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Assessment of Interactions between Yield Components of Common Vetch Cultivars in Both Conventional and Low-Input Cultivation Systems

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Citation: Greveniotis, V.; Bouloumpasi, E.; Zotis, S.; Korkovelos, A.; Ipsilandis, C.G. Assessment of Interactions between Yield Components of Common Vetch Cultivars in Both Conventional and Low-Input Cultivation Systems. *Agriculture* **2021**, *11*, 369. https://doi.org/10.3390/agriculture11040369

Academic Editors: Panagiotis Madesis and Irini Nianiou-Obeidat

Received: 26 March 2021
Accepted: 16 April 2021
Published: 19 April 2021

Abstract: The primary purpose of this study was to explore yield stability of common vetch varieties based on the stability index, with a specific aim of exploring common vetch variety behavior regarding the yield of legumes under both conventional and low-input cultivation systems. Six varieties of common vetch (*Vicia sativa* L.), namely, cv. Filippos, cv. Omiros, cv. Alexandros, cv. Tempi, cv. Zefyros and cv. Pigasos, were used. The cultivation was conducted using a strip-plot design with the six varieties randomized within each plot in two farming systems (conventional and low-input). Filippos was the best variety in conventional farming for seed yield, followed by Omiros. Omiros was the best variety in the low-input farming system for seed yield. Comparisons between conventional and low-input farming systems generally did not display any effect on stability estimations, but revealed the varieties that exhibit stable performance even in low-input farming systems. Stability analysis via the AMMI1 and GxE biplot analysis for one main factor showed two groups of varieties for seed yield with similar behavior. Genotype and environment distribution were used to group varieties that showed better performance in certain environments for seed yield but with differences in comparison to other traits. Correlations between traits showed the positive relation of seed yield to the number of pods per plant, the number of seeds per pod, the pod length, the mean weight of pods and, especially, the hay weight ($r = 0.771$), a useful finding for indirect selection for breeders. The results provide valuable data regarding the genetic material, its adaptability and stability in varied environments and suitability for low-input cultivation systems.

Keywords: inputs; trait stability index; pods; GxE; common vetch

1. Introduction

Organic and, in many cases, traditional farming is a production system that maintains soil, ecosystems and human health. It is based on various ecological processes, biodiversity, low input and adapted cycles in local conditions. The main target is to optimize agricultural systems through agronomic improvement and therefore needs suitable varieties for low-input cultivation systems. In such systems, the need to reduce inputs (fertilizers, water, pesticides, energy) is a true challenge for both plant breeders and farmers. The objectives of plant breeders should be the shift from high-performance varieties towards the varieties achieving nutrient economy and fitting to local environments [1]. Therefore, the genetic material has to exhibit high adaptability to a wide range of different environments characterized by high heterogeneity [2].

Common vetch (*Vicia sativa* L.) is a widespread legume crop in the Mediterranean Basin and Western Asia [3,4]. Vetches (genus *Vicia* L., tribe Viciae, family Fabaceae) are cultivated in many areas around the world, with a global production area of approximately 416,552 ha in 2019. The main centers of production are located in Ethiopia, the Russian Federation, Australia, Turkey and Syria. The cultivation area of common vetch and other vetches in Greece was 31,977 ha in 2017 according to official data, the average annual yield was 1784 kg ha^{-1} and the crop production yield amounted to 57,060 tons in the same year [5]. Due to the vetch's nutritional value for animal feed as a legume, it is preferred by farmers both for its hay and grains, enriching in parallel the cultivation fields by fixing the atmospheric nitrogen in the soil [2,6].

Vetch is considered compatible with organic or low-input farming systems. It reserves the atmospheric nitrogen and thus benefits subsequent crops (usually cereals) and yields satisfactorily in cultivation areas [7]. It also copes well with weeds and other biotic and abiotic stresses. Appropriate varieties must be chosen carefully to adapt in heterogeneous and low-input environments and thus extensive experimentation is needed [8]. Some researchers have proposed variety mixtures instead of searching for adaptability of single varieties in order to maintain productivity and stability [9]. In farm production, varieties that perform well and express phenotypic stability or other important characteristics are promoted to farmers [10].

Fasoulas [11] proposed the ratio of 1/CV (the coefficient of variation) between the mean and standard deviation for estimating stability and, later, Fasoula [12] used the squared form as a stability criterion. The concept of use of the coefficient of variation (CV) for stability estimations was concluded by Edmeades and Daynard [13] and Tollenaar and Wu [14], while Edmeades and Deutch [15] used many parameters for estimating stability, leading to the proposal of genotype evaluations in multiple environments. Furthermore, extended experimentation was used in common vetch to assess the available germplasm for its adaptability and expression of certain characteristics under multi-environmental conditions in order to ensure stability of performance [16].

In the current study, our primary purpose was to explore yield stability of common vetch varieties based on the stability index as described by Fasoula [17]. The specific purpose of our work was to investigate common vetch variety behavior concerning the yield of legumes (pods) under both conventional and low-input cultivation systems and, in parallel, to propose the best varieties for certain cultivation areas, as well as to assess the relationship between characteristics as a breeding selection tool.

2. Materials and Methods

2.1. Crop Establishment and Experimental Procedures

Field experiments were conducted in two consecutive years (2010–2011 and 2011–2012) in four different locations. Coordinates according to the WGS 1984 geographic coordinate system are provided.

(A) In the farm of the Technological Educational Institute of Western Macedonia in Florina, Greece (latitude, 40°46′ N; longitude, 21°22′ E; elevation, 705 m a.s.l.). The soil type was characterized as sandy loam (SL): sand, 62%; silt, 26.9%; clay, 11.1%. The chemical properties of the soil were as follows: conventional: N-NO_3, 16.1 mg kg^{-1}; P-Olsen, 26.4 mg kg^{-1}; K, 236 mg kg^{-1}; pH_{H20}, 6.32; organic matter, 1.29%; and $CaCO_3$, 1.7 (%). Low-input system: N-NO_3, 17.4 mg kg^{-1}; P-Olsen, 25.1 mg kg^{-1}; K, 224 mg kg^{-1}; pH_{H20}, 6,29; organic matter, 1.32%; and $CaCO_3$, 1.9 (%).

(B) In Trikala, Greece (latitude, 39°55′ N; longitude, 21°64′ E; elevation, 120 m a.s.l.). The soil type was characterized as sandy clay loam (SCL): sand, 48.6%; silt, 19.2%; clay, 32.2%. The chemical properties of the soil were as follows: conventional: N-NO_3, 12.7 mg kg^{-1}; P-Olsen, 11.8 mg kg^{-1}; K, 168 mg kg^{-1}; pH_{H20}, 8.15; organic matter, 2.21%; and $CaCO_3$, 7.54 (%). Low-input system: N-NO_3, 13.6 mg kg^{-1}; P-Olsen, 11.5 mg kg^{-1}; K, 176 mg kg^{-1}; pH_{H20}, 8.11; organic matter, 2.39%; and $CaCO_3$, 7.63 (%).

(C) In Kalambaka, Greece (latitude, 39°64′ N; longitude, 21°65′ E; elevation, 190 m a.s.l.). The soil type was silty clay (SiC): sand, 14.6%; silt, 41.2%; clay, 44.2%. The chemical properties of the soil were as follows: conventional: N-NO_3, 11.39 mg kg^{-1}; P-Olsen, 7.62 mg kg^{-1}; K, 96.3 mg kg^{-1}; pH_{H20}, 8.05; organic matter, 2.14%; and $CaCO_3$, 3.58 (%). Low-input system: N-NO_3, 12.01 mg kg^{-1}; P-Olsen, 7.56 mg kg^{-1}; K, 98.7 mg kg^{-1}; pH_{H20}, 8.08; organic matter, 2.21%; and $CaCO_3$, 3.65 (%).

(D) In Giannitsa, Greece (latitude, 40°77′ N; longitude, 22°39′ E; elevation, 10 m a.s.l.). The soil type was clay (C): sand, 9.1%; silt, 37.5%; clay, 53.8%. The chemical properties of the soil were as follows: conventional: N-NO_3, 15.1 mg kg^{-1}; P-Olsen, 17.4 mg kg^{-1}; K, 274 mg kg^{-1}; pH_{H20}, 7.69; organic matter, 3.26%; and $CaCO_3$, 5.23 (%). Low-input system: N-NO_3, 16.1 mg kg^{-1}; P-Olsen, 15.9 mg kg^{-1}; K, 261 mg kg^{-1}; pH_{H20}, 7.65; organic matter, 3.51%; and $CaCO_3$, 5.37 (%).

Those locations were selected deliberately because of their varied environmental conditions. Basic weather data (mean monthly temperatures in °C and rainfall in mm) for each experimental site based on daily records are presented in Figure 1.

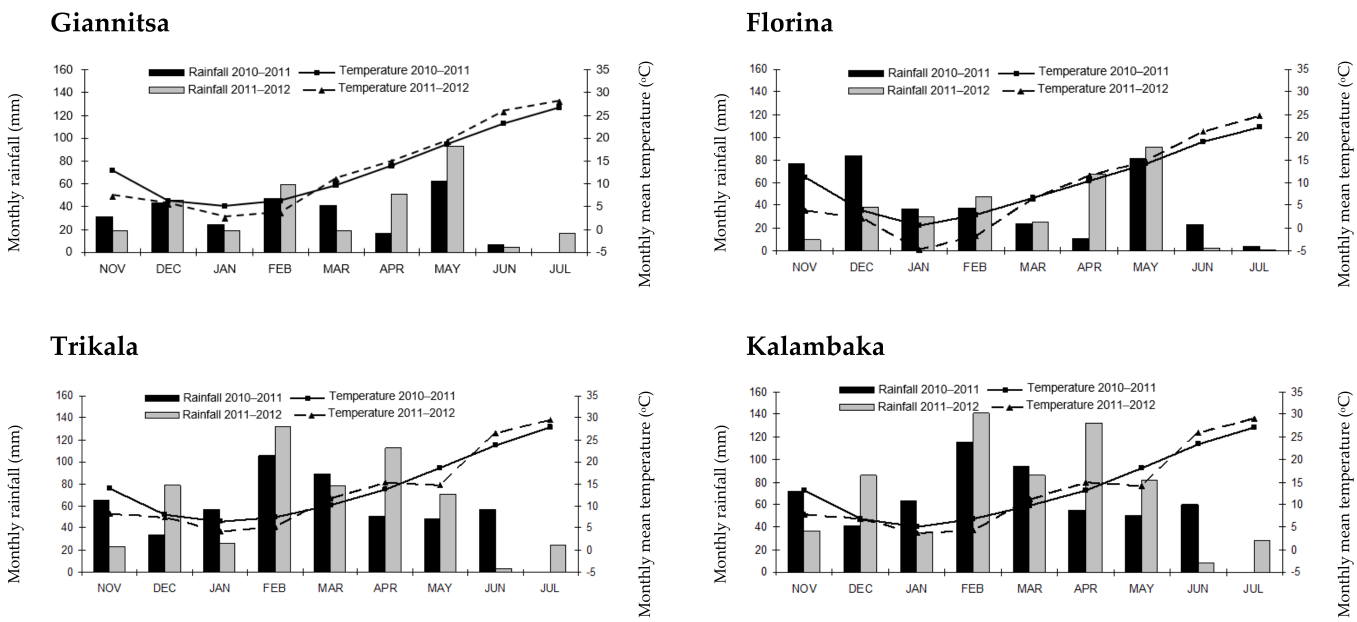


Figure 1. Basic weather data (mean monthly temperatures in °C and rainfall in mm) based on daily records for two years.

Six varieties of common vetch (*Vicia sativa* L.), namely, cv. Filippos, cv. Omiros, cv. Alexandros, cv. Tempi, cv. Zefyros and cv. Pigasos, were used. The cultivation was conducted using a strip-plot design with the six varieties randomized within each plot. Each plot consisted of seven rows 5 m in length and the rows were spaced 25 cm apart. The plot size was 8.75 m^2.

Two types of cultivation approaches were selected: under low-input and conventional farming systems.

Fertilization of experimental plots cultivated under the conventional farming system consisted of the nitrogen and phosphorus fertilizer (element level) applied before sowing at the rate of 30 and 50 kg ha^{-1}, respectively. The selected fields were cultivated conventionally for years preceding the experiment.

For low-input cultivation, no fertilizers or other agrochemicals were applied during the experiment in all four different locations, while prior to establishment of the experiment in

2010, the fields had been in a two-year rotation consisting of bread wheat/legume without nutritional supplementation or other agrochemical inputs.

Weeds appearing in the experimental area were removed by hand. The seeds were sown in early November and the harvest of legumes was completed in late June.

2.2. Measurements

The traits measured were as follows: seed yield (kg ha^{-1}), thousand kernel weight (g), number of pods per plant, number of seeds per pod, number of seeds per plant, pod length (cm), pod width (mm), (mean) pod weight (g), hay weight (kg ha^{-1}), plant height (cm).

Seed yield (kg ha^{-1}) and hay weight (kg ha^{-1}) were estimated based on the data recorded for each plot and variety. Hay yield was calculated by subtracting the weight of seeds from the total biomass weight.

For the estimation of plant height (cm) and yield components (number of pods per plant, number of seeds per pod, number of seeds per plant, pod length, pod width), ten plants were randomly selected per plot. In order to measure the (mean) pod weight (g), 10 pods per plant were weighted, while for the thousand kernel weight (g), five random samples per plot were used.

2.3. Data Analysis

Stability estimations were based on stability index $(\overline{x}/s)^2$, where $\overline{x}$ and s are the entry mean yield and the standard deviation, respectively [17].

Trait correlations were examined using the Pearson coefficient according to Steel et al. [18], and the significance of all the statistics was checked at $p < 0.05$ using SPSS ver. 25. Stability analysis was performed using the free version of PB Tools over locations and years for each characteristic and the statistical tools were the AMMI1 and (GGE) biplot analysis.

3. Results

Stability estimations are presented in Tables 1–3. In Table 1, indices are calculated across environments for all the traits measured. Seed yield stability showed low values (<50), while the number of seeds per plant showed very high values (>500) and almost the same was found for pod width (>450). Low values were also found for other traits such as the number of pods per plant, pod weight and hay yield.

The remaining traits showed intermediate values. The two farming systems displayed slight differences not affecting stability estimations. Differences between environments also did not affect stability estimations.

For seed yield stability, the Giannitsa area showed the highest values (near 50) for both cultivation systems. In Table 1, the Giannitsa area showed the highest values for almost all the traits, indicating a favorable environment for vetch cultivation that can ensure high and stable performance. Some specific traits were favored in other environments (as presented for Florina and Trikala). The number of seeds per plant showed a very high value in the Giannitsa area (951) for conventional cultivation, followed by Florina in both cultivation systems.

Table 1. Trait stability index across environments for two farming systems: seed yield (kg ha^{-1}), thousand kernel weight (g), number of pods per plant, number of seeds per pod, number of seeds per plant, pod length (cm), pod width (mm), (mean) pod weight (g), hay weight (kg ha^{-1}), plant height (cm).

	Environments	Seed Yield (kg ha^{-1})	Thousand Kernel Weight (g)	Number of Pods per Plant	Number of Seeds per Pod	Number of Seeds per Plant	Pod Length (cm)	Pod Width (mm)	Pod Weight (g)	Hay Yield (kg ha^{-1})	Plant Height (cm)
Conventional	Giannitsa	49	175	38	89	951	225	755	46	43	241
	Florina	47	210	67	62	937	320	455	26	47	311
	Trikala	37	198	59	60	588	211	669	47	30	270
	Kalambaka	37	178	59	79	598	253	481	60	33	365
Low-input	Giannitsa	48	187	56	104	722	191	907	57	46	296
	Florina	33	204	76	63	835	296	487	36	36	238
	Trikala	44	185	87	67	544	248	651	53	44	380
	Kalambaka	39	184	58	65	739	210	447	67	47	404
Conventional and low-input	Giannitsa	37	167	44	97	827	172	778	51	42	269
	Florina	30	192	68	63	887	282	471	30	34	273
	Trikala	27	175	66	64	554	214	617	51	26	318
	Kalambaka	23	171	54	72	645	215	452	64	28	387

Table 2. Trait stability index across genotypes for the two farming systems: seed yield (kg ha^{-1}), thousand kernel weight (g), number of pods per plant, number of seeds per pod, number of seeds per plant, pod length (cm), pod width (mm), (mean) pod weight (g), hay weight (kg ha^{-1}), plant height (cm).

	Genotypes	Seed Yield (kg ha^{-1})	Thousand Kernel Weight (g)	Number of Pods per Plant	Number of Seeds per Pod	Number of Seeds per Plant	Pod Length (cm)	Pod Width (mm)	Pod Weight (g)	Hay Yield (kg ha^{-1})	Plant Height (cm)
Conventional	Filippos	209	547	67	74	683	1126	1120	58	120	350
	Omiros	175	1562	35	54	375	623	1119	75	284	331
	Alexandros	92	780	50	78	1101	585	708	67	33	296
	Tempi	37	521	53	80	1256	425	887	73	47	249
	Zefyros	46	1275	45	64	1435	859	1179	83	52	309
	Pigasos	30	1103	77	76	285	422	389	82	28	262

Table 2. *Cont.*

	Genotypes	Seed Yield (kg ha^{-1})	Thousand Kernel Weight (g)	Number of Pods per Plant	Number of Seeds per Pod	Number of Seeds per Plant	Pod Length (cm)	Pod Width (mm)	Pod Weight (g)	Hay Yield (kg ha^{-1})	Plant Height (cm)
Low-input	Filippos	145	474	71	69	771	524	1108	81	96	335
	Omiros	351	1977	55	61	380	502	1261	96	341	367
	Alexandros	180	693	58	72	808	750	1263	70	75	298
	Tempi	46	385	52	90	699	457	1102	85	74	292
	Zefyros	26	945	47	66	1373	490	943	95	36	278
	Pigasos	44	1102	76	68	390	474	493	78	25	328
Conventional and low-input	Filippos	40	418	63	72	723	538	1083	68	57	345
	Omiros	43	1392	41	58	381	412	1190	86	70	353
	Alexandros	35	445	53	75	933	552	846	70	31	301
	Tempi	36	340	50	86	905	392	872	78	46	273
	Zefyros	28	650	42	66	1394	442	936	89	36	295
	Pigasos	35	889	72	73	327	380	433	81	25	289

Table 3. Combined trait stability index across genotypes and environments for the two farming systems: seed yield (kg ha^{-1}), thousand kernel weight (g), number of pods per plant, number of seeds per pod, number of seeds per plant, pod length (cm), pod width (mm), (mean) pod weight (g), hay weight (kg ha^{-1}), plant height (cm).

	Genotypes	Seed Yield (kg ha^{-1})	Thousand Kernel Weight (g)	Number of Pods per Plant	Number of Seeds per Pod	Number of Seeds per Plant	Pod Length (cm)	Pod Width (mm)	Pod Weight (g)	Hay Yield (kg ha^{-1})	Plant Height (cm)
						Giannitsa					
Conventional	Filippos	472	694	36	78	8074	2079	750	69	555	366
	Omiros	165	2265	127	86	746	2769	2983	77	494	245
	Alexandros	160	795	37	78	532	525	1917	73	40	299
	Tempi	70	887	51	68	2450	356	1059	94	64	217
	Zefyros	70	1192	66	126	2763	1136	1646	112	52	198
	Pigasos	57	1290	132	80	2835	304	664	83	69	213
Low-input	Filippos	167	424	40	78	6655	741	1022	52	107	370
	Omiros	700	2612	148	100	829	634	2417	102	454	272
	Alexandros	190	310	66	95	528	1070	2964	78	128	250
	Tempi	48	639	58	100	624	304	957	103	114	217
	Zefyros	38	1116	87	124	3830	722	2195	122	75	275
	Pigasos	47	1340	81	98	4683	313	2227	77	97	292

Table 3. *Cont.*

	Genotypes	Seed Yield (kg ha^{-1})	Thousand Kernel Weight (g)	Number of Pods per Plant	Number of Seeds per Pod	Number of Seeds per Plant	Pod Length (cm)	Pod Width (mm)	Pod Weight (g)	Hay Yield (kg ha^{-1})	Plant Height (cm)
						Florina					
Conventional	Filippos	233	977	117	77	5002	1389	2906	28	268	451
	Omiros	179	1232	63	40	258	743	966	44	274	362
	Alexandros	149	568	84	68	4487	518	448	40	61	258
	Tempi	47	732	49	97	1682	867	714	44	78	264
	Zefyros	55	1186	129	47	51,452	864	3825	40	68	359
	Pigasos	39	937	78	91	42,065	958	187	76	74	327
Low-input	Filippos	119	441	126	69	4699	998	1066	80	152	290
	Omiros	473	2266	93	40	258	524	3095	66	383	301
	Alexandros	140	586	63	47	4713	1297	1323	38	102	172
	Tempi	32	652	65	80	528	689	1576	48	62	214
	Zefyros	30	853	66	69	35,609	1336	1521	59	28	176
	Pigasos	32	985	87	84	23,877	583	245	55	39	281
						Trikala					
Conventional	Filippos	118	384	130	64	297	1600	1860	82	71	306
	Omiros	258	1894	22	57	855	670	1230	85	183	372
	Alexandros	59	959	80	67	2233	1038	1564	76	19	324
	Tempi	24	441	87	57	736	529	1274	71	41	370
	Zefyros	31	1255	73	45	4774	637	754	87	71	350
	Pigasos	26	1274	87	55	294	317	1058	109	30	175
Low-input	Filippos	119	502	111	71	280	1475	1517	99	135	351
	Omiros	214	1989	62	57	362	564	1491	92	200	475
	Alexandros	181	1270	81	109	766	753	1243	89	51	503
	Tempi	53	301	125	80	2900	989	1539	66	124	360
	Zefyros	45	997	139	47	1936	975	574	124	115	251
	Pigasos	45	1083	125	48	308	506	1742	121	30	274

Table 3. *Cont.*

	Genotypes	Seed Yield (kg ha^{-1})	Thousand Kernel Weight (g)	Number of Pods per Plant	Number of Seeds per Pod	Number of Seeds per Plant	Pod Length (cm)	Pod Width (mm)	Pod Weight (g)	Hay Yield (kg ha^{-1})	Plant Height (cm)
						Kalambaka					
Conventional	Filippos	241	378	208	58	2764	780	1558	101	90	546
	Omiros	117	1158	147	56	2952	627	797	94	509	394
	Alexandros	63	620	54	106	2538	998	1365	80	41	335
	Tempi	38	541	113	85	3512	438	1417	95	86	338
	Zefyros	33	1565	24	71	854	788	1270	142	73	344
	Pigasos	17	1154	74	73	341	690	2004	80	14	321
Low-input	Filippos	159	395	87	51	1682	772	1903	121	115	341
	Omiros	670	1499	115	77	2819	365	747	101	716	370
	Alexandros	165	1566	58	61	2830	405	1297	106	73	457
	Tempi	40	736	129	73	2525	759	1513	160	95	321
	Zefyros	23	1060	22	49	2424	453	871	107	110	433
	Pigasos	47	925	89	56	194	545	2675	71	24	354

Table 2 depicts the differences between the six varieties. The various traits displayed low, high or intermediate values, but some varieties displayed increased values for stability estimations. Filippos was the best common vetch variety in conventional farming for seed yield (209), followed by Omiros (175). The latter was the best variety in the low-input farming system for seed yield (351). Combined estimations showed that Omiros (43) and Filippos (40) appeared to be the most stable varieties for seed yield. Omiros exhibited very good stability for the thousand kernel weight (>1300), while Zefyros appeared to be the most stable for the number of seeds per plant (>1300). Within environments, Omiros showed extremely high values for the thousand kernel weight (especially in Giannitsa and Trikala), including over 2000. Regarding the seed yield, Omiros appeared to be a very stable choice for Giannitsa, Florina, Trikala and Kalambaka in the low-input farming system, while other varieties showed specific adaptability in the four different environments. Some impressive results were retrieved for various traits and different varieties, with above 1100 stability index values, indicating extreme stability performance of these varieties for specific traits.

Comparisons between the conventional and low-input farming systems generally did not affect stability estimations, but revealed varieties that exhibit stable performance, even in the low-input farming system.

In Table 3, stability indices combine both environmental and genotypic behavior for all the traits for the two cultivation systems. Florina displayed some extreme stability index values in both cultivation systems for the number of seeds per plant, indicating a perfect environment for seed production purposes due to stable contribution.

The AMMI1 and GxE biplots can explore both environmental and genotype behavior concerning all the traits for stability and performance. The AMMI1 and GxE biplots were used to analyze stability and adaptability of the varieties in the different environments over the years of experimentation. For yield, both AMMI1 and the GGE biplot analyses clustered the varieties in two groups, the one expressing high yield and the other with low yield. Both groups seemed to be stable, expressing low variability between them within environments (Figure 2). Thousand kernel weight (TKW) seemed to be stable between the environments, while two of the varieties expressed the highest TKW of all (Figure 3). For the number of seeds per plant, the adaptation map showed a pattern indicating specific adaptability for varieties and environments (Figure 4). The hay yield showed that the varieties were not stable between the environments. The depiction of the varieties in Figure 5 showed specific adaptability between the environments. The analysis of AMMI1 and GGE biplots for the environments showed that there are two that are stable and favorable for all the traits.

Correlations between Characteristics

Correlations between traits (Table 4) showed the positive correlation of seed yield to the number of pods per plant (r = 0.172), number of seeds per pod (r = 0.116), pod length (r = 0.116), mean weight of pods (r = 0.109) and especially hay weight (r = 0.771). The number of pods per plant is positively correlated to pod width and hay weight. Some other positive or negative correlations are presented in Table 4.

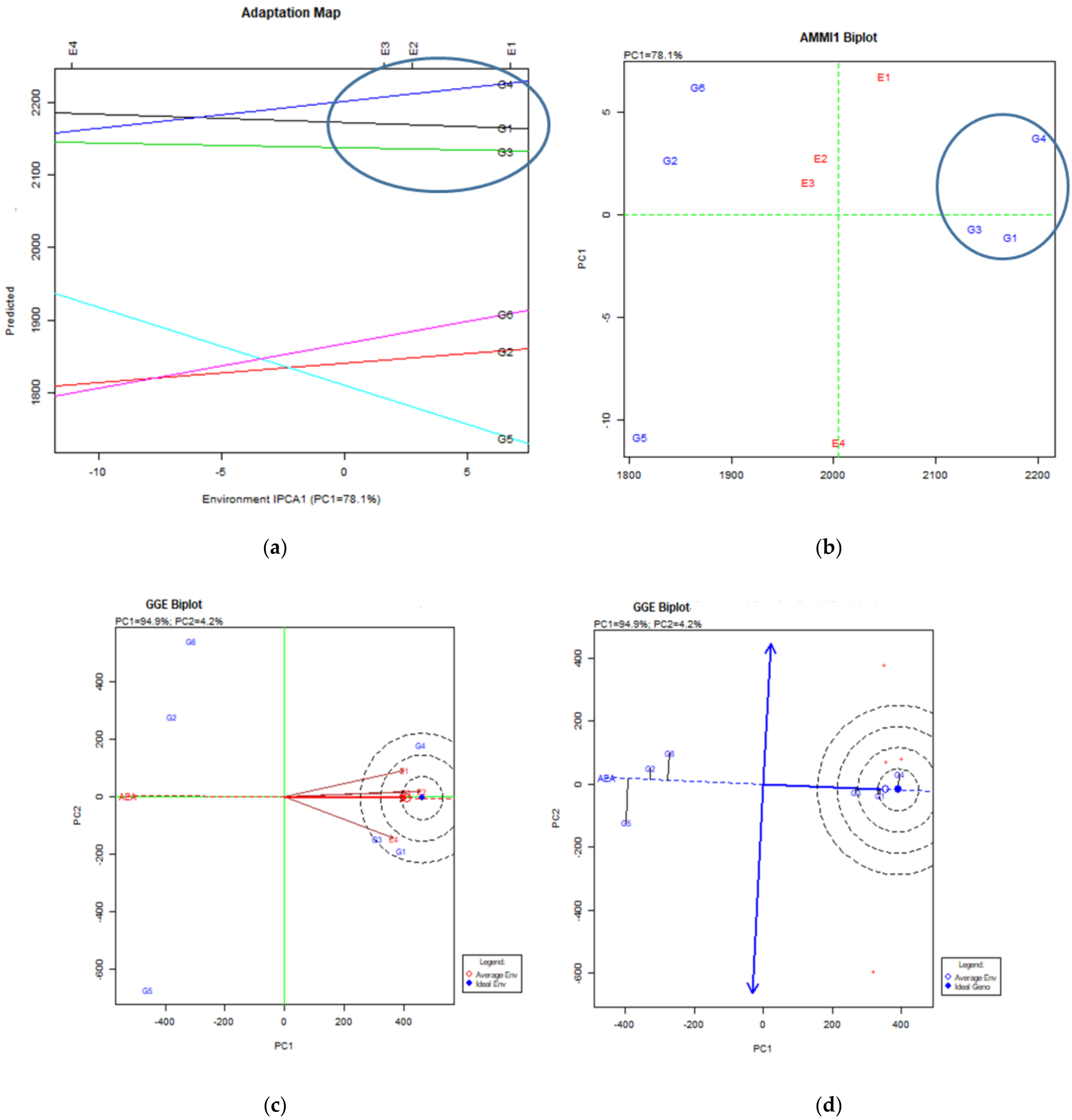
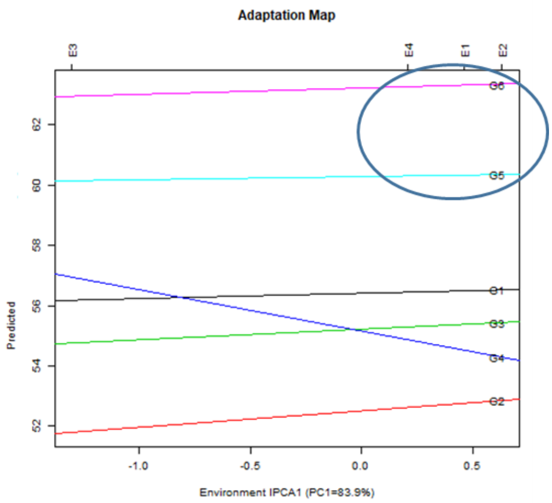


Figure 2. Stability analysis for seed yield (kg ha^{-1}) based on (**a**) the adaptation map where the *X*-axis (PC1) visualizes the stability of varieties over environments and the *Y*-axis—the performance of varieties for the trait; (**b**) the AMMI1 biplot where the *Y*-axis is the one visualizing the trait performance and the *X*-axis (PC1) visualizes the stability of varieties over environments; (**c**) the GGE biplot for environments depicting the stability of the environments over years via the placement as near as possible to the ideal and average environment; (**d**) 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 which are as close to the AEA axis as possible.



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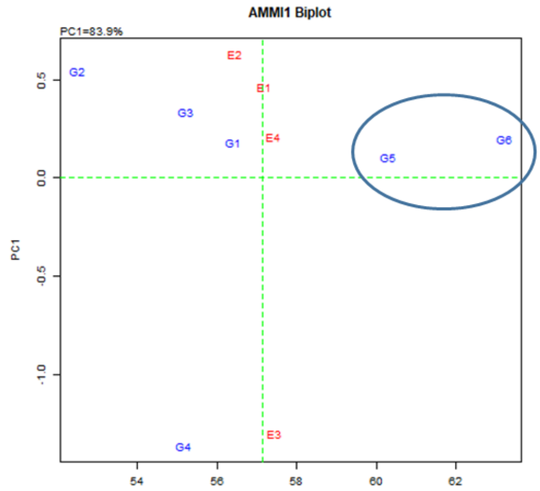

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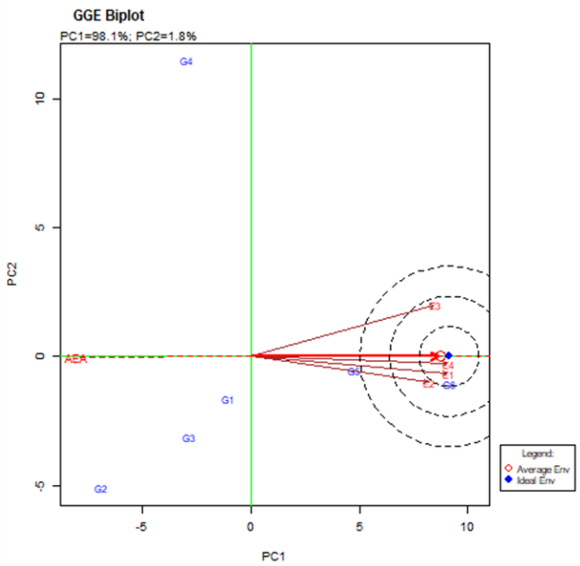

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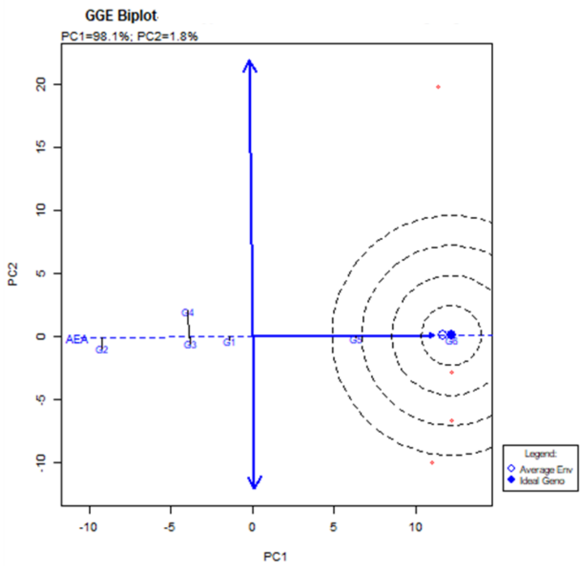
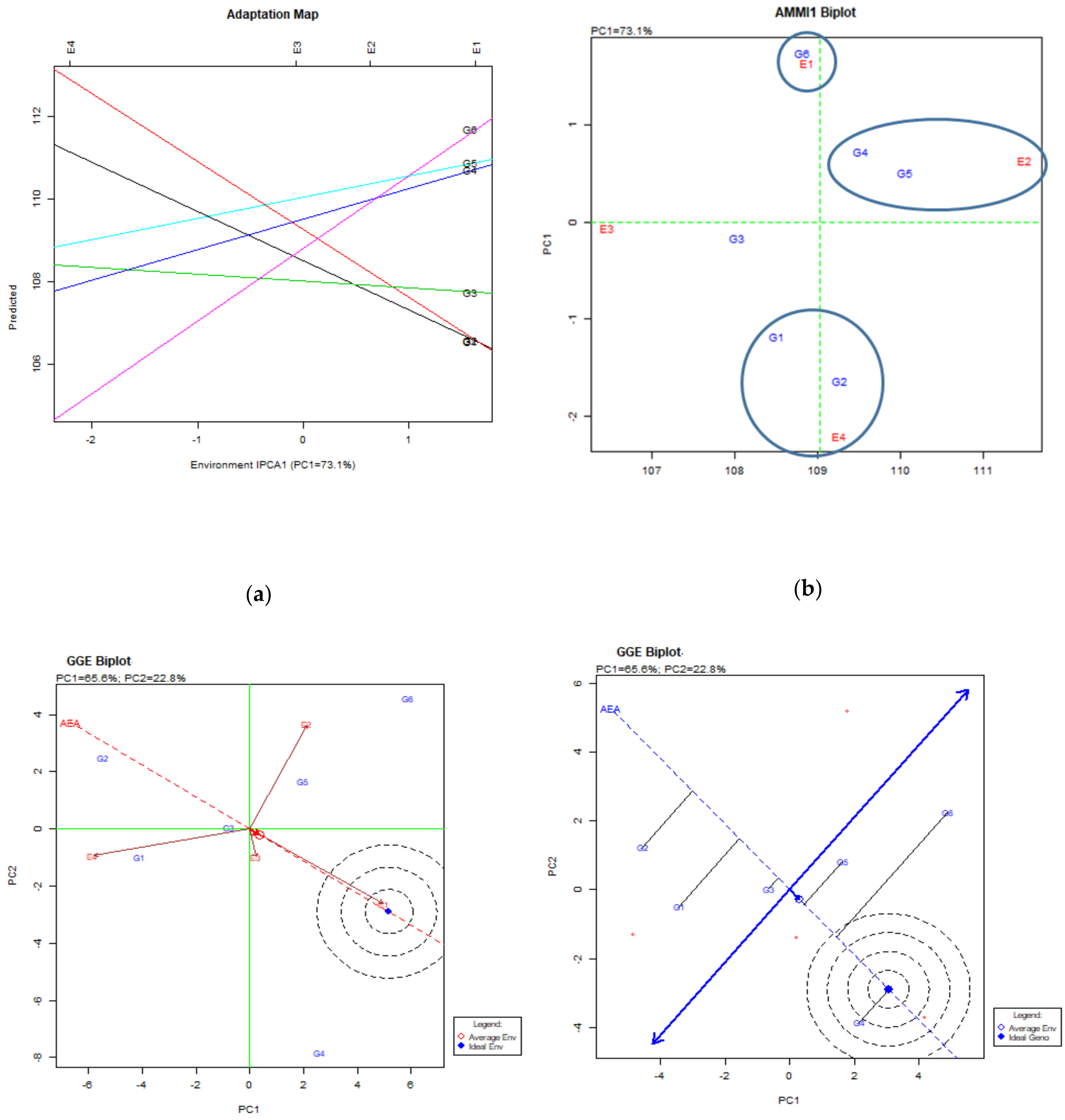


(**d**)

Figure 3. Stability analysis for thousand kernel weight (g) based on (**a**) the adaptation map where the *X*-axis (PC1) visualizes the stability of varieties over environments and the *Y*-axis—the performance of varieties for the trait; (**b**) 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; (**c**) the GGE biplot for environments depicting the stability of the environments over years via the placement as near as possible to the ideal and average environment; (**d**) 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 which are as close to the AEA axis as possible.

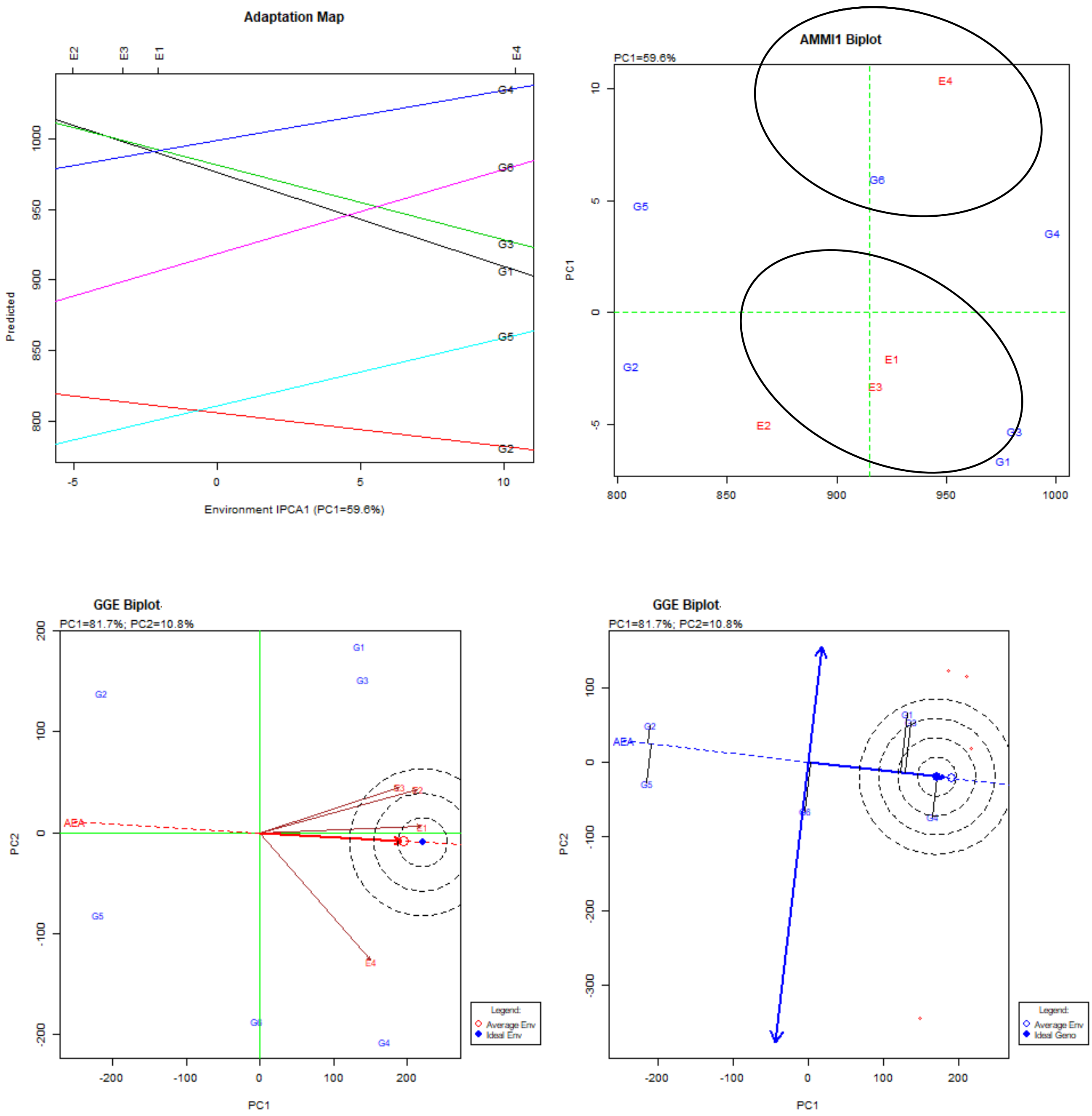


(**a**) (**b**)

(**c**) (**d**)

Figure 4. Stability analysis for the number of seeds per plant based on (**a**) the adaptation map where the *X*-axis (PC1) visualizes the stability of varieties over environments and the *Y*-axis—the performance of varieties for the trait; (**b**) 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; (**c**) the GGE biplot for environments depicting the stability of the environments over years via the placement as near as possible to the ideal and average environment; (**d**) 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 which are as close to the AEA axis as possible.

(**a**) (**b**)



(**c**) (**d**)

Figure 5. Stability analysis for hay yield (kg ha^{-1}) based on (**a**) the adaptation map where the *X*-axis (PC1) visualizes the stability of varieties over environments and the *Y*-axis—the performance of varieties for the trait; (**b**) 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; (**c**) the GGE biplot for environments depicting the stability of the environments over years via the placement as near as possible to the ideal and average environment; (**d**) 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 which are as close to the AEA axis as possible.

Table 4. Correlations between all the traits measured: seed yield (kg ha^{-1}), thousand kernel weight (g), number of pods per plant, number of seeds per pod, number of seeds per plant, pod length (cm), pod width (mm), (mean) pod weight (g), hay weight (kg ha^{-1}), plant height (cm).

	Seed Yield (kg ha^{-1})	**Thousand Kernel Weight (g)**	**Number of Pods per Plant**	**Number of Seeds per Pod**	**Number of Seeds per Plant**	**Pod Length (cm)**	**Pod Width (mm)**	**Pod Weight (g)**	**Hay Yield (kg ha^{-1})**
Thousand kernel weight (g)	−0.007								
Number of pods per plant	0.172 **	0.027							
Number of seeds per pod	0.116 *	0.057	−0.106 *						
Number of seeds per plant	−0.003	0.039	0.031	−0.182 **					
Pod length (cm)	0.116 *	0.079	0.042	0.064	0.024				
Pod width (mm	−0.032	−0.070	−0.209 **	0.138 **	−0.093	0.046			
Pod weight (g)	0.109 *	0.081	0.042	0.122 *	0.017	−0.104 *	−0.066		
Hay yield (kg ha^{-1})	0.771 **	0.028	0.148 **	0.140 **	0.033	0.132 **	−0.184 **	0.075	
Plant height (cm)	0.078	0.046	0.031	0.079	−0.053	0.000	0.002	0.053	0.097

* differences significant at $p < 0.05$; ** differences significant at $p < 0.01$.

4. Stability Analysis, Total Results and Discussion

Stability of performance is the main purpose of plant breeders in many research works in maize [19] and in vetch [2,20]. In our research, the two farming systems showed differences in variety expression, but overall the different farming systems did not affect stability expression of the traits tested. In combination with the GGE biplot analysis, the two farming systems revealed the most stable varieties across all the environments, as well as the more stable varieties in specific environments. Additionally, some varieties displayed stability in low-input farming systems, which is a common practice in many cultivation areas to support livestock nutrition needs. Variety Filippos was generally stable across the environments, but Omiros was the most stable variety regarding seed yield, especially in low-input farming systems. The availability of suitable varieties is very important in order to maintain productivity (yielding performance) in low-input organic farming systems [21,22]. Aydemir et al. [23], through the application of various statistic techniques and the GGE biplot, concluded that several yield components such as biological yield, straw yield, forage yield and natural plant height resulted in highly significant variations that can be utilized as selection criteria in breeding programs for common vetch. The GGE biplot may help breeders with choosing the proper genotypes for certain environments.

4.1. Seed Yielding Ability

Regarding the seed yielding ability, Figure 2a, the adaptation map which, according to the environment IPCA1, explains 78.1% of variability, shows that E3 (Trikala), E2 (Florina) and E1 (Giannitsa) are the favorable environments, with E1 (Giannitsa) being the most favorable among them. Environment E4 (Kalambaka) was the least productive. Across the genotypes, G3 (Alexandros), G1 (Filippos) and G4 (Tempi) expressed high yielding ability, and G4 (Tempi) was the most productive. The PC1 factor of the AMMI1 analysis expressed 78.1% of environmental variability, which is relatively high and gives consistent results. According to the AMMI1 biplot, the most stable environments were E2 (Florina) and E3 (Trikala) and the most favorable was E1 (Giannitsa). Environment E4 (Kalambaka) was stable but less productive compared to all others. The GGE biplot for environments analysis, as expressed by the two axes (PC1 and PC2), explained 94.9% and 4.2% of variability, respectively. The overall expression of 97.1% was very high, thus contributing to the consistency of the results. Regarding the stability of the environments based on the GGE biplot, environments E2 and E3 appear to be stable over years and close to the ideal environment. Environment E1 seems to be a little less stable and is depicted near the first circle of stability, which means that it is acceptably stable as well. The GGE biplot figure for the genotype stability analysis expressed the same level of variability as for the environments, 97.1%, which is very high. The analysis of the varieties showed that the most stable were G4 (Tempi) and G1 (Filippos), with G3 (Alexandros) following very closely. Regarding the average and the ideal environments, both of them seem to be very close, which is an indication of the adaptation of the G4, G1 and G3 varieties in the testing environment. The remaining varieties appear to be stable enough but not productive.

4.2. Thousand Kernel Weight (TKW)

The adaptation map for the thousand kernel weight (TKW) according to IPCA1 explains a high portion of variability, amounting to 83.9%. In this figure, the favorable environments are E4 (Kalambaka), E1 (Giannitsa) and the most favorable is E2 (Florina), while the environment expressing the least productivity is E3 (Trikala). The variety having the highest TKW was G6 (Pigasos), followed by G5 (Zefyros). Regarding the best varieties for TKW and yield, varieties expressing both high yield and high TKW were not found; only either one of these traits was expressed highly in any of the varieties. Therefore, it is obvious that both traits follow quantitative genetic heritability and are negatively correlated. The AMMI1 biplot expressed 83.9% of the variability and showed the same findings for the varieties as described above. Furthermore, with regard to the environments, the most stable was found to be E4 (Kalambaka), followed by E1 (Giannitsa) and E2 (Florina), with the least favorable being E3 (Trikala). The GGE biplot for the environment analysis expressed overall 99.9% of the variability; 98.1% for PC1 and 1.8% for PC2. According to Figure 3, the average and the ideal environment are almost identical, and E4 (Kalambaka), E1 (Giannitsa) and E2 (Florina) are extremely close to the average environment and the ideal environment. Environment E3 that is less favorable is also stable and in the radius of the first and second circle from the ideal environment. The GGE biplot for genotypes showed that the G6 (Pigasos) variety is the most stable and desirable for TKW as almost identical values are depicted for the average environment and the ideal environment. Variety G5 (Zefyros) is very stable and within the range of desirable varieties.

4.3. Number of Seeds per Plant

The adaptation map for the number of seeds per plant showed lack of clear grouping for environments, but there is specific adaptability for varieties and environments. For example, the E1 (Giannitsa) environment favored the G6 (Pigasos) variety, which was the most productive among all the varieties, while G1 (Filippos) and G2 (Omiros) were classified last. On the contrary, G1 (Filippos) and G2 (Omiros) were the most productive varieties in the E4 (Kalambaka) environment, while G6 (Pigasos) was the least productive variety. Similar results are presented in the AMMI1 biplot figure. The GGE biplot for environments showed that the average environment was far away from the ideal for this trait. The GGE biplot for genotypes explained 88.4% of the total variability and showed that even though the average environment was far from the ideal, the G4 (Tempi) variety was quite close to the ideal genotype.

4.4. Hay Yield

The adaptation map for hay yield showed that specific adaptability existed between E4 (Kalambaka) and the varieties G6 (Pigasos) and G4 (Tempi). Furthermore, specific adaptability appeared between the environments E1 (Giannitsa) and E3 (Trikala) and the varieties G1 (Filippos) and G3 (Alexandros). The same conclusion was drawn from the AMMI1 biplot analysis, which explained 59.6% of the variability. The GGE biplot for environments showed that the average and the ideal environments were very close and explained 92.5% (PC1: 81.7%, PC2: 10.8%) of the variability. Regarding the classification of the environments, environment E1 (Giannitsa) followed by E2 (Florina) and E3 (Trikala) were close to the average and the ideal environments. The GGE biplot for genotypes explained the same amount of variability (92.5%) and appeared to be very close to the points of the average environment and the ideal genotype (Figure 5d). Variety G4 (Tempi) was very close to the ideal genotype, followed by the G1 (Filippos) and G3 (Alexandros) varieties.

Tiryaki et al. [24] observed the importance of correlations between yield and other yield parameters. In our work, correlations showed a significant relation between seed yield and some other traits like pod length, number of pods per plant, number of seeds per pod, and thus, indirect seed yield improvement may be based on pod length improvement, which is considered a stable trait with regard to our results retrieved from the stability index.

5. Conclusions

Correlations showed a significant relation between seed yield and some other traits. Indirect seed yield improvement may be implemented by improving pod length, which generally shows high stability indices.

Comparisons between conventional and low-input farming systems generally did not affect stability estimations, but revealed varieties that exhibited stable performance, even in low-input farming systems. Among the six common vetch varieties studied, Filippos and Omiros were found to be generally stable varieties, especially Omiros that exhibited high stability index values in low-input farming systems.

Varieties G4 (Tempi) and G2 (Omiros) appeared to be stable and productive across all the environments for yield, number of seeds per plant and hay yield. Especially for yield, G4 (Tempi), G1 (Filippos) and G2 (Omiros) were found to be stable varieties, G5 (Zefyros) and G6 (Pigasos) were stable for TKW, G6 (Pigasos), G5 (Zefyros) and G4 (Tempi)—for the number of seeds per plant, while G4 (Tempi), G1 (Filippos) and G3 (Alexandros) were stable for hay yield. Regarding the environments, E1 (Giannitsa) was found to be the most favorable for stable productivity, followed by E2 (Florina).

Many varieties showed stable performance across the environments or in specific environments and could be recommended for similar ecological areas. Some of them, like Omiros, were appropriate for low-input systems and seed yield, while others were more stable in conventional farming. Depending on the trait in question (for improvement or cultivation purposes), we can now choose the best variety for the best environment and farming system.

Author Contributions: Conceptualization, V.G. and S.Z.; methodology, V.G. and S.Z.; investigation, V.G. and E.B.; statistical analysis, A.K. and V.G., writing—original draft preparation, V.G. and C.G.I.; writing—review and editing, E.B., A.K. and C.G.I.; visualization, A.K. and V.G.; supervision, S.Z., project administration, S.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

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