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Evaluation and characterisation of a collection of wild Spanish populations of the genera *Elymus* and *Thinopyrum* using morphological and agronomical traits

Rosa María NIETO-LÓPEZ, Carlos CASANOVA, Consuelo SOLER*

Department of Plant Breeding and Biotechnology, I.N.I.A
La Canaleja, P.O. Box 1045, 28800 Alcalá de Henares (Madrid), Spain

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Abstract – Quantification of the variability in wild species is a necessary step before determining their possible future use in plant breeding. A collection of 29 wild Spanish populations of the genera *Elymus* and *Thinopyrum* was characterised using 22 morphological and agronomical characteristics. Field studies were performed over two years, 1994 and 1995. Frequencies were calculated for qualitative and quantitative traits. Pearson's product-moment correlation coefficient was used to analyse inter-population variation using frequency data. Means and coefficients of variation were calculated for quantitative characteristics. Analysis of variance was performed for each species to study differences between intra- and inter-population variability. Similar degrees of variability were observed between quantitative and qualitative traits in all the species studied (*T. junceum*, *T. junceiforme*, *E. caninus* and *E. hispanicus*). Differences in variability were found at the level of species and population. The relationships between these differences and biological and environmental factors are discussed.

Elymus / *Thinopyrum* / variability / evaluation / characterisation

Résumé – Évaluation et caractérisation d'une collection de populations sauvages espagnoles des genres *Elymus* et *Thinopyrum*, sur la base de caractères morphologiques et agronomiques. La quantification de la variabilité des espèces sauvages est un pas nécessaire avant leur possible utilisation dans l'amélioration végétale. Une collection de 29 populations sauvages espagnoles des genres *Elymus* et *Thinopyrum* a été caractérisée à l'aide de 22 caractères morphologiques et agronomiques. Les études en champ ont été réalisées pendant deux années, 1994 et 1995. Les fréquences ont été calculées pour les caractères qualitatifs et quantitatifs. Le coefficient de la corrélation produit-moment de Pearson a

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*Correspondence and reprints
llinares@inia.es

été utilisé pour analyser la variation interpopulationnelle, à partir des données des fréquences. Les moyennes et les coefficients de variation ont été calculés pour les caractéristiques quantitatives. L'analyse de la variance dans chaque espèce a permis d'étudier les différences entre la variabilité intra et interpopulationnelle. Des niveaux semblables de variabilité ont été observés entre caractères quantitatifs et qualitatifs dans toutes les espèces étudiées. Des différences de variabilité ont été trouvées au niveau des espèces et de la population. Les relations entre ces différences et des facteurs biologiques et de l'environnement sont discutés.

Elymus / *Thinopyrum* / variabilité / évaluation / caractérisation

1. Introduction

The aim of plant cultivation is to increase cultivar production whilst maintaining genetic variability. For most traits it is sufficient to ensure variability in the primary "gene pool", but it is often necessary to make crosses with more distant species [2]. The genus *Thinopyrum*, belonging to the perennial tribe *Triticeae*, has traditionally been of interest to wheat breeders since many of the species in this group hybridise with wheat and are resistant to disease, drought and salinity. *Thinopyrum* consists of three species complexes: *T. junceum*, *T. elongatum* and *T. intermedium* [3]. The species included in the complex *T. junceum* found in Spain are *T. junceum* (L.) Löve, with a distribution around the European and Asian Mediterranean seashore, and *Thinopyrum junceiforme* (Löve & Löve), which is found around Baltic and Atlantic coasts.

According to the genomic classification of Löve [9], *Elymus* is the largest genus of the tribe *Triticeae*, with more than 150 perennial species. It is also the most widespread, growing in Europe, Asia, North America, South America, New Zealand and Australia [3]. Many *Elymus* species have good fodder qualities, are highly productive in favourable conditions, and are resistant to different diseases [3, 14, 18]. According to the genomic classification of Löve [9], two representatives of this genus are found in Spain: *E. caninus* (L.) Linnaeus and *E. panormitanus* (Parl.) Tzvelev. *E. caninus* grows in the Cantabrian Range, the Pyrenees, Galicia (northwestern Spain) and the Central and Iberian Ranges (central Spain). Its southern limit lies at 37° north. *E. panormitanus*

(Parl.) Tzvelev is found in the southern part of the Iberian Peninsula [10]. In 1986, Talavera [16], using morphological characteristics, considered the Spanish variant of *E. panormitanus* to be a distinct species and named it *E. hispanicus*. In an earlier, molecular study made by the present authors (unpublished), the results suggested that *E. hispanicus* should be viewed as a species in its own right.

The description of agronomically useful characteristics is an important pre-requisite for effective and efficient utilisation of germplasm collections in breeding programmes [4]. The objectives of this work were to evaluate, characterise and maintain 29 wild Spanish populations of the genera *Elymus* and *Thinopyrum*, analyse their inter- and intrapopulational phenotypic variations, detect specific characteristics of interest and determine the relationships between them and environmental factors.

2. Materials and methods

2.1. Plant material

The plant material consisted of twenty-nine wild Spanish populations of the genera *Elymus* and *Thinopyrum* (Tab. I). This material forms part of the living collection of wild relatives of cultivated *Triticeae* obtained from natural environments [15] and maintained at the Plant Breeding and Biotechnology Department of the I.N.I.A (La Canaleja, Madrid, Spain). In order to maintain the original structure of the natural population, each sample was formed by approximately 100 ears collected at random from each population according to Hawkes [7].

In the autumn, seeds were germinated on filter paper and transferred to small containers in the greenhouse. Seedlings were planted in the field at the end of winter. This process was performed from 1993 to 1994 and from 1994 to 1995 at the La Canaleja Research Station, I.N.I.A., Alcalá de Henares (Spain).

A total of 30 plants were scored from each population. Populations were divided into three blocks. Each block contained 14 plants from each popula-

tion arranged in a row. Observations were made on the 10 central plants. Separation between plants within a row and between rows was 50 cm. Pre-planting fertilisation consisted of 300 kg/Ha of N:P:K in the ratio of 8:24:8. After planting, a further 150 kg/Ha of ammonium nitrate (26%) was applied. Plants were irrigated once after planting and then every 15 days during the months of June and July.

Table I. Populations (PO.) of *T. junceum*, *T. junceiforme*, *E. caninus* and *E. hispanicus* analysed. The geographical origin (by province) in Spain, altitude (meters), latitude, longitude, temperature (T, °C) and pluviometry (P, mm) are indicated.

PO.	Province	Altitude	Latitude	Longitude	T(°C)	P(mm)
<i>T. junceum</i>						
0036	Almería	3	36°50'15"N	02°21'00"W	17.9	231
0045	Murcia	2	37°43'45"N	00°44'10"W	17.3	231
0102	Tarragona	1	41°07'50"N	01°36'15"W	15.8	478
0103	Tarragona	2	41°08'05"N	01°37'00"W	15.8	478
0126	Valencia	2	39°29'35"N	00°19'20"W	16.9	422
0153	Tarragona	1	40°35'30"N	00°42'40"E	16.8	576
0525	Granada	3	36°42'15"N	03°27'35"W	18.0	455
0526	Granada	3	36°43'10"N	03°32'50"W	18.0	455
0527	Málaga	2	36°27'25"N	05°02'60"W	18.6	648
1042	Valencia	2	39°05'00"N	00°12'45"W	16.9	422
1043	Valencia	1	39°24'10"N	00°19'40"W	16.9	422
1044	Barcelona	1	41°36'10"N	02°37'50"E	16.4	593
<i>T. junceiforme</i>						
528	Cádiz	2	36°00'45"N	05°36'30"W	17.2	749
530	Cádiz	1	36°32'00"N	06°14'15"W	16.7	546
<i>E. caninus</i>						
0053	Oviedo	1370	42°59'45"N	05°45'50"W	8.00	1140
0484	Granada	1450	37°58'50"N	02°32'00"W	10.10	1166
0513	Madrid	1400	40°51'50"N	03°45'50"W	10.10	895
0514	Madrid	1300	40°53'15"N	03°46'45"W	10.10	895
0515	Segovia	950	41°17'25"W	03°42'15"N	11.40	468
1054	Huesca	1400	42°38'30"N	00°33'40"E	9.90	1152
1058	Huesca	700	42°26'30"N	00°23'15"E	11.0	1158
1061	Huesca	1050	42°38'20"N	00°13'00"E	9.90	1152
1071	Andorra	760	42°36'20"N	00°06'45"W	10.60	793
1091	Andorra	1400	42°30'00"N	01°30'50"E	9.10	1321
<i>E. hispanicus</i>						
475	Jaén	1280	37°54'45"N	02°55'30"W	15.70	772
485	Granada	1820	36°57'34"N	02°42'53"W	17.70	360
488	Granada	1210	37°18'10"N	03°26'45"W	13.00	740
489	Granada	1430	37°08'00"N	03°24'00"W	13.00	740
523	Granada	1200	37°00'25"N	04°12'35"W	16.90	524

2.2. Characteristics examined

The selection of morphological traits for evaluation was based on the descriptions made by different authors of the genera *Elymus* and *Thinopyrum* [1, 5, 8, 10, 13]. Agronomical characteristics of interest, such as days to heading, days to maturity, and seed production related traits were also included the study. During 1993-1994 the following traits were scored: (1) growth habit of young plants [1 erect to 3 prostrate], (2) stem pubescence of young plants [1 none to 3 pubescent], (3) stem colour [1 green to 3 purple], (4) leaf surface pubescence [1 none to 2 pubescent], (5) auricle colour at heading [1 green to 2 purple], (6) leaf texture [1 smooth to 2 rough], (7) kernel type [1 naked to 3 covered], (8) growth habit at maturity [1 erect to 5 prostrate], (9) flag leaf area [length \times width \times 0.70 [10]], (10) plant height (cm), (11) spike length (mm), (12) rachis length (mm), (13) number of spikelets per spike, (14) spike density (mm per rachis internode), (15) spikelet width (mm), (16) glume length (mm), (17) awn length (mm), (18) lemma length (mm), (19) number of kernels per spike, (20) fertility $[(K \times 100)/(S-1) \times 2]$, K being the number of kernels, and S the number of spikelets], (21) heading date (days after 31 March), and (22) maturity date (days after 31 March).

During 1994/5, only the traits numbered from 10 to 20 were scored.

2.3. Statistical analyses

Frequencies were calculated for each qualitative trait in each population and species. Analysis of variance, averages and coefficient of variation for quantitative traits were calculated with the STATGRAPHICS PLUS programme (Manugistics Inc. and Statistical Graphics Corporation). All quantitative and qualitative values of the year 1993-94, except for spike density and fertility (which are combinations of other values), were used to construct a matrix of population frequencies. In order to transform the values of quantitative traits to frequencies, equal classes were established with an approximate interval of twice the standard deviation

of the specific character. The matrix of frequencies was used to estimate the similarity between populations using Pearson's product-moment correlation coefficient [11]. The NTSYS, Numerical Taxonomy System for PCs, package was used in this analysis [12].

3. Results

Differences were found in the germination and seed production rates of the different genera studied. In general, populations of *Thinopyrum* had lower germination rates than those of *Elymus*.

3.1. Qualitative traits

Frequencies per species for each qualitative character were calculated (Tab. II). The traits for growth characteristic and leaf surface pubescence were found to be different for each genus. Most young plants of *Thinopyrum* were erect or semi-erect. In contrast, most plants of *Elymus* were prostrate or semi-erect. At maturity, the frequency of prostrate and semi-erect plants increased in *Thinopyrum*, while most *Elymus* plants remained erect or slightly prostrate. *Thinopyrum* showed no variability in leaf surface pubescence - all plant samples were pubescent. However *Elymus* did show variability for this character.

At the level of species, *E. hispanicus* showed the least variability; only 4 of the 8 traits analysed were found to be variable. The most and least variable populations were 0523 and 0485 with 4 and 2 variable traits respectively (Tab. III).

E. caninus and *T. junceum* were variable for a larger number of traits, each population having a different level of variability. Populations 0515 and 0053 of *E. caninus* were polymorphic for 6 traits and one trait respectively. In *T. junceum*, populations 1043 and 1044 showed variability for 5 traits while populations 0102 and 0526 showed variability for 2 traits (Tab. III).

Populations of *T. junceiforme* showed similar traits to those of *T. junceum*. The most obvious

Table II. Frequencies (%) for each class for qualitatively scored characters in each species.

Character	Class	<i>T. junceum</i>	<i>T. junceiforme</i>	<i>E. caninus</i>	<i>E. hispanicus</i>
Growth habit of young plants	1 erect	81	93	0	4
	2	18	7	16	81
	3 prostrate	1	0	84	15
Stem pubescence of young plants	1 none	78	100	60	100
	2	2	0	3	0
	3 pubescent	19	0	37	0
Stem colour of young plants	1 green	3	0	4	18
	2	94	77	51	82
	3 purple	3	23	45	0
Leaf surface pubescence	1 none	0	0	79	50
	2 pubescent	100	100	21	50
Auricle colour at heading	1 green	94	56	87	100
	2 purple	6	44	13	0
Leaf texture	1 smooth	100	100	0	0
	2 rough	0	0	100	100
Kernel type	1 naked	2	11	0	1
	2	0	15	5	0
	3 covered	98	74	95	99
Growth habit at maturity	1 erect	22	0	8	0
	2	38	11	92	100
	3	35	33	0	0
	4	4	29	0	0
	5 prostrate	1	27	0	0

differences were that *T. junceiforme* had a higher frequency of plants with purple auricles, naked kernels and greater prostrate growth characteristic (Tab. II).

3.2. Quantitative traits

For two years, quantitative variation was analysed statistically for each species (Tab. IV) and population (Tabs. V and VI). At the genus level, the *Thinopyrum* species analysed either lacked awns or had only rudimentary structures. *Thinopyrum* spikelets appeared wider and the lemmas were longer than in *Elymus*. In contrast, the

Elymus species showed wider leaves, more spikelets per spike, and higher spike densities than those of *Thinopyrum*.

At the species level, the annual means varied according to certain tendencies. In *T. junceum*, the means of the variables related to plant vigour, such as, height, length of spikes and number of spikelets, decreased in the second year, while the variables related to spike productivity, such as spikelet width, number of kernels and fertility, increased. When comparing *T. junceiforme* with *T. junceum* it was observed that *T. junceiforme* showed smaller means for most traits, but the tendencies for the second year were similar to those of *T. junceum*, e.g., means related to vigour decreased

Table III. Presence (1) and absence (0) of variability in each population of the four species analysed for each character.

	Growth habit of young plants	Stem pubescence of young plants	Stem color of young plants	Leaf surface pubescence	Auricle colour at heading	Kernel type	Growth habit at maturity	Total
<i>T. junceum</i>								
0036	1	0	1	0	0	0	1	3
0045	1	0	1	0	0	1	1	4
0102	0	0	0	0	1	0	1	2
0103	1	0	0	0	1	1	1	4
0126	1	1	1	0	0	0	1	4
0153	0	1	1	0	1	0	1	4
0525	1	1	10	0	0	0	1	4
0526	0	1	0	0	0	0	1	2
0527	1	1	0	0	1	0	1	4
1042	1	0	0	0	1	1	1	4
1043	1	1	1	0	1	0	1	5
1044	1	0	1	0	1	1	1	5
Total	9	6	7	0	7	4	12	
<i>T. junceiforme</i>								
0528	1	0	1	0	1	1	1	5
0530	0	0	1	0	1	1	1	4
Total	1	0	2	0	2	2	2	
<i>E. caninus</i>								
0053	1	0	0	0	0	0	0	1
0484	1	1	1	0	1	0	0	4
0513	1	0	1	0	1	0	0	3
0514	1	1	1	0	0	1	1	5
0515	1	1	1	0	1	1	1	6
1054	1	0	1	1	1	1	0	5
1058	1	0	1	1	1	1	0	5
1061	1	0	1	1	1	0	1	5
1071	1	0	1	0	0	1	1	4
1091	1	0	1	1	0	0	1	4
Total	10	3	9	4	6	5	5	
<i>E. hispanicus</i>								
0475	1	0	1	1	0	0	0	3
0485	1	0	0	1	0	0	0	2
0488	1	0	1	1	0	0	0	3
0489	1	0	1	1	0	0	0	3
0523	1	0	1	1	0	1	0	4
Total	5	0	4	5	0	1	0	

and means related to spike productivity increased. The means of plant height, spike length, spikelet length, glume length, spikelet width, lemma length, kernel number and fertility of *E. caninus* increased significantly ($P < 0.01$) during the second year.

The species *E. hispanicus* seemed to have more vigour than *E. caninus*, but its spikes were less

dense and the glumes and lemmas were bigger than those of *E. caninus*. Tendencies of this species during the second year were more similar to those of *Thinopyrum* than to those of *E. caninus*.

Although the average values per species and population varied annually, in *T. junceum* it was observed that some populations behaved similarly

Table IV. Means for quantitative traits for two years and four species.

Trait	<i>T. junceum</i>		<i>T. junceiforme</i>		<i>E. caninus</i>		<i>E. hispanicus</i>	
	94	95	94	95	94	95	94	95
Flag leaf area (cm ²)	6.2		5.6		12.3		14.1	
Plant height (cm)	76.3**	66.2	59.3	58.3	73.3**	81.6	90**	86.4
Spike length (mm)	230.4	224.5	155.7	148.3	198.9**	209.6	219.5**	202.9
Rachis length (mm)	206.9	201.2	132.4	124.7	178.8**	200.3	202.5**	185.5
Number of spikelets per spike	9.7	9.6	9.7	8.8	24.6	24.1	17.2*	15.9
Spike density (mm/internode)	4.4	4.6	6.6	6.2	13.5**	11.6	8	8
Spikelet width (mm)	6.4**	8.8	6.4**	7.8	3**	3.1	3.1**	3.9
Glume length (mm)	15.9	15.7	12.6**	11.6	9.3**	9.9	12.4**	15.2
Awn length (mm)					10.5	10.1	9.4**	10.5
Lemma length (mm)	15.4*	15.7	13.3	13.7	9.7**	10.2	12.6	12.8
Number of kernels per spike	9.9**	24.1	5.9	6.4	5.6**	55.4	9**	35.5
Fertility	58.1**	141.5	32.6	39.2	11.9**	115.9	28.8**	121.3
Heading date, days after 3/31	68.8	69.6	62.3*	65.8	78.4**	81.2	58.3	57.4
Maturity date, days after 3/31	110.0**	103.0	106.5	105.9	110.1**	106.7	94.03**	88.9

*, ** Means between years differ at P = 0.05 and 0.01 respectively.

over both years (Tab. V). Populations with higher values for plant height the first year - 0045 (94.4 cm) and 0153 (93.7 cm) - were also the tallest the second year - 0045 (79.9 cm) and 0153 (76.3 cm) - and populations with lower values for plant height the first year - 0525 (66.6 cm) and 0527 (68.6 cm) - were also the shortest the second year - 0525 (60.0 cm) and 0527 (59.0 cm). Population 1044 had bigger spikes and a greater number of spikelets for both years. Population 1043 had a higher number of kernels per spike over both years. Taking into account days to maturity and days to heading, population 1044 had the longest and population 527 the shortest cycle for both years.

The populations of *E. caninus* and *E. hispanicus* maintained extreme values both years only for characteristics such as awn length, days to heading, and days to maturity. In *E. caninus*, populations 0513 and 0484 had the largest and shortest cycles

respectively for both years. The same occurred with populations of 0489 and 0523 of *E. hispanicus* (Tab. VI).

Phenotypic diversity of populations and species (Tab. VII) was studied using the coefficient of variation (CV) which provides an estimate of variation among groups [19]. In the study of variability of quantitative characteristics, the density and fertility of the spikes was not used because they are combinations of other traits. The average CV per year and species was lower for *E. hispanicus*.

An analysis of variance was performed for each species to study inter-populational variability. Table VIII shows the F-value and significance of this analysis. Significant differences among populations show larger variability among populations than within them. For *T. junceum*, *E. caninus* and *E. hispanicus*, populations differed significantly ($P < 0.01$) for both years and for most of the characteristics studied. The two *T. junceiforme* popula-

Table V. Means per year and population of *Thinopyrum*.

Population	Year	Plant height (cm)	Spike length (mm)	Rachis length (mm)	Number of spikelets per spike	Spikelet width (mm)	Glume length (mm)	Lemma length (mm)	Number kernels per spike	Days to heading	Days to maturity	Spike Fertility	Spike density	Flag leaf area (cm ²)
<i>T. junceum</i>														
0036	94	68.7	176.6	153.9	9.0	6.4	15.1	14.4	9.5	70.6	108.0	54.5	5.5	7.5
	95	62.3	151.2	129.5	8.7	8.2	14.5	14.8	23.6	70.7	105.9	151.7	6.5	
0045	94	94.4	275.0	249.8	10.6	6.5	18.4	17.5	4.0	74.0	111.3	23.2	3.9	9.2
	95	79.9	241.2	217.2	10.1	9.0	17.0	17.1	20.2	72.9	105.2	108.4	4.4	
0102	94	77.3	235.6	212.6	9.9	7.3	15.6	15.8	12.9	72.3	111.5	62.9	4.2	6.4
	95	72.5	242.6	218.1	9.9	10.0	15.4	15.8	21.1	72.4	103.8	113.0	4.2	
0103	94	75.0	254.0	231.8	10.3	7.0	15.8	15.6	7.0	74.0	114.3	35.6	4.1	6.9
	95	67.3	266.3	240.6	10.6	8.9	15.8	15.8	23.8	71.0	103.9	120.8	4.0	
0126	94	79.0	245.1	222.6	10.6	6.8	14.8	14.9	13.4	71.2	113.6	71.5	4.4	7.3
	95	63.9	252.4	229.1	10.1	9.1	15.2	15.6	27.9	70.4	104.1	152.4	4.0	
0153	94	93.7	242.7	218.9	9.9	6.9	15.3	15.8	11.4	66.8	109.3	63.7	4.1	5.4
	95	76.3	229.5	207.7	10.3	8.4	14.3	15.6	29.1	68.4	103.5	152.9	4.6	
0525	94	66.6	178.2	153.6	8.2	6.3	15.3	15.2	11.3	65.5	105.5	77.9	4.8	4.4
	95	60.0	173.7	151.11	8.2	8.1	15.3	15.1	23.6	65.7	99.3	163.6	4.9	
0526	94	80.2	195.6	171.7	8.7	5.9	16.3	15.3	12.8	65.2	106.2	84.4	4.5	5.4
	95	64.0	185.3	163.3	8.6	8.4	15.5	15.3	21.8	63.4	99.9	142.6	4.8	
0527	94	68.6	170.3	144.6	7.8	6.3	16.1	15.6	8.4	62.3	103.6	64.5	4.7	4.6
	95	59.0	175.5	150.3	8.5	8.4	15.8	15.6	20.3	60.5	96.3	140.6	5.2	
1042	94	77.0	263.5	241.3	10.4	5.9	15.4	14.9	11.1	70.0	112.5	60.7	3.9	5.6
	95	67.5	255.8	235.3	10.3	8.7	14.7	15.2	27.3	69.3	104.0	150.2	4.0	
1043	94	72.9	252.7	230.4	10.1	6.1	15.6	14.9	14.8	71.5	116.5	79.8	4.1	7.0
	95	67.6	266.2	244.4	10.4	8.8	16.6	15.7	34.9	71.4	103.7	189.3	3.9	
1044	94	69.9	292.6	270.2	11.5	6.8	16.0	15.0	4.4	81.9	118.1	20.2	3.9	5.9
	95	61.4	311.9	284.5	10.6	10.4	17.8	16.6	18.6	82.6	110.0	100.4	3.5	
<i>T. junceiforme</i>														
0528	94	56.4	154.1	129.5	9.6	6.3	12.7	13.4	6.7	63.4	106.4	37.6	6.7	6.1
	95	53.4	150.5	124.8	9.2	8.4	11.4	13.8	6.5	63.7	104.4	35.4	6.4	
0530	94	65.2	158.9	138.4	9.9	6.5	12.4	13.1	4.1	60.2	106.7	22.6	6.4	4.5
	95	69.3	144.2	124.5	8.1	6.7	12.0	13.4	6.2	66.2	106.0	46.4	5.7	

tions studied did not differ significantly with regard to most characteristics.

3.3. Cluster analysis

A matrix of frequencies was obtained using data for both quantitative and qualitative characteristics corresponding to 1994. This matrix was analysed using the Pearson product-moment coefficient. Cluster analysis was performed using the UPGMA method. Figure 1 shows the separation between the

four species studied. The similarity index for separation between the genera *Thinopyrum* and *Elymus* was 0.28. *Elymus* species showed more variation between them (with a similarity index of 0.64) than species of *Thinopyrum* (with a similarity index of 0.75).

All the populations in this study appeared separated. Maximum separation between populations was 0.82, 0.9, 0.74 and 0.85 for *T. junceum*, *T. junceiforme*, *E. caninus* and *E. hispanicus* respectively.

Table VI. Means per year and population of *Elymus*.

Population	Year	Plant height (cm)	Spike length (mm)	Rachis length (mm)	Number of spikelets per spike	Spikelet width (mm)	Glume length (mm)	Awn length (mm)	Lemma length (mm)	Number kernels per spike	Days to heading	Days to maturity	Spike fertility	Spike density	Flag leaf area (cm ²)
<i>E. caninus</i>															
0053	94	70.4	201.8	175.6	20.7	3.0	9.2	10.6	10.2	2.9	76.7	111.6	7.2	11.5	12.9
	95	93.5	211.2	201.0	21.9	3.0	9.9	10.2	10.3	42.6	74.7	99.5	101.0	10.4	
0484	94	89.1	229.7	217.7	23.4	3.0	9.6	12.1	11.2	6.8	66.7	95.6	14.7	10.2	10.2
	95	85.0	187.4	178.9	19.6	3.0	8.8	6.9	10.1	29.9	70.8	96.3	76.9	10.5	
0513	94	64.9	186.9	169.9	24.3	3.0	8.8	6.9	10.0	6.9	91.5	124.6	14.3	13.9	12.2
	95	73.2	223.6	214.3	23.8	3.1	10.8	7.8	11.6	39.7	93.9	125.2	82.3	10.6	
0514	94	67.3	170.8	154.6	21.9	3.0	8.6	7.5	9.8	6.0	73.1	107.2	15.0	13.7	11.0
	95	82.3	198.4	188.4	23.3	3.1	9.3	7.7	10.2	56.8	76.3	104.2	129.0	11.9	
0515	94	79.6	214.5	200.7	24.1	3.0	9.8	6.0	10.3	12.4	70.3	99.4	25.9	11.6	11.7
	95	90.1	224.0	213.9	24.5	3.1	9.9	5.8	10.1	72.0	73.8	98.9	158.6	11.1	
1054	94	91.1	191.2	167.3	23.7	3.0	9.3	11.7	9.2	4.8	83.2	116.0	9.9	13.9	15.0
	95	60.8	184.2	176.0	22.8	3.1	9.3	11.3	9.7	25.8	91.6	113.5	52.8	12.7	
1058	94	71.8	196.9	174.2	27.9	3.0	9.3	11.3	9.2	3.2	79.6	110.6	6.4	15.7	12.6
	95	76.3	209.2	199.1	26.1	3.2	9.6	11.6	9.6	65.4	86.3	112.7	125.6	12.8	
1061	94	71.2	211.0	188.5	27.1	3.0	9.1	12.0	9.1	3.0	79.9	108.5	5.8	14.0	14.5
	95	85.5	239.1	229.4	27.2	3.1	10.2	11.5	10.5	59.1	83.6	106.6	109.5	11.6	
1071	94	76.9	193.5	167.7	24.1	3.0	10.4	14.6	9.3	5.7	74.3	108.1	12.1	13.8	12.9
	95	86.1	196.6	187.6	23.0	3.2	10.8	12.2	10.1	45.8	76.5	100.0	103.8	11.8	
1091	94	71.8	196.5	174.8	27.6	3.0	9.2	12.5	9.0	3.8	89.6	120.6	7.0	15.4	10.4
	95	84.5	214.3	206.5	26.9	3.2	9.6	11.8	9.4	103.8	85.3	111.9	198.4	12.7	
<i>E. hispanicus</i>															
0475	94	94.0	238.5	221.1	17.8	3.3	12.7	9.5	12.8	8.2	59.9	94.8	25.3	7.7	15.7
	95	88.8	218.5	203.3	16.6	3.8	15.7	10.1	13.1	25.9	62.4	92.6	84.9	7.7	
0485	94	85.0	212.5	194.3	18.4	3.3	12.6	11.2	12.6	10.4	58.8	94.3	30.3	9.0	20.4
	95	80.3	177.6	160.1	14.7	3.9	14.7	11.0	13.3	39.7	54.5	86.9	141.0	8.6	
0488	94	97.8	231.2	217.1	18.9	3.1	13.5	9.2	13.4	10.5	54.6	92.1	29.3	8.3	11.1
	95	89.5	212.1	194.2	18.1	4.1	15.7	10.5	13.3	51.2	54.2	86.6	151.3	8.8	
0489	94	81.7	213.0	193.9	17.8	3.0	11.4	9.1	11.9	5.0	73.0	104.5	15.8	8.7	9.5
	95	89.1	225.2	205.1	17.7	3.7	16.2	11.3	12.4	19.0	69.4	96.8	58.9	8.1	
0523	94	89.0	200.8	184.0	13.0	3.1	11.6	8.0	12.0	10.1	49.2	87.3	40.1	6.6	12.2
	95	84.5	184.9	167.9	12.7	3.8	13.9	9.2	12.1	37.6	50.2	83.9	155.6	7.0	

4. Discussion

The clear separation between the genera *Elymus* and *Thinopyrum* observed in the dendrogram of Figure 1 is in agreement with the genomic classification of Löve [9], but not with the morphological classification of Flora Europaea [10]. Flora Europaea considers both genera as *Elymus*. At the species level it was observed that the separation between the two species of *Thinopyrum* was small-

er than that between the two representatives of *Elymus*. The results suggest that the genomes of *E. caninus* and *E. hispanicus* are less related than those of *T. junceum* and *T. junceiforme*, which in fact are variations of the same E genome [17].

Elymus species had better germination rates, more spikelets per spike, higher spike density and a higher number of seeds than those of *Thinopyrum*. This might be related to the different reproductive systems of the two genera. In *Elymus* species there is only sexual reproduction, while in

Table VII. Coefficients of variation (%) for quantitative traits for two years and four species.

Trait	<i>T. junceum</i>		<i>T. junceiforme</i>		<i>E. caninus</i>		<i>E. hispanicus</i>	
	94	95	94	95	94	95	94	95
Flag leaf area (cm ²)	45.5		44.6		36.3		40.9	
Plant height (cm)	20.2	25.1	14.6	23.6	16.5	20.6	10.1	10.6
Spike length (mm)	27.2	30.8	16.5	25	16.1	16.9	13.4	15.2
Rachis length (mm)	30	33.8	19.2	30.1	18.4	17.5	15.1	17
Number of spikelets per spike	20.7	20.1	18.3	29.2	16.8	16.6	18.4	19.6
Spikelet width (mm)	17.5	19.8	18.1	15.7	2	10.5	11.5	13.3
Glume length (mm)	13.9	15.2	12	12.9	13.9	11.7	16.5	11.8
Lemma length (mm)	12	10.9	10.7	9.4	12.7	11.2	12.5	9.9
Awn length (mm)					37.1	32.6	34.4	18.2
Number of kernels per spike	92.3	56.6	124.1	101.2	129.1	70.9	77.6	55.6
Heading date, days after 3/31	9.8	11.0	10.5	9.2	13.6	15.1	18.1	18.1
Maturity date, days after 3/31	5.6	5.5	5.1	12.2	10.2	11.7	9.6	8.1
Mean*	26.8	22.9	26.7	26.8	26.0	20.3	22.2	17.9

* Without awn length.

Table VIII. F-test values and significance for two years and four species.

Trait	<i>T. junceum</i>		<i>T. junceiforme</i>		<i>E. caninus</i>		<i>E. hispanicus</i>	
	94	95	94	95	94	95	94	95
Flag leaf area (cm ²)	7.80**		4.11**		3.70**		27.08**	
Plant height (cm)	12.79**	3.90**	13.26**	8.04*	12.44**	10.75**	22.37**	5.78**
Spike length (mm)	22.82**	22.03**	0.32 NS	0.18 NS	9.40**	7.36**	10.15**	19.17**
Rachis length (mm)	24.91**	22.02**	1.24 NS	0.00 NS	11.92**	7.24**	10.43*	17.21**
Number of spikelets per spike	12.47**	6.78**	0.28 NS	1.12 NS	12.56**	10.93**	31.49**	24.56**
Spikelet width (mm)	3.57**	3.93**	0.13 NS	23.05**	0.96 NS	1.22 NS	4.90**	2.90*
Glume length (mm)	5.85**	5.55**	0.39 NS	0.98 NS	5.33**	7.14**	5.44**	9.42**
Awn length (mm)					27.67**	21.22**	4.01**	5.85**
Lemma length (mm)	6.29**	3.98**	0.66 NS	0.59 NS	12.87**	9.93**	4.46**	6.18**
Heading date, days after 3/31	35.25**	27.03**	2.43 NS	1.13 NS	32.26**	16.10**	32.83**	23.02**
Maturity date, days after 3/31	31.29**	16.00**	0.02 NS	0.10 NS	38.37**	23.80**	17.23**	21.39**

*, ** Means among populations in each species differ at $P = 0.05$ and 0.01 respectively.

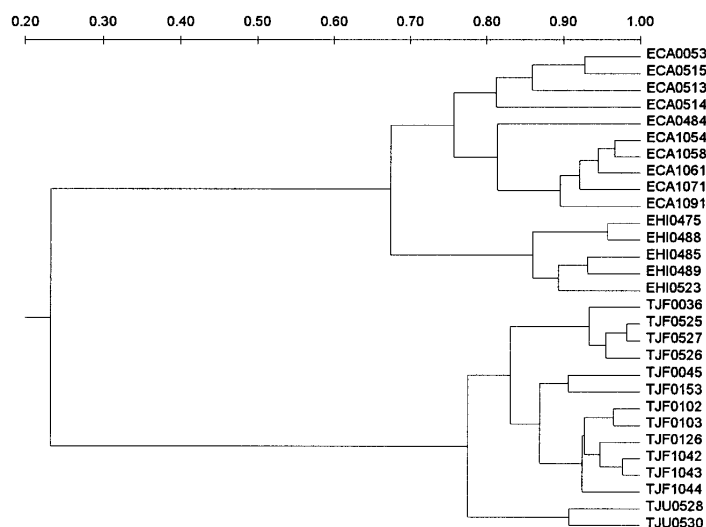


Figure 1. Dendrogram obtained for *T. junceum* (TJU), *T. junceiforme* (TJF), *E. caninus* (ECA), and *E. hispanicus* (EHI) by the UPGMA method.

Thinopyrum species there is both sexual and asexual reproduction (rhizomatous).

The means of characteristics related to spike fertility increased in all species during the second year. This was probably due to the different climatological conditions. The first year of study was warmer and drier than the second, and this could have affected seed formation. Characteristics related to vigour increased the second year only for the species *E. caninus*. This could be related to the habitat - there is greater humidity and the temperature is lower where this species grows.

Using analysis of variance to compare populations, it was observed that, with the exception of *T. junceiforme* (only two populations were analysed), inter-population variability was greater than intra-population variability in all species. This is typical of autogamous populations [6].

The results for the qualitative traits were in accordance with those for the quantitative traits which consider *E. hispanicus* to be the less variable species. This could be due to the fact that the populations of *E. hispanicus* selected for this study were found within the same geographical area, in the south of the Iberian Peninsula, the only ecological habitat for this species in Spain.

Population 1044 of *T. junceum*, which grows in the northernmost area from which the studied plants were collected, was also that with the longest cycle and the biggest spikes. Population 527, which grows in the southernmost area, was the shortest and showed the lowest mean number of days to heading and maturity. In the dendrogram of Figure 1, groups of populations appeared to be related to latitude. The first subgroup included the southern populations from Almería (0036), Málaga (0527) and Granada (0525 and 0527). A second subgroup included the northern populations between Barcelona (1044) and Murcia (0045). Groups within *E. caninus* did not seem to be influenced by latitude. Table I shows that variations between populations of *T. junceum* were only slight with respect to altitude (these plants grow in coastal areas), but were greater with respect to latitude. In populations of *E. caninus*, there were variations with respect to both parameters.

The collection of wild populations studied showed a high level of morphological and agronomical variability which may be useful in future breeding programmes.

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