

## Yield of peperina (*Minthostachys mollis* (Kunth.) Griseb.) populations in the year following planting: response to cropping regimen

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### Abstract

In Argentina there is a large market for aromatic plants, a trade that reaches its maximum importance in the mountain areas of Córdoba in the centre-west of the country. Of the native species, *Minthostachys mollis* (Kunth.) Griseb., or the peperina, is the most sought-after, and studies have begun to look for ways to sustainably cultivate crops of this species. The aim of the present work was to determine the response of different peperina populations to cropping (the partial harvest of growing plants). Eight populations from different original locations were grown in the mountains of the Córdoba province under different cropping regimens (i.e., different cropping times and number of cropping events). Plant production and persistence were recorded for each regimen. Large variations were observed in dry matter content and the quantities of essential oil produced; the *genotype x environment* interaction was found to have a significant effect («environment» refers to that produced by the cropping regimen). The differences between populations in terms of yield and in response to management must be known if clones are to be selected for crop improvement. The sustainable use of high yield populations subject to the best cropping regimen could increase the profits associated with cultivation of this species.

**Key words:** aromatic herbs, crop performance, dry matter, essential oils.

### Resumen

#### Comportamiento productivo de poblaciones de peperina, *Minthostachys mollis* (Kunth.) Griseb., en el año de implantación, según distintos momentos de cosecha

En Córdoba, Argentina, se encuentra muy difundida la explotación y comercialización de aromáticas, siendo las zonas serranas que corresponden al área centro-oeste del país donde adquiere mayor relevancia. De las especies nativas, la peperina, *Minthostachys mollis* (Kunth.) Griseb., se encuentra entre las que han sufrido mayor extracción. Se han comenzado estudios buscando un cultivo sustentable de esta especie, siendo entonces muy importante la caracterización y evaluación para el manejo y mejora. El objetivo de este trabajo fue determinar la respuesta a cortes productivos efectuados en el cultivo de distintas poblaciones nativas de peperina. El ensayo se ubicó en las serranías de la provincia de Córdoba, donde se evaluaron ocho poblaciones de dos procedencias distintas. Los tratamientos planteados se definieron combinando tres niveles del factor «número de cortes» y tres épocas del año en las que fueron efectuados los cortes. Se evaluó la producción y la persistencia de las plantas en respuesta a los tratamientos. Se encontró gran variación en rendimiento tanto de materia seca como de aceites esenciales entre las poblaciones evaluadas y una fuerte interacción genotipo por ambiente, considerando como ambiente aquel generado por las distintas modalidades de corte. Las diferencias entre poblaciones, encontradas a nivel de producción y como respuesta al manejo, son fundamentales para comenzar con la selección de clones en vista a una optimización de la producción bajo cultivo. El uso sustentable de poblaciones de alto rendimiento y la apropiada modalidad de cosecha aumentarían la rentabilidad del cultivo de peperina.

**Palabras clave:** plantas aromáticas, cultivo, materia seca, aceites esenciales.

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## Introduction

There is a growing argentinean and international market for aromatic plants, owed mainly to the «return» to so-called «natural» products, part of which includes a search for new flavours and aromas. In Argentina, native plant species are indiscriminately gathered by collectors who sometimes rip them out roots and all, with no care for their phenological state nor for the ability of the species to recover from such treatment. This behaviour has a strong impact on natural plant resources, modifies the environment, and leads to irrecoverable losses of germplasm through genetic erosion (Montenegro, 1987; Ojeda *et al.*, 2000; Roig, 2001).

The peperina (*Minthostachys mollis* (Kunth.) Griseb. = *Minthostachys verticillata* (Gris.) Epling.), a member of the family Lamiaceae, is one of the most sought-after native plants; it has thus suffered more than most at the hands of collectors. The genus *Minthostachys* is widely distributed in the Andes from Venezuela and Colombia to Argentina, where it is found in the Provinces of Salta, Jujuy, Catamarca, Tucumán, La Rioja (north-west), San Luis and Córdoba (centre-west). It is in the mountains of Córdoba, however, where the trade in these plants reaches its greatest proportions (Alkire *et al.*, 1994; Gupta, 1995; Bocco *et al.*, 1997).

The peperina is a perennial, aromatic semi-shrub some 0.3-2.0 m in height. It has white tubular flowers in summer and reproduces by both seeds, but can also be achieved through eye cuttings. Its aroma is similar to that of mint, and it is used to make a tea said to have stimulant, anti-spasm, anti-diarrhoea, anti-cholera, anti-emetic and digestive properties. It is also used in the manufacture of liqueurs and *mate compuesta* (*mate* with regional herbs). The species has been included in the National Argentine Pharmacopoeia since its sixth edition (Boletín Oficial, 1978).

Dried and chopped peperina leaves and twigs make up the product demanded; there is no difference in price with respect to essential oil content (Boelcke, 1989; Bonzani and Ariza Espinar, 1993; Gupta, 1995). In fact there is no attempt whatsoever to determine quality in this respect: the product is simply bought by dry weight and left to merchants and consumers to determine its organoleptic value.

If the peperina is to be cultivated and its sustainable use promoted, then good quality, quantity and continuity of production have to be achieved. The charac-

terisation and assessment of native populations adapted to grow in the region is therefore of prime importance.

Given the great demand for peperina and the few studies ever performed regarding its cultivation, a project was undertaken with a view to its domestication, determining the necessary conditions for its proper management. Domestication would allow the conservation of the species in the wild since less would be gathered. There is evidence to suggest that when cultivated, plants can be cropped in their first year. However, no studies have been performed to discover when the best moment(s) might be, nor how often the plants can be cropped without causing their death. The aim of the present work was to determine the response of different native populations of peperina, when grown as a crop, to different cropping regimens during the first year after planting.

## Material and Methods

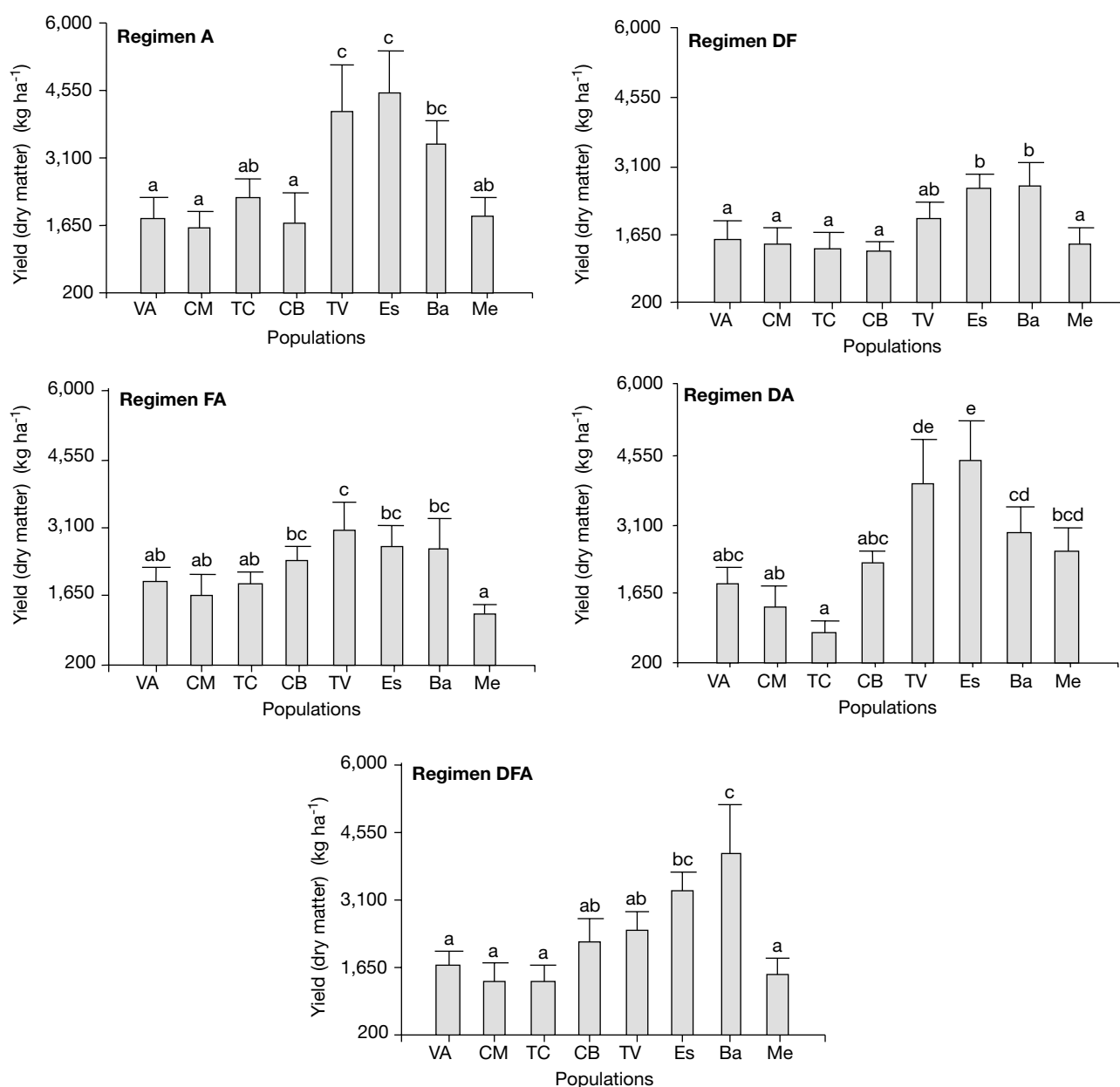
The trial was performed in the mountain area of the Province of Córdoba, Argentina, (Dept. de la Granja, 31° 01' 21" S, 64° 14' 20" W), a region where the peperina grows wild. Plants belonging to eight populations from around Argentina [Villa Allende (VA), Capilla del Monte (CM), Tala Cañada (TC), Cuesta Blanca (CB) and Merlo (Me), all in the centre-west of the country, and from Tafi del Valle (TV), Escaba (Es) and Balcosna (Ba) from the north-west] were cultivated from seeds. The first 120 days of their lives were spent under glass before being transplanted to the field in the spring.

The experiment was arranged in a complete block split-plot design with three replicates. In the main plots the cropping regimens were assigned, and each plot was divided in eight subplots (one for each population). Each subplot contained 15 plants (0.5 m between

**Table 1.** Cropping regimens

Regimen	No. of cropping events	Cropping month		
		December	February	April
A	1			×
DF	2	×	×	
FA	2		×	×
DA	2	×		×
DFA	3	×	×	×

A: April single cropping. DF: December-February double cropping. FA: February-April double cropping. DA: December-April double cropping. DFA: December-February-April triple cropping.



**Figure 1.** Potential yield (dry matter in kg ha<sup>-1</sup>) for the different populations under the different regimens. Populations: VA (Villa Allende), CM (Capilla del Monte), TC (Tala Cañada), CB (Cuesta Blanca), TV (Tafi del Valle), Es (Escaba), Ba (Balcosna), Me (Merlo). Regimens: A, April single cropping; DA, December-April double cropping; DF, December-February double cropping; FA, February-April double cropping; DFA, December-February-April triple cropping. Different letters indicate significant differences ( $p < 0.05$ ).

plants). Rows were 0.7 m apart. The final plant density was 25,000 plants ha<sup>-1</sup>.

The different populations were subjected to different regimens involving different cropping times during the growth period of the first year after planting, combined with different numbers of cropping events (Table 1). All cropping was performed

in summer and autumn before the first frost, which in this region begins in April; winter dormancy follows. Plants were cropped 20 cm above the soil; the aerial part of the plant is generally used with no discrimination between leaves and twigs (Bocco *et al.*, 1997). Plant production and persistence was recorded under the different regimens. All plants were watered

twice weekly. All recommended cultivation practices were performed.

Plant mortality (percentage of dead plants per subplot) was recorded at each cropping date to compare the adaptation of the different populations to cultivation. Plant weights were used to calculate expected yield per hectare. The cropped material was dried in a cool, shady place with good ventilation until constant weight was obtained. The potential yield was based on the yield of dry matter ( $\text{kg ha}^{-1}$ ), whereas true yield was determined by multiplying the potential yield by the mortality percentage. In those regimens in which plants were cropped more than once, the potential yield was considered to be the sum of all croppings. Means were compared by ANOVA and the Fisher's LSD test using the InfoStat program (InfoStat, 2003).

In addition to the above, another 15 plants per population were monitored over the growth cycle. The aerial part of each was weighed in December, February and April in order to construct growth curves.

The oil content of the dry matter was determined by steam distillation, the oil and water separating in the collection vessel because of the difference in their densities. The volume and weight of the oil obtained was recorded to determine the oil yield (g oil per 100 g dry plant matter). The potential oil yield per hectare was determined from the oil yield and the potential yield of dry matter per hectare.

## Results and Discussion

The interaction *cropping regimen x population* had a significant effect ( $p < 0.05$ ) on yield. Figure 1 shows the mean potential yields in dry matter obtained under each regimen.

When the plants were cropped three times (once in December, February and April, Regimen DFA, Table 2) the yield of the last cropping was low for all populations, although significant differences ( $p < 0.05$ ) were seen among them. Populations Es, Ba and TV (from the north-west) gave the highest yields in all cropping regimens, the maximum being obtained with Es under the single cropping regimen (Regimen A,  $4,530 \text{ kg dry matter ha}^{-1}$ ). It also showed the highest potential yield ( $4,440 \text{ kg dry matter ha}^{-1}$ ) in the December-April double cropping regimen (Regimen DA). The Ba population provided the highest yields in the DFA regimen ( $4,117 \text{ kg of dry weight ha}^{-1}$ ).

**Table 2.** Percentage mortality of *piperina* populations under different cropping regimens

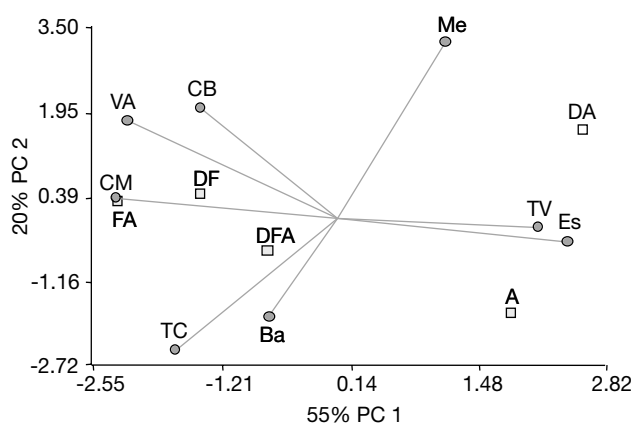
Population	Regimen					Mean
	A	DF	DA	FA	DFA	
Villa Allende	5.0	0.0	5.0	40.0	80.0	26.0
Capilla del Monte	30.0	0.0	20.0	40.0	90.0	36.0
Tala Cañada	5.0	10.0	10.0	30.0	70.0	25.0
C. Blanca	20.0	10.0	10.0	40.0	50.0	26.0
Tafi del Valle	15.0	0.0	10.0	10.0	30.0	13.0
Escaba	5.0	0.0	10.0	0.0	0.0	3.0
Balcosna	5.0	0.0	0.0	20.0	30.0	11.0
Merlo	5.0	10.0	5.0	50.0	90.0	32.0
Media	11.3	3.8	8.8	35.0	48.8	

Cropping regimens: A: April single cropping. DF: December-February double cropping. FA: February-April double cropping. DA: December-April double cropping. DFA: December-February-April triple cropping.

No significant differences were seen in yield between the populations from the centre-west of the country (VA, CM, TC, CB and Me) under any cropping regimen.

The pattern of interaction between the environments created (i.e., by the different regimens) and the populations was examined by PCA analysis of the residuals from the additive model (i.e., with no *cropping regimen x population* interaction).

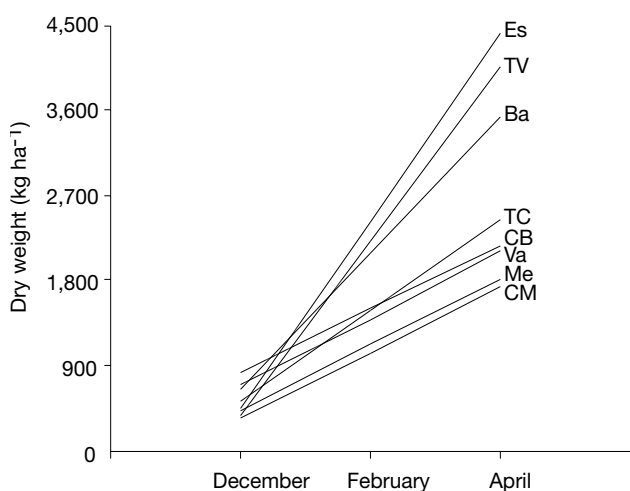
Figure 2 shows a biplot of the first two principal components used to explore the *cropping regimen x*



**Figure 2.** Biplot of PCA analysis to examine the pattern of the *population x regimen* interaction. Populations: VA (Villa Allende), CM (Capilla del Monte), TC (Tala Cañada), CB (Cuesta Blanca), TV (Tafi del Valle), Es (Escaba), Ba (Balcosna), Me (Merlo). Regimens: A, April single cropping; DA, December-April double cropping; DF, December-February double cropping; FA, February-April double cropping; DFA, December-February-April triple cropping.

population interaction. The graph explains 75% of the total variability owed to the interaction of the populations and the regimens. In agreement with the configuration of the points representing the populations and those representing the environments, the interaction is mainly explained by the different behaviours of the TV and Es populations compared to those of the rest. These populations provided better yields with the single cropping regimen (A) and the December-April double cropping regimen (DA), while the VA, CM, TC and CB populations provided relatively better yields with the February-April double cropping regimen (FA). Under this regimen, the differences seen between the north-western and central-western populations were less pronounced than between those recorded for other regimens, the reason being that the north-western populations grew less well.

Figure 3 shows the adjusted linear fits for the growth of the different populations during the first year following planting. The north-western and central-western populations differed in terms of mean growth per month ( $881 \text{ kg ha}^{-1}$  and  $370 \text{ kg ha}^{-1}$  respectively). For the central-western CB and VA populations, the  $R^2$  values (linear determination coefficient) were 0.44 and 0.69 respectively. The growth rate of these populations was reduced from February onward.



**Figure 3.** Change in yield of dry matter ( $\text{kg ha}^{-1}$ ) over the growing season following planting for the eight peperina populations. Populations: VA ( $y = -0.1 + 699.6 x$ ,  $R^2 = 0.69$ ), CM ( $y = -327.6 + 684.3 x$ ,  $R^2 = 0.95$ ), TC ( $y = -428.9 + 956.4 x$ ,  $R^2 = 0.90$ ), CB ( $y = 179.8 + 663.3 x$ ,  $R^2 = 0.44$ ), TV ( $y = -1483.9 + 1852.6 x$ ,  $R^2 = 0.99$ ), Es ( $y = -1537.9 + 1984.4 x$ ,  $R^2 = 0.99$ ), Ba ( $y = -812.8 + 1540.3 x$ ,  $R^2 = 0.98$ ), Me ( $y = -265 + 695 x$ ,  $R^2 = 0.99$ ).

Table 2 shows plant mortality results for the different regimens over the growth season. Those plants that could not withstand the cropping regimens (mainly those of the central-western population) died.

Since the true yields of the populations were affected by their mortality rate, differences were detected with respect to their potential yield (Fig. 4).

The *cropping regimen*  $\times$  *population* interaction also significantly ( $p < 0.05$ ) affected the essential oil content of the plants. To obtain an overall idea of the amounts of oil produced, the relationship between dry weight per hectare and accumulated oil yield ( $\text{L ha}^{-1}$ ) was determined (Table 3). Great variation was seen in the behaviour of each population under the different regimens (which explains the significance of the interaction). Similar observations have been reported for *Salvia officinalis* (Putiesvky *et al.*, 1986), which provides greater yields if cut only once in the autumn.

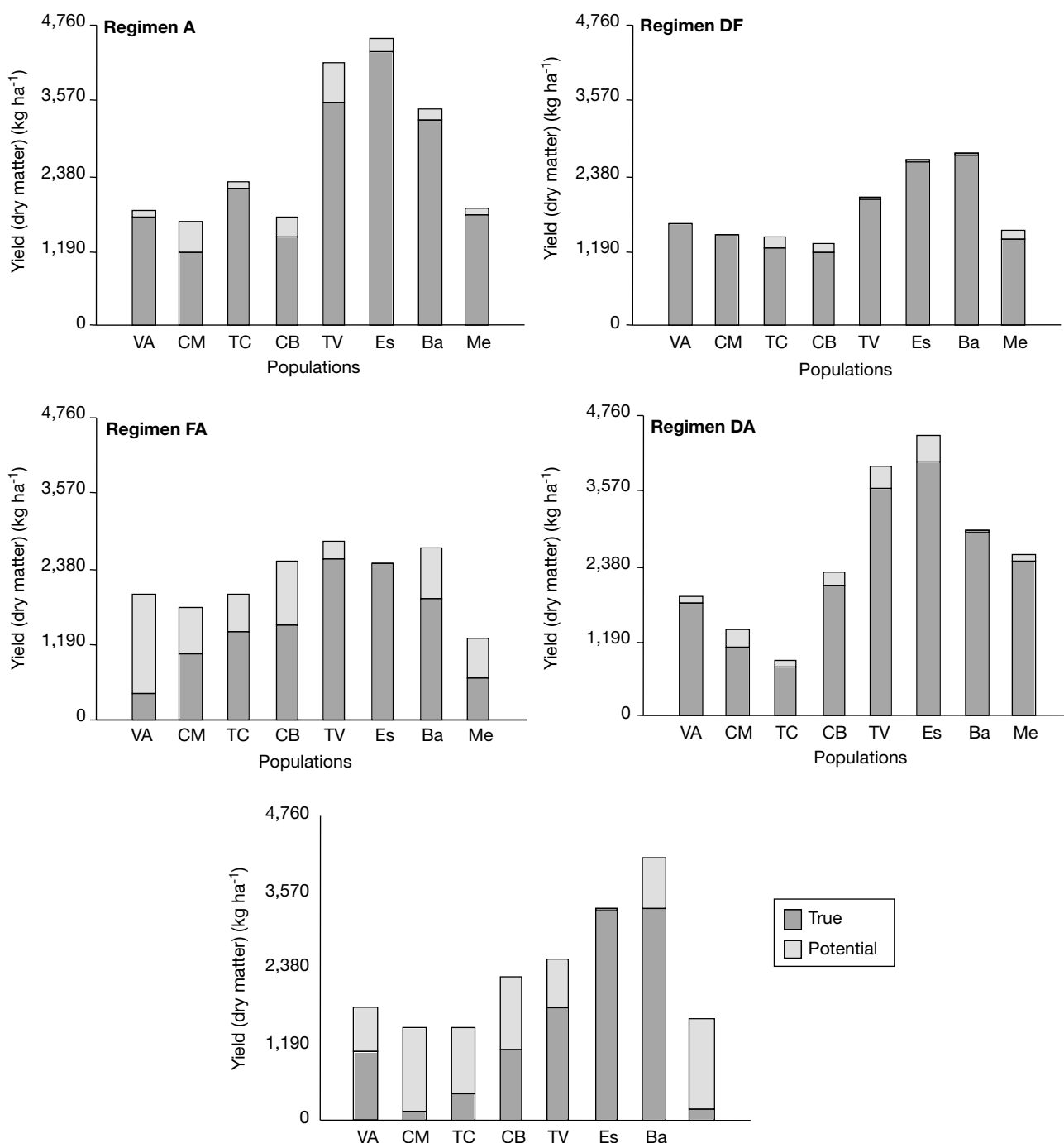
If the essential oil yields of the different populations are compared to their dry matter yields, it can be seen that those with the most oil are generally not those with the greatest dry matter yields. The TV population gave very much higher oil yields (per hectare) than the rest of the populations in the single cropping A regimen.

In conclusion, these results show there is great variation among the different populations tested with respect to dry matter and oil yields. The *genotype*  $\times$  *environment* interaction (i.e., the environment induced by the cropping regimen) was very significant. The north-western populations adapted better to cultivation and provided higher yields, with growth concentrated towards the end

**Table 3.** Potential oil yield ( $\text{L ha}^{-1}$ ) for the different populations under the different cropping regimens

Population	Regimen					Mean
	A	DF	DA	FA	DFA	
Villa Allende	12.8	58.6	13.3	36.3	77.6	39.7
Capilla Monte	8.5	19.2	29.8	53.0	26.3	27.3
Tala Cañada	22.2	38.0	14.3	33.8	47.8	31.2
Cuesta Blanca	1.3	13.2	64.2	77.5	22.8	35.8
Tafi del Valle	104.5	11.1	38.0	18.9	24.6	39.4
Escaba	0.6	15.6	16.1	27.2	27.7	17.4
Balcosna	76.7	11.3	22.9	11.5	16.2	27.7
Merlo	40.5	15.4	37.0	12.4	25.0	26.0
Media	33.4	22.8	29.4	33.8	33.5	30.6

Cropping regimens: A: April single cropping. DF: December-February double cropping. FA: February-April double cropping. DA: December-April double cropping. DFA: December-February-April triple cropping.



**Figure 4.** Yield (dry matter ha<sup>-1</sup>) - both potential and as affected by mortality (true) - for the eight populations of peperina.

of the season. The single cropping regimen (A) provided the best results – this practice is therefore recommended. It also allows a period of time before the first frosts during which plants can recover and accumulate reserves, helping it to resprout in the following growth season. Knowing the differences between populations with respect to yield and response to management is vital if production is to be

optimised under cultivation conditions and the highest yielding populations selected for genetic improvement. The use of such populations and an appropriate cropping regimen could increase the profitability of peperina production. Further work is needed to evaluate the response of cropping and plant persistence over subsequent years of cultivation.

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