = 0.60), and negatively to specific weight (r = −0.54), axis (spindle) weight (r = −0.44), spindle diameter (r = −0.40) and plant height (r = −0.49). Thus, only correlated traits could be used in the sense of replacing a difficult to improve trait such as yield with another one that could contribute to improved stability. Having this in mind, prolificacy exhibiting no correlation to yield cannot be used for indirect improvement of yield, although being the trait with the highest values of stability indices. A reliable criterion for indirect selection for high stability of yield could be a negative selection for specific weight, due to (a) the significantly negative, but poor correlation found and (b) the generally high stability indices that may depict high heritability [3,4]. Secondly, number of kernel rows could also help, because of the positive correlation and the high stability indices. According to Greveniotis et al. [11–13], correlations could be very useful for indirect selection of yield traits, using as selection criteria traits that exhibit high stability index values, and possibly higher heritability.

Genotypes considered more stable according to the values of stability index, are: for yield hybrid Costanza, followed by 31Y43, for specific weight open-pollinated lines 7F and 1F, for 1000-kernel weight hybrid 33A46 followed by 31Y43 and Famoso, axis (spindle) weight open-pollinated line 8F, for spike weight open-pollinated line 8F and hybrid LG3535, for number of kernels per spike hybrid Costanza, for spike length hybrid 31Y43, for spike diameter hybrids 31Y43, 6818 and open-pollinated lines 2F and 4T, for number of kernel rows hybrids 31Y43 and Costanza, for spindle diameter open-pollinated line 6F, for height of main spike open-pollinated lines 2T and 5F, for plant height open-pollinated lines 1T and 4T, for prolificacy open-pollinated lines 1T, 5F and 9F, and finally for kernels per row hybrid Eleonora and open-pollinated line 4T. Trait inheritance is combined to high stability indices and in many cases traits such as specific weight and spindle diameter, exhibited high values and according to Fasoulas [3] a qualitative type of inheritance.

Table 3. Trait stability index $(\bar{x}/s)^2$ across genotypes and environments for tested traits: yield (kg ha^{-1}), specific weight (g L^{-1}), 1000-kernel weight (g), axis (spindle) weight (g), spike weight (g), number of kernels per spike, spike length (cm) and diameter (mm), number of kernel rows, spindle diameter (mm), main spike and plant height (cm), prolificacy, and number of kernels per row, in Giannitsa region.

Genotypes	Yield (kg ha^{-1})	Specific Weight (g L^{-1})	1000-Kernel Weight (g)	Axis (Spindle) Weight (g)	Spike Weight (g)	Number of Kernels per Spike	Spike Length (cm)	Spike Diameter (mm)	Number of Kernel Rows	Spindle Diameter (mm)	Height of Main Spike (cm)	Plant Height (cm)	Prolificacy	Number of Kernels per Row
31Y43	144.2	68.5	75.8	10.1	71.5	65.5	170.7	206.4	143.9	27.6	61.7	28.4	413.8	31.6
FACTOR	139.6	137.7	32.9	14.4	9.7	22.7	113.1	207.9	97.6	44.6	57.6	26.5	681.4	52.8
COSTANZA	137.4	379.9	117.7	26.7	72.3	235.0	60.0	242.3	158.5	38.6	36.1	66.2	1781.7	58.0
ARMA	165.8	118.3	83.4	38.3	19.9	61.0	88.0	112.6	184.7	71.3	52.2	39.7	735.1	60.4
31A34	103.1	125.0	58.6	14.9	32.3	28.4	128.7	151.7	264.6	75.4	296.8	21.0	207.0	38.9
ELEONORA	86.6	180.4	59.8	9.5	32.3	17.5	130.0	330.9	225.7	43.9	104.7	25.0	35.2	377.5
FAMOSO	88.8	197.7	91.1	44.2	30.7	52.8	72.8	232.7	96.6	52.1	38.8	52.1	216.9	59.8
6818	54.5	586.5	45.5	30.0	25.3	41.8	419.7	294.4	89.5	64.7	78.3	38.8	1338.1	57.9
MITIC	55.9	192.2	87.1	7.8	13.5	11.5	109.0	279.9	156.9	21.4	72.4	31.7	232.5	77.5
6040	45.5	123.2	56.9	9.0	21.7	19.7	52.8	209.6	231.3	77.7	33.2	55.6	18.6	191.0
KERMESS	39.2	267.4	51.4	63.4	14.4	11.9	40.8	140.1	100.0	48.8	31.0	47.0	210.8	32.8
31G98	65.6	178.1	43.1	12.1	66.7	15.9	144.9	150.8	119.6	65.8	71.4	16.5	370.4	40.9
LG3535	51.8	194.7	1245.3	15.9	38.2	17.9	75.7	165.6	253.5	23.1	56.3	19.0	57.4	28.3
33A46	55.5	260.8	89.3	22.8	124.7	102.1	64.8	418.6	70.9	55.9	63.8	50.9	171.1	33.4
31P41	119.8	128.2	25.1	19.0	28.9	19.8	197.3	332.2	124.5	50.1	37.6	16.9	195.3	17.9
1T	25.8	307.9	63.1	33.8	22.1	39.9	45.6	152.0	65.0	35.1	125.4	31.5	784.1	18.5
2T	23.1	178.8	35.7	11.5	16.4	42.4	52.5	158.4	68.1	51.8	138.9	35.1	826.2	44.1
3T	24.0	124.7	18.8	16.6	36.3	50.1	41.2	149.5	350.7	42.3	28.4	54.3	61.9	46.6
4T	36.4	298.7	42.2	5.0	28.9	138.6	106.7	470.5	173.0	68.4	132.9	47.3	169.8	105.9
5T	25.9	273.4	51.2	63.3	35.9	22.6	67.2	165.9	57.9	26.5	48.7	111.6	307.5	43.1
1F	14.7	334.4	21.9	67.4	52.7	15.1	91.9	144.2	112.3	132.4	92.8	63.5	197.3	183.9
2F	32.9	195.5	26.2	23.4	12.5	30.5	98.3	262.7	89.5	34.0	41.5	19.9	564.4	20.9
3F	20.0	196.5	27.2	11.8	17.1	15.5	38.4	109.4	199.3	46.1	66.3	45.2	315.5	55.6
4F	21.2	330.3	71.4	18.1	36.7	15.0	84.3	455.6	202.3	94.4	126.7	56.1	38.4	131.2
5F	9.5	463.1	74.7	14.8	66.5	21.0	85.4	216.4	143.0	64.0	177.6	64.2	611.5	57.1
6F	16.5	155.1	38.0	19.1	18.8	39.7	62.2	375.9	136.9	126.8	38.3	29.5	50.5	42.7
7F	19.6	589.0	43.1	49.7	16.8	44.5	59.6	300.5	150.7	64.7	34.2	83.4	527.9	34.7
8F	13.3	225.8	15.7	24.1	48.0	17.4	130.6	129.6	107.5	40.8	91.9	26.0	871.3	23.5
9F	16.9	1722.5	84.4	53.5	69.9	45.8	53.1	183.0	160.3	77.7	49.5	57.6	528.9	36.7
10F	37.9	247.6	25.0	8.2	106.9	12.7	87.9	86.4	53.1	44.5	197.8	35.3	213.9	60.9

Table 4. Trait stability index $(\bar{x}/s)^2$ across genotypes and environments for tested traits: yield (kg ha^{-1}), specific weight (g L^{-1}), 1000-kernel weight (g), axis (spindle) weight (g), spike weight (g), number of kernels per spike, spike length (cm) and diameter (mm), number of kernel rows, spindle diameter (mm), main spike and plant height (cm), prolificacy, and number of kernels per row, in Florina region.

Genotypes	Yield (kg ha^{-1})	Specific Weight (g L^{-1})	1000-Kernel Weight (g)	Axis (Spindle) Weight (g)	Spike Weight (g)	Number of Kernels per Spike	Spike Length (cm)	Spike Diameter (mm)	Number of Kernel Rows	Spindle Diameter (mm)	Height of Main Spike (cm)	Plant Height (cm)	Prolificacy	Number of Kernels per Row
31Y43	114.6	133.8	182.7	21.5	48.6	167.1	266.3	434.3	344.8	149.0	41.4	71.1	124.1	132.8
FACTOR	102.1	142.1	59.9	24.3	17.6	50.3	94.6	216.4	211.5	62.0	70.3	44.3	36.7	131.3
COSTANZA	135.5	121.4	23.1	4.9	20.4	138.2	127.4	136.9	384.2	81.7	110.9	132.6	50.0	41.2
ARMA	56.3	209.8	45.7	11.5	67.7	41.5	41.6	277.3	40.5	59.4	99.0	53.0	126.4	55.2
31A34	106.2	121.9	63.3	12.1	22.6	97.4	45.5	525.1	154.6	48.3	189.3	29.6	34.1	111.9
ELEONORA	62.0	221.1	26.5	39.8	38.5	16.8	47.2	468.6	75.6	18.5	54.2	68.4	288.9	60.2
FAMOSO	58.1	249.9	47.9	24.0	53.5	8.1	33.7	235.4	113.6	56.6	45.6	39.6	138.7	57.0
6818	75.8	159.5	54.0	18.4	22.0	11.6	256.0	241.3	59.7	42.6	34.3	29.0	608.2	35.8
MITIC	49.9	320.1	44.3	16.5	49.2	30.9	286.9	101.2	88.4	62.2	47.3	36.3	297.2	221.6
6040	60.6	307.4	358.4	8.2	30.4	28.3	84.8	110.1	282.9	54.2	94.4	48.0	431.1	69.8
KERMESS	60.2	340.6	60.4	41.4	25.9	7.7	188.9	236.9	112.7	35.3	106.1	51.1	40.4	50.8
31G98	61.4	171.5	99.4	8.5	14.0	18.5	121.4	114.1	428.0	33.9	37.1	44.0	39.1	57.1
LG3535	88.4	437.1	59.9	15.6	43.0	111.8	35.7	131.7	204.6	48.7	74.8	30.8	28.9	119.2
33A46	74.6	235.9	418.8	4.9	50.3	26.2	47.4	423.5	206.5	28.9	53.0	35.7	224.0	65.0
31P41	37.1	423.1	24.4	18.6	18.5	15.9	147.3	171.2	143.7	40.5	53.0	54.2	44.8	91.4
1T	12.6	330.0	135.2	35.9	39.5	9.7	75.9	125.5	552.5	32.0	168.2	94.1	605.9	55.4
2T	14.6	178.3	59.5	46.6	25.1	14.6	54.6	220.6	63.4	60.6	85.5	30.7	106.6	65.4
3T	10.9	411.7	51.9	32.6	17.9	11.9	56.3	132.7	253.5	16.3	339.4	71.4	48.8	70.3
4T	7.3	282.7	29.3	13.2	60.2	40.2	51.5	172.6	128.0	50.6	77.5	80.4	679.2	118.2
5T	13.3	89.5	229.1	20.4	25.0	15.6	45.8	318.7	160.1	120.4	31.7	15.7	63.3	38.4
1F	59.3	784.6	69.5	16.5	33.0	152.9	87.0	125.7	124.5	40.4	75.8	57.9	56.8	44.3
2F	55.9	196.0	62.2	19.3	16.1	40.4	34.8	205.3	99.2	135.6	54.7	35.5	28.0	157.1
3F	57.4	303.5	132.3	47.1	27.5	70.7	53.5	91.2	157.8	64.6	59.2	37.4	47.5	127.9
4F	59.4	415.7	52.4	10.7	15.6	49.1	99.8	226.7	44.9	55.8	41.7	38.6	348.1	47.7
5F	57.9	87.8	31.9	14.9	42.3	8.7	90.4	135.8	1388.1	71.1	1046.8	26.7	612.0	68.5
6F	57.7	1056.1	38.6	11.1	21.8	22.9	116.7	453.5	156.2	212.8	35.5	88.8	63.0	32.7
7F	99.2	619.9	43.1	8.1	37.3	63.6	101.8	429.3	86.8	80.6	52.1	112.8	588.6	27.0
8F	101.4	280.8	46.9	37.2	47.1	46.6	29.1	277.9	68.5	143.5	92.7	129.4	251.3	54.3
9F	88.2	548.3	28.2	15.3	60.2	5.8	60.2	201.0	110.3	44.5	60.1	24.1	333.9	76.3
10F	48.1	561.4	35.9	10.2	16.5	13.9	44.1	293.6	170.5	64.7	86.2	31.7	50.3	94.8

Table 5. Trait stability index $(\bar{x}/s)^2$ across genotypes and environments for tested traits: yield (kg ha^{-1}), specific weight (g L^{-1}), 1000-kernel weight (g), axis (spindle) weight (g), spike weight (g), number of kernels per spike, spike length (cm) and diameter (mm), number of kernel rows, spindle diameter (mm), main spike and plant height (cm), prolificacy, and number of kernels per row, in Trikala region.

Genotypes	Yield (kg ha^{-1})	Specific Weight (g L^{-1})	1000-Kernel Weight (g)	Axis (Spindle) Weight (g)	Spike Weight (g)	Number of Kernels per Spike	Spike Length (cm)	Spike Diameter (mm)	Number of Kernel Rows	Spindle Diameter (mm)	Height of Main Spike (cm)	Plant Height (cm)	Prolificacy	Number of Kernels per Row
31Y43	103.9	206.4	86.9	17.3	11.5	32.4	165.6	170.5	218.5	62.4	53.8	18.9	54.4	146.2
FACTOR	60.2	113.8	129.7	11.3	28.7	75.7	148.1	99.4	380.5	31.2	53.8	29.3	609.9	79.4
COSTANZA	142.1	92.0	73.0	5.7	31.2	88.7	92.2	150.6	262.1	28.3	68.1	27.2	50.1	113.3
ARMA	69.7	155.0	19.3	9.0	40.8	46.6	57.1	133.4	447.5	38.5	86.7	23.1	639.9	294.9
31A34	85.4	177.8	41.4	12.8	31.7	71.6	138.1	191.6	266.5	47.7	54.0	59.8	350.3	130.0
ELEONORA	61.5	398.9	161.0	19.8	65.3	50.0	94.1	188.5	370.6	89.8	40.9	24.8	336.5	147.8
FAMOSO	61.9	272.6	239.5	23.6	42.6	27.0	94.8	99.9	113.1	34.9	60.9	41.7	168.7	138.1
6818	62.1	171.3	231.8	19.9	24.0	95.6	100.1	277.6	389.7	87.5	75.4	16.6	26.5	211.3
MITIC	176.6	224.6	51.3	25.2	21.5	34.3	75.4	268.6	110.8	118.3	119.5	24.9	38.6	83.9
6040	37.0	57.3	44.3	13.8	31.5	19.1	88.2	290.1	87.3	153.5	64.8	48.0	582.4	129.9
KERMESS	42.3	105.3	66.7	10.0	30.4	129.8	89.5	177.6	130.2	55.7	49.3	29.7	39.8	224.2
31G98	72.0	719.7	39.6	13.5	21.5	15.9	132.5	241.9	141.1	24.2	78.0	22.8	49.1	88.6
LG3535	26.4	347.6	40.5	16.4	62.3	15.2	81.5	317.7	129.6	57.3	79.1	13.3	242.0	63.6
33A46	39.7	376.4	133.5	14.8	13.3	246.0	83.5	283.7	91.1	91.0	113.7	17.7	38.3	93.3
31P41	31.4	332.2	238.7	189.1	35.4	19.7	117.6	212.3	336.0	22.4	49.3	87.4	388.7	126.8
1T	42.0	392.8	72.1	19.4	24.3	10.4	73.4	264.3	104.9	72.0	50.2	60.2	643.9	27.7
2T	45.9	240.0	148.5	77.1	23.3	43.5	134.6	131.0	139.5	57.3	80.9	25.8	68.3	51.1
3T	45.9	456.5	36.0	14.3	25.4	16.5	74.9	276.1	138.4	1620.9	63.1	29.6	153.6	184.0
4T	49.6	206.4	57.2	12.8	33.8	27.9	231.8	727.9	82.2	217.1	92.1	50.1	370.5	72.9
5T	50.1	262.9	109.7	10.5	95.9	9.2	57.0	142.9	182.0	88.4	137.1	54.8	129.9	43.1
1F	3.7	757.7	41.2	12.8	16.0	49.2	112.9	124.2	147.4	89.9	89.0	27.1	276.6	45.1
2F	7.8	147.8	33.0	28.9	21.4	28.3	63.8	317.0	228.6	121.0	56.2	29.8	41.1	203.1
3F	18.1	731.0	84.9	5.3	41.9	27.3	43.7	290.4	103.3	178.8	137.1	56.4	398.7	126.0
4F	9.4	333.3	51.4	9.9	20.3	42.8	84.6	142.7	65.2	74.0	64.9	45.9	589.3	74.9
5F	18.7	599.7	47.7	27.3	25.4	16.8	46.0	128.2	193.0	85.8	53.2	30.4	288.4	67.7
6F	15.4	196.2	44.7	44.0	17.8	25.5	399.3	147.2	98.5	76.7	39.6	66.1	420.0	141.6
7F	19.8	271.1	16.3	8.9	16.0	9.9	37.1	130.3	69.1	37.3	54.4	30.4	25.4	104.4
8F	12.8	181.9	68.6	21.8	87.2	10.5	92.2	97.3	120.2	20.9	57.8	53.9	773.6	197.9
9F	17.1	241.9	22.9	14.1	24.6	21.2	104.5	67.6	107.3	71.6	55.1	58.1	2835.6	91.9
10F	22.6	281.8	32.2	66.7	20.0	17.4	61.4	242.8	190.0	85.8	66.6	54.5	36.4	62.7

Table 6. Trait stability index $(\overline{x}/s)^2$ across genotypes and environments for tested traits: yield, yield (kg ha^{-1}), specific weight (g L^{-1}), 1000-kernel weight (g), axis (spindle) weight (g), spike weight (g), number of kernels per spike, spike length (cm) and diameter (mm), number of kernel rows, spindle diameter (mm), main spike and plant height (cm), prolificacy, and number of kernels per row, in Kalambaka region.

Genotypes	Yield (kg ha^{-1})	Specific Weight (g L^{-1})	1000-Kernel Weight (g)	Axis (Spindle) Weight (g)	Spike Weight (g)	Number of Kernels per Spike	Spike Length (cm)	Spike Diameter (mm)	Number of Kernel Rows	Spindle Diameter (mm)	Height of Main Spike (cm)	Plant Height (cm)	Prolificacy	Number of Kernels per Row
31Y43	135.9	124.1	81.8	8.9	39.8	40.2	113.9	379.7	188.7	41.3	49.8	44.1	48.2	154.6
FACTOR	155.5	84.0	84.3	10.8	42.7	35.5	84.5	410.7	293.1	98.7	42.6	20.1	64.3	302.4
COSTANZA	161.5	192.3	74.8	19.6	35.1	98.7	231.3	821.2	879.7	38.6	130.4	570.6	763.0	242.3
ARMA	72.7	113.7	96.5	16.5	24.1	58.4	104.5	164.8	359.0	54.6	45.0	24.9	521.5	79.9
31A34	105.2	223.9	35.5	57.3	40.0	16.5	90.6	137.4	141.0	37.1	60.9	115.6	428.5	99.1
ELEONORA	100.2	123.9	70.3	10.0	27.7	52.6	41.9	117.4	88.8	52.5	71.5	26.5	735.1	173.7
FAMOSO	71.5	357.5	99.4	28.5	14.4	266.7	61.5	285.5	96.6	86.5	96.9	18.7	606.8	71.5
6818	58.3	502.5	189.7	13.8	20.6	55.3	140.8	201.0	135.7	58.2	55.9	31.9	163.3	53.9
MITIC	64.4	104.6	41.2	7.5	31.8	45.5	80.4	286.7	112.0	33.3	46.4	53.8	427.2	86.8
6040	37.7	213.8	224.3	7.4	38.0	32.5	54.4	160.0	148.0	63.3	89.0	26.8	53.1	26.1
KERMESS	45.9	191.4	80.8	19.6	94.0	9.5	82.3	232.8	141.3	62.5	60.1	29.1	305.8	44.1
31G98	89.6	391.1	46.0	15.1	33.5	44.4	132.0	149.5	302.7	218.2	82.9	40.1	308.8	96.3
LG3535	49.4	93.8	32.1	32.3	32.1	39.9	107.7	405.4	248.4	93.8	37.5	29.1	288.6	51.0
33A46	88.4	437.1	59.9	15.6	43.0	111.8	35.7	131.7	204.6	48.7	74.8	30.8	28.9	40.1
31P41	32.0	67.9	59.7	12.0	21.4	13.0	94.7	333.8	335.4	78.6	64.2	26.2	763.4	46.8
1T	24.2	286.0	27.0	22.8	17.9	12.2	59.1	309.1	111.4	86.1	111.1	54.8	484.0	41.2
2T	23.2	187.9	47.3	16.6	46.2	64.8	70.8	427.1	54.7	76.6	84.4	39.7	58.5	66.0
3T	21.2	330.7	48.7	26.2	74.7	20.0	53.4	388.7	61.3	43.6	33.1	40.7	33.7	61.3
4T	16.0	1372.6	230.6	11.9	31.8	27.5	52.2	202.8	68.6	46.6	37.0	46.3	370.6	191.8
5T	34.4	240.6	43.7	17.2	16.9	22.4	63.2	121.7	76.4	69.7	266.0	182.7	232.5	89.3
1F	23.3	561.8	31.7	36.7	46.0	27.3	137.3	231.6	162.9	48.1	100.3	47.4	224.1	65.7
2F	13.8	254.2	25.0	17.9	15.6	75.2	52.4	581.7	96.2	62.7	63.4	100.5	448.7	87.4
3F	16.8	226.1	34.8	25.0	7.9	36.0	25.7	389.9	64.0	16.4	78.8	36.7	191.4	59.5
4F	15.5	191.2	59.8	15.9	17.9	18.7	71.2	61.1	92.8	70.0	55.9	38.4	165.0	68.4
5F	18.0	203.2	91.2	14.6	25.8	12.4	24.0	189.1	165.7	76.8	102.6	55.0	712.0	111.4
6F	12.4	216.3	35.6	12.1	30.3	12.6	69.0	316.1	61.9	91.2	38.9	37.2	208.3	30.2
7F	12.8	513.5	48.9	15.5	47.1	13.0	196.0	132.0	323.2	96.8	45.4	65.3	636.0	77.5
8F	12.7	443.2	31.0	23.4	24.0	17.4	35.8	157.9	85.4	79.2	82.1	49.3	34.4	24.4
9F	14.1	326.5	29.9	80.2	26.0	14.7	666.0	210.7	62.7	55.8	53.8	149.2	538.3	156.7
10F	10.7	305.5	20.3	15.2	41.8	16.9	49.0	161.6	129.9	54.9	46.9	52.0	698.4	107.2

Table 7. Trait stability index $(\bar{x}/s)^2$ across genotypes for tested traits: yield (kg ha^{-1}), specific weight (g L^{-1}), 1000-kernel weight (g), axis (spindle) weight (g), spike weight (g), number of kernels per spike, spike length (cm) and diameter (mm), number of kernel rows, spindle diameter (mm), main spike and plant height (cm), prolificacy, and number of kernels per row.

Genotypes	Yield (kg ha^{-1})	Specific Weight (g L^{-1})	1000-Kernel Weight (g)	Axis (Spindle) Weight (g)	Spike Weight (g)	Number of Kernels per Spike	Spike Length (cm)	Spike Diameter (mm)	Number of Kernel Rows	Spindle Diameter (mm)	Height of Main Spike (cm)	Plant Height (cm)	Prolificacy	Number of Kernels per Row
31Y43	95.1	119.3	98.0	11.5	28.8	49.6	165.0	259.8	222.5	49.6	55.5	32.8	83.6	72.6
FACTOR	66.2	121.9	66.1	14.7	19.2	32.7	111.4	163.3	194.9	53.6	51.6	29.3	83.5	80.2
COSTANZA	109.2	160.2	52.4	8.1	29.1	130.2	95.5	177.3	236.4	40.4	69.7	48.8	90.7	67.9
ARMA	72.0	143.0	44.3	14.2	33.5	48.6	68.3	165.3	124.2	48.9	69.5	33.5	293.1	77.3
31A34	79.7	161.6	44.2	12.9	26.2	31.8	80.2	200.7	189.9	52.2	76.1	31.7	93.8	47.8
ELEONORA	53.6	205.7	56.1	12.9	38.2	27.6	62.7	164.6	138.5	36.8	64.4	25.9	89.1	115.6
FAMOSO	69.2	263.7	91.9	24.7	30.6	22.8	58.9	179.3	109.2	51.4	56.3	35.1	181.5	66.2
6818	56.4	264.8	72.9	20.0	23.5	31.4	108.4	265.6	103.9	60.9	55.7	27.9	77.2	59.8
MITIC	63.6	171.0	48.1	12.2	22.5	26.1	111.9	182.6	112.3	43.0	62.6	36.0	109.1	61.0
6040	44.6	126.0	87.8	9.6	29.2	25.7	64.9	184.3	141.0	73.9	59.6	38.3	42.6	61.0
KERMESS	45.1	185.6	66.7	17.1	25.0	13.6	67.8	166.3	85.8	37.0	51.4	35.0	72.4	54.4
31G98	75.4	284.2	51.8	11.8	21.0	20.8	129.4	163.6	188.9	47.1	64.4	28.6	79.3	41.4
LG3535	37.1	192.9	57.0	18.2	41.8	26.1	55.9	178.0	187.8	45.1	55.1	22.8	69.9	48.0
33A46	60.6	316.2	101.1	9.9	29.3	66.1	45.6	237.4	124.0	47.1	70.1	30.5	55.5	42.0
31P41	38.5	140.1	43.0	19.5	22.2	16.2	121.0	242.9	153.1	41.4	49.3	27.5	71.6	43.9
1T	16.9	302.8	54.9	22.9	24.7	12.6	63.0	175.2	121.0	49.2	73.7	55.5	577.4	29.8
2T	18.9	210.6	45.4	22.5	25.0	28.5	67.9	173.6	75.0	62.4	97.2	34.3	85.3	43.0
3T	13.1	273.2	33.0	19.6	29.2	20.3	51.7	203.3	139.3	37.5	51.5	44.6	54.5	55.3
4T	12.9	325.1	52.3	9.2	37.1	41.5	76.6	241.2	93.6	70.7	71.8	56.2	338.8	103.5
5T	15.9	180.6	75.6	19.6	28.5	16.7	56.6	171.9	90.8	52.7	58.1	44.2	130.3	49.6
1F	8.3	404.0	33.2	22.4	30.4	31.6	100.7	152.2	137.1	60.8	78.1	40.8	129.4	33.6
2F	11.5	196.3	28.3	22.6	16.0	27.9	57.8	243.2	108.2	54.1	57.8	36.1	52.0	53.8
3F	13.3	273.4	49.3	9.6	16.1	28.3	39.8	145.3	111.2	41.7	73.2	41.3	134.6	59.3
4F	13.5	286.8	61.4	11.6	20.0	26.6	87.5	135.9	81.7	74.7	65.7	46.4	90.5	62.4
5F	14.4	202.9	40.4	18.3	37.2	14.5	47.5	156.3	221.8	65.0	95.1	42.5	452.8	64.5
6F	13.6	250.6	39.6	17.3	21.6	22.7	87.3	217.0	108.4	99.3	38.3	45.3	91.6	41.3
7F	14.8	438.8	33.4	13.7	18.5	18.1	70.1	188.1	112.7	62.9	49.0	51.4	76.7	46.6
8F	11.5	256.7	32.9	27.3	41.9	18.3	53.8	153.7	86.1	45.2	76.8	50.0	99.8	39.8
9F	12.4	373.0	33.4	20.6	23.1	14.0	80.5	125.0	89.7	63.9	54.4	42.9	478.7	45.0
10F	14.8	335.6	28.9	14.1	26.7	16.1	58.1	162.6	106.5	65.2	67.9	40.7	73.4	70.1

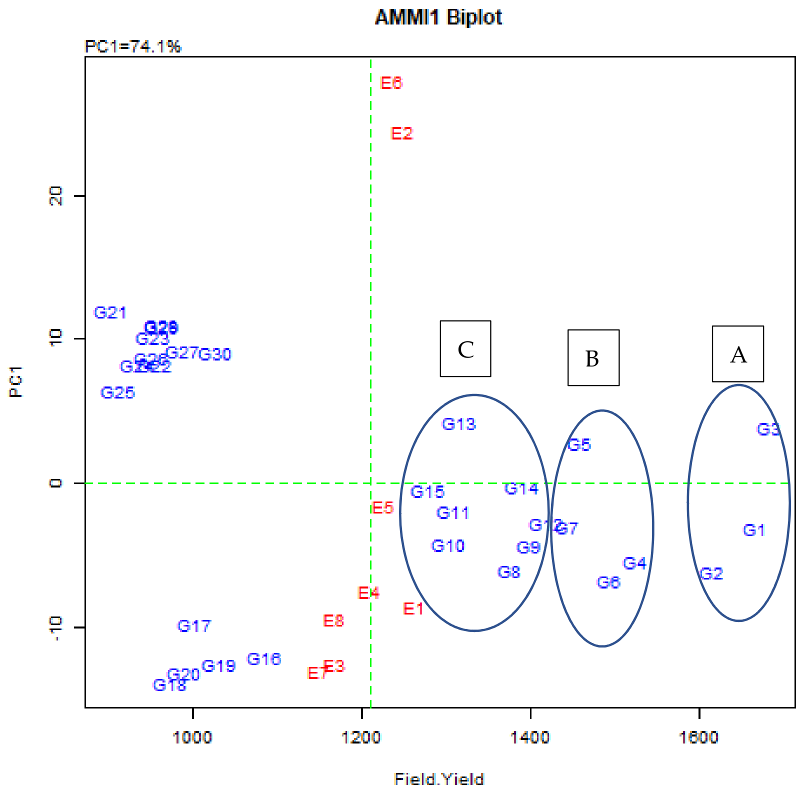
Table 8. Correlations between all traits measured: yield (kg ha^{-1}), specific weight (g L^{-1}), 1000-kernel weight (g), axis (spindle) weight (g), spike weight (g), number of kernels per spike, spike length (cm) and diameter (mm), number of kernel rows, spindle diameter (mm), main spike and plant height (cm), prolificacy, and number of kernels per row.

	Yield (kg ha^{-1})	**Specific Weight (g L^{-1})**	**1000-Kernel Weight (g)**	**Axis (Spindle) Weight (g)**	**Spike Weight (g)**	**Number of Kernels per Spike**	**Spike Length (cm)**	**Spike Diameter (mm)**	**Number of Kernel Rows**	**Spindle Diameter (mm)**	**Height of Main Spike (cm)**	**Plant Height (cm)**	**Prolificacy**
Specific weight (g L^{-1})	−0.54 *												
1000-kernel weight (g)	0.51 *	−0.32											
Axis (spindle) weight (g)	−0.44 *	0.15	−0.28										
Spike weight (g)	0.05	−0.11	0.09	0.13									
Number of kernels per spike	0.61 *	−0.22	0.24	−0.49 *	0.12								
Spike length (cm)	0.51 *	−0.24	0.18	−0.21	−0.27	0.19							
Spike diameter (mm)	0.24	−0.20	0.30	−0.08	−0.07	0.20	0.32						
No of kernel rows	0.60 *	−0.43 *	0.14	−0.34	0.18	0.44 *	0.39	0.11					
Spindle diameter (mm)	−0.40 *	0.28	−0.10	−0.02	−0.16	−0.18	0.02	0.04	−0.25				
Height main spike (cm)	−0.11	0.06	−0.16	0.04	0.32	0.13	−0.28	−0.31	0.06	−0.06			
Plant height (cm)	−0.49 *	0.47 *	−0.32	0.05	−0.01	0.03	−0.27	−0.20	−0.30	0.34	0.16		
Prolificacy	−0.25	0.24	−0.17	0.21	0.17	−0.17	−0.18	−0.27	−0.04	0.13	0.32	0.45 *	
Number of kernels per row	0.27	−0.27	0.18	−0.46 *	0.30	0.23	0.04	0.07	0.13	−0.08	−0.01	−0.11	−0.01

* Correlations significant at the 0.05 level (2-tailed).

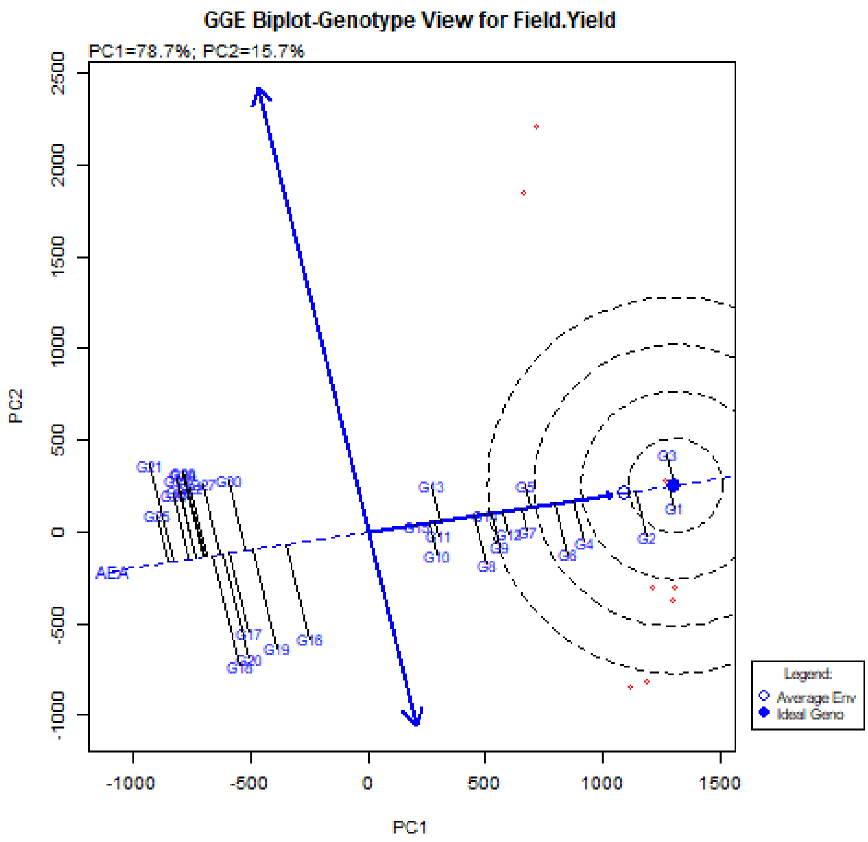
31Y43 and Costanza proved to be the more stable hybrids, while line 4T was found also stable in many characteristics. Environments promoting stability were Florina for yield and some yield components, Giannitsa for prolificacy, while in many cases means were almost the same. Both stability and inheritance estimations may be performed only in multi-location or multi-genotype evaluations and not in multi-factor experiments as reported by Greveniotis et al. [19].

From GGE biplot in Figure 2a,b, genotypes favoured in certain environments were easily distinguished with high precision. Kaplan et al. [20] concluded that GGE biplot method with different perspectives could be used for assessment of silage characteristics of maize genotypes grown in different environments. In our analysis, GGE biplot for yield distributed genotypes in a different way for Florina on the basis of one main factor and managed to depict Trikala differential response on the basis of two factors (nearly all the variance of the experiment). Almost the same was found for 1000-kernel weight and for specific weight, where there was a wide core for similar responding genotypes. This analysis of variance showed highly significant G × E effects for grain yield. Stability across environments should be further tested in multiple environments through years to confirm genotype behavior, based also on the findings of Greveniotis et al. [11–13]. High yielding but not stable hybrids across environments could be recommended only for the specific environments where they performed satisfactory [21]. We also are in agreement with previous researchers since our study revealed that genotypes, environments and G × E interaction were significant for stability of yield. The genotypes performed differently with respect to yield in each environment. AMMI biplot showed significant variability among the environments.



a

Figure 2. *Cont.*



b

Figure 2. Stability analysis for seed yield (kg ha^{-1}) based on (**a**) the AMMI1 biplot where the *Y*-axis is the one visualizing the trait performance and the *X*-axis (PC1) visualizes the stability of varieties over environments, the E signs represent the environments combined with the years. The E1, E2, E3 and E4 are the environments Giannitsa, Florina, Trikala and Kalambaka, respectively for the year 2011 and the E5 to E8 are the same environments for the year 2012, G signs represent the genotypes used as follows PR31Y43 (G1), FACTOR (G2), COSTANZA (G3), ARMA (G4), PR31A34 (G5), ELEO-NORA (G6), FAMOSO (G7), DKC6818 (G8), MITIC (G9), DKC6040 (G10), KERMESS (G11), PR31G98 (G12), LG3535 (G13), PR33A46 (G14), PR31P41 (G15), 1T (G16), 2T (G17), 3T (G18), 4T (G19), 5T (G20), 1F (G21), 2F (G22), 3F (G23), 4F (G24), 5F (G25), 6F (G26), 7F (G27), 8F (G28), 9F (G29), 10F (G30); (**b**) the GGE biplot for varieties depicting the stability of the varieties over environments where the productive varieties are those to the right on the AEA vector and the stable ones are those closest to the AEA axis as possible.

Regarding the stability analysis using the tools of AMMI1 biplot (Figure 2a) and GGE biplot (Figure 2b) resulted in the same information. Based on the AMMI1 graph, there are 14 genotypes expressing stability and yield above the general average. All these genotypes can be divided into three groups the A group consisted of three genotypes G1 (PR31Y43), G3 (COSTANZA) and G2 (FACTOR) which were the most productive and stable over all genotypes. The B group of quite high yield, which consisted of G4 (ARMA), G5 (PR31A34), G6 (ELEONORA), G7 (FAMOSO) and the C group of higher from the general average yield but not very high, which consisted of G12 (PR31G98), G9 (MITIC), G14 (PR33A46), G8 (DKC6818), G10 (DKC6040), G 11 (KERMESS), G13 (LG3535), and G 15 (PR31P41). All the above-mentioned genotypes are desirable since they are stable with high yielding ability.

Based on the GGE biplot for varieties it is obvious that in the first concentric circle, the average environment and the ideal genotype are depicted along with G1 (PR31Y43), G3 (COSTANZA) and G2 (FACTOR) genotypes. Between the second and third concentric circles the G4 (ARMA) and G8 (DKC6818) genotypes and are situated, and between the third and fourth concentric circles there are the G5 (PR31A34), G7 (FAMOSO), G12 (PR31G98), and G9 (MITIC) genotypes. All these genotypes are desirable because they expressed stability since they were placed near the axes of AEA and close to the ideal genotype. All the other genotypes were of lower yielding ability and lower stability. Both analyses of AMMI and GGE were in accordance with similar results.

4. Conclusions

Environmental fluctuations were significant, but this multi-genotype analysis revealed the most stable hybrids, open-pollinated lines, traits and environment favouring stability. Stability estimations can be preferably performed as a multi-genotype analysis with stability index criterion as described in our work. The most stable and with qualitative inheritance characteristics are considered specific weight and spindle diameter. These characteristics could be very useful for indirect selection of yield. The best environment for promoting yield stability was Florina and the more stable hybrids were 31Y43, COSTANZA and FACTOR.

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