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Morphological and agronomical characterization of eggplant genetic resources from the Sicily area

Fabio D'Anna and Leo Sabatino *
Department of Agriculture and Environmental Systems, University of Palermo, Viale delle Scienze Ed. 5, 90128 Palermo, Italy.
**e-mail: leo.sabatino@unipa.it*

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Abstract

The eggplant is a vegetable crop widely grown throughout Sicily both in greenhouse and open field. This study was carried out by the Department of Agri-Environmental Systems at the University of Palermo in the Spring/Summer of 2011 in open fields. The aim of the study was to characterize 6 eggplant ecotypes (G1-G6) and three eggplant varieties (Birgah, Black bell and Viola di Firenze) from a morphological, phenological and production point of view, gathered from Sicily and the smaller islands. The genotypes G1 and G3 were found to be more productive than the varieties used in the test field. Ecotype G1 produced fruits which were dark violet and highly glossy, and produced the lowest percentage of discarded fruits, ecotype G2 had a high marketable fruit yield per plant, whereas populations G3, G5 and G6 were found to have a high average fruit weight. The 6 ecotypes were found to be highly non-uniform as regards both the plant and fruit morphological characteristics. Concerning the ratio between the fruit length and maximum diameter, ecotype G1 was found not to differ from G3 and, similarly, G5 was found to be not significantly different from G6. The ecotypes G1, G3, G5 and G6 produced higher or equal yields compared to the 3 varieties tested in the field study. The shorter period between the planting phenological stage and the flowering stage was found in ecotype G2. This earliness is also reflected in an earlier production stage with potential positive effects at commercial level.

Key words: Morphological characterization, ecotype, productivity, *Solanum melongena*, Sicily.

Introduction

Sicily was an obvious port of call on numerous cultural and trade routes, given its strategic geographical position, and is one of the most interesting centres of origin and differentiation of vegetable crops in the Mediterranean Basin.

Over the course of the centuries, farmers have selected various genotypes of each species, adapting them to the soil and climate requirements without paying any particular heed to genetic pureness, but rather allowing the crops to crossbreed spontaneously with wild species in the vicinity. On Sicily alone, over an area of 26,000 km^2, there are an estimated 2,650 taxa, including both specific and intraspecific taxa [8].

This relaxed attitude of the farmers created intraspecific variability leading to genotypes, which were suited to the growth environment, resistant to environmental stress and plant diseases, and with improved qualitative and organoleptic properties [11].

Crop improvement to increase productivity has always relied on genetic diversity and, therefore, on the ability of the crop to adapt to soil and climate changes, and it is due to this selection process, used by farmers over the years, that most of the biodiversity has been preserved [12].

The local populations are genotypes of remarkable intrinsic value; their ability to adapt to their original environment could make them more suited to sustainable horticulture than hybrids and varieties created in different soil and climate conditions and which often require higher energy inputs.

This is exactly why we consider the aim of this study, that is the rediscovery, recovery, preservation and characterization of local eggplant (*Solanum melongena* L.) ecotypes, to be crucial, as these ecotypes risk genetic erosion if not adequately safeguarded.

The eggplant belongs to the Solanaceae family but, it would seem, its area of origin is not clear. Expert opinion cites the Indies as the centre of origin and China as a secondary centre of diversification [5], only to arrive in Europe around 1300. It was introduced into Italy during the following century, though initially grown only as an ornamental crop and it was only after the 16th century that the fruits were used as food. Today, the eggplant is grown widely throughout the tropical zones and in the temperate regions of the world.

The fruit of the eggplant is classified as a non-climacteric berry, which can grow to various sizes, shapes and colours depending on the genotype. Violet is one of the most common colours; the result of anthocyanins in the epicarp, and this colour can be intensified by the presence of chlorophyll pigments in the layers found under the skin [3]. The anthocyanins are pigments contained in the cell vacuoles [3, 15] and belong to the group of phenolic flavonoids [17]; compounds found in great number in eggplant berries and known for their antioxidant properties [2, 14]. Previous studies show that growth environment, cultivation techniques, genotypes and soil type influence the production of these flavonoids [13, 16] and, as a consequence, anthropic selection has focused on creating black coloured varieties, such as 'Black Beauty', 'Black Campana', 'Mercato Florida', 'Long Black' and others, which are widespread and some of which are still used today [4, 10]. There are also many local black eggplant ecotypes [7].

The eggplant ecotypes found in Sicily had very dark fruits, such as G2 and G1, but also no colour at all, such as G3.

Materials and Methods

The field trial was carried out in the open field during the spring-summer of 2011 at the experimental fields of the Department of Agri-environmental Systems at Palermo University (38°09'26''N 13°20'01''E).

Ecotypes G1, G2, G3, G4, G5 and G6 were evaluated. Ecotypes G2 and G6 were taken from the Marsala area (Trapani), ecotype G1 from Sciacca (Agrigento), ecotype G3 from Bagheria (Palermo), ecotype G4 from Pantelleria (Trapani) and ecotype G5 from Mazara del Vallo (Trapani). In addition, three varieties (Birgah, Black bell and Viola di Firenze) from the National Registry of Varieties were also tested. For each ecotype and variety the randomized block design with three replications of 10 plant blocks were been adopted.

Plants and flower observations were taken during the phenological phase, which spanned the period between first inflorescence and pre-harvest. Fruit evaluation was effectuated on the first completely developed fruits.

The planting of all the ecotypes took place on 15^{th} May 2011 using seedlings with their root ball. The length of various phenophases was recorded until the end of the production period for every genotype observed.

Cultivation took place using growth techniques already in use for open-field eggplant cultivation in Sicily. Seedling bed was prepared through medium-deep ploughing (35 cm) and de-clodding using a rotary harrow. Aged manure was added as a soil amendment at a rate of 40 t ha^{-1}. A drip irrigation system was installed under a 20 µm thick film of black PE.

During the test, a 0.5 m planting distance and a 1 m inter-row distance layout was adopted, thereby obtaining a density of 2 plants/m^2. Thirty plants were used for each genotype. A form of free cultivation technique was used and pruning and de-leafing took place only when required.

The quantity of fertilizing units used for fertigation was calculated on the basis of nutrient uptake estimation (kg t^{-1}), expected yields and soil mineral content [5], and was estimated as the following: 250 kg ha^{-1} of N, 150 kg ha^{-1} of P and 250 kg ha^{-1} of K.

Quantitative data on average yields per plant and qualitative data, such as average fruit weight and the average number of fruits per plant, were recorded and correlation analysis was carried out on these last two parameters. Yield, based on the qualitative properties of the berries (D.L. n. 306/2002), was divided into marketable yield and unmarketable yield. Data was also collected on various morphological characteristics, such as plant height, fruit length and maximum fruit diameter, and the ratio between these last two was determined.

All the percentage data was subjected to angular transformation (□ = arcsen$(p/100)^{1/2}$) and all the data underwent analysis of the variance. The difference between the averages was evaluated using a significance level of P≤0.05 (Duncan test).

Results

The highest total average yield per plant was obtained by ecotype G3, which provided production levels, which were markedly higher, even compared to the varieties from the National Registry of Horticultural varieties included in the test (Birgah, Black bell and Viola di Firenze). Good results were obtained from ecotypes G5 and G6, showing statistically non-significant differences between the two. Ecotypes G2 and G4 were found to be less productive (Table 1).

Regarding the average marketable yield per plant, good results were obtained from ecotype G1, which, in addition to giving good yield levels, was also found to give the lowest percentage of non-marketable fruits of all the genotypes in the field. However, G3, G5 and G6 also produced an average unmarketable fruits percentage very close to the varieties in the field. Ecotype G3 did not show any statistically significant difference to that of the variety Birgah, while G5 and G6 produced intermediate levels which fell between Black bell and Viola di Firenze (Table 1).

The ecotype G2 was found to have the highest average number of marketable fruits per plant. This was followed by G3 but with a statistically significant difference between the two. Ecotypes G4, G5 and G6 produced the lowest levels, though not demonstrating any statistically significant difference between them. As regards the average weight of the marketable fruits, the variety Birgah produced the largest fruits, followed by ecotypes G3 and G5, which did not show any significant difference between the two. The ecotype G1 produced fruits with an average weight which was not found to be statistically different to the varieties Black bell and Viola di Firenze. The fruits with the lowest weight were produced by G2 (Table 1).

Correlation analysis was conducted on the average fruit yield per plant and the average berry weight. Results of the analysis showed that as the average weight of the fruit increased, the average berry yield per plant decreased. This correlation reached a significance level of 5% (Fig. 1).

The various ecotypes in this study were found to have several morphological characteristics in common. One of these characteristics was anthocyanin colour of the hypocotyls in the seedling, which was found to differ in intensity between the genotypes in the study (Table 2).

The anthocyanin colour was also found in the stem of the plant and was present in all the genotypes in the study for entire length of the production cycle (Table 3).

The habit was also deemed of great interest; a characteristic which undoubtedly influences the microclimate conditions of the

Table 1. Production traits of the eggplant ecotypes and varieties tested.

Genotype	Average total production /plant [kg]	Average marketable /plant [kg]	Average number marketable fruits/plant [n]	Average Weight marketable Fruits [g]	Average unmarketable Fruit Production /plant [%]	Average number unmarketable Fruit/plant [%]
G1	3.8 b	3.5 b	8.51 bc	409.05 c	7.77 g	11.69 d
G2	2.9 d	2.4 f	15.69 a	156.03 e	17.32 bc	20.83 c
G3	5.8 a	4.9 a	9.01 b	548.00 b	14.97d	20.69 c
G4	2.4 e	1.8 g	5.17 d	350.79 d	24.39 a	34.76 a
G5	3.3 c	2.9 de	5.50 d	526.83 b	12.89 e	25.78 bc
G6	3.2 c	2.7 e	5.13 d	528.59 b	16.33 cd	24.01 bc
Birgah	3.4 c	2.9 d	3.87 d	762.94 a	13.87 d	29.80 ab
Black bell	3.3 c	3.0 d	7.30 c	409.81 c	10.50 f	18.29 c
Viola di Firenze	3.9 b	3.2 c	7.60 bc	422.04 c	18.86 b	23.74 bc

In each column, figures followed by the same letter are not statistically different, based on the Duncan test (P≤0.05).

Table 2. Main characteristics of seedlings of the 6 eggplant ecotypes.

Ecotype	Anthocyanin colour of hypocotyls	Intensity of anthocyanin colour of hypocotyls
G1	present	very weak
G2	present	weak
G3	present	weak
G4	present	weak
G5	present	strong
G6	present	strong

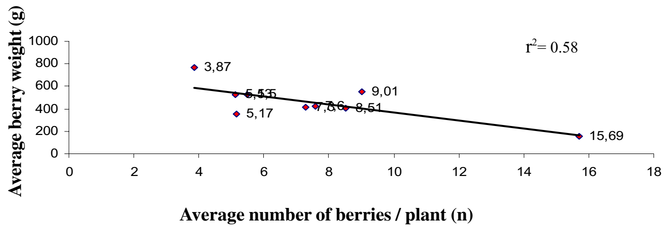

Figure 1. Relationship between the average number of fruits per plant and the average marketable fruit weight.

phyllospere. G1, G5 and G6 exhibited a semi-erect habit, ecotypes G3 and G4 exhibited a slightly different growth habit in that they were found to have a prostrate habit, whilst G2 had an erect habit (Table 3).

The size of the leaf blade was found to be small in ecotypes G2 and G4, medium sized in G5, G3 and G1 but large in G6. The degree of sinuation of the leaf margin varied from strong in ecotype G4, to absent in ecotype G2. A common characteristic among the 5 ecotypes was the weak leaf undulation, except in G1, which was found to have medium leaf undulation of the leaf blades (Table 3).

As regards the flowers, the only ecotype found to have a multi-flowered inflorescence was G2, with an inflorescence of small, dark purple flowers (Table 4).

Concerning the main characteristics of the berry, the berry shape was the initial aspect under evaluation, and the genotypes in the study showed marked differences. Only 2 of the 6 ecotypes produced fruits with the same shape, that is G3 and G5, which had an ovoid shape. G6 produced globular fruits, G4 produced obovate fruits, G1 produced pear-shaped fruits and ecotype G2 produced cylindrical fruits (Table 5).

The main skin colour of 5 of the genotypes was violet, whereas ecotype G3 was white in skin colour. The fruits of G5 and G6 were found to have stripes and G6 also had a degree of mottling. Ecotype G1 was of particular interest in that its skin was remarkably dark with a high level of glossiness. One characteristic of G2 was the greenish colour of the flesh (Table 6).

The tallest plants were found in the two varieties Birgah and

Table 4. Main characteristics of the flowers of the six eggplant ecotypes.

Ecotypes	no. flowers/inflorescence	Size	Intensity of purple colour
G1	1	medium	light
G2	More than 3	small	dark
G3	1	medium	light
G4	1	medium	light
G5	1	medium	light
G6	1	medium	medium

Table 5. Main morphological characteristics of the fruits of the six eggplant ecotypes.

Ecotypes	Shape	Ribbing	Apex of fruit	Size of calyx	Length of stalk
G1	Pear-shaped	weak	indented	medium	medium
G2	cylindrical	absent or very weak	rounded	medium	medium
G3	ovoid	weak	rounded	large	medium
G4	obovate	absent or very weak	indented	large	short
G5	ovoid	medium	rounded	medium	medium
G6	globular	medium	rounded	large	medium

Black bell, followed by ecotype G2. Ecotype G3 was found to produce the shortest plants; however, no statistically significant differences were found with G1 and G6 (Table 7).

Other data collected concerned the shape index, in particular the ratio between the maximum diameter and the length. The highest values for this ratio were found in ecotype G2; explained by the fact that it was cylindrical in shape, whilst the lowest value was found in G6, the only globular fruit, although this value did not show any significant difference to ecotype G5 and the variety Black bell (Table 7).

The phenological phase of flowering began with ecotype G2, which took place at the end of the first ten days of June. The other ecotypes began flowering 10 days afterwards. This earliness was also reflected in the production cycle, which finished approx. 7 days earlier than the other biotypes (Fig. 2).

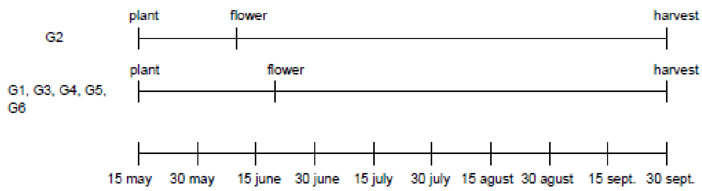

Figure 2. Phenogram of the 6 eggplant ecotypes.

Table 3. Main characteristics of plant, stem and leaves of the six eggplant ecotypes.

	Plant	Stem			Leaves		
Ecotypes	Habit	Anthocyanin colouration	Intensity of Anthocyanin colouration	Pubescence	Size of leaf blade	Sinuation of margin	Leaf undulation
G1	Semi-erect	present	very weak	medium	medium	medium	medium
G2	erect	present	medium	weak	small	absent or very weak	absent or very weak
G3	prostrate	present	very weak	medium	medium	weak	weak
G4	prostrate	present	very weak	weak	small	strong	absent or very weak
G5	Semi-erect	present	medium	medium	medium	medium	weak
G6	Semi-erect	present	strong	medium	large	medium	weak

Table 6. Main characteristics of skin and flesh colouration of the 6 eggplant ecotypes.

Ecotypes	Main colour of skin	Intensity of main colour	Glossiness	Mottling	Striping	Importance of striping	Density of striping	Colour of flesh
G1	violet	very dark	strong	absent	absent	-	-	whitish
G2	violet	very dark	medium	absent	absent	-	-	greenish
G3	white	-	weak	absent	absent	-	-	whitish
G4	violet	medium	medium	absent	absent	-	-	whitish
G5	violet	light	medium	absent	present	medium	medium	whitish
G6	violet	medium	weak	present	present	medium	medium	whitish

Table 7. Main size characteristics of the plant and fruit of the 6 eggplant ecotypes.

Ecotypes	Plant height [cm]	Fruit length [cm]	Fruit diam. [cm]	length/diam.
G1	48.33 d	15.50 c	11.83 c	1.31 c
G2	66.33 b	27.00 a	6.05 d	4.48 a
G3	48.11 d	14.50 c	12.42 b	1.17 c
G4	60.44 c	17.67 b	11.00 c	1.66 b
G5	64.67 bc	15.33 c	14.50 ab	1.06 cd
G6	52.56 d	12.53 d	11.89 c	1.05 cd
Birgah	77.78 a	11.67 d	15.67 a	0.74 e
Black bell	78.55 a	15.5 c	14.50 ab	1.08 cd
Viola di Firenze	61.33 bc	12.00 d	14.65 ab	0.82 d

In each column. figures followed by the same letter were not statistically different, based on the Duncan test ($P \leq 0.05$).

Conclusions

The production of high quality vegetables is often linked to the use of local ecotypes [6, 9]. These ecotypes are subjected to low-environmental impact agricultural techniques, typical of the areas from which they are selected, and this allows qualitatively high levels to be reached, often higher than registered varieties. Indeed, the prolonged use by farmers of genotypes selected from different soil and climate conditions can even lead to financial loss [1].

Of the ecotypes, G3 and G1 reached production levels which were markedly superior to the varieties. Quality characteristics, such as unmarketable fruits, skin colour, glossiness and flesh colour, produced by the ecotype G1 were highly sought after on the local market.

Therefore, the recovery, characterisation and diffusion of old, native populations is not the start of agricultural and cultural regression but rather the chance to help face ecological issues and those concerning agro-ecosystem sustainability.

In conclusion, the results of this study provide new knowledge on the agronomic behaviour of several accessions. Local ecotypes could happily be taken into consideration as part of new crop systems as they clearly reached a certain level of production efficiency and an average fruit weight similar to, or even higher than, those of the traditional varieties used as a reference.

The high average fruit weights, of biotypes G3 and G1 in particular, would increase the labour productivity for harvesting. Furthermore, the use of these genotypes would produce berries with the added value of 'being typical'; a characteristic which is very important when attempting to add economic value to a product.

References

[1]Babcock, B. A. and Clemens, R. 2004. Geographical indications and property rights: Protecting value-added agricultural products. MATIC Briefing Paper 04-MBP 7. Iowa State University, Ames, IA, 51 p.

[2]Cao, G., Sofic, E. and Prior, R. L. 1996. Antioxidant capacity of tea and common vegetables. Journal of Agricultural and Food Chemistry **44**:3426-3431.

[3]Daunay, M. C., Aubert, S., Frary, A., Doganlar, S., Lester R. N., Barendse, G., van der Weerden, G., Hennart, J. W., Haanstra, J., Dauphin, F. and Jullian, E. 2004. Eggplant (*Solanum melongena* L.) fruit colour: Pigments, measurements and genetics. In Voorrips, R.E. (ed.). Proceedings XIIth Meeting on Genetics and Breeding of Capsicum & Eggplant. Noordwijkerhout, the Netherlands, Plant Research International, pp. 108-116.

[4]Daunay, M. C. 2008. Eggplant. In Prohens, J. and Nuez, F.(eds). Handbook of Plant Breeding: Vegetables **II**. Springer, New York, NY, USA, pp. 163-220.

[5]La Malfa, G. 1990. Scienza e tecniche delle produzioni vegetali. Orticoltura pp. 793-811.

[6]Piergiovanni, A. R. and Laghetti, G. 1999. The common bean landraces from Basilicata (southern Italy): An example of integrated approach applied to genetic resources management. Genet. Res. Crop. Evol. **46**:47-52.

[7]Prohens, J. and Nuez, F. 2001. Variedades tradicionales de berenjena en España. Vida Rural **130**:46-50.

[8]Raimondo, F. M., Gianguzzi, L. and Ilardi, V. 1992. Inventario delle specie "a rischio" nella flora vascolare della Sicilia. Quaderni di Botanica Ambientale Applicata **3**:65-132.

[9]Rao, R., Corrado, G., Bianchi, M., Di Mauro, A. and (GATA)4. 2006. DNA fingerprinting identifies morphologically characterized 'San Marzano' tomato plants. Plant Breed. **125**:173-176.

[10]Savin, F. 1996. L'aubergine dans le bassin méditerranéen (hors Turquie). PHM Revue Horticole **374**:50-52.

[11]Schiavi, M., Masera, R., Lorenzoni, C. and Soressi, G. P. 1991. Metodi utilizzati per il miglioramento genetico della Dorata di Parma. Agricoltura Ricerca n. **82**. Ismea,. Roma, pp. 21-30.

[12]Schippmann, U., Leaman, D. J. and Cunningham, A. B. 2002. Impact of cultivation and gathering of medicinal plants on biodiversity: Global trends and issues. Biodiversity and the Ecosystem approach in Agriculture, Foresty and Fisheries. FAO, Rome, 21 p.

[13]Singh, A. P., Luthria, D., Wilson, T., Vorsa, N., Singh, V., Banuelos, G. S. and Pasakdee, S. 2009**.** Polyphenol content and antioxidant capacity of eggplant pulp. Food Chemistry **114**:955-961.

[14]Stommel, J. R. and Whitaker, B. D. 2003. Phenolic acid composition of eggplant fruit in a germplasm core subset. Journal of the American Society for Horticultural Science **128**:704-710.

[15]Timberlake, C. F. 1981. Anthocyanins in fruit and vegetables. In Friend, J. and Rhodes, M. J. C. (eds). Recent Advances in the Biochemistry of Fruit and Vegetables. Academic Press, New York, pp. 221-247.

[16]Todaro, A., Cimino, F., Rapisard, P., Catano, A., Barbagallo, R. N. and Spagna, G. 2009. Recovery of anthocyanins from eggplant peel. Food Chemistry **114**:434-439.

[17]Vinson, J. A., Hao, Y., Su, X. and Zubik, L. 1998. Phenol antioxidant quantity and quality in food: Vegetables. Journal of Agricultural and Food Chemistry **46**:3630-3634.