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Adaptability of 'Monti Dauni' Bean Ecotypes in Plain Areas

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***Abstract*—**The bean (*Phaseolus vulgaris* L.) is one of the best known of the legumes, and it has a long cultivation tradition in Italy. The territory of "*Subappennino Dauno*" (southern Italy) is at around 700 m a.s.l. and is predominantly grown with cereals, olive trees and grapevines. Ecotypes of white beans to eat dry (such as cannellini beans) are also grown, which are sought for their palatability, high digestibility, and ease of cooking. However, these are not easy to find on the market due to their low production in relatively small areas and on small family farms that use seeds handed down from generation to generation. The introduction of these ecotypes in plain areas of the Puglia region would provide an opportunity to promote the diffusion of this type of bean. To investigate the adaptability of these ecotypes in plain environments (Cerignola, in southern Italy) a comparative trial was carried out between three 'Monti Dauni' ecotypes (E1, E2, E3) that are native to mountain areas and the similar commercial variety, 'Cannellini'. The data provide useful information about the quantitative and qualitative characteristics of these ecotypes when grown in lowland environments. Ecotype E3 provided the greatest bean production (2.34 t ha^{-1}) compared to 'Cannellini' (1.28 t ha^{-1}) and the other ecotypes (0.55 and 0.40 t ha^{-1}, for E1 and E2, respectively), due to its greater plant growth and the larger size of the seed (and thickness, in particular). Finally, ecotype E2 provided the greatest protein content (31.2%), although not significantly different from the commercial cultivar 'Cannellini' (32.1%).

***Keywords*—**'Monti Dauni' bean, ecotypes, adaptability in plain areas, quali-quantitive.

I. Introduction

DRY beans (*Phaseolus vulgaris* L.) are a good source of protein, carbohydrate, vitamins and minerals. These are the best known of the legumes, and they have a long cultivation tradition in Italy [1].

Legumes, including the bean, are the crops that have experienced the greatest decreases in cultivation acreage in recent decades, due to their lower competitiveness in cropping systems and their decreasing consumption. However, there is a growing rediscovery of varieties and local ecotypes that are limited to particular areas, and especially to the mountains. These are deeply rooted in tradition and have been adapted to the specific climatic conditions of cultivation of these territories. These also have a role in the preservation of biodiversity, as a resource for the development of rural areas [2]. Indeed, the European Agricultural Policy has assigned a prominent role to the contribution of legume crops to sustainable agriculture and the environmental.

The main agronomic advantage of beans is the ability of symbiotic *Rhizobium bacteria* to fix substantial amounts of nitrogen, thus either almost entirely eliminating, or at least greatly reducing, the need for supplemental supplies of this critical macronutrient. These legumes provide nitrogen as an available and renewable resource, with positive pre-crop effects seen for their inclusion in crop rotation. Beans enable the diversification of the agroecosystem; i.e., planned biodiversity over time via changing crop rotation, and in space as an intercrop. This also indirectly enhances the associated diversity of the wild flora and fauna, and the soil microbes that can affect the sustainability of agricultural systems [3]. It is well known that from a nutritional point of view, the quality of beans depends on several parameters, including protein, minerals, lipid, fibre, carbohydrate, energy value, percentage of seed coat, hydration, and cooking time [4].

Organoleptic qualities are an important factor for the market value of such legumes, especially in developed countries where they have regained prestige in the diet. This is due in part to health problems that are related to meat consumption, as well as the discovery of the benefits of legumes in the diet, and the protection they afford against colon disease [5], [6].

One of the most highly appreciated aspects of beans in gastronomy is their texture, although the main chemical components for this characteristic are uncertain, for both the seed coat and the cotyledon [7]. The content of protein and starch (with its components) must contribute to the texture, considering their quantitative importance in the seed, and their properties in other foods [8], [9], with similar findings in beans [10].

Part of the food quality is also represented by their typicality and tradition. In recent years, efforts have been made to include the 'Monti Dauni' bean in the national list of traditional food products [11], although as indicated, it remains difficult to find on the market because of its low production.

The 'Monti Dauni' bean is best known in the Capitanata province (Apulia region, southern Italy). This is a mountain area that stretches along the southern sub-Apennine Dauno ridge, and which includes, in particular, the agricultural towns of Faeto, Anzano di Puglia, Monteleone di Puglia, Orsara and Panni (Fig. 1) [12]. The average altitude of this area is 700 m a.s.l., and it comprises a natural environment that includes forests of various types, pastures, streams, lakes, and pools. It is suitable for growing cereals, olives, grapes and vegetables. In addition, for a very long time, local ecotypes of bean have

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been grown in small plots, as they are mainly intended for family consumption [13].

Fig. 1 Map of the Capitanata province

The cultivation technique for the 'Monti Dauni' bean consists of operations that are partially mechanised and partially manual. The soil is prepared by ploughing and subsequent milling, and the sowing deposits 5 to 6 seeds per dibbling. In recent years, an alternative to this technique that is spreading is precision drilling using a common pneumatic seed drill. This method saves on the labour and facilitates other farming operations, including the harvest, which can be performed mechanically.

The plants of the 'Cannellini' bean ecotype have an indeterminate growth habit, and provide white seeds for human consumption. These are between 7 mm and 15 mm long and of variable shape, from round to flat [12]. Their use is determined by their very pleasant flavour, high digestibility, and ease of cooking, due to their thin integument. In particular, the thin integument is affected by the limited calcium content in the soil, and the environmental conditions of the Monti Dauni area. However, the bean acreage in the Monti Dauni territory, and consequently the bean production, is very low compared to consumer demand [13].

In 2008, the Department of Agricultural Sciences, Food and the Environment at the University of Foggia began a research project entitled: "The study of 'Monti Dauni' beans", funded by the Community of Monti Dauni. This involved the initial distribution of a questionnaire to several local farms, to obtain information on the agronomic techniques that have been adopted for bean cultivation. Subsequently, 15 dry bean 'Monti Dauni' ecotypes were sampled from several farms, and underwent physicochemical and genetic analysis, in comparison with the commercial 'Cannellini' variety, that was used as the control. Cluster analysis to determine the relationships among the genotypes allowed their separation into five groups of homogeneous bean types. The morphological characteristics of these plants and the physicochemical properties of the beans showed variability among the genotypes compared, with significant differences in some cases, and small or non-significant differences in others [14]. In particular, there were significant differences between the ecotypes compared to cv. 'Cannellini' for plant height, number of pods per plant, and number of seeds per pod. For the dry bean physicochemical characteristics, the local ecotypes had smaller beans, with lower protein content, higher percentage of fibre, and lower weight of seed coat, compared to cv. 'Cannellini' [14].

For the genetic characterisation of the local ecotypes in comparison with cv. 'Cannellini', the study was conducted using microsatellite molecular markers (simple sequence repeats) for 7 microsatellite loci selected from those in the literature: 1 Drought, Bng91-R2, PV-ag001, ag004-Pv, Pv-AT004, Pv-at007 and VA-ag001. Most of these showed good polymorphism, which allowed clear identification of the genotypes. While the genetic analysis showed differences among the beans across several farms, it identified five homogeneous groups of ecotypes [15].

As mentioned above, given the low bean production in these mountain areas, the introduction of bean ecotypes into plain areas of the Apulia region might be a good opportunity to promote wider diffusion of this bean. However, the difference in climate conditions between the two distribution areas has to be considered. Generally, in the Monti Dauni area, the growing period for beans (from May to September) is characterised by mean monthly temperatures below 20°C, and rainfall that is about 60% higher than in the plain areas, where irrigation is necessary as the rainfall is low in the spring to summer period. Despite these differences, previous studies have provided encouraging data on the maintenance of certain qualitative characteristics of 'Monti Dauni' bean ecotypes even when grown on the plains [16].

The objective of the present trial was to evaluate the adaptability of three of these 'Monti Dauni' bean ecotypes (E1, E2, E3) to the plains of the Apulia region, through analysis of the various plant and yield parameters. For this purpose, the three ecotypes of 'Monti Dauni' that provided the best quanti-qualitative yields in previous studies were chosen.

II Materials and Methods

The trial was carried out in 2008 in an open field at the experimental farm of the 'Pavoncelli' Agricultural Institute in Cerignola, in the Apulia region of southern Italy (41° 16' 00" N; 15° 54' 00" E; altitude, 120 m a.s.l.). The main physicochemical characteristics of the soil are reported in Table I.

Three ecotypes of 'Monti Dauni' beans (E1, E2, E3) that are routinely cultivated in the mountainous areas of Monti Dauni were compared with the commercial cv. 'Cannellini', which was here considered as the control. The sowing took place on 21 May, 2008, on soil previously ploughed and fertilised with 100 units P_2O_5. The sowing distances were 70 cm between rows and 10 cm within the rows, which resulted in a theoretical spacing of 14.2 plants m^{-2}.

The experimental design was a randomised block with three repetitions, for a total of 12 plots of 21 m^2 each (10 m × 2.1 m) and a sampling area of 1.4 m^2 (2.0 m × 0.7 m). The preceding field use was as bare fallow.

TABLE I
PHYSICOCHEMICAL CHARACTERISTICS OF THE SOIL IN THE EXPERIMENTAL FIELD (0-30 CM DEPTH)

Characteristic	Units	Datum
Sand (2.0 > Ø <0.02 mm)	%	46.1
Loam (0.02> Ø <0.002 mm)	%	37.5
Clay (Ø < 0.002 mm)	%	16.4
pH (in H_2O)		6.9
EC_e	dS m^{-1}	1.8
Total nitrogen (Kjeldhal)	‰	1.3
P_2O_5 (Olsen)	mg kg^{-1}	50.0
K^+	mg kg^{-1}	820
Organic matter (Walkley-Black)	%	2.3
Moisture at field capacity (-0.03 MPa)	%	24.0
Moisture at wilting point (-1.5 MPa)	%	9.8
Bulk density	t m^{-3}	1.25

During the growing cycle, five irrigation events took place using drip irrigation, with a seasonal volume applied of 1,000 m^3 ha^{-1}. For weed control, weeding was performed when the plants were at the stage of the 4th to 5th true leaves.

The harvesting of the dry ripening beans was on 4 September, 2008, for cv. 'Cannellini' and the E1 and E3 ecotypes, and on 12 September, 2008, for the E2 ecotype. At harvesting time, the morphological characteristics of the plants (i.e., height, number of pods per plant, pod length, number of seeds per pod) and the bean yield were determined. Subsequently, the morphological (i.e., 100-seed weight, bean diameter, and percentage seed coat (episperm) on a weight basis), technological (i.e., moisture and hydration index), and nutritional (i.e., protein) characteristics were determined for the dried beans.

The percentage seed coat was determined following the soaking of samples for 24 h at 20°C (500 g beans in 2,500 ml tap water). After soaking, the coats on randomly chosen beans were separated from the rest of the bean (endosperm plus embryo) and were dried to constant weight. This provided the calculation of the ratio of the seed coat weight to the total bean weight (i.e., the seed coat proportion, as a percentage) [17].

The hydration index was determined according to the method reported by Berrios et al. [18], by soaking 10.00 ±0.01 g beans on a dry weight basis (dwb) in 100 ml distilled water under ambient conditions for up to 24 h. Every hour, the soaking beans were removed from the water, and blotted with a paper towel to remove excess water. The water absorption was then expressed as the percentage of water absorption as calculated in terms of grams of water absorbed per 100 g beans dwb, according to (1):

$$\text{Percentage water absorption} = \frac{\text{Weight soaked beans} - \text{Weight dry beans}}{\text{Weight dry beans}}\ x\ 100 \quad (1)$$

The crude protein of the beans was determined using the Kjeldahl method [19], with the quantification of the amount of nitrogen using a selective ammonium electrode. The crude protein content was then calculated as %N × 6.25.

All of the data collected were subjected to analysis of variance (ANOVA) using the JMP software (SAS Institute, Cary, NC, USA). Furthermore, statistical discrimination of the means was performed using Tukey's tests.

III RESULTS AND DISCUSSION

A. Climate

The climate of the plain area where the trial was carried out during the growing cycle of these bean crops (May to September) was characterised by mean temperatures from 22.0°C to 28.0°C, and rainfall in June of 47 mm, in July of 0 mm, and in August of 27 mm. These data were compared with those recorded for the Monti Dauni area (Faeto weather station: 41° 19' 00" N, 15° 09' 00" E; altitude, 541 m a.s.l.) in these middle months of the bean cycle (June, July, August; Fig. 2). They showed differences in average temperatures of 7°C (plain: 25.7°C; mountain: 18.7°C) and in total rainfall of 29.7 mm (plain: 74.3 mm; mountain: 104.0 mm) over these three months (Fig. 2). The climatic conditions of the plains, therefore, required the use of irrigation to support the water needs of the plants.

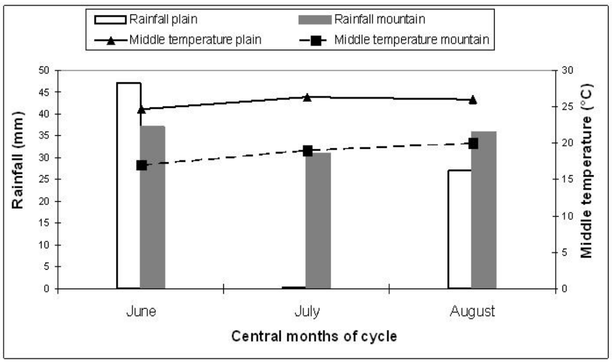

Fig. 2 Monthly mean temperatures and monthly rainfall at the test sites of Cerignola (plain) and Faeto (Monti Dauni)

B. Morphological Characteristics of the Plants

Table II shows the mean qualitative data and the results of the ANOVA relative to all of the parameters assessed. Ecotype E3 showed significantly greater plant height (mean, 862 mm), compared to 'Cannellini' and the other ecotypes (497-548 mm). The tallest plants of ecotype E3 positively affected the number of pods per plant. Indeed, for ecotype E3, the mean number of pods per plant (68.8) was significantly greater than all of the others (43.2-48.6). The mean lengths of the pods varied significantly from 83 mm for ecotype E3 to 71 mm for ecotype E1 and 69 mm for ecotype E2 ('Cannellini', at 80 mm, was only significantly different from ecotype E2). Finally, the number of seeds per pod of ecotype E3 (3.9) was significantly greater than for 'Cannellini' and ecotypes E1 and E2 (1.9-2.7).

The experimental design was a randomised block with three repetitions, for a total of 12 plots of 21 m^2 each (10 m × 2.1 m) and a sampling area of 1.4 m^2 (2.0 m × 0.7 m). The preceding field use was as bare fallow.

TABLE II
QUALITATIVE PARAMETERS AND ANOVA ANALYSIS OF THE PLANTS AND BEANS

Characteristic	Cv.	Ecotype		
	'Cannellini'	E1	E2	E3
Plant height (mm)	548.0 B	510.0 B	497.0 B	862.0 A
Pods per plant (n)	48.6 b	44.2 b	43.2 b	68.8 a
Length of the pods (mm)	80.0 AB	71.0 BC	69.0 C	83.0 A
Beans per pod (n)	2.3 B	2.7 B	1.9 B	3.9 A
Bean yield (t ha^{-1})	1.28 B	0.55 C	0.40 C	2.34 A
Hundred-bean weight (g)	40.2 A	21.8 C	16.8 C	34.1 B
Bean length (mm)	14.7 A	11.5 C	11.0 D	12.1 B
Bean width (mm)	7.0 A	5.3 B	4.8 B	7.3 A
Bean thickness (mm)	4.7 B	4.3 C	3.9 D	5.1 A
Integument (%weight dry bean)	9.2 C	10.4 B	11.7 A	7.3 D
Moisture (%)	8.6 B	8.4 B	8.4 B	9.3 A
Hydration index (%)	126.3 A	120.3 AB	124.5 A	113.5 B
Protein (% dry matter)	32.1 a	28.4 bc	31.2 ab	27.4 c

*Values with different letters are significantly different at $P < 0.05$ (small letters) and $P < 0.01$ (capital letters), according to Tukey's tests.

C. Bean Yield

The greatest bean yield was obtained with ecotype E3 (2.34 t ha^{-1}), which was significantly greater than 'Cannellini' (1.28 t ha^{-1}), which was also significantly greater than ecotypes E1 and E2 (0.55 t ha^{-1}, 0.40 t ha^{-1}, respectively). The yield of ecotype E3 was considered as particularly good here, as it was also higher than that reported by Araujo and Teixeira [20] in a trial of full-field cultivation of 18 varieties of common bean.

D. Morphological Characteristics of the Beans

The hundred-seed weight was instead significantly greater for 'Cannellini', followed by ecotype E3, which was also significantly greater than the comparable weights of ecotypes E1 and E2. This was largely due to the significantly greater bean length, of 14.7 mm for 'Cannellini', compared to 11.5 mm, 11.0 mm and 12.1 mm for ecotypes E1 to E3, respectively. However, the bean width was similar for ecotype E3 and 'Cannellini', which were significantly greater than ecotypes E1 and E2. The thickness of the beans was significantly different across all of these genotypes, from ecotype E3 (5.1 mm) to 'Cannellini' (4.7 mm), to ecotype E1 (4.3 mm) and ecotype E2 (3.9 mm).

For the percentage of the tegument in terms of the seed weight, this also varied significantly across all of these genotypes, from 11.7% for ecotype E2, via ecotype E1 and 'Cannellini', to E3, at 7.3%. Here, it is appropriate to note that a lower percentage of seed coat is linked to a shorter cooking time, and thus a more appreciated baked product [20].

E. Technological Characteristics of the Beans

The bean moisture measurements were significantly different only for the highest level of ecotype E3 (9.3%), compared to 'Cannellini' and ecotypes E1 and E2 (8.4%-8.6%). These bean moisture levels obtained here are also consistent with those reported in the literature (generally 8%-11%; [16]). The hydration indices were again similar for 'Cannellini' and ecotypes E1 and E2 (120.3%-126.3%), but significantly greater than for ecotype E3 (113.5%). It is known that in addition to the percentage of the tegument, the hydration index of these beans also affects the cooking time. In this case, the greater hydration index indicates greater recovery of water, with the consequent shorter cooking time and lower percentage of hard beans. However, this capacity of water absorption of the beans is a parameter that can be strongly influenced by climatic fluctuations during the crop cycle [21].

F. Nutritional Characteristics of the Beans

Beans have always had a major role in the human diet due to their interesting nutritional properties. Indeed, this legume provides a relatively low-cost food that can be stored for long periods without difficulty, and at the same time, they provide high protein levels that can improve diets that are otherwise relatively poor [22]. Currently, the protein in such bean crops represents a valid alternative to protein of animal origin in developing countries [23].

Here, the higher protein content of the 'Cannellini' beans (32.1%) was similar to that of ecotype E2 (31.2%). In contrast, ecotypes E1 and E3 showed significantly lower, and similar, protein content (28.4%, 27.4%, respectively), although these represent values that still remain satisfactory.

IV. CONCLUSIONS

White beans to eat dry (such as cv. 'Cannellini') are sought for their palatability, high digestibility, and ease of cooking, and these are grown in Monti Dauni in the Apulia region of southern Italy. The present study investigated the adaptability of some ecotypes of this bean to the plain areas of the Puglia region, which are characterised by a warmer and drier environment than their area of origin of Monti Dauni, and thus where irrigation is also needed. Despite the climatic differences between these two areas, the data obtained open up the possibility of growing these beans on the southern plains of Puglia. This was particularly seen for ecotype E3, in terms of plant development, and beans with greater yield and less integument. Therefore, these 'Monti Dauni' bean ecotypes require safeguarding, particularly for their qualitative characteristics that deserve to be valued in economic terms. More attention should thus be directed towards these beans by the institutions for the enhancement of local populations of plant species of great value and that are often in danger of extinction. This process can take advantage of European Union legislation and should involve the farmers themselves, who need to be the main actors in such initiatives.

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