The nabicol: a horticultural crop in northwestern Spain

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Summary

Nabicol (*B. napus* L. var. *pabularia*) is a traditional crop in the Northwest of Iberian Peninsula (South of Galicia and North of Portugal) where it is grown during the winter season on small farms and gardens using traditional varieties. A collection of 36 populations of nabicol from Galicia (northwestern Spain) was evaluated during 2002 and 2003 in two locations and two growing seasons (spring/summer and autumn/spring) for twenty eight agronomic and morphological traits. The objectives of this study were to: (i) evaluate a collection of nabicol landraces from northwestern Spain, (ii) determine suitability of this germplasm as a summer crop and (iii) study the genetic diversity among local populations. Significant differences were observed among populations for most traits. Genotype × environment interaction was significant for most of them. Spring/summer growing season could be recommended for growing nabicol but resistance to Lepidoptera pests attacking *Brassica* crops should be improved. Most populations had an agronomic value similar to the commercial variety. The most promising variety for horticultural use was MBG-BRS0063 which showed the highest yield. Morphological and agronomic data were subjected to cluster analysis and four groups were defined with a group clustering most populations. The low genetic diversity could be explained because populations were collected in close geographical areas and the selection made by farmers was always for a horticultural use. These results give information about the diversity and breeding value of the nabicol Spanish germplasm, which could be useful in breeding programs.

Introduction

The main use of *Brassica napus* L. in the world is for oilseed production. In several European countries, *B. napus* crops are also grown for edible leaves for both human consumption and fodder, and they belong to *B. napus* var. *pabularia* group. There are different common names for these crops such as Siberian kale, rape kale or Hanover salad. In Galicia (northwestern Spain), they are mainly used for human consumption with the common name of 'nabicol' (Cartea et al., 2004). Initially, the nabicol crop was classified as a tetraploid of *Brassica oleracea* (L.) but further cytological (Ordás & Baladrón, 1985) and isoenzymatic studies (Arús et al., 1987) classified this crop as *B. napus*.

Nabicol is an important vegetable in the Northwest of the Iberian Peninsula (South of Galicia and North of Portugal) where tradicional varities are grown during the winter season on small farms and gardens. At present, *B. napus* is a minority crop compared with other *Brassica* crops grown in Galicia, but its use is expanding and in some areas it has replaced other traditional crops, such as turnip-greens and/or turnip-tops (*B. rapa* L. ssp. *rapa*). Several taxonomic studies and agronomic evaluations for *Brassica* landraces grown in the northwestern of Iberian Peninsula have been published by different authors in Portugal (Monteiro & Williams, 1989; Dias et al., 1993; Dias & Monteiro, 1994) and in Spain (Cartea et al., 2003; Picoaga et al., 2003). These works showed a wide morphological and genetic variability among *B. oleracea* crops. However, *B. napus* germplasm has been scarcely studied and there is no information concerning the morphological and agronomic attributes of nabicol crops grown in Galicia for human consumption. Only two previous studies were done on nabicol populations concerning their origin and genetic diversity (Cartea et al., 2004) and their content of fatty acids and glucosinolates on seeds (De Haro et al., 1995).

Although wild populations of *B. napus* have not been found and its origin is not entirely clear, it is believe that *B. napus* was originated in southern Europe. It probably appeared first in an agricultural environment where the two parents, *B. oleracea* and *B. rapa*, were present (Gómez-Campo & Prakash, 1999). The origin of the local nabicol populations grown in Galicia is also unclear. Cartea et al. (2004) studied the relationships among Galician and British *B. napus* germplasm for horticultural use using RAPD markers and showed that Spanish and British populations might have an independent origin and the Spanish entries had a lower diversity.

Since other crops of the species such as rape (*B. napus* var. *oleifera*) or rutabaga (*B. napus* var. *rapifera*) may be grown in two seasons, spring/summer and autumn/winter, nabicol populations may also be able to grow throughout two growing seasons but such ability has not been studied yet. Rape winter cultivars are usually more productive (Kimber & McGregor, 1995) but in some cases, spring cultivars have a higher yield than winter ones (Rife & Zeinali, 2003). The effect of planting date on yield components has been studied on other *Brassica* crops such as Brussels sprouts (Everaarts & Moel, 1998), cauliflower and broccoli (Mihov & Antonova, 2001) and rape (Auld et al., 1984; Miralles et al., 2001). Under the environmental conditions of northwestern Spain, the spring/summer season would permit to harvest the leaves from March until July and to perform a second sown in September. In this way, product for fresh market could be obtained during almost all the year.

The objectives of this study were: (i) to evaluate the agronomic and morphological characteristics of nabicol landraces collected throughout northwestern Spain, (ii) to determine the suitability of this germplasm as a summer crop and (iii) to study the genetic diversity among local populations.

Material and methods

A collection of 36 populations of nabicol (*B. napus* var. *pabularia*) was evaluated in this study. Thirty five populations are landraces collected throughout northwestern Spain (Cartea et al., 2004) and one is a commercial population from North of Portugal used as a check. Seeds of the local populations were collected in the eighties directly from the growers and they are currently maintained in cold storage at the Misión Biológica de Galicia since then (Ordás & Baladrón, 1985). The populations were evaluated during two years (2002 and 2003) and two growing seasons (spring/summer and autumn/spring) in two locations in northwestern Spain: Pontevedra (42º 24' N, 8º 38' W) and Fornelos de Montes (42º 20' N, 8º 26' W). Both locations have a humid climate with an annual rainfall of about 1600 mm in Pontevedra and about 3500 mm in Fornelos de Montes. The soil type is acid sandy loam. Populations were planted in multipot-trays and seedlings were transplanted into the field at the five-six leaves stage. Transplanting dates were on 7 March 2002 in Pontevedra and on 22 March 2002 in Fornelos de Montes for the spring/summer season and on 18 September 2002 in Pontevedra and on 30 September 2002 in Fornelos de Montes for the autumn/spring season. Populations were evaluated in a 6 × 6 lattice design with three replications. Each experimental plot consisted of two rows with 10 plants per row. Rows were spaced 0.9 m apart and plants between rows 0.6 m apart. Cultural operations, fertilization and weed control were made according to local practices.

Data were recorded on 28 morphological and agronomic traits following the IBPGR *Brassica* and *Raphanus* descriptors list (IBPGR, 1990) (Table 1). Individual analyses of variance were performed for each trait according to the analysis for a 6 × 6 triple lattice design (Cochran & Cox, 1957). Means adjusted for lattice block effects were obtained using the LATTICE procedure of SAS (SAS Institute, 2000) and were used in the combined analysis across environments. Environments, populations and population × environment interaction were considered fixed effects. The pooled error mean square was calculated as reported by Cochran & Cox (1957). Comparisons of means were performed for each trait using Fisher's protected least significant difference (LSD) at $p = 0.05$ (Steel et al., 1997). Analyses were made using the GLM procedure of SAS (SAS Institute, 2000).

The Ward-MLM (Modified Location Model) program of SAS (Franco et al., 1998) was used to compute the similarity and distances matrices among observations using the Gower's distance (Gower, 1971). Groups were formed using the UPGMA (Unweighted Pair Group Method Using Arithmetic Averages) clustering method (Romesburg, 1984) with the Gower's distance which allows the use of continuous and discrete variables simultaneously. All computations were performed using the NTSYS-PC package (Rohlf FJ, 2000).

Results and discussion

Brassica napus var. pabularia is cultivated in Galicia (Northwest Spain) in a small area, mainly in the coastland, with a homogeneous climate conditions. Only a few varieties are cultivated in inland regions. Both locations chosen in this work, Pontevedra and Fornelos de Montes, represent this two different environments, Pontevedra as a coastland region and Fornelos as a inland region. In Fornelos de Montes during spring/summer season, varieties had a poor development because the soil and climate conditions were not the optimum for this crop. In most cases plants could not reach a reproductive stage. For this reason data were available only from three environments. There were, environment 1: spring/summer season in Pontevedra (coast area); environment 2: autumn/spring season in Pontevedra,; and environment 3: autumn/spring season in Fornelos de Montes (inland area). The analysis of variance combined across environments showed that populations were significantly different for early vigor, fresh yield, dry yield, traits related to plant morphology (plant height, stem width, petiole length, and number of secondary stems), traits related to earliness (days to flowering, days to maturity, period of flowering, and days to formation of siliques), and those related to seed yield (silique length and number of seeds per silique) (Table 2). Differences among environments were significant for all traits and the environment × population interaction was significant for most of them (Table 2).In spite of this interaction, populations were stable for most traits, having a similar performance for most traits in the environments 1 and 2, although the agronomic value was different in the environment 3 (data not showed). The genotypes with highest yield and best early vigor coincides in the environment 1 and 2, but not in 3. The two first environments represent suitable conditions for nabicol crop while environment 3 represent stress conditions, with high annual rainfall, cool temperature at early vegetative stages, and acid soil. Consequently, populations did not differ significantly for most traits at Fornelos de Montes.

Concerning the agronomical traits more related to the horticultural use of this crop, both fresh and dry yields would be the most important ones. In spite of significant environment × population interaction for both traits, populations differed significantly (p<0.05) only in the environment 2 (data not showed). Overall environments, MBG-BRS0063, a population come from coastland, showed both the highest fresh yield (5.8 t h^{-1}) and dry yield (4.6 t h^{-1}) while the fresh and dry yields for the commercial variety were 2.4 and 1.4 t h^{-1}, respectively (Table 3). MBG-BRS0063 also presented tall plants and intermediate values for early vigor (3.1), days to flowering (157 days) and days to maturity (238 days). In contrast, two populations, MBG-BRS0329 and MBG-BRS0356, showed the lowest values for most agronomic traits, including fresh and dry yields (Table 3). Both populations were collected from the inland of Galicia and they might be not adapted to the environmental conditions of the coast region where crop is usually grown and where experiments were carried out.

Early vigor is an important agronomic trait because show the ability of genotypes to compete with weeds, which are abundant in this region. Differences on days to flowering and maturity were observed among populations. Earliness was not related to the geographical origin of the germplasm being evaluated. MBG-BRS0035, MBG-BRS0034, and MBG-BRS0037 were the earliest (less than 130 days to flowering and less than 215 days to maturity) and differed significantly from the commercial variety for days to flowering whereas MBG-BRS0356 was the latest (182 days to flowering and 265 days to maturity). Regarding plant height, two accessions, MBG-BRS0107 and MBG-BRS0134 were the highest populations.

Populations were similar for qualitative traits related to plant morphology such as leaf lobes, plant growth habit, leaf color, leaf hairiness, and leaf bloom (data not showed). Leaves were glaucous and without hairiness, similar to kales and cabbages (*B. oleracea*) and unlike turnips (*B. rapa*). The populations showed the same plant growth habit (tall plants with a lot of secondary stems), except two of them, MBG-BRS0356 and MBG-BRS0378 which had a different plant morphology. Morphological diversity within each population was observed for the above mentioned traits because of some degree of cross-pollination may occur in nabicol, as it happens in rapessed (Becker et al., 1992).

As we mentioned above, Fornelos (environment 3) represented stress conditions. Although the plants showed less damage by Lepidoptera pests and lodging in this environment, the fresh and dry yield were lower than the other two environments, and the populations showed short plants with less leaves (Table 4), suggesting that its appropriate to grow this crop in the coastland.

Although nabicol is a cool season crop, we have studied the agronomic performance of local populations grown as spring/summer crops to evaluate their potential for fresh market in hot season. To evaluate the populations performance in different growing seasons, comparisons were made between environments 1 and 2 (Table 4). All populations had a normal development in spring/summer season except MBG-BRS0356, which did not reach the flowering stage in the hot season. The populations had a best agronomic performance in their early growth phases for some traits in the spring/summer season. They showed less lodging, more secondary stems, and better early vigor than in autumn/spring season (Table 4). Temperatures and photoperiod were high in the spring/summer season contributing to a fast development of the plants. However, genotypes were more attacked by *Brassica* pests in the spring/summer season than in the autumn/spring season. Damage rating and percentage of plants attacked by larvae of *Brassica* pests were higher in spring/summer than in autumn/spring (Table 4) because the vegetative stage of crop development coincide with the peak of the larval populations of Lepidoptera pests (Picoaga et al., 2003) and consequently, genotypes cannot escape to larval attack. Regarding the earliness, the populations started to flower 72 days before and reached the maturity stage 89 days before in spring/summer growing season than in autumn/spring season and fresh and dry yields were reduced by 30% and 25%, respectively in spring/summer season. Yield loss caused by modification in the sowing date has also been reported in other *Brassica* crops, such as rape (Mendham et al., 1981) or broccoli (Mihov & Antonova, 2001) while the delay of flowering in late seasons has been observed in rape (Mendham et al., 1981; Auld et al., 1984). Furthermore, populations had the best performance for seed traits when they were grown on the autumn/spring growing season, i. e. the traditional date.

Although nabicol populations sowed a reduction on fresh and dry yields in the spring/summer season, the agronomic performance was good enough and similar to commercial variety except for resistance to *Brassica* pests. Particularly, MBG-BRS0063 showed the highest yield (fresh and dry) but it had a high damage rating and high percentage of damaged plants in the spring/summer season (data not shown) and consequently, most leaves cannot be used for human consumption in fresh market. Some populations evaluated in this work showed certain level of resistance under high natural infestation conditions (data not shown), as they occurred in spring/summer season, and they could be used to improve resistance on MBG-BRS0063. On the other hand, sources of resistance on *Brassica oleracea* germplasm grown in Galicia has been identified in a previous experiment under artificial infestation with *Mamestra brassicae* (Picoaga et al., 2003).

In the cluster analysis, the 36 populations were grouped into four clusters (Figure 1). The cluster A, composed by nine populations, included the earliest accessions being also characterized for having a high number of secondary stems. The cluster B was the largest and included most of the local populations along with the commercial variety (MBG-BRS0373) from the North of Portugal. This cluster grouped midseason populations from different origin (inland and coastal regions) and it was possible to distinguish two subgroups. Subgroup B1 formed for most populations and subgroup B2 formed for two accessions MBG-BRS0063 and MBG-BRS0113. The population MBG-BRS0063, as previously mentioned, had the best agronomic performance with the highest yields and low lodging whereas MBG-BRS0113 was characterized by high values for traits related to seed yield as number of seeds per silique, weight of 1000 seeds, and silique length. The clusters C and D were separated from the main groups, each of them formed by one accession. Cluster C is constituted by MBG-BRS0378 (inland population) which was late for flowering and maturity and showed a plant growth habit different from other populations. Cluster D is formed by one accession, MBG-BRS0356 (inland population), which was extra late and characterized by short plants without secondary stems, and low yields. These 36 populations were mainly grouped by their earliness and were not related to their geographic origin (inland and coastland) of material. Results of the present work coincide with the classification of the same landraces performed by Cartea et al. (2004) using RAPD markers who grouped most populations in one cluster. However, results of this work are in disagreement with the morphological classification of *Brassica oleracea* landraces from Portugal performed by Dias et al. (1993), who grouped the populations on the basis of their geographical origin and not on the basis of their morphological differences.

The low level of genetic variability among nabicol germplasm grown in Galicia showed by the cluster analysis could be attributed to a common genetic origin (Cartea et al., 2004) and also to the small geographic area (near the border with Portugal) where this crop is grown.

In conclusion, the nabicol populations evaluated in this study showed a good agronomic performance, like the commercial variety, and they could be recommended for fresh production by growing as autumn/spring crops. In spite of the low genetic diversity observed, MBG-BRS0063 was the most promising population, displaying desirable agronomic traits and high yields and, it could be used directly by growers or be included in selection programs. The spring/summer growing season could be recommended for growing nabicol but resistance to Lepidopterous pests attacking *Brassica* crops should be improved.

These results demonstrate the diversity and breeding value of nabicol germoplasm

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Table 1. Traits evaluated in a study of 36 populations of nabicol grown for two years and two growing seasons in two locations in northwestern Spain.

Traits	Description
A. Observations in juvenile development	
Early vigor	Subjective scale from 1 (very poor) to 5 (excellent)
Damage rating	Subjective scale from 1 (wholly damage) to 9 (no damage) scale
Damaged plants	percentage of plants attacked by Lepidoptera pests
B. Observations in vegetative period	
Plant growth habit	1-3 scoring (1= short plants without secondary stems, 3= tall plants with secondary stems)
Leaf color	1-3 scoring (1= green, 2= dark green, 3= purple green)
Leaf hairiness	1-4 scoring (1= absent, 2= sparse, 3= intermediate, 4= abundant)
Leaf bloom	1-4 scoring (1= absent and 4= glaucous)
Leaf lobes	0 (absent), 1 (present)

Lodging	percentage of leaning plants
Fresh yield (t h^{-1})	average fresh weight of a leaf × average number of leaves per plant
Dry yield (t h^{-1})	average dry weight of a leaf × average number of leaves per plant
Plant height (cm)	distance from soil to the top of the plant
Plant diameter (cm)	diameter of the widest point on plant
Stem width (mm)	diameter of the widest point on stem
Leaves / plant (no.)	average number of leaves per plant
Leaf index	leaf blade width / leaf length including petiole ratio
Petiole length (cm)	length of leaf petiole measured where blade intercepts with petiole
Length of vegetative stem (cm)	length distance from soil to the highest point on vegetative or pre-flowering apex
Secondary stems (no.)	average number of secondary stems per plant
C. Observations in flowering period and maturity period	
Length of floral stem (cm)	distance from vegetative or pre-flowering apex to the top of the plant
Days to flowering	days from transplanting until 50% of plants have the first flower
Period of flowering	days from beginning of flowering until 100% plants lose all flowers

Days to formation of siliques	days from transplanting until 50 % of plants have green siliques
Days to maturity	days from transplanting until 50 % of plants per plot have dry siliques and mature seeds
Period of maturity	days from formation of siliques until 100% plants have dry siliques.
D. Silique and seed observations	
Silique length	average silique length (cm)
Seeds per silique	average number of seeds per silique
Weight of 1000 seeds	weight of 100 seeds and multiplied by 10 (g)

Table 2. Mean squares of the combined analysis of variance across three environments for agronomic traits in the nabicol populations studied.

	Sources of variation				
Traits	Populations (P)	Environments (E)	P × E	df[1]	Error
Early vigor	0.35 **	1.16 **	0.18	210	0.11
Damage rating	1.02	203.02 **	0.85	210	0.54
Damaged plants	45.99	33372.70 **	54.00	210	63.93
Lodging	331.90	7833.30 **	245.94**	210	100.00
Fresh Yield	336.13 *	16027.03 **	223.57 **	173	52.71
Dry Yield	5.99 **	226.12 **	3.23 **	173	0.85
Plant height	1129.37 **	53138.02 **	439.63 **	208	108.94
Plant diameter	72.95	6331.42 **	68.85**	208	50.55
Stem width	26.48 **	2342.21 **	13.61 **	208	4.58
Leaves / plant	144.48	28883.62 **	100.30 **	173	47.20
Leaf index	0.01	0.02 *	0.01 **	173	0.01
Petiole length	50.38 **	156.84 **	5.93 **	173	4.04
Secondary stems	2.80 **	130.15 **	1.14	208	0.54
Length vegetative stem	173.65	1375.87 **	214.52 **	208	47.20
Length floral stem	550.22	33426.84 **	366.92 **	208	120.08
Days to flowering	355.82 **	56115.03 **	123.85**	208	12.50
Period of flowering	175.62 **	4531.88 **	75.54	208	107.29

Formation of siliques	340.87 **	59223.29 **	142.33 **	208	18.87
Days to maturity	203.73 *	79821.21 **	113.53 **	208	22.87
Period of maturity	49.58	2520.64 **	34.88 *	208	23.64
Silique length	75.22 **	2193.72 **	18.07 **	168	11.90
Seeds per silique	8.35**	273.48 **	3.28 *	162	2.10
Weight of 1000 seeds	0.64	60.94 **	0.25 **	162	0.13
df	35	2	70		

*, ** Significant at $p < 0.05$ and at $p < 0.01$, respectively.

[1] Degrees of freedom for pooled error.

Table 3. Comparisons of means and range of variation among 36 populations of nabicol evaluated in three environments in northwestern Spain for 13 traits that showed significant differences in the analysis of variance combined across environments.

Population	Early vigor	Fresh yield	Dry yield	Plant height	Stem width	Petiole length	Secondary stems
	(1-5)	——— ($t\ h^{-1}$) ———		cm	mm	cm	(no.)
MBG-BRS0014	3.1	2.6	1.5	135.7	23.6	10.3	3.2
	(2.9-3.4)	(0.7-3.6)	(0.3-2.5)	(106.0-159.3)	(15.2-39.4)	(9.8-11.3)	(0.5-6.4)
MBG-BRS0028	3.3	3.8	1.5	164.0	25.3	4.2	2.2
	(2.8-3.6)	(0.4-6.8)	(0.2-2.5)	(130.2-182.7)	(15.2-31.1)	(2.7-6.7)	(0-5.2)
MBG-BRS0029	3.6	3.4	1.0	148.2	21.4	3.6	2.6
	(3.1-4.0)	(0.5-6.4)	(0.2-1.4)	(119.1-183.8)	(12.8-33.0)	(0-8.8)	(0.5-5.3)
MBG-BRS0034	2.6	4.1	1.4	147.4	18.6	1.4	3.1
	(1.7-3.1)	(0.2-7.6)	(0.1-2.9)	(107.6-177.14)	(12.3-28.9)	(0.2-3.1)	(0.2-6.5)

MBG-BRS0035	3.1	3.5	1.3	143.9	19.1	9.6	3.5
	(3.0-3.3)	(0.4-6.2)	(0.2-2.6)	(117.7-171.4)	(13.4-26.3)	(6.0-12.4)	(0.4-7.4)
MBG-BRS0037	2.9	3.6	1.6	140.2	18.1	10.8	3.2
	(2.6-3.1)	(0.3-5.6)	(0.1-3.7)	(103.6-162.8)	(13.5-27.2)	(7.2-13.6)	(0.1-7.5)
MBG-BRS0039	3.2	3.0	1.4	149.7	22.9	0.8	2.4
	(3.0-3.4)	(0.5-6.7)	(0.2-2.5)	(126.0-162.0)	(17.3-30.0)	(0.5-1.1)	(0.3-4.9)
MBG-BRS0041	3.1	2.1	1.1	151.4	23.4	1.4	1.5
	(3.0-3.3)	(0.2-3.4)	(0.1-2.0)	(105.0-178.6)	(14.6-29.4)	(0-2.8)	(0.1-2.8)
MBG-BRS0044	3.0	2.1	1.1	152.2	22.3	1.1	1.8
	(2.7-3.3)	(0.3-3.8)	(0.1-2.1)	(119.8-170.5)	(18.3-27.7)	(0.1-2.3)	(0.3-3.3)
MBG-BRS0048	3.1	3.2	0.9	163.7	25.8	3.9	1.2
	(3.0-3.2)	(0.4-7.0)	(0.2-1.3)	(136.5-180.7)	(18.0-34.4)	(2.1-6.8)	(0-2.1)
MBG-BRS0054	3.1	2.8	1.5	140.6	20.4	10.0	3.2
	(2.2-4.2)	(0.3-5.0)	(0.1-3.1)	(110.9-161.1)	(15.3-29.0)	(5.8-14.1)	(0.1-8.8)
MBG-BRS0056	3.2	3.2	1.4	147.0	20.5	12.9	2.1

	(3.0-3.6)	(0.3-5.0)	(0.1-2.2)	(114.3-176.1)	(15.0-30.1)	(8.6-16.7)	(0.0-5.3)
MBG-BRS0061	2.8	2.8	1.0	143.1	20.1	9.3	3.0
	(2.6-3.1)	(0.6-4.0)	(0.2-1.5)	(107.0-169.2)	(15.0-28.5)	(7.0-12.3)	(0.6-6.7)
MBG-BRS0063	3.1	5.8	4.6	147.6	28.5	10.2	1.1
	(3.0-3.3)	(0.6-11.7)	(0.3-11.0)	(115.7-173.8)	(18.5-34.1)	(8.6-12.2)	(0.1-2.3)
MBG-BRS0065	3.3	4.0	1.0	157.2	22.9	9.9	2.3
	(3.0-3.6)	(0.6-8.8)	(0.3-1.7)	(130.6-185.3)	(19.1-29.1)	(6.7-11.8)	(0.4-4.8)
MBG-BRS0068	3.4	4.6	1.4	145.5	21.6	2.8	3.0
	(3.3-3.4)	(0.1-8.0)	(0.1-2.2)	(110.8-177.4)	(14.9-30.0)	(0.1-4.6)	(0.1-6.1)
MBG-BRS0073	3.4	2.9	1.4	157.4	25.4	0.2	2.1
	(3.1-3.7)	(0.5-5.2)	(0.2-2.9)	(133.9-169.8)	(21.0-29.6)	(0.0-0.2)	(0.5-3.9)
MBG-BRS0079	2.4	1.4	0.4	160.8	22.5	5.7	3.3
	(2.0-2.8)	(0.3-2.0)	(0.1-3.3)	(121.4-196.9)	(16.5-25.8)	(5.1-6.1)	(0.3-8.1)
MBG-BRS0085	3.4	3.0	1.2	150.0	21.5	10.8	3.2
	(3.3-3.5)	(0.3-5.8)	(0.2-1.8)	(123.0-173.8)	(13.9-32.9)	(7.0-17.2)	(0.8-6.8)

MBG-BRS0087	2.6	2.9	1.2	154.1	23.8	9.5	2.3
	(1.7-3.5)	(0.5-4.2)	(0.2-1.8)	(111.7-198.3)	(18.1-26.7)	(6.7-13.7)	(0.7-5.3)
MBG-BRS0090	3.0	1.5	1.0	151.0	20.5	7.2	2.2
	(2.9-3.0)	(0.2-2.6)	(0.1-2.2)	(110.5-179.6)	(14.6-31.7)	(5.2-9.6)	(0.5-4.6)
MBG-BRS0092	3.2	1.7	0.9	153.3	22.0	8.2	1.9
	(3.0-3.3)	(0.3-2.5)	(0.1-1.7)	(109.4-184.2)	(15.1-27.1)	(4.1-15.6)	(0.2-2.8)
MBG-BRS0105	2.7	2.6	0.8	142.8	21.8	10.9	1.9
	(2.5-3.0)	(0.3-4.6)	(0.1-1.3)	(104.4-166.5)	(14.6-27.3)	(3.9-15.3)	(0.7-3.2)
MBG-BRS0107	3.5	2.8	1.0	168.9	22.1	7.9	2.2
	(3.0-4.1)	(0.3-5.3)	(0.1-1.6)	(125.9-195.8)	(14.8-27.9)	(3.9-10.5)	(0-3.9)
MBG-BRS0110	3.1	3.1	0.8	156.3	23.6	9.8	1.8
	(2.9-3.5)	(0.4-5.9)	(0.2-1.2)	(123.2-181.4)	(15.8-27.9)	(7.2-13.2)	(0.2-3.8)
MBG-BRS0113	3.3	2.3	0.9	166.1	23.7	9.9	2.7
	(3.0-3.9)	(0.6-4.1)	(0.3-1.3)	(123.9-191.2)	(18.5-29.3)	(7.9-12.0)	(0.6-6.1)
MBG-BRS0131	3.3	3.8	1.3	151.0	26.4	1.0	1.5

	(2.9-3.5)	(0.5-7.3)	(0.2-2.3)	(121.8-176.8)	(17.1-34.3)	(0.7-1.4)	(0.1-3.4)
MBG-BRS0134	3.9	3.5	2.1	166.7	24.5	2.8	2.6
	(3.3-4.3)	(0.2-5.8)	(0.1-4.6)	(145.9-201.1)	(20.7-32.2)	(0.1-7.9)	(0.1-6.0)
MBG-BRS0329	2.7	1.7	0.8	132.0	22.6	8.3	1.2
	(2.2-3.0)	(0.1-3.3)	(0.0-1.6)	(92.0-170.2)	(10.3-30.2)	(4.7-11.8)	(0.1-2.8)
MBG-BRS0333	2.1	1.3	0.7	148.6	20.6	5.7	2.3
	(1.0-3.4)	(0.2-2.0)	(0.1-1.3)	(98.0-188.5)	(11.4-27.1)	(5.0-7.1)	(0.0-6.1)
MBG-BRS0337	2.6	2.1	1.8	132.1	23.3	7.9	1.5
	(2.3-2.8)	(0.6-3.6)	(0.2-3.9)	(112.2-153.3)	(14.6-33.5)	(4.7-12.6)	(0.6-2.9)
MBG-BRS0346	3.0	2.8	0.8	139.6	20.2	1.0	2.2
	(2.7-3.4)	(0.5-4.8)	(0.2-1.4)	(107.6-159.4)	(14.8-26.5)	(0-2.5)	(0.5-4.5)
MBG-BRS0356	2.3	1.0	0.8	94.9	20.8	3.8	0.1
	(2.0-2.7)	(0.2-1.7)	(0.1-1.5)	(85.7-104.1)	(13.8-27.8)	(3.0-4.6)	(0.1-0.1)
MBG-BRS0373	**3.2**	**2.4**	**1.4**	**124.7**	**23.9**	**10.7**	**0.9**
	(2.9-3.6)	**(0.2-3.9)**	**(0.1-2.4)**	**(108.4-134.6)**	**(14.6-36.4)**	**(5.8-18.0)**	**(0.5-1.4)**

MBG-BRS0374	2.8	3.2	1.7	148.0	22.4	7.0	1.6
	(2.6-3.0)	(0.5-6.5)	(0.2-3.4)	(106.4-171.7)	(14.8-30.0)	(3.9-10.2)	(0.1-3.9)
MBG-BRS0378	3.1	4.3	1.0	134.5	28.8	3.0	1.0
	(2.5-3.8)	(0.7-9.4)	(0.4-1.6)	(113.1-155.3)	(17.5-35.5)	(1.5-5.5)	(0.3-1.9)
LSD (5%)	0.7	2.3	1.6	22.3	6.1	3.9	1.8
Mean	3.0	2.6	1.1	145.3	22.6	6.5	1.8

Accession in bold correspond with commercial nabicol variety.

Table 3. (continue) Comparisons of means and range of variation among 36 populations of nabicol evaluated in three environments in northwestern Spain for 13 traits that showed significant differences in the analysis of variance combined across environments.

Population	Days to flowering	Period of flowering	Formation siliques	Days to maturity	Silique length	Seeds per silique
	——— (d) ———				cm	no.
MBG-BRS0014	138.5	74.4	156.2	219.4	6.7	16.5
	(84.3-166.0)	(57.7-86.5)	(97.3-186.0)	(149.3-262.3)	(6.0-7.3)	(14.7-19.2)
MBG-BRS0028	161.9	56.8	178.7	237.2	6.0	16.4
	(131.3-177.7)	(35.7-77.1)	(147.7-195.0)	(201.0-260.7)	(5.4-6.6)	(14.2-19.5)
MBG-BRS0029	135.6	77.5	151.6	217.4	6.5	16.7
	(78.3-165.9)	(68.7-88.5)	(87.3-185.3)	(147.3-260.0)	(5.0-7.4)	(12.5-21.0)
MBG-BRS0034	126.4	76.0	147.1	211.3	7.0	16.4
	(53.0-164.7)	(65.0-91.4)	(65.3-191.7)	(129.0-259.3)	(5.8-7.9)	(11.5-20.6)

MBG-BRS0035	123.6	88.6	144.6	212.5	6.2	14.8
	(55.7-158.4)	(83.7-92.5)	(68.7-182.7)	(132.7-258.3)	(6.1-6.3)	(13.9-15.9)
MBG-BRS0037	127.0	77.2	143.0	211.0	6.3	12.8
	(53.3-172.0)	(71.5-82.3)	(69.7-182.7)	(133.3-253.7)	(5.6-7.1)	(9.5-15.2)
MBG-BRS0039	152.1	67.8	168.6	231.5	6.6	15.6
	(105.0-181.7)	(55.3-79.5)	(126.7-192.2)	(183.0-264.0)	(5.4-7.5)	(11.3-18.8)
MBG-BRS0041	148.0	71.5	170.3	231.6	6.2	15.0
	(106.0-171.7)	(55.0-81.5)	(131.3-192.9)	(184.0-259.7)	(5.6-6.5)	(11.2-18.1)
MBG-BRS0044	143.9	75.4	169.2	229.7	6.1	15.0
	(98.7-167.6)	(54.0-89.0)	(127.7-191.6)	(180.3-261.3)	(5.3-7.1)	(12.5-18.3)
MBG-BRS0048	156.1	56.3	173.3	231.6	6.2	17.2
	(106.0-184.9)	(47.0-64.5)	(127.3-198.0)	(180.0-263.7)	(5.6-7.0)	(15.1-20.5)
MBG-BRS0054	132.5	67.2	156.0	215.6	6.6	19.1
	(81.7-158.9)	(52.0-77.7)	(95.3-193.7)	(153.3-255.7)	(5.7-7.3)	(15.1-21.6)
MBG-BRS0056	142.4	70.0	159.5	222.2	6.5	17.0

	(89.3-169.0)	(62.7-76.3)	(103.3-189.4)	(163.3-255.3)	(5.3-7.5)	(14.5-19.8)
MBG-BRS0061	133.8	63.0	151.0	215.1	6.4	16.3
	(76.0-163.7)	(55.0-71.6)	(87.3-183.7)	(147.3-255.3)	(5.2-7.1)	(14.7-17.9)
MBG-BRS0063	157.0	68.5	178.6	238.0	6.4	17.2
	(109.0-191.3)	(53.3-86.5)	(132.3-208.8)	(181.3-273.7)	(5.4-7.4)	(14.6-21.5)
MBG-BRS0065	143.6	68.1	161.8	226.4	6.5	18.0
	(94.0-169.3)	(51.7-77.5)	(111.0-187.9)	(167.3-259.3)	(5.5-7.4)	(14.8-23.4)
MBG-BRS0068	143.0	73.2	159.3	225.1	5.9	14.2
	(97.3-166.8)	(64.3-81.5)	(107.0-186.3)	(167.0-262.3)	(4.7-6.9)	(7.3-19.8)
MBG-BRS0073	148.4	62.0	169.2	228.9	5.3	14.3
	(108.0-169.5)	(51.3-71.3)	(131.3-188.7)	(184.3-255.3)	(4.2-5.9)	(10.0-17.0)
MBG-BRS0079	159.7	58.2	177.0	234.3	6.2	16.2
	(126.3-180.6)	(41.0-75.5)	(145.7-196.3)	(202.0-258.0)	(5.3-6.8)	(11.9-19.0)
MBG-BRS0085	130.5	73.6	155.5	220.2	6.4	15.5
	(68.7-163.9)	(67.3-78.0)	(103.0-181.7)	(158.0-255.7)	(5.5-7.2)	(13.6-17.5)

MBG-BRS0087	157.4	61.0	167.5	227.8	5.4	16.8
	(129.0-175.4)	(43.0-73.4)	(126.0-188.5)	(179.0-262.3)	(5.1-5.8)	(15.0-18.3)
MBG-BRS0090	145.6	58.4	163.5	227.9	5.8	11.9
	(96.7-172.6)	(46.3-69.2)	(119.3-188.0)	(172.0-261.7)	(5.0-6.5)	(8.6-14.6)
MBG-BRS0092	146.6	60.8	167.6	230.7	6.1	15.0
	(109.3-165.7)	(42.0-81.3)	(131.7-187.7)	(180.7-262.0)	(5.3-6.9)	(12.6-18.5)
MBG-BRS0105	150.2	66.2	171.2	229.7	6.3	14.2
	(128.0-166.4)	(40.0-81.6)	(135.7-190.5)	(188.3-258.3)	(5.7-6.9)	(11.7-16.9)
MBG-BRS0107	141.2	71.5	168.1	222.7	6.4	17.0
	(106.0-160.8)	(53.3-83.5)	(130.3-193.0)	(166.7-256.0)	(5.8-6.9)	(14.1-20.2)
MBG-BRS0110	147.5	69.5	164.7	227.9	6.9	15.6
	(100.7-171.0)	(62.7-187.7)	(120.7-187.7)	(177.1-259.7)	(5.6-7.6)	(12.6-17.9)
MBG-BRS0113	151.4	64.0	172.5	225.6	8.0	16.6
	(105.7-178.3)	(47.0-75.0)	(126.7-196.0)	(170.7-256.7)	(7.4-9.0)	(12.5-20.7)
MBG-BRS0131	158.8	65.2	177.1	241.4	7.1	16.6

	(126.0-177.0)	(42.0-77.7)	(145.0-193.9)	(201.7-267.0)	(5.8-8.0)	(15.4-18.8)
MBG-BRS0134	139.8	61.2	156.9	220.8	7.2	16.4
	(92.3-164.5)	(50.0-68.0)	(99.0-186.0)	(159.0-256.3)	(5.5-8.2)	(12.3-20.3)
MBG-BRS0329	161.1	53.2	178.1	228.4	6.4	17.4
	(128.7-180.4)	(37.0-63.7)	(144.0-206.0)	(171.7-261.7)	(5.2-7.4)	(15.3-18.8)
MBG-BRS0333	162.1	52.5	179.0	236.3	6.0	16.3
	(129.7-184.9)	(35.7-63.4)	(145.7-201.7)	(202.3-260.0)	(5.1-6.7)	(14.1-20.4)
MBG-BRS0337	150.2	65.3	170.2	233.2	6.5	14.2
	(102.3-180.6)	(60.1-75.5)	(133.0-191.3)	(185.7-265.0)	(5.5-7.5)	(10.7-17.6)
.MBG-BRS0346	148.2	62.8	164.8	224.6	7.0	15.7
	(100.3-174.7)	(45.7-82.5)	(115.0-192.0)	(168.3-258.3)	(6.6-7.3)	(14.3-18.0)
MBG-BRS0356	181.6	70.6	195.3	264.5	6.4	16.6
	(179.3-183.9)	(69.6-71.5)	(189.7-201.0)	(256.0-276.0)	(6.3-6.6)	(14.6-18.6)
MBG-BRS0373	**150.8**	**61.0**	**169.8**	**228.8**	**6.0**	**12.5**
	(100.3-181.0)	**(55.3-65.1)**	**(121.3-195.3)**	**(177.7-262.7)**	**(5.5-6.8)**	**(10.3-16.5)**

MBG-BRS0374	152.5	64.4	169.8	228.6	6.8	13.6
	(104.7-179.8)	(50.0-76.0)	(119.7-197.0)	(176.0-259.7)	(6.1-7.7)	(10.5-17.6)
MBG-BRS0378	165.3	61.6	189.9	244.7	6.4	11.9
	(135.3-193.8)	(35.3-85.5)	(160.0-208.0)	(205.0-271.7)	(5.7-7.1)	(10.4-14.8)
LSD (5%)	18.3	14.3	19.6	17.5	0.7	3.0
Mean	152.3	66.5	166.5	220.2	6.4	15.6

Accession in bold correspond with commercial nabicol variety.

Table 4. Means and range of variation for 23 agronomic traits for 36 populations of nabicol grown for two locations and growing seasons in northwestern Spain.

	Location 1		Location 2	
Traits	Spring/summer season (Environment 1)	Autumn/spring season (Environment 2)	Autumn/spring season (Environment 3)	LSD (5%)
Early vigor (1-5)	3.3 a	3.0 b	2.9 b	0.2
	(2.2 - 4.2)	(1 - 4)	(1.7-4.1)	
Damage rating (1-9)	2.3 c	7.4 b	9.0 a	0.4
	(1.6 - 3.4)	(6.6 - 9)	(8.7-9)	
Damaged plants (%)	67.8 a	6.8 b	0.0 c	3.1
	(42.2 - 87.1)	(0 - 11.4)	(0-0)	

Lodging (%)	10.9 b	31.3 a	0.0 c	8.4
	(0 - 40.5)	(0 - 100)	(0-0)	
Fresh yield (t h^{-1})	20.3 b	29.9 a	0.4 c	0.7
	(11.1 - 37.3)	(12.7 - 81.8)	(0.1-0.7)	
Dry yield (t h^{-1})	2.9 b	3.6 a	0.2 c	0.5
	(0.7 - 4.5)	(0.8 - 7.3)	(0.1-0.4)	
Plant height (cm)	165.2 a	164.3 a	115.0 b	6.4
	(54.4 - 198.3)	(104 - 201.1)	(85.7-145.9)	
Plant diameter (cm)	55.5 a	56.4 a	38.8 b	3.8
	(42.0 - 71.4)	(43.6 - 76.3)	(21.3-60.9)	
Stem width (mm)	21.6 b	30.2 a	16.1 c	1.8
	(12.8 - 33.4)	(25.8 - 39.4)	(10.3-21.5)	
Leaves / plant (number)	65.5 a	65.2 a	13.1 b	5.1
	(33.8 - 95.9)	(37.6 - 92.4)	(6.2-20.4)	
Leaf index	0.39 b	0.42 ab	0.5 a	0.1

	(0.32 - 0.49)	(0.35 - 0.58)	(0.4-1.2)	
Petiole length (cm)	4.7 a	6.4 b	4.3 c	1.1
	(0.2 - 9.9)	(0 - 13.5)	(0-10)	
Secondary stems (number)	4.6 a	1.5 b	0.3 c	0.5
	(0 - 8.8)	(0 - 2.9)	(0-1.1)	
Length vegetative stem (cm)	25.8 a	17.7 b	17.7 b	3.1
	(10.4 - 54.4)	(10.1 - 29.2)	(12.5-25.7)	
Length floral stem (cm)	137.7 b	146.5 a	97.1 c	8.8
	(90.1 - 192.5)	(89.0 - 175.3)	(70.2-125.3)	
Days to flowering (days)	100.5 b	172.3 a	167.8 a	5.3
	(53 - 135.3)	(155.7 - 193.8)	(156.3-179.3)	
Period of flowering (days)	53.2 b	72.7 a	73.1 a	4.1
	(23.7 - 83.7)	(57.2 - 92.5)	(57.5-89.5)	
Formation of siliques (days)	118.2 b	190.3 a	189.0 a	5.6
	(65.3 - 160)	(181.7 - 206)	(176.6-208.8)	

Days to maturity (days)	172.1 c	260.8 a	248.0 b	2.8
	(129 - 205)	(253.7 - 276)	(237-259)	
Period of maturity (days)	53.9 c	70.5 a	59.0 b	5.0
	(27.7 - 64)	(55.7 - 86.3)	(49.5-69.4)	
Silique length (cm)	55.6 c	71.2 a	65.4 b	2.0
	(42.1 - 73.7)	(58.1 - 89.9)	(54.3-80.3)	
Seeds per silique (number)	13.3 c	18.6 a	14.8 b	0.9
	(7.3 - 21.5)	(14.6 - 23.4)	(10.5-17.7)	
Weight of 1000 seeds (g)	1.74 b	3.90 a	4.1 a	0.3
	(0.62 - 3.76)	(2.73 - 5.23)	(1.97-5.40)	

Means with the same letter within the same row do not differ significantly (LSD 5%).