PROJECT ON UNDERUTILIZED MEDITERRANEAN SPECIES

Rocket: a Mediterranean crop for the world

Report of a workshop
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S. Padulosi and D. Pignone, editors

International Plant Genetic Resources Institute
IPGRI

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The Underutilized Mediterranean Species (UMS) Project is an initiative supported by the Italian Government which seeks to improve the conservation and sustainable use of the valuable but neglected plant genetic resources present in the Mediterranean region. The project's objectives are to promote the conservation of genetic resources of UMS, both *ex situ* and *in situ*, to encourage the safeguarding of information relative to the conserved germplasm and to foster collaboration among institutions and organizations within the Mediterranean region. The project operates primarily through networking efforts spread throughout the region. Networks have already been established for rocket, hulled wheats and oregano; efforts are also underway, in collaboration with FAO, to strengthen genetic resources activities for wild pistachio species. Members of the UMS Networks carry out an agreed workplan with their own resources while IPGRI coordinates the networks and provides financial support for the organization of technical meetings. IPGRI also contributes to raising public awareness on the importance of better conservation and use of underutilized species.

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Preface

This publication represents the outcome of the second meeting of the Rocket Genetic Resources Network, an initiative launched in 1994 in the framework of IPGRI's project on Underutilized Mediterranean Species (UMS).

The proceedings contain scientific contributions related to genetic resources, breeding and cultivation aspects of rocket, representing an extremely useful tool for all those interested in the cultivation and improvement of this crop. In particular, the paper on cultivation in the Veneto region can well be considered the first thorough scientific presentation ever made of rocket cultivation techniques in greenhouse environments. Apart from this paper, other contributions from India, Israel, Portugal and Turkey provide an overview of the degree of cultivation, uses and popularity of the crop around the world.

Chapter III on International Cooperation provides a useful insight into the activity of the Rocket Network and supplies information on the initiatives promoted by UMS for safeguarding the genetic resources of this multipurpose crop.

Promotion of better use of plant genetic resources represents the core activity of the UMS project as well other IPGRI initiatives in the area of neglected/ underutilized species. The ultimate goal of all these efforts is the establishment of a sustainable conservation of these species through the promotion of their use.

Rocket, like other minor species on which IPGRI is currently working, is a key crop, selected for raising awareness on the great potentials of our agrobiodiversity wealth, and to show how little of this richness actually represents the basis of our agricultural systems.

It is estimated that of the 7000 edible species around the world only a tiny fraction, amounting to 150 or so, are in fact being commercialized, rocket being one of those left out. A greater attention to rocket and to other neglected species represents an important step towards both agricultural and diet diversification which ultimately contribute to improving our quality of life.

We pursue this goal in the hope that our agrobiodiversity heritage will in this way be passed on to future generations.

S. Padulosi
Coordinator, Underutilized Mediterranean Species project

Acknowledgements

IPGRI wishes to express its thanks to the University of Padova, the Germplasm Institute of Bari and the Ente Sviluppo Agricolo Veneto (Centro Po di Tramontana) for the warm hospitality and support provided for the organization of this Workshop.

I. Genetic Resources, Breeding and Cultivation

Present status of rocket genetic resources and conservation activities

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Introduction

'Rocket' is a collective name: it indicates many species within the Brassicaceae whose leaves are characterized by a more or less pungent taste and are, therefore, used to flavour salads. Variation of taste and pungency is great, depending on the species, its genetic diversity and the environment. In the Mediterranean region three main rocket species can be found, along with several other taxa also occurring wild throughout the region. These three species used for human consumption are:

- ***Eruca sativa*** Miller: a diploid, annual, species which flowers in spring and whose seeds are ready for collecting in late spring. It seems to prefer rather rich soils even though it can be found mixed with ruderal flora in very marginal areas. It is frequently cultivated, although domestication cannot be considered complete. A wild type, known as subspecies *vesicaria* (L.) Cav., is also rather well represented in the Mediterranean flora.
- ***Diplotaxis tenuifolia*** (L.) DC.: a diploid and perennial species, in the sense that the roots can survive winters and produce new sprouts in the next spring; it flowers from late spring to autumn and its seeds are generally ready for collecting in autumn. It seems to be very well adapted to harsh and poor soils, and often it can compete well with other species in calcareous shallow soils. This species has succulent leaves and is much appreciated in cuisine. In some Italian areas *D. tenuifolia* is also cultivated (see Pimpini and Enzo elsewhere in these proceedings), but it is mostly collected from the wild and sold in small bunches in local markets.
- ***Diplotaxis muralis*** (L.) DC.: polyploid and perennial, in the same sense as *D. tenuifolia*. It flowers from summer to autumn and its seeds are ready for collecting in autumn. It grows in similar habitats as *D. tenuifolia* and is also collected from the wild to be sold in the markets. It seems less adapted to cultivation because of its procumbent growth habit, which is the main character distinguishing it from *D. tenuifolia*.

The above-mentioned nomenclature follows the Flora of Italy (Pignatti 1982). This is probably not a complete classification; however, it is being used here for practical reasons (for a more thorough classification of *Diplotaxis* see Martínez-Laborde elsewhere in these proceedings).

Uses of rocket

Rocket is widely used in Europe and in many countries it is regarded as a speciality food or even a delicacy. In most European languages the word used for indicating these species may seem to derive from the root *roc*, which in early Latin meant "harsh, rough" with a possible reference to the bitter taste of its leaves, and from which the Latin name *eruca* derived.

In Italy, no summer salad would be complete without a few leaves of 'rughetta' or 'rucola' (Italian names for rocket). Also in France, especially in Provence and in the south in general, 'roquette' is a major component of the many different kinds of salads so popular in the French diet. Rocket is used also as a vegetable (and not just as a condiment), in the sense that cooked leaves are used for the preparation of

special dishes like 'pasta e rucola' or 'bresaola' a sort of dry meat seasoned with cheese, rocket leaves and olive oil (Bianco 1995).

Besides culinary uses, rocket is also considered a medicinal plant with many reported properties, including its strong aphrodisiac effect known since Roman times. Among other less intriguing medicinal properties, there is also its depurative effect and it is a good source of vitamin C and iron (Bianco 1995 and references therein).

In Egypt, particular ecotypes with large leaves are used as salad species instead of other more expensive and less adaptable species like lettuce. These large-leaved ecotypes are reported to lack a pungent taste (Mohamedien 1995).

In the Indian subcontinent, and in Pakistan in particular, special ecotypes of *E. sativa* are cultivated for seed production. The seeds are used to extract an oil often named 'jamba oil' which has many interesting uses such as for illumination or in the production of pickles (Padulosi 1995). Detailed information on these uses is contained in the paper of Bandhari and Chandel elsewhere in these proceedings.

In the Americas, rocket has reached the consumers following the European immigrants who have brought this crop into their diet, especially with the younger generations searching for 'natural food'. Furthermore, the oil of *E. sativa* is rich in erucic acid, an important industrial compound and attempts to exploit the potential of this species as an industrial oil crop are also being made (Fig. 1).

Conserving rocket germplasm: who and where

When IPGRI's Rocket Genetic Resources Network was established in Valenzano, in March 1994, the Germplasm Institute (IdG) and the Volcani Centre of Israel, Bet Dagan, took on the responsibility of surveying which institutions hold rocket genetic resources around the world. The preliminary results of this investigation were presented at the first meeting of the Rocket Network held in Lisbon in November 1994 (Pignone and Ngu 1995). Since then other institutes have responded to the request for information and now it is possible to draw a clearer picture of the present status of rocket genetic resources collections:

1. *Eruca sativa* is generally the most represented species in genebank collections. Good collections of this species are present in the genebanks of Gatersleben (IPK) and Braunschweig (FAL) in Germany, at IdG in Italy, at Wellsbourne (HRI) in the UK and at Ames, Iowa (USDA) in the USA. The only good collection of *Diplotaxis* species is the one maintained at the Universidad Politecnica of Madrid, Spain, whose curator is Prof. Gomez Campo. Besides this collection, other genebanks possess just a few samples of *Diplotaxis* species. As a follow-up to the Lisbon meeting, over the last few years IdG has intensified its efforts to better collect and safeguard genetic *Diplotaxis* species (see below).
2. From the FAL collection of *Eruca*, 85 samples originate from Pakistan. All these samples are likely to belong to the ecotype selected to produce oil from its seeds [these samples were actually gathered by the FAL genebank to carry out research on *Eruca* seed oil (Frese, pers. comm.)]. The remaining *Eruca* collection available in Europe is likely to be made up of horticultural types and consists of fewer than 50 samples, of which 24 are of Italian origin and 10 are from Egypt. The rest of Europe is quite underrepresented with regard to *Eruca* genetic resources.

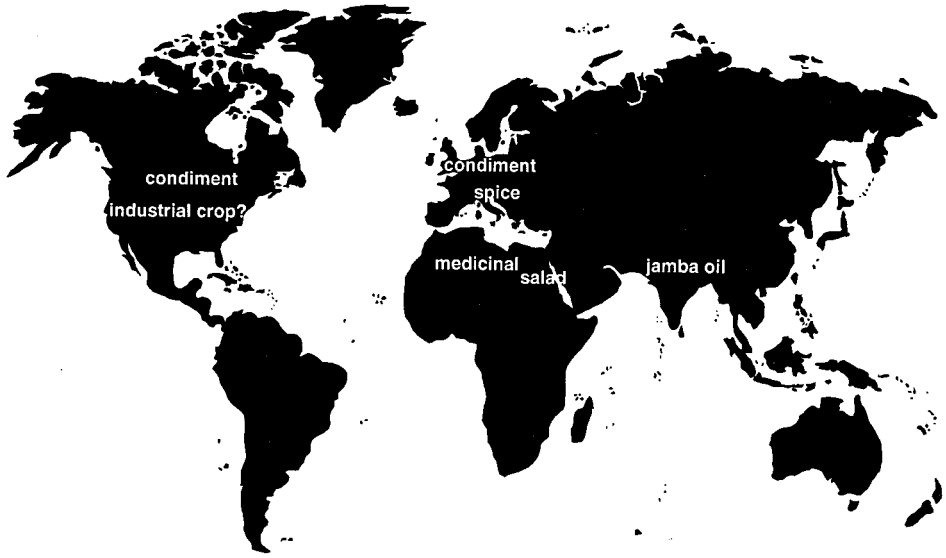

Fig. 1. Uses of rocket throughout the world.

3. Since roughly 50% of the samples are of Italian origin, and since their origin is not always very clear, it can be speculated that in the present collection of *Eruca* there is a certain level of duplication. Sampling has been conducted occasionally without using a well-defined strategy. In fact, specific collecting missions have never been mounted for this species. For these reasons, the genetic resources of *Eruca* even in Italy have surely been badly sampled and the variation present in this collection might presumably be little representative of the area (Fig. 2). On the other hand, it is not possible to speculate in more detail on this subject, since no study on the genetic variation of Italian material seems to have been conducted until now.
4. The situation of *Diplotaxis* genetic resources is quite different. Prof. Gomez Campo, in the framework of his project on wild Mediterranean Brassicaceae, and also stimulated by the Rocket Network initiative, has planned *ad hoc* collecting missions for all the species belonging to this genus. The result is that for these species, the sampling is much more uniform (Fig. 3), with their genetic resources now being safely preserved in the Madrid genebank. Moreover, Prof. Gomez Campo and Prof. Martínez-Laborde have so far conducted many studies on the taxonomic and genetic variation of this collection.
5. Presently, little is known on the collection held by the USDA genebank (particularly poor is the information on the exact collection sites of these samples). However, it is likely that much of their material has been obtained by exchange with European institutions and has not been directly collected by the USDA. Additionally, some material has a complex origin in the sense that the provenance written in the data files does not correspond to the country of origin (this is especially true for material that has undergone exchanges through various institutions). A list of the USDA material sorted by the reported origin is given in Table 1. Using the Germplasm Resources Information Network (GRIN) World Wide Web server and the access via Internet it has been possible to reconstruct, at least in part, the passport data of that material.

Fig. 2. Holdings of *Eruca* listed in the rocket network database.

Fig. 3. Holdings of *Diplotaxis* listed in the rocket network database.

Table 1. Origin of rocket samples stored at the USDA genebank

Origin	No. of samples
USA	1
UK	2
Pakistan	114
Turkey	9
India	9
Egypt	1
Iran	11
Afghanistan	3
Spain	2
Poland	1
Cyprus	1
Czechoslovakia	1

Rocket genetic resources activity at IdG

The Germplasm Institute is one of the over 300 main entities of the CNR, the Italian National Research Council (Consiglio Nazionale delle Ricerche), and is located in Bari, southeast Italy. It represents the only Italian genebank *sensu stricto*, that is the only public institution specifically and institutionally devoted to plant genetic resources (PGR) collection, conservation, documentation and evaluation. The IdG was established in 1970 with the name Germplasm Laboratory (Laboratorio del Germoplasma) and gained the status of Institute in 1981, when the President of CNR recognized "its outstanding activity in the preservation of plant genetic resources of use to the Mediterranean and European agriculture". The Institute deals essentially with crop germplasm and stores nearly 80 000 accessions representing more than 40 genera and almost 600 species, including the world's sixth largest collection of wheat and the world's third largest collection of *Vicia faba* (FAO 1996). The activity of IdG, from the late 1980s onwards, has been focusing greater attention on the wild relatives of cultivated species (Perrino 1995).

Before the Rocket Network was launched, rocket species had been receiving minor attention from IdG collecting teams. Only a few samples had in fact been collected during these missions organized by IdG until that time. Some collections had been made in Abruzzi, Lazio, Apulia and Basilicata regions in the mainland and in Sicily and Sardinia in the islands (Fig. 4). For some samples the exact origin was unknown since they had been obtained by donation from other institutes. In all, 32 samples were collected.

Moreover, by examining the status of the collections held at IdG it can be seen that rocket has never been investigated in evaluation programmes, owing to the lack of general evaluation projects on the Brassicaceae. Also, because of the allogamous behaviour of these species, multiplication of the material had been left at the minimum, if not avoided whenever possible. As a consequence, the samples of rocket present in IdG were not available for distribution. In general the lack of activity on these species was due to their minor economic importance which led to a lesser allocation of money for applied research on these minor species and to a reduced academic research interest. One of the main achievements of the Underutilized Mediterranean Species project (UMS) is to have promoted awareness on these neglected species through the establishment of the Rocket Network.

After the Lisbon meeting, as a consequence of the increased awareness of the neglected status of the rocket collections, the question of the conservation of the genetic resources of these species was brought to the attention of the Scientific

Fig. 4. Collection of rocket samples by the IdG until 1994.

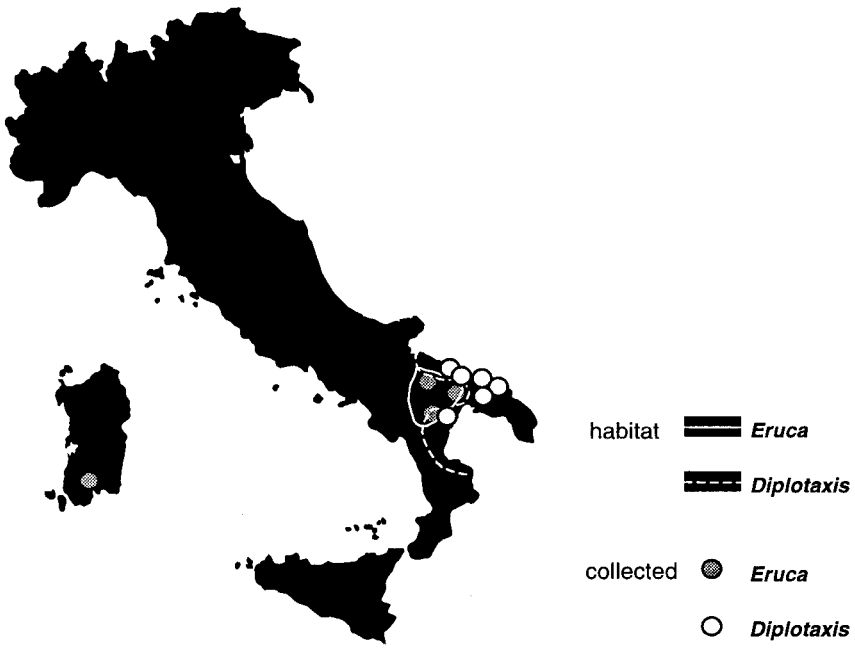

Fig. 5. Exploration and collection of rocket by the IdG in 1994-96.

Council of IdG, which discussed the need to intensify the activity on rocket, and both *Eruca* and *Diplotaxis* species were thus included in the list of high-priority species to be secured during IdG collecting missions. The Scientific Council also convened to allocate some (albeit very limited) core funding to this task.

After this historical background, I wish to review those activities undertaken by IdG on rocket over the last few years.

Collecting rocket GR 1994-96

Several explorations and collections were carried out during the last 2 years. *Diplotaxis* samples (*D. tenuifolia* and / or *D. muralis)* were collected in the provinces of Bari, Lecce and Matera (Fig. 5). The sampling intensity around Lecce was fairly consistent. Moreover the samples collected in Metaponto (Matera province) might possibly include an interesting type, morphologically resembling *D. muralis* but having 2*n*=22 chromosomes (further collections of germplasm and herbarium are needed to gather more material and seek confirmation of these findings). *Diplotaxis* seems to be widely spread along the coastal areas of both Apulia (Adriatic and Jonian seas) and Basilicata regions (Jonian sea), whereas it seems to be less represented in the inner areas or at altitudes above 400 m asl. *Eruca* samples were collected in the provinces of Bari, Brindisi, Matera and Cagliari. With regard to *Eruca* material from Apulia and Basilicata it seems that this species is more easily found in the inner parts of these regions, apparently being absent from the coastal area (Fig. 5). The material collected in Cagliari does not follow this rule; in fact, both collecting sites in that area were close to the sea, and one in particular was thriving a few meters from the beach of Is Arenas, a famous touristic site near Cagliari. It has to be pointed out that both samples collected near Cagliari had peculiar characteristics: they clearly belonged to *E. sativa* subsp. v*esicaria*, had a very pungent and bitter taste, a luxuriant growth and were very prolific.

Multiplication of IdG rocket collection

In order to obtain enough seeds to allow distribution of samples and safe deposit of a duplicate of the collection, it was necessary to start a proper multiplication procedure. The problem associated with this multiplication was essentially connected with the allogamous nature of these Brassicaceae. The multiplication in purity was actually not a big problem *per se* since the IdG is equipped with a facility for ensuring complete isolation. The problem was essentially how to develop a simple system to allow multiplication of rocket species also in places not possessing specific equipment. We were able to find a kind of nylon / cloth fabric, made out of many aggregated threads, which would allow gas exchanges but at the same time stop pollen or insects from passing through. Small multiplication plots of 90 x 90 cm were established and planted with 40 plants, previously grown in a cold greenhouse. When the floral buds started to appear, the fabric was laid over the plot and the edges buried in the ground (Fig. 6) to create a complete barrier; the fabric was held in place by an iron structure in the form of two crossed arches. The results were quite encouraging and other similar solutions are being studied to overcome some problems essentially associated with the shape of the isolation cages. The main advantage of this approach is that isolation structures of the kind described here are easy to build and very economical. Therefore they could be proposed even for small institutions, like small research centres or small producers, to maintain their stocks in genetic purity at little cost. There are some additional points about the maintenance of these stocks but they will be addressed later.

Development of a common database for the rocket network

One of the commitments of the IdG after the Lisbon meeting was the development of a database that could be common to all institutions holding rocket genetic resources (GR) regardless of the species. This database should contain all the relevant information on the samples collected or maintained and should be flexible to allow future expansion. Some databases developed by other institutions were

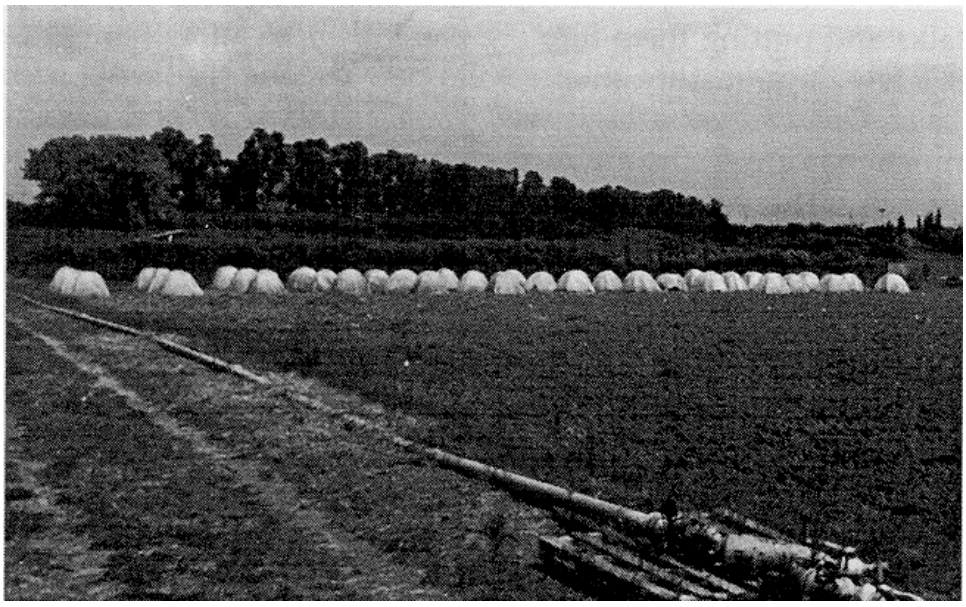

Fig. 6. Multiplication of rocket under insulation cages at the IdG (Metaponto).

examined, e.g. the one developed for *Brassica* sp. by Theo van Hintum at the CPRO-DLO, Wageningen, The Netherlands. Moreover, other institutions were requested, through a questionnaire, to send their data in electronic format to allow the completion of the Rocket Network Database. The FAL and the University of Madrid responded promptly and their data, together with the data of IdG, formed the prototype of the database that is described in Table 2. The logical significance of some fields is straightforward, while other fields need an explanation. ERDBNUM is an internal enumeration index and DONID and DONNUM fields indicate respectively the identification of the donor institution and the relative number. Two pairs of these identifiers are present, for a simple reason: one has to consider that the Rocket Network receives samples from national genebanks ('donor 1' or donating institution) which might have collected that material directly or received it in exchange from some other centres ('donor 2'). The fields COL_INST, COUNTRY, COL_SITE, LAT, LONG and ALT apply only to the material collected directly by 'donor 1' and generally do not apply to exchanged materials, unless the donating institutions have records of such information. The COL_SOUR field indicates the origin of the material, i.e. whether it has been obtained by farmers, collected directly, or purchased in markets, and so on, and not the nation or the site of collection which are instead to be entered in the COUNTRY and COL_SITE fields. A prototype is now available containing slightly less than 200 entries. A copy of this database, which is compatible with Database III (DB3) format, will be distributed to Network members and to other genebanks to allow them to input their data in the same format. Along with this database another file with the donor coding will also be sent. If any institution is not included on that list, it should notify the Network coordinator for its updating accordingly.

Constraints to rocket germplasm management

In our experience, the main constraints in this area are:

- **Low seed germination.** This depends mainly on the fact that the siliques of theses species are dehiscent and easily split up at maturity. Therefore, while collecting mature siliques, spread their seeds and oblige collectors to harvest

material that is not yet fully mature. This means that the maturation will occur after collecting. One system that has been tried at IdG is collecting a lot of stalks and putting them into big paper bags to allow natural desiccation. After a few days, mature silique will open and the seeds will accumulate in the bag. One can get a high seed yield in this way, and even though the germination is lower, the numbers compensate for this deficiency.

- **Oily seeds.** There are reports in the literature that oily seeds are less easily stored and much care has to be taken with their desiccation and storage. At IdG, we have little experience on this subject and therefore more information from seed physiologists should be sought on how to best preserve them.
- **Capsules opening at maturity.** The influence of this point on seed germination has been discussed earlier. It is important to stress now that for multiplication purposes the dehiscence of fruits poses another question: the material near maturity needs daily inspection and careful collecting in order to minimize seed loss. In insulated conditions this implies a lot of labour with an increased cost. This point is of some importance, especially for genebanks which plan large-scale multiplications and have allocated few funds to rocket and other underutilized species.
- **Possibility of contamination with local pollen.** As just stated, the necessity to open the isolation cages for plant care may allow the entrance of foreign pollen into the isolation space, especially in those areas where rocket grows spontaneously near the multiplication field. This implies that the allocation of the multiplication facility has to be chosen very carefully, possibly exploring in previous years those areas less infested by wild rocket. The irony is that, in this case, germplasmists always looking for rocket need to find ways in which to get rid of it!
- **Possibility of increasing self-incompatibility.** During multiplication in insulation it has been noticed that the level of self-compatibility of these species reported as strictly allogamous is rather high. Nevertheless, in the next generations problems might arise owing to inbreeding depression or to the build-up of an incompatibility system. Many allogamous species have internal genetic mechanisms limiting their possibility of selfing over a long period. Unfortunately, both *Eruca* and *Diplotaxis* have not been sufficiently studied from this point of view. The issue is, however, not a minor one since it has importance when one needs to select commercial varieties of rocket. In this case the possibility of breeding a true variety is linked with the possibility of maintaining the stocks in purity throughout selfing. Otherwise one needs to choose alternative strategies such as maintenance of artificial populations through appropriate mixtures of genotypes. It seems to me that this point should receive much more attention by geneticists and plant breeders.

Questions for the future

The last 2 years have been very productive for the Rocket Network, and this success allows some optimism for the future. Nevertheless some points have to be brought to the attention of the participants of this workshop. The first is the minor funding of this activity. It is essential that all Network participants be proactive in finding some *ad hoc* financial support for the Network; otherwise, the risk is that after a first phase of voluntary enthusiasm, this activity will cease. Even a little funding could increase the commitment of Network members.

Table 2. Structure of the prototype of the Rocket Network Database

Field name	Description
ERDBNUM	Database number
GENUS	Genus
SPECIES	Species
SUBSPEC	Subspecies
LOCNAME	Local name for the crop
CVNAME	Cultivar name for registered or local varieties
DONID1	Identifier of the donor institution 1
DONNUM1	Relative number
DONID2	As DONID1 for exchanged material
DONNUM2	Relative number
COL_INST	Collecting institution
COUNTRY	Collecting country
COL_SITE	Collection locality
LAT	Latitude
LONG	Longitude
COL_SOUR	Origin of the collected material
ALT	Altitude (metres asl)
NOTE	Note field

It appears also that much remains to be done in the area of collecting rocket genetic resources, especially in those countries where few or no samples have been gathered. For instance, from a preliminary look at the rocket database it appears that France is largely underrepresented and because of the popularity of rocket there, we believe that it must be present in several places. A more detailed analysis of the holdings will probably produce an even less optimistic picture. Two priorities have to be established: collecting and evaluating genetically the present collection to estimate the genetic diversity present. These objectives are indispensable to plan a future cost-efficient genetic resources activity in rocket.

The development of a definitive version of the database is also an important task, since it will make it possible to obtain a clearer picture of germplasm availability. Therefore all participants have to put their maximum efforts into updating the database as soon as they get their own copy. At IdG we are experimenting with the possibility of putting the rocket database on Internet, so that every scientist or producer will be able to connect to it directly. A page dedicated to the Rocket Network is already present at the URL http://WWW.BA.CNR.IT/~GERMDP02/ROCKET.HTML which is periodically updated by IdG. I hope that by next spring you will be able to find a preliminary version of the Rocket Network Database on line.

Finally, Dr Padulosi told me that the development of the Rocket Descriptor List is in its final stage. It is hoped that within the next few months a final version will be distributed to all Network members. This represents an important step forward, as it will strengthen cooperation with the producers, encouraging ultimately the use and conservation of rocket, the main objectives of this Network.

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A brief account of the genus *Diplotaxis*

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Variation in *Diplotaxis*

The genus *Diplotaxis* DC. is fairly well known, mostly because of a few species that have become quite widespread in several countries, even almost cosmopolitan in the case of *D. tenuifolia* and *D. muralis*. But *Diplotaxis* includes about 30 species, plus several additional infraspecific taxa (listed in Table 1 together with their geographical distribution). Figure 1 shows the number of species and infraspecific taxa reported or estimated for each country around the Mediterranean basin and the Near East. The western Mediterranean area appears as a clear centre of diversity for the genus.

In morphological and cytological data, the group displays a considerably large amount of infrageneric variability.

Chromosome numbers are known for most *Diplotaxis* species, as shown in Tables 2, 3 and 4, compiled by Gómez-Campo and Hinata (1980) with additional contributions from Al-Shehbaz (1978), Amin (1972), Fernandes and Queirós (1970-71), Martínez-Laborde (1991) and Romano *et al.* (1986). These data indicate that practically all taxa are diploid. Cytological variability in *Diplotaxis* does not rely on polyploidy, but mostly on diploidy. The series of gametic numbers ranges from n=7 in *D. erucoides*, through n=8, 9, 10 and 11, to n=13 in *D. harra*, whereas only *D. muralis* has n=21 (although 2n=22 has been recently reported by Pignone and Galasso (1995)).

In most cases, interspecific boundaries are associated with genomic divergence, so that interfertility is by no means widespread in the genus. On the basis of the available data, Harberd (1972), together with Takahata and Hinata (1983), found that 13 species of *Diplotaxis* should be classified in 11 cytodemes. According to Warwick and Black (1993), 27 species belong to 19 cytodemes, but in any case little grouping seems possible on this basis.

Morphological variability is shown by many characters. These plants can be annuals or perennials, with leafy or subscapose stems. The indumentum on stems, leaves and sepals can be made of hairs of different size, position and density. Leaf shapes range from almost entire to pinnate. Petals can vary considerably in size, shape, colour and venation; they are usually yellow, but can also be white or purple, whereas the nervation pattern can be kladodromous or brochidodromous. Variation in the silique includes size, shape and the particular characteristics of the beak. The beak also shows variation in size and shape, and can be either more or less compact, seedless, as found in *D. tenuifolia* and *D. muralis*, or hollow, provided with 1-2 ovules that eventually can become 1-2 seeds, as can be seen in *D. erucoides* or *D. virgata*. The seeds are usually arranged in 2 rows, occasionally in one as in *D. siifolia*, or even in 3-4 rows per locule, as in *D. harra* or *D. siettiana*. The seeds vary in size and also in shape; although in most cases they are elliptic or slightly ovoid, in *D. siifolia* they are notably spherical (Figs. 2, 3).

A numerical analysis carried out using 47 morphological characters and 39 OTUs (Operational Taxonomic Units), representing 18 species and 7 subspecies of *Diplotaxis* (Martínez-Laborde 1988) led to an ordination of OTUs in which three main groups, one of them with three subgroups, could be distinguished. These groups, produced from morphological data, proved to fit fairly well with the distribution of

Table 1. Species and infraspecific taxa of *Diplotaxis*† and main area of distribution

Taxon	Area
D. acris (Forsk.) Boiss. var. *acris*	Egypt, Near East to Iraq
var. *duveyrieriana* (Coss.) Coss.	S Algeria, S Tunisia, S Libya, N Chad
D. assurgens (Del.) Thell.	central and N Morocco
D. berthautii Br.-Bl. and Maire	central Morocco
D. brachycarpa Godr.	N Algeria
D. brevisiliqua (Coss.) Mart.-Laborde	NE Morocco, NW Algeria
D. catholica (L.) DC. var. *catholica*	Spain, Portugal, N Morocco
var. *rivulorum* (Br.-Bl. and Maire) Maire	central Morocco
D. erucoides (L.) DC. subsp. *erucoides*	Europe, North Africa, Near East to Iraq
subsp. *longisiliqua* (Coss.) Gómez-Campo	N Algeria
D. glauca (J. A. Schmidt) O.E. Schulz	Cape Verde
D. gracilis (Webb) O.E. Schulz	Cape Verde
D. griffitthii (Hook.f. and Thomps.) Boiss.	Afghanistan, Pakistan
D. harra (Forsk.) Boiss. subsp. *harra*	North Africa, W Asia to Iran
subsp. *crassifolia* (Rafin.) Maire	Sicily
subsp. *lagascana* (DC.) O. Bolòs and Vigo	SE Spain
D. hirta (Chev.) Rustan and Borgen	Cape Verde
D. ibicensis (Pau) Gómez-Campo	Ibiza, Formentera, Cabrera, E Spain
D. ilorcitana (Sennen) Aedo *et al.*	E Spain
D. kohlaanensis A. Miller and J. Nyberg	N Yemen
D. muralis (L.) DC. subsp. *muralis*	Europe, N Algeria, Near East, America, etc.
subsp. *ceratophylla* (Batt.) Mart.-Laborde	NE Algeria, N Tunisia
D. nepalensis Hara	W Nepal
D. ollivierii Maire	S Morocco
D. pitardiana Maire	S Morocco, S Algeria, Mauritania
D. scaposa DC.	Lampedusa
D. siettiana Maire	Alboran
D. siifolia Kunze subsp. *siifolia*	SW Iberian Penisula, N Morocco, NW Algeria
subsp. *bipinnatifida* (Coss.) Mart.-Laborde	S Morocco
subsp. *vicentina* (Samp.) Mart.-Laborde	SW Portugal
D. simplex (Viv.) Sprengel	S Morocco to Egypt
D. tenuifolia (L.) DC. subsp. *tenuifolia*	Europe, North Africa, Near East, America, etc.
subsp. *cretacea* (Kotov) Sobr. Vesp.	NE Ukraine, S Russia
D. tenuisiliqua Del. subsp. *tenuisiliqua*	central and N Morocco, NW Algeria
subsp. *rupestris* (J. Ball) Mart.-Laborde	central Morocco
D. villosa Boulos and Jallad	Jordan
D. viminea (L.) DC. var. *viminea*	Europe, North Africa, Near East
var. *integrifolia* Guss.	Europe, North Africa, Near East
D. virgata (Cav.) DC.	Spain and Portugal, Morocco
f. *sahariensis* Coss.	SE Morocco, SW Algeria
D. vogelii (Webb) O.E. Schulz	Cape Verde

† In some cases the status is doubtful or should be changed

chromosome numbers and seem to correspond to what could be called 'natural' groups within the genus.

The *D. tenuifolia* group includes taxa with seedless beak and petals mostly brochidodromous (Table 2). Most of them are annuals with subscapose stems, but *D. tenuifolia* is perennial and has leafy stems (Figs. 4, 5). Two additional characters, of phytochemical nature, reinforce the group. First, the petal extracts of these species lack the very common aglycone kaempferol, which is however present in their leaves and otherwise widespread in the genus (Sánchez-Yélamo 1994). And second, a strong, acrid smell comes out from their foliage, which most probably is due to

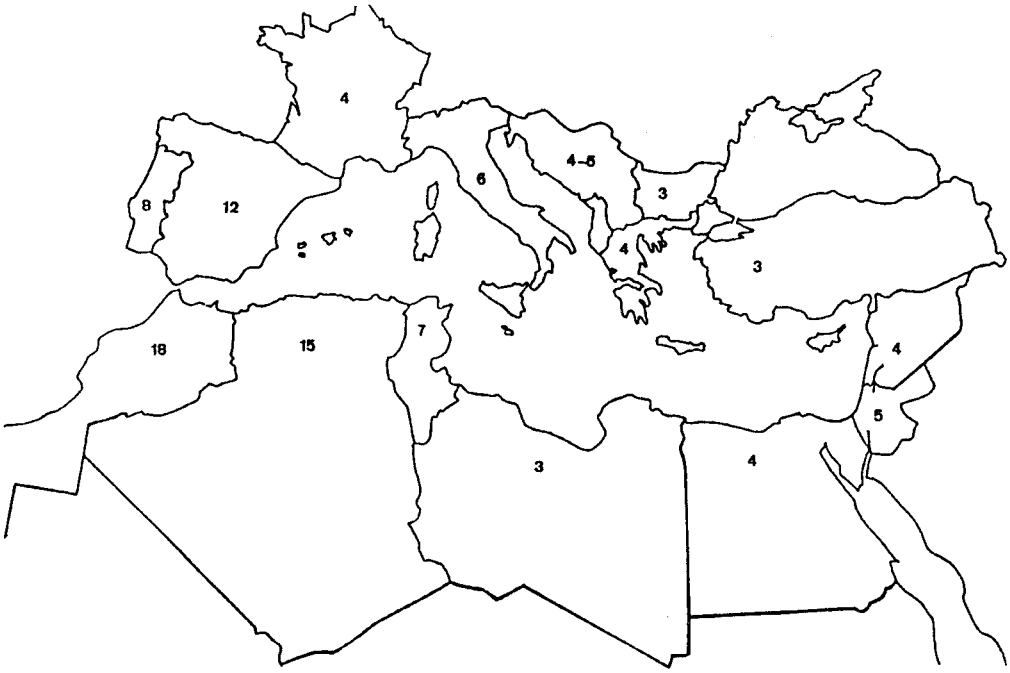

Fig. 1. Number of species and infraspecific taxa in each country around the Mediterranean basin and the Near East.

Table 2. Taxa of the *Diplotaxis tenuifolia* group and their known chromosome numbers

Taxon	No.
D. tenuifolia (L.) DC. subsp. *tenuifolia*	11
D. tenuifolia (L.) DC. subsp. *cretacea* (Kotov) Sobr. Vesp.	11
D. simplex (Viv.) Sprengel	11
D. viminea (L.) DC. var. *viminea* and var. *integrifolia* Guss.	10
D. muralis (L.) DC. subsp. *muralis*	21
D. muralis (L.) DC. subsp. *ceratophylla* (Batt.) Mart.-Laborde	?
D. scaposa DC.	?

Table 3. Taxa of the *Diplotaxis harra* group and their known chromosome numbers

Taxon	No.
D. harra (Forsk.) Boiss. subsp. *harra*	13
D. harra (Forsk.) Boiss. subsp. *crassifolia* (Rafin.) Maire	13
D. harra (Forsk.) Boiss. subsp. *lagascana* (DC.) O. Bolòs and Vigo	13
D. hirta (Chev.) Rustan and Borgen	13
D. gracilis (Webb) O.E. Schulz	13
D. glauca (J.A. Schmidt) O.E. Schulz	13
D. vogelii (Webb) O.E. Schulz	?
D. kohlaanensis A. Miller and J. Nyberg	?
D. pitardiana Maire	?
D. nepalensis Hara	?
D. villosa Boulos and Jallad	?
D. acris (Forsk.) Boiss. var. *acris*	11
D. acris (Forsk.) Boiss. var. *duveyrieriana* (Coss.) Coss.	?
D. griffitthii (Hook.f. and Thomps.) Boiss.	?

Table 4. Taxa of the three subgroups of the third group of *Diplotaxis* and their known chromosome numbers

Taxon	No.
D. erucoides (L.) DC. subsp. *Erucoides*	7
D. erucoides (L.) DC. subsp. *longisiliqua* (Coss.) Gómez-Campo	7
D. ibicensis (Pau) Gómez-Campo	8
D. brevisiliqua (Coss.) Mart.-Laborde	8
D. ilorcitana (Sennen) Aedo *et al.*	8
D. siettiana Maire	8
D. assurgens (Del.) Thell.	9
D. berthautii Br.-Bl. and Maire	9
D. catholica (L.) DC. var. *catholica*	9
D. catholica (L.) DC. var. *rivulorum* (Br.-Bl. And Maire) Maire	?
D. tenuisiliqua Del. subsp. *Tenuisiliqua*	9
D. tenuisiliqua Del. subsp. *rupestris* (J. Ball) Mart.-Laborde	?
D. virgata (Cav. DC.) subsp. *Virgata*	9
D. virgata (Cav. DC.) f. *sahariensis* Coss.	?
D. siifolia Kunze subsp. *Siifolia*	10
D. siifolia Kunze subsp. *bipinnatifida* (Coss.) Mart.-Laborde	?
D. siifolia Kunze subsp. *vicentina* (Samp.) Mart.-Laborde	10
D. brachycarpa Godr.	†
D. ollivierii Maire	?

† Count still unpublished.

volatile isothiocyanates. This group comprises three taxa with *n*=11: *D. tenuifolia*, including subsp. *cretacea*, and *D. simplex*; *D. viminea* has *n*=10 and differs from the rest in having much smaller flowers. Also with a different chromosome number, *D. muralis* subsp. *muralis* has *n*=21 and is considered to be an allotetraploid from *D. viminea* and *D. tenuifolia*. The analysis of several isozymes (Sánchez-Yélamo and Martínez-Laborde 1991) supported the hybrid origin, and also showed a considerable similarity of patterns within the whole group. The other subspecies, *D. muralis* subsp. *ceratophylla* (Fig. 6), also appeared in this group. Little is known about *D. scaposa*, but it is morphologically close to *D. muralis* and seems to belong in this group.

A second, very small group includes two OTUs, representing two subspecies of *D. harra* (Fig. 7). They are perennials with leafy stems, petals with brochidodromous nerviation, and seedless beak. Several other taxa could be added here (Table 3). The four species from Cape Verde – *D. gracilis*, *D. glauca*, *D. hirta* and *D. vogelii* – are morphologically very similar to *D. harra*; at least the first three have *n*=13 chromosomes, and two of them have even been reduced to subspecies of *D. harra* (Sobrino Vesperinas 1993). Other species, also morphologically close to *D. harra* but with unknown chromosome numbers, are *D. villosa*, *D. kohlaanensis*, *D. nepalensis* and *D. pitardiana*.

A difficult case is that of *D. acris*. This species has larger flowers with purple petals, but is morphologically very similar to the *D. harra* group in most other respects. However, it has *n*=11 chromosomes – instead of 13 – and shows no evident affinity with the *D. tenuifolia* group. The same is valid for *D. griffithii*, of unknown chromosome number but very close to *D. acris*.

The third group is the most numerous and heterogeneous, and includes three subgroups (Table 4). Taxa here are in general annuals with leafy stems, petal nervation generally kladodromous, and a frequently seminiferous beak. The two subspecies of *D. erucoides* (Fig. 8) are the only taxa with brochidodromous petals and

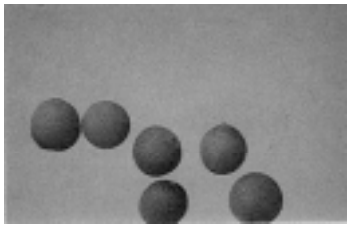

Fig. 2. Seeds of *Diplotaxis siifolia.*

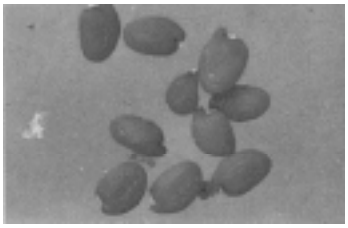

Fig. 3. Seeds of *Diplotaxis harra.*

Fig. 4. *Diplotaxis tenuifolia* (right).

Fig. 5. Perennial rots in *Diplotaxis tenuifolia.*

Fig. 6. *Diplotaxis muralis* subsp. *cerathophylla.*

Fig. 7. *Diplotaxis harra* subsp. *lagascana* (right).

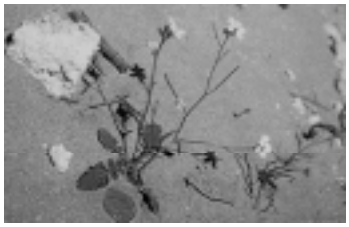

Fig. 9. *Diplotaxis siifolia* subsp. *vicentina* (above).

Fig. 8. *Diplotaxis erucoides* subsp. *erucoides* (left).

Fig. 10. *Diplotaxis assurgens*: plant habit.

Fig. 11. *Diplotaxis assurgens*: flowers.

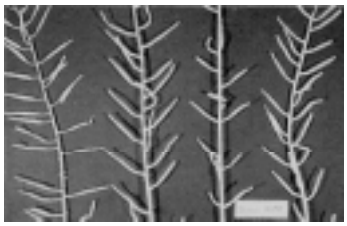

Fig. 12. *Diplotaxis assurgens*: fruits.

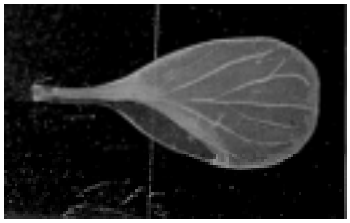

Fig. 13. *Diplotaxis catholica:* petal.

Fig. 14. *Diplotaxis catholica*: leaf variation (below).

Fig. 15. *Diplotaxis virgata* (right).

Fig. 16. *Diplotaxis brachycarpa* (far right).

Fig. 17. *Diplotaxis viminea.*

Fig. 18. *Diplotaxis siettiana*: inflorescences.

Fig. 19. *Diplotaxis siettiana*: habit.

also the only one with *n*=7 chromosomes. A second subgroup is that made of species with *n*=8 chromosomes, either with a seminiferous silique beak (*D. ibicensis* and *D. brevisiliqua)* or a seedless one (*D. ilorcitana* and *D. siettiana)* and stem with retrorse, more or less appressed hairs. All other species have one or two seeds (or ovules) in the beak. The only species here known to have *n*=10 chromosomes is *D. siifolia* (Fig. 9), with spherical seeds and almost pinnate leaves. The remaining taxa have ellipsoid to ovoid seeds and, at least most of them, *n*=9 chromosomes. Two species are characterized by their subamplexicaule, more or less clasping upper leaves, *D. assurgens* (Figs. 10, 11, 12) and *D. tenuisiliqua*, whereas *D. catholica* (Figs. 13, 14) has

a much divided foliage and *D. virgata* (Fig. 15) is usually quite hairy. The most distinct taxon appears to be *D. brachycarpa* (Fig. 16), with siliques and silique beak of very peculiar shape. Lastly, it is very difficult to find affinities between *D. ollivieri* and other taxa. This species, of which little more is still known, is characterized by linear foliar segments and seedless beak.

Studies on the relationships among species of *Diplotaxis* carried out by other authors led to not much different conclusions. Takahata and Hinata (1986), working with 30 OTUs – representing 12 species – and 53 morphometric traits, obtained a quite comparable grouping of four clusters, one corresponding to the *D. tenuifolia* group, one to *D. harra* group, and the remaining two to the third group. A survey based on chloroplast DNA of 24 species and subspecies (Warwick *et al.* 1992) indicated that the two main lineages found in subtribe Brassicinae (Warwick and Black 1993) also exist in the genus. In the consensus tree these taxa formed six groups, three belonging to each lineage. In the Rapa / Oleracea lineage one group is formed by the *n*=11 species on the one hand, and the *n*=13 species on the other, whereas *D. muralis* and *D. viminea* (Fig. 17) grouped together but independently; the third group was constituted by *D. erucoides.* In the Nigra lineage one group was formed by the *n*=8 species, the other big group included those with *n*=9 plus *D. siifolia,* and *D. brachycarpa* remained separate.

Geographical distribution and conservation

The species and subspecies of *Diplotaxis* vary considerably with respect to the range of their geographical distribution (Table 1). In two species, *D. muralis* and *D. tenuifolia,* the type subspecies have become almost cosmopolitan weeds that can be found even in America or Australia, whereas the other subspecies have a considerably restricted area of distribution: *D. muralis* subsp. *ceratophylla* to northeast Algeria and northwest Tunisia, and *D. tenuifolia* subsp. *cretacea* to chalk soils in northern Ukraine and southern Russia. Within the same group, *D. viminea* is considerably widespread in central and southern Europe, North Africa and the Near East, and *D. simplex* extends across North Africa, whereas the almost unknown *D. scaposa* has only been collected in the island of Lampedusa, Italy.

The *D. harra* group seems to exhibit an east-west diversification. Four species – *D. gracilis, D. glauca, D. vogelii* and *D. hirta* – are endemic to Cape Verde islands, and *D. pitardiana* grows in southern Morocco, southern Algeria and Mauritania. To the east, *D. villosa* is restricted to Jordan, *D. kohlaanensis* grows in northern Yemen and *D. nepalensis* is endemic to western Nepal. On the other hand, *D. harra* covers almost the whole area, extending from Morocco to Iran and Pakistan, and includes two restricted subspecies: *D. harra* subsp. *lagascana,* on more or less gypsic soils in southeast Spain, and *D. harra* subsp. *crassifolia* in Sicily. Most taxa here grow in considerably dry habitats. Close to this group, and also growing in subdesertic conditions, *D. acris* var. *acris* occurs in the Near East, whereas var. *duveyrieriana* grows in southern Algeria, southern Tunisia, southern Libya and northern Chad, and *D. griffithii* replaces it in Pakistan and Afghanistan.

In the case of *D. erucoides,* again the type subspecies is widespread around the Mediterranean basin, whereas *D. erucoides* subsp. *longisiliqua* (=*D. cossoniana*) is endemic to northern Algeria. The four species with *n*=8 chromosomes are fairly restricted in distribution: *D. ilorcitana,* on more or less gypsic areas of eastern Spain, and *D. brevisiliqua,* which extends from northeast Morocco to northwest Algeria, are the most widespread, *D. ibicensis* grows on coastal sites in Ibiza, Spain and a few other islands, and *D. siettiana* (Fig. 18) is limited to one population in the small island of Alboran.

In the remaining group, *D. siifolia* is distributed on sandy soils along the Atlantic coast of the Iberian Peninsula and Morocco, and occurs also on the Mediterranean coast of northwest Algeria; it comprises subsp. *vicentina*, endemic to the southwest corner of Portugal, and subsp. *bipinnatifida*, along southern Morocco. The most widespread species in this group is *D. virgata*, with the type subspecies growing in the central and southern Iberian Peninsula, f. *sahariensis* occurring in southeast Morocco and southwest Algeria, and additional variants extending across most of Morocco and western Algeria. Also *D. catholica* var. *catholica* grows on the western, mostly siliceous half of the Iberian Peninsula, and extends to northern Morocco, whereas var. *rivulorum* (=*D. rivulorum*) occurs in central Morocco. Other species occur only in North Africa, mostly in Morocco: *D. assurgens* is endemic to central Morocco, *D. ollivieri* is only known from a few localities in the south, and the more extended *D. tenuisiliqua* grows in most of Morocco and West Algeria, with subsp. *rupestris* in the south; only the very peculiar *D. brachycarpa* is a narrow endemism in Algeria.

Those species with a narrowly restricted distribution are threatened to various extents. Although the weedy or ruderal habit that characterizes most of these taxa seems to protect them against many disturbances, there are cases in which their survival is in real peril. An extreme case is that of *D. siettiana*, of which the only known population has not been found for the last 10 years, and might well be considered extinct. Other narrow endemics may be or become exposed to different threats, and for many of them there is no germplasm kept in any seed bank. Some of them, like *D. muralis* subsp. *ceratophylla* and *D. scaposa*, almost unknown to us, but probably relevant in relation to rocket cultivation, should deserve some collection efforts, in order to be able to study and better preserve them.

Uses

The species of *Diplotaxis* have not been much utilized by man. The leaves of several species are used as green salad vegetables, somewhat in the way *Eruca* is eaten, due to their peculiar, pungent taste. At least in some species, such taste might be related to the strong flavour that readily comes from the foliage when it is crushed, or even touched, probably due to volatile isothiocyanates. Although glucosinolates have been fairly studied in *Eruca* seeds, the only information available for *Diplotaxis* seems to be the contribution by Al-Shehbaz and Al-Shammary (1987), who found two compounds (2-hydroxy-3-butenyl and p-hydroxybenzyl) in seeds of *D. harra*, and only one (allyl) in those of *D. erucoides*.

The use of *D. tenuifolia* as a vegetable has been recorded in France at least since the last century where, according to Vesque (1885, cited by Ibarra and La Porte 1947), it was eaten as a substitute for rocket, and Italy (Parlatore 1893), where it continues to be increasingly used for salads and other dishes and is cultivated mainly in the south (Bianco 1995). The regular presence of adventitious buds on its roots, from which new shoots easily appear, makes this species behave, under certain conditions, as an invasive weed (Caso 1972). However, such a trait might well represent, in a Mediterranean situation, an advantage for its propagation and cultivation.

Also *D. muralis* can be used in a similar way, but it seems to be, at least in Italy, less appreciated than *D. tenuifolia* (Pignone and Api Ngu 1995). No records have been found on the utilization of the other species of the group, like *D. viminea* or *D. simplex*. However, the very short life-cycle of *D. viminea* and the dry habitats preferred by *D. simplex* may encourage their cultivation or the use of their genetic resources for rocket improvement.

The use of *D. acris*, also an interesting plant from desert regions, is apparently similar. According to data from collectors reported by Hedge *et al.* (1980), its leaves

have a pungent taste and are eaten by people in Iraq. Boulos (1977) reports the use of these leaves as green salad in Jordan, where it is also considered a good grazing plant, especially for sheep.

There are several other species of *Diplotaxis* which seem to be a good source of forage and might potentially become vegetable crops. Camels and sheep graze on *D. harra* (hairy rocket) in Iraq (Hedge *et al*. 1980). The closely related *D. villosa* (locally called 'harra') is also grazed in Jordan (Boulos 1977), although very little information is available on this rare, much undercollected species. Also *D. erucoides* in Iraq (Hedge *et al*. 1980) and Spain (Sennen 1930), together with *D. assurgens*, *D. catholica* and *D. virgata* in Morocco (Nègre 1961) have been reported to be grazed by animals.

Both *D. tenuifolia* (Caso 1972) and *D. erucoides* (Rigual and Magallon 1972) have been reported as good melliferous plants. Medicinal uses of *D. harra* in the Near East (Yaniv 1995) and of *D. tenuifolia* in Italy (De Feo *et al*. 1993) also have been reported.

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How do we use *Eruca* to improve *Brassica* crops?

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Brassica napus (genome AACC, *n*=19), oilseed rape, is an amphidiploid species derived from the spontaneous hybridization of *B. oleracea (*CC, *n*=9) and *B. rapa* (AA, *n*=10). It is likely that there are potentially important agronomic traits in species and related genera, such as *Eruca sativa,* which are related to *Brassica.* The A and C genomes of *B. napus* are similar to each other, and pairs of homoeologous chromosomes can be identified. Despite the similarity, the homoeologous chromosomes do not pair with each other at meiosis, preventing recombination between the A and the C genomes (Parkin *et al.* 1995). Owing to this strict control of chromosome pairing, hybridization between naturally occurring *B. napus* and *E. sativa* is unlikely to result in recombination between chromosomes of either the A and the C genomes and chromosomes of the *E. sativa*.

However, in synthetic forms of *B. napus*, developed by the artificial hybridization of *B. oleracea* and *B. rapa*, control of chromosome pairing is relaxed, and extensive recombination occurs between the A and the C genomes. Thus to enhance the introgression of genes from *E. sativa* into *Brassica* at the John Innes Centre, we have developed a novel amphidiploid between *B. rapa* and *E. sativa* using the method of ovary culture and embryo rescue described by Mithen and Magrath (1992). The synthetic amphidiploid, although fertile, is very self-incompatible but can be propagated through vegetative cuttings. The synthetic amphidiploid has been successfully crossed to the oilseed rape cultivar Westar although embryo rescue had to be used to obtain the new hybrid. Subsequent crossing and selfing should result in a set of oilseed rape inbred lines containing parts of the *E. sativa* genome.

Some accessions of *E. sativa* have been shown to possess resistance to the stem canker pathogen, *Leptosphaeria maculans* (Tewari *et al.* 1995), which is an important fungal pathogen of oilseed rape. Currently, the resistance of *E. sativa* to the fungal pathogen *Pyrenopeziza brassicae* is being tested in our laboratory. This pathogen causes light leaf spot disease in oilseed rape and new sources of resistance would be of value in oilseed rape breeding programmes.

The synthetic amphidiploid has also been successfully hybridized to horticultural forms of *B. rapa* (Chinese cabbage) and, through a crossing and selfing programme, inbred lines containing part of the *Eruca* genome should be obtained. One character of particular interest and importance that could be transferred from *E. sativa* to *B. rapa* is flavour. A mustard oil, 4-methylthiobutyl isothiocyanate, is responsible for the flavour of *E. sativa*. Isothiocyanates are derived from glucosinolates, which are secondary metabolites containing a glycone moiety and a variable aglycone side chain that are found in both *E. sativa* and *B. rapa*. *E. sativa* and *B. rapa* differ in both their side chain lengths and their side chain modifications and thus produce different flavours. *Erusca sativa* contains 4-methylthiobutyl glucosinolate and a small amount of 4-methylsulphinylbutyl glucosinolate. In contrast, *B. rapa* contains 3-butenyl, 2-hydroxy-3-butenyl, 4-pentenyl and 2-hydroxy-4-pentenyl glucosinolates. We are hoping to combine many of the textures of salad brassica such as Chinese cabbage with the characteristic flavour of *E. sativa*.

Methylsulphinylbutyl isothiocyanate induces enzymes which have anticancer activity and is found in both the genera *Eruca* and *Brassica*. This glucosinolate does not occur in *B. rapa* and it has much greater anticancer potency than those

isothiocyanates which do occur in *B. rapa* (Zhang *et al.* 1992). It may therefore be possible to alter the flavour composition and the nutritional value of *B. rapa* through the introgression of *Eruca* genes.

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Seed morphology of some taxa belonging to genus *Diplotaxis* D.C. and *Eruca* Miller

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Introduction

In recent years, the specialization of techniques used to assess seed vigour and germinability, or applied in gametophytic selection and transgenic plants, has provided valuable elements for crop improvement or for the safeguarding of genetic diversity even in crops that, for too long, have been scarcely – if at all – used by people (Morinaga 1934; Labana *et al.* 1977; Gorini 1979; Arora and Lamba 1980; Goth and Webb 1980; Lamba and Arora 1981; Des and Lal 1982; Matsuzawa and Sarashima 1986; Mascagno 1987; Kanthaliya *et al.* 1990; Amla and Dhingra 1991; Hammer *et al.* 1992; Nuez and Bermejo 1992; Anonymous 1993; De Leonardis *et al.* 1996a, 1996b).

The use of flowering brassicas as a source of food has always been of great interest to botanists (Tonzig 1941; Beijerink 1947; Garnier 1961; Leclerc 1966; Maugini 1973; Tomaselli 1974; De Capite 1984; Gastaldo 1987; Biagi and Speroni 1988; Anzalone 1989).

The culinary use of seeds of *Sinapis alba* and *S. arvensis* was already known at the time of Theophrastus (4th century BC). In families like the Brassicaceae, which show distinct homogeneity of morphological characters, SEM (Scanning Electronic Microscope) analysis of the seed coat and the use of data for seed size can be useful diacritical features – as they are in pollen studies (Maurizio and Louveaux 1960; Perez De Paz 1977, 1980; De Leonardis *et al.* 1984, 1986, 1989a, 1989b, 1995; Díez 1987; Hodgkin 1985, 1987; Hodgkin and Lyon 1986) – in assessing their proper classification, the possible effects of anthropic selection and, last but not least, in detecting cases of seed adulteration (Cauda 1914; Musil 1948; Berggren 1960, 1962; Vaughan 1970; Vaughan and Whitehouse 1971; Corner 1976; Mulligan and Bailey 1976; Buth and Ara 1981; Matarese Palmieri 1990-91; Brochmann 1992; De Leonardis and Fichera 1994).

Materials and methods

Seed material was provided by Professors Gomez Campo and Martínez Laborde of the Polytechnic University of Madrid, Spain. Full names of species used in the text are those adopted by the institutions providing the germplasm.

Seeds were examined under the stereomicroscope (Wild M8) and under the SEM (Philips) after specimens had been dehydrated in the alcohol series and gold coated. The terminology used in this work follows that of Berggren (1981). The seed colour was scored according to Kornerup and Wanscher's manual (1978).

The 20 taxa examined were coded with the initial of the genus D (*Diplotaxis*) or E (*Eruca*) followed by the specimen number (e.g. D3 =*Diplotaxis muralis*, etc.). Table 1 shows the average values for seed length, width and thickness.

Results and discussion

The results of these investigations are reported as follows, according to the alphabetical order of the species analyzed (L=length, W=width, T=thickness).

Table 1. Taxa examined under stereomicroscopy and their average dimensions (mm)

Codes	Taxa	Length (L)	Width (W)	Thickness (T)
D1	*Diplotaxis brachycarpa*	1.05	0.60	0.55
D2	*Diplotaxis berthautii*	0.82	0.60	0.45
D3	*Diplotaxis muralis*	1.06	0.72	0.62
D4	*Diplotaxis assurgens*	0.87	0.64	0.62
D5	*Diplotaxis virgata*	0.79	0.51	0.47
D6	*Diplotaxis siettiana*	0.64	0.48	0.42
D7	*Diplotaxis siifolia*	0.89	0.82	0.82
D8	*Diplotaxis viminea*	0.95	0.58	0.47
D9	*Diplotaxis brevisiliqua*	0.77	0.49	0.45
D10	*Diplotaxis tenuifolia*	1.12	0.75	0.58
D11	*Diplotaxis harra*	0.86	0.50	0.37
D12	*Diplotaxis simplex*	0.83	0.58	0.48
D13	*Diplotaxis longisiliqua* subsp. *cossoniana*	1.02	0.63	0.50
D14	*Diplotaxis ibicensis*	0.73	0.47	0.42
D15	*Diplotaxis erucoides*	1.00	0.71	0.58
D16	*Diplotaxis tenuisiliqua*	0.88	0.63	0.61
D17	*Diplotaxis catholica*	0.88	0.65	0.63
E18	*Eruca pinnatifida* var. *aurea*	1.47	0.99	0.55
E19	*Eruca vesicaria*	1.35	0.83	0.77
E20	*Eruca sativa*	1.44	1.04	0.80

Diplotaxis assurgens (Del.) Gren.
Shape: elliptical
Side outline: elliptical
Transversal outline: subcircular
Radicular shape: not evident
Radicular extremity: as long as cotyledon, little curved, subacute
Cotyledon extremity: subobtuse
Basal cut: little evident
Radicular and cotyledonous furrow: not evident
Hilum and micropyle: covered with funicular tissue
Tegument: reticulum with narrow lumina
Colour: orange brown
Measurements: **L.** 0.80(0.87)0.95 mm; **W.** 0.60(0.64)0.75 mm; **T.** 0.60(0.62)0.65 mm.

Diplotaxis berthautii Br. Bl. et Maire (Fig. 1)
Shape: ovate
Side outline: elliptical
Transversal outline: widely elliptical
Radicular shape: wide 0.2 mm
Radicular extremity: long 0.1 mm as regards as to cotyledonous, little curved, subacute
Cotyledonous extremity: subobtuse
Basal cut: little evident
Radicular and cotyledonous furrow: evident
Hilum and micropyle: covered with funicular tissue
Tegument: reticulum with medium lumina
Colour: light brown yellow
Measurements: **L.** 0.80(0.82)0.85 mm; **W.** 0.55(0.60)0.65 mm; **T.** 0.40(0.45)0.50 mm.

Diplotaxis brachycarpa Godr.
Shape: elliptical
Side outline: tightly elliptical
Transversal outline: widely elliptical
Radicular shape: indistinct
Radicular extremity: just longer than that one cotyledonous, lightly curved, subacute
Cotyledonous extremity: subobtuse
Basal cut: little evident
Radicular and cotyledonous furrow: not evident
Hilum and micropyle: covered with funicular tissue
Tegument: reticulum scarcely prominent
Colour: egg-yellow
Measurements: **L.** 1.0(1.05)1.15 mm; **W.** 0.50(0.60)0.60 mm; **T.** 0.50(0.55)0.60 mm.

Diplotaxis brevisiliqua (Coss.) Mart. Laborde
Shape: elliptical
Side outline: elliptical
Transversal outline: subcircular
Radicular shape: wide 0.1 mm
Radicular extremity: as long as cotyledonous, little curved, subacute
Radicular extremity: subobtuse
Basal cut: evident
Radicular and cotyledonous furrow: little evident
Hilum and micropyle: hilum subcircular, very little funicular tissue
Tegument: reticulum with very narrow lumina
Colour: light brown yellow
Measurements: **L.** 0.70(0.77)0.85 mm; **W.** 0.45(0.49)0.55 mm; **T.** 0.40(0.45)0.42 mm.

Diplotaxis catholica (L.) DC. (Fig. 2)
Shape: widely elliptical
Side outline: elliptical
Transversal outline: subcircular
Radicular shape: extremity just longer than that one cotyledonous, subobtuse
Cotyledonous extremity: subobtuse
Basal cut: not evident
Radicular and cotyledonous furrow: not evident
Hilum and micropyle: covered with funicular tissue as the subcircular hilum as the micropilum
Tegument: reticulum with wide lumina
Colour: orange brown and green olive
Measurements: **L.** 0.85(0.88)0.90 mm; **W.** 0.60(0.65)0.70 mm; Th 0.60(0.63)0.65mm.

Diplotaxis erucoides (L.) DC.
Shape: elliptical
Side outline: tightly elliptical
Transversal outline: elliptical
Radicular shape: 0.1 mm wide
Radicular extremity: as long as cotyledonous, subacute
Cotyledonous extremity: subobtuse
Basal cut: little evident

Radicular and cotyledonous furrow: evident
Hilum and micropyle: covered with funicular tissue
Tegument: reticulum with very narrow lumina
Colour: egg-yellow
Measurements: **L.** 0.95(1.00)1.05 mm; **W.** 0.65(0.71)0.75 mm; **T.** 0.55(0.58)0.65 mm.

Diplotaxis harra (Forsk) Boiss.
Shape: elliptical
Side outline: strictly elliptical
Transversal outline: ovate
Radicular shape: in the medium area of the seed 0.1 mm wide
Radicular extremity: 0.1 mm longer than that one cotyledonous, lightly curved, subacute
Cotyledonous extremity: subobtuse
Basal cut: little evident
Radicular and cotyledonous furrow: very distinct
Hilum and micropyle: covered with funicular tissue
Tegument: reticulate-rugulate
Colour: egg-yellow
Measurements: **L.** 0.80(0.86)0.90 mm, **W.** 0.45(0.50)0.55 mm, **T.** 0.30(0.37)0.40 mm.

Diplotaxis ibicensis (F.Quer.) Gz. Campo (Fig. 3)
Shape: elliptical
Side outline: tightly elliptical
Transversal outline: widely elliptical
Radicular shape: not evident
Radicular extremity: as long as the cotyledonous, curved, subacute
Cotyledonous extremity: subacute
Basal cut: little evident
Radicular and cotyledonous furrow: not evident
Hilum and micropyle: covered with funicular tissue
Tegument: reticulate-rugulate
Colour: light brown yellow
Measurements: **L.** 0.70(0.73)0.80 mm; **W.** 0.45(0.47)0.50 mm; **T.** 0.40(0.42)0.50 mm.

Diplotaxis longisiliqua DC. subsp. *cossoniana* (Reut) Maire et Weiller (Fig. 4)
Shape: elliptical
Side outline: tightly elliptical
Transversal outline: elliptical
Radicular shape: 0.2 mm wide
Radicular extremity: long 0.1 mm as regards as the cotyledonous, curved, subacute
Cotyledonous extremity: subacute
Basal cut: evident
Radicular and cotyledonous furrow: very evident
Hilum and micropyle: covered with funicular tissue
Tegument: reticulum with very narrow lumina
Colour: light brown yellow
Measurements: **L.** 0.95(1.02)1.10 mm; **W.** 0.60(0.63)0.70 mm; **T.** 0.45(0.50)0.55 mm.

Diplotaxis muralis (L.) DC.
Shape: elliptical
Side outline: elliptical
Transversal outline: widely elliptical
Radicular shape: 0.2 mm wide
Radicular extremity: 0.2 mm longer than cotyledonous extremity, curved, subacute
Cotyledonous extremity: subacute
Basal cut: very evident
Radicular and cotyledonous furrow: very evident
Tegument: reticulum with very narrow lumina
Colour: orange brown
Measurements: **L.** 1.0(1.06)1.10 mm; **W.** 0.70(0.72)0.75 mm; **T.** 0.60(0.62)0.65 mm.

Diplotaxis siettiana Maire
Shape: elliptical
Side outline: widely elliptical
Transversal outline: subcircular
Radicular shape: 0.1 mm wide
Radicular extremity: longer than the cotyledonous, curved, subacute
Cotyledonous extremity: subobtuse
Basal cut: little evident
Radicular and cotyledonous furrow: very evident.
Hilum and micropyle: hilum subcircular, micropile covered with funicular tissue
Tegument: reticulum with narrow lumina
Colour: light brown yellow
Measurements: **L.** 0.60(0.64)0.70 mm; **W.** 0.45(0.48)0.50 mm; **T.** 0.40(0.42)0.45 mm.

Diplotaxis siifolia G. Kunze (Fig. 5)
Shape: subcircular
Side outline: circular
Transversal outline: circular
Radicular shape: not evident
Radicular extremity: as long as the cotyledonous, curved, subobtuse
Cotyledonous extremity: subobtuse
Basal cut: absent
Radicular and cotyledonous furrow: not evident
Hilum and micropilum: hilum subcircular, funicular tissue reduced or absent
Tegument: reticulate-rugulate
Colour: light brown yellow
Measurements: **L.** 0.85(0.89)0.95 mm; **W.** 0.80(0.82)0.85 mm; **T.** 0.80(0.82)0.85 mm.

Diplotaxis simplex (Viv.) Sprengel
Shape: widely elliptical
Side outline: elliptical
Transversal outline: widely elliptical
Radicular shape: 0.2 mm large
Radicular extremity: 0.1 mm large, curved, subacute
Cotyledonous extremity: 0.1mm large, curved and subacute
Basal cut: little evident
Radicular and cotyledonous furrow: very evident
Hilum and micropyle: subcircular, funicular tissue only on basal cut

Tegument: reticulum with narrow lumina
Colour: egg-yellow
Measurements: **L.** 0.75(0.83)0.85 mm; **W.** 0.55(0.58)0.60 mm; **T.** 0.45(0.48)0.50 mm.

Diplotaxis tenuifolia (L.) DC.
Shape: widely elliptical
Side outline: tightly ovate
Transversal outline: elliptical
Radicular shape: 0.2 mm wide
Radicular extremity: 0.2 mm longer than cotyledonous extremity, curved, subacute
Cotyledonous extremity: subobtuse
Basal cut: very evident
Radicular and cotyledonous furrow: evident the first, the either almost absent
Hilum and micropyle: covered with funicular tissue
Tegument. reticulum with medium lumina
Colour: orange brown
Measurements: **L.** 1.05(1.12)1.20 mm; **W.** 0.70(0.75)0.80 mm; **T.** 0.55(0.58)0.60 mm.

Diplotaxis tenuisiliqua Del.
Shape: elliptical
Side outline: elliptical
Transversal outline: elliptical
Radicular shape: not evident
Radicular extremity: 0.1 mm longer than cotyledonous extremity, curved, subacute
Cotyledonous extremity: subobtuse
Basal cut: little evident
Radicular and cotyledonous furrow: not evident
Hilum and micropyle: covered with funicular tissue
Tegument: reticulum with medium lumina
Colour: orange-yellow
Measurements: **L.** 0.80(0.88)0.95 mm; **W.** 0.60(0.63)0.65mm; **T.** 0.55(0.61)0.65 mm.

Diplotaxis viminea (L.) DC. (Fig. 6)
Shape: elliptical
Side outline: tightly elliptical
Transversal outline: widely elliptical
Radicular shape: 0.2 mm large
Radicular extremity: 0.1 mm long, curved, subacute
Cotyledonous extremity: subobtuse
Basal cut: very evident
Radicular and cotyledonous furrow: evident only the radicular furrow
Hilum and micropyle: covered with funicular tissue
Tegument: reticulum scarcely prominent
Colour: orange brown and green olive
Measurements: **L.** 0.90(0.95)1.10 mm; **W.** 0.50(0.58)0.65 mm; **T.** 0.40(0.47)0.55 mm.

Diplotaxis virgata (Cav.) DC.
Shape: elliptical
Side outline: elliptical
Transversal outline: subcircular
Radicular shape: not evident

Radicular extremity: as long as the cotyledonous, little curved, subacute
Cotyledonous extremity: subobtuse
Basal cut: little evident
Radicular and cotyledonous furrow: not evident
Hilum and micropyle: hilum subcircular, little funicular tissue
Tegument: reticulum with narrow lumina
Colour: orange brown
Measurements: **L.** 0.75(0.79)0.85 mm; **W.** 0.50(0.51)0.55 mm, **T.** 0.40(0.47)0.50 mm.

Eruca pinnatifida (Desf.) Pomel var. *aurea* (Batt.) Maire (Fig. 7)
Shape: ovate
Side outline: elliptical
Transversal outline: tightly elliptical
Radicular shape: 0.25 mm wide
Radicular extremity: as long as the cotyledonous, subobtuse
Cotyledonous extremity: subobtuse
Basal cut: very evident
Radicular and cotyledonous furrow : very evident
Hilum and micropyle: covered with a wide wing of funicular tissue
Tegument: reticulum with narrow lumina
Colour: egg yellow
Measurements: **L.** 1.40(1.47)1.55 mm; **W.** 0.90(0.99)1.05 mm; **T.** 0.50(0.55)0.60 mm.

Eruca sativa Boiss.et Reut. (Fig. 8)
Shape: from ovate to widely elliptical
Side outline: widely elliptical
Transversal outline: from subcircular to subrhombic
Radicular shape: 0.3 mm wide
Radicular extremity: as long as the cotyledonous, curved, subacute
Basal cut: very evident
Radicular and cotyledonous furrow. very evident
Hilum and micropyle: covered with funicular tissue
Tegument: reticulum with very narrow lumina
Colour: from yellow brown to green olive
Measurements: **L.** 1.35(1.44)1.50 mm; **W.** 0.95(1.04)1.10 mm; **T.** 0.75(0.80)0.85 mm.

Eruca vesicaria (L.)Cav.
Shape: from widely elliptical to widely ovate
Side outline: widely elliptical
Transversal outline: subcircular
Radicular shape: 0.3 mm wide
Radicular extremity: as long as the cotyledonous, curved, subacute
Cotyledonous extremity: subobtuse
Basal cut: very evident
Radicular and cotyledonous furrow: very evident
Hilum and micropyle: covered with funicular tissue
Tegument: reticulum with very narrow lumina
Colour: from yellow brown to green olive
Measurements: **L.** 1.30(1.35)1.45 mm; **W.** 0.80(0.83)0.90 mm; **T.** 0.70(0.77)0.85 mm.

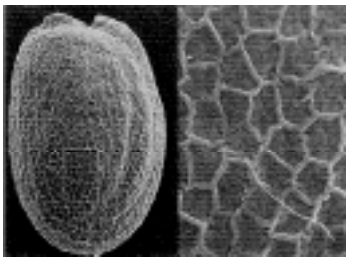

Fig. 1. *Diplotaxis berthautii*: seed; reticulum with narrow lumina.

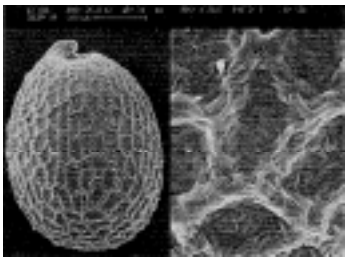

Fig. 2. *Diplotaxis catholica*: seed; reticulum with wide lumina.

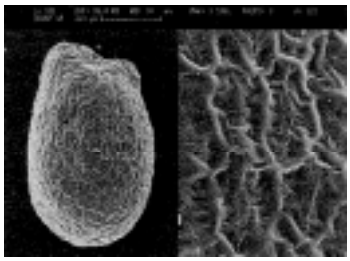

Fig. 3. *Diplotaxis ibicensis*: seed; reticulum scarcely prominent.

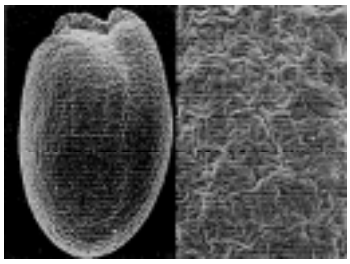

Fig. 4. *Diplotaxis longisiliqua* subsp. *cossoniana*: seed; reticulate-rugulate ornamentation.

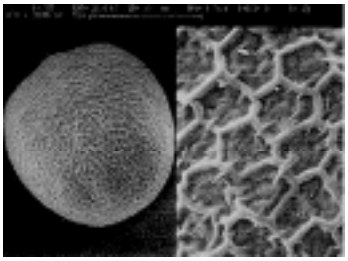

Fig. 5. *Diplotaxis siifolia*: seed; reticulum with medium lumina.

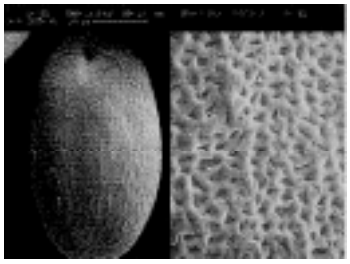

Fig. 6. *Diplotaxis viminea*: seed; reticulum with very narrow lumina.

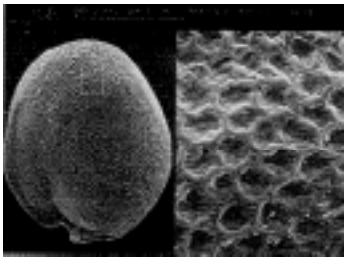

Fig. 7 (left). *Eruca pinnatifida* var. *aurea*: seed; reticulum scarcely prominent with subcircular lumina.

Fig. 8 (right). *Eruca sativa*: seed; reticulum with subcircular lumina.

On the basis of these biometric data, and particularly referring to colour, ornamentation, length, width and thickness of the seeds, we are able to clearly typify and differentiate the 20 taxa studied.

The taxa belonging to the genus *Diplotaxis* show seed reticulum length ranging from 0.64 to 1.20 mm, width from 0.45 to 0.85 mm, thickness from 0.30 to 0.85 mm, whereas seed coat and colour vary largely in type and tonality.

Within the three analyzed entities of the genus *Eruca*, a greater morphobiometric interspecific homogeneity has been detected which clearly distinguishes them from the other taxa belonging to *Diplotaxis*. The most important discriminative character between these two genera is represented by the seed length, which in *Eruca* varies from 1.30 to 1.55 mm (Fig. 9).

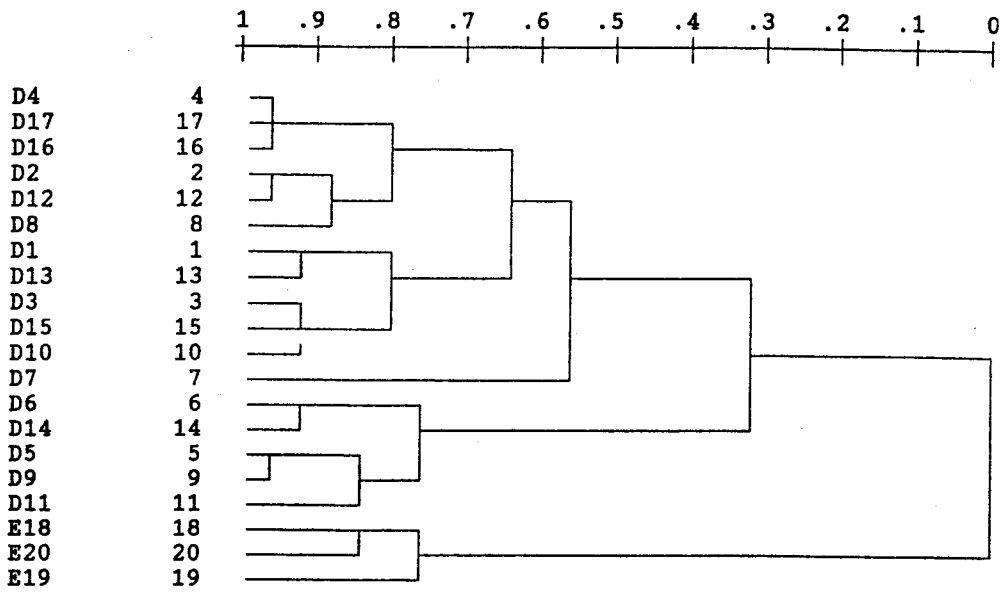

Fig. 9. Hierarchical cluster analysis dendrogram of seed affinity between 20 specimens based upon three characters and using the Kulczynski similarity ratio and Complete linkage methods.

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Cytological study on rocket species by means of image analysis system

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Introduction

Rocket is a crop that has been known for many centuries. Romans utilized it broadly as a vegetable and condiment plant. Although different species are referred to under the common name of rocket, the most common ones are those belonging to *Eruca* and *Diplotaxis* genera. These genera belong to the subtribe Brassicinae, which includes 10 genera, according to the classification made by Schulz (1919, 1923, 1936).

The economic interest in rocket is growing. This is particularly due to the diffusion of ready-to-use salads (4th generation of vegetables) that extend the shelf life of rocket leaves and preserve their freshness and the typical scent. However, a good number of varieties to meet the large market demand are still lacking. To achieve this goal, it is necessary to proceed to a systematic collection of germplasm in different regions of the Mediterranean area, where rocket occurs spontaneously and where targeted crop genetic improvement would yield great benefits.

With regard to genetic improvement, the role played by cytological studies is essential to contribute to a deeper characterization of the species and thus to a more sensible classification of their genetic resources. A direct impact of these studies is most evident in hybridization activities.

It is known that Brassicaceae generally have chromosomes that are difficult to observe, owing to their very small size. This is also true of *Eruca* and *Diplotaxis*, whose chromosome number in many species is the only known cytological information, any other indication on the morphology being lacking (Warwick and Anderson 1993).

Recently, the use of image analysis, also applied to the karyotyping of plant chromosomes in species with difficult chromosomes, has allowed the accomplishment of detailed karyotypes (Venora *et al.* 1991, 1995a, 1995b, 1995c; Ocampo *et al.* 1992; Venora and Saccardo 1993; Venora and Padulosi 1997).

This paper reports on the use of this innovative technique for the karyotyping of some rocket species (*Eruca* and *Diplotaxis*) which have so far not been investigated for this purpose.

Materials and methods

Seeds of *Eruca vesicaria* subsp. *sativa* (Mill.) Thell., *Eruca vesicaria* subsp. *pinnatifida* (Desf.) Emb. and Maire and *Diplotaxis tenuifolia* (L.) DC. were kindly supplied by Prof. Gomez-Campo of the Universidad Politecnica de Madrid (ETSIA).

Seeds were germinated on moist filter paper in Petri dishes kept in the dark at room temperature. For the analysis of the somatic chromosomes, young and turgid primary roots (0.5-1 cm long) were cut off and pretreated in a saturated water solution of 1,4 dichlorobenzene for 2 hours at 15°C. They were then fixed in ethanol-acetic acid (3:1) for 24 hours at 4°C, after a thorough rinsing in water. The staining process was performed following the Feulgen technique by hydrolyzing the material in 5N hydrochloridric acid at room temperature for 55 minutes. The stained roots were then squashed in 45% acetic acid and mounted in Entellan (Merk).

The microscopic investigation was conducted by using a Zeiss Axioplan 2 microscope connected to an image analysis system KS400 Kontron, with dedicated to karyotyping software 'KSChromo' that enables more reliable results than the traditional hand-made karyotyping procedure (Venora *et al.* 1991). Total chromosome length, as well as the length of short arms, long arms and satellites, were all measured with this computerized system.

All the data obtained by each plate were loaded in the dedicated software 'Karyo 95' for the better matching of chromosome couples, which was done automatically on the basis of each chromosome data (Pavone *et al.* 1995).

The short/long arm ratio does not include the satellite. The nomenclature of Levan *et al.* (1964) was followed in classifying the chromosomes.

With regard to chromosomal indices, the classification of Stebbins (1971), the TF% index (Huziwara 1962) and the Rec and Syi indices (Greilhuber and Speta 1976) were used. The classification of Stebbins (1971) is based on the relative frequency of chromosomes with a long arm ratio greater than 2 and on the ratio between the lengths of the longest and the shortest chromosomes in the complement. The TF% index is expressed by the ratio between the sum of the lengths of the short arms of individual chromosomes and the total length of the complement. The Rec index expresses the average of the ratios between the length of each chromosome and that of the longest one. The Syi indicates the ratio between the average length of the short arms and the average length of the long arms.

Results and discussion

Figure 1 shows a typical metaphase plate with 22 chromosomes. In Figure 2 are represented the idiograms of the haploid complement of *Eruca vesicaria* subsp. *sativa*, *E. pinnatifida* and *D. tenuifolia*, obtained by using the image analysis system and the software 'Karyo 95'. The 3 species' chromosome number is $2n=22$, which is in agreement with previous reports from Warwick and Anderson (1993).

The asterisks indicate the dissimilar pairs between the two *Eruca* species; the greater differences concern the first pair and the ninth pair (in general such differences are attributable to chromosomal rearrangements due to pericentromeric inversions).

The idiogram of *D. tenuifolia* shows a karyogram similar to *Eruca*, but each chromosome is longer, and the karyotype formula is different.

The karyotypic data have also been used to speculate on the degree of karyotype evolution in each species (Fig. 3). On the basis of these preliminary results, it seems that the two *Eruca* species are relatively more evolved than *Diplotaxis* species, from a karyotypic point of view, while being very similar to each other.

Additional work is, however, necessary to confirm these data, possibly by using a greater amount of seeds and good metaphase plates. This study has been useful in providing cytogenetic information on these little-studied species. It has also been particularly successful in karyotyping (with the use of image analysis system) such difficult chromosomes as those of *Eruca* and *Diplotaxis*.

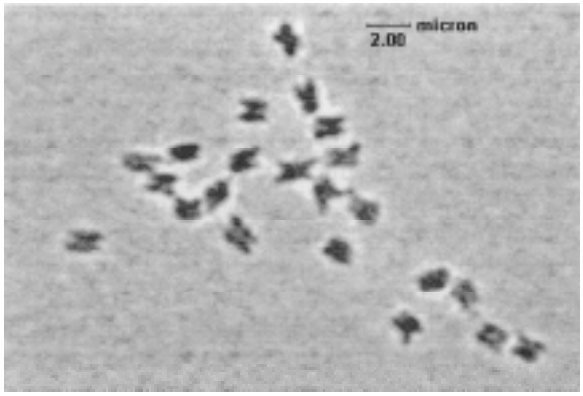
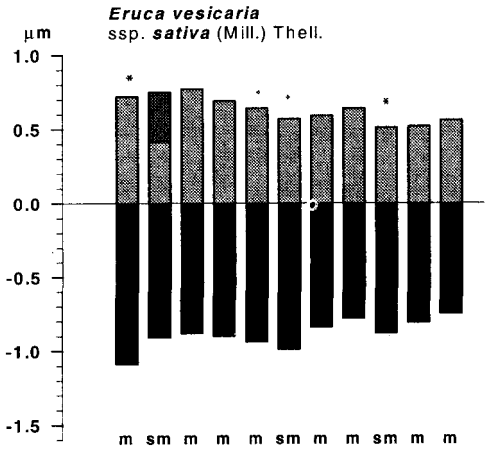
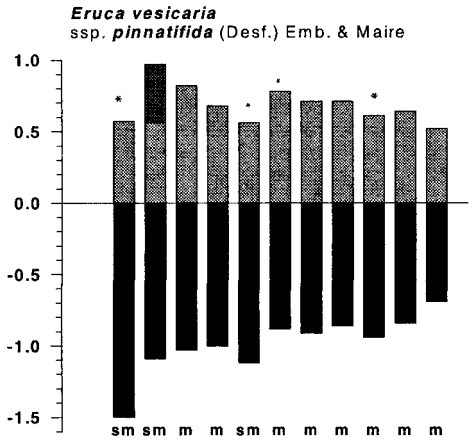


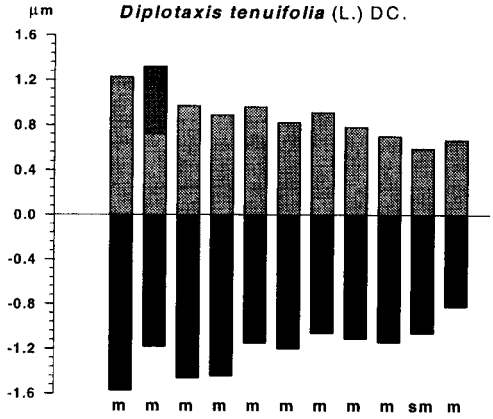
Fig. 1. Metaphase plate of *Eruca sativa* 2*n*=22.



Kariotipic Formula = sm^{sc}+8m+2sm (2n=22)
Haploid complement length 16.73 µm.



Kariotipic Formula = sm^{sc}+8m+2sm (2n=22)
Haploid complement length 18.43 µm.



Karyotype Formula = m^{sc}+10m+ sm (2n=22)
Haploid complement length 23.03 µm

Fig. 2. Idiogrammatic representation of the haploid complement of each species studied.

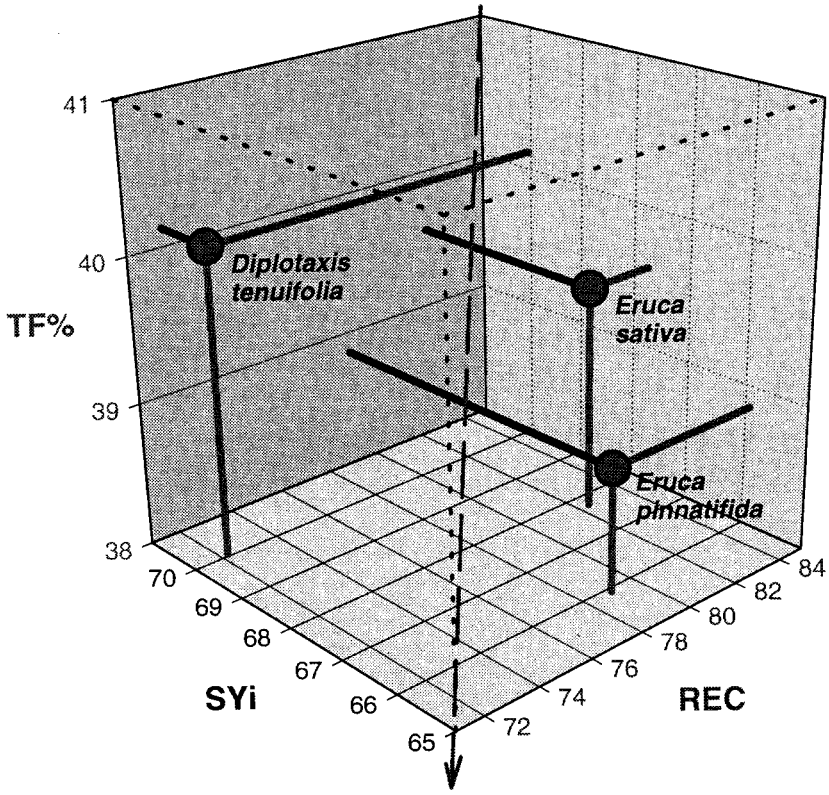


Fig. 3. Karyotype symmetry of studied species with REC, SYi and TF% indices.

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Up-to-date developments on wild rocket cultivation

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Introduction

Wild rocket, *Diplotaxis tenuifolia* (L.) D.C., is a member of the Brassicaceae family, characterized by a perennial and suffruticose habit at its base. It is found endemic in most Mediterranean countries and in Northern and Eastern Europe. It thrives in many kinds of soils (preferably calcareous) in fields, roadsides, waste places, beaches and rock crevices.

Its leaves, entire to pinnatifid, have a piquant flavour resembling that of *Eruca vesicaria* (L.) subsp. *sativa* (Mill.) Thell. (rocket salad) and are eaten raw in salads or cooked in many dishes (including pizza). Flowers are used as a garnish (Bianco 1995). Older leaves, which are too piquant to be consumed raw, can be pureed and added to sauces and soups (Facciola 1990).

Baldrati (1950) reported that in Fano (central Italy) seedlings of *E. vesicaria* with cotylydon leaves and two to four leaves were sold in markets. These tender leaves are still used to prepare a delicate salad called 'persichina'.

In southern Italy, *Diplotaxis* species have been used as a food for a long time, but their popularity is now increasing remarkably. In fact, more and more restaurants are offering dishes with rocket as the main ingredient. A list of 35 old traditional Apulian recipes along with some new ones which can be tasted in famous restaurants throughout Italy was compiled by Bianco (1995).

Rocket was believed to have aphrodisiac properties (Fernald 1993) and for this reason in the past its growth was forbidden in monastery gardens (Mascagno 1987). Virgilius, the ancient Roman poet, praised the aphrodisiac virtues of rocket ('*et venerum revocans eruca morantem*'=the rocket excites the sexual desire in drowsy people) and Lucius Junius Moderatus Columella (1st century AD) in the Garden Poem (Cult. Hort. L., X, 108) affirms: "*Excitat veneri tardo eruca maritos*" (=rocket excites as the lovers embrace the lazy husbands (Penso 1986)).

Rocket is used in traditional pharmacopoeia for many different purposes: it is antiphlogistic, astringent, depurative, diuretic, digestive, emollient, tonic, stimulant, laxative, stomachic, anti-inflammatory for colitis, antiscorbutic and rubefaciens (Arietti 1965; Uphorf 1968; Ellison *et al.* 1980; Anonymous 1988, 1991; De Feo and Senatore 1993).

An infusion at 4-8% is used against itching, chilblains, scalds and urticaria. Among other applications is the preparation of a lotion to enhance hair regrowth and to fight against greasy scalps (Ellison *et al.* 1980), as a tonic for the face, to eliminate gum inflammation (Anonymous 1988) and to cure catarrh and hoarseness (Mascagno 1987).

The market demand is often met by harvesting the plant from the wild rather than by cultivating it. In Italy it is common to find the crop grown in a traditional way in backyards and small gardens together with basil, sage and other herbs. Wild rocket can be easily spotted in Italian vegetable marketplaces where it is often supplied directly by the peasants. But in the last few years the presence of cultivated plants is increasing remarkably, also due to the appearance of the so-called '4th generation' vegetables.

These vegetables are neatly prepared and sold in sealed plastic bags after having been sorted, cleaned and trimmed. This type of packaging does in fact enhance the shelf life of wild rocket which deteriorates quickly in marketplaces where no protection is provided to reduce wilting of leaves. The price of wild rocket in sealed plastic bags ready to be used is around US$8/kg in Italian supermarkets.

In Italy wild rocket is cultivated in both field and greenhouse conditions.

Adequate soil moisture is needed to obtain good tender leaves. In fact, though the crop is well adapted to dry soils, irrigation increases its yield noticeably.

A few words should be added here to stress the importance of investigating the optimization of water uptake by wild rocket.

The increasing demand of fresh water for civil and industrial needs as observed in the last few years in all the most industrialized countries has caused a decrease in the amount used for agricultural purposes. Moreover, in the Mediterranean areas the indiscriminate exploitation of groundwater has deteriorated water quality (increase in salinity) which often causes heavy damage to irrigated crops and soil fertility. An increase in the salinity of the soil nutrient solution causes crops to extract water from soil with more energy expenditure, which means growth and yield reduction and, in extreme cases, death. Therefore it is very important to identify which phenological stages are most sensitive to water salinity in wild rocket.

Seed germination is one of the biological processes most sensitive to stress conditions, particularly salt stress (Khatri *et al*. 1991). The root zone is richer in salt because of the capillary rise of soil water solution and evaporation from the soil surface. High salt concentrations in soil solution make water absorption by seeds difficult. Water is necessary for enzyme activation and for reserve substance demolition, translocation and use.

Wild rocket is directly seeded or transplanted. Transplants are made using pots filled with peat-lite seedling medium. Apart from some indications given by Bianco (1995), Baggio and Pimpini (1995) and Pezzuto *et al.* (1996), no information is available on the cultural practices for wild rocket, though some research has been carried out on *E. vesicaria* for plant spacing (Takaoka and Minami 1984; Kara 1989; Branca and Minissale 1996), fertilization (Kheir *et al*. 1991; Ventrella *et al*. 1993; Santamaria *et al*. 1995, 1996) and irrigation with brackish water (Pezzuto *et al*. 1996).

Increased plant density, nitrogen fertilization and irrigation have resulted in increased yields of many leafy vegetables. Results of experiments on wild rocket in these fields are, however, not yet available. Therefore, to fill this gap, this paper reports on the results of experiments carried out by the Institute for Industrial Vegetables of Bari, with the purpose of evaluating the response of sown or transplanted wild rocket to nitrogen rate, plant density and saline water on yield and seed germination. A full account of these studies is available in other publications (Bianco and Minissale 1996; Pezzuto *et al*. 1996).

Materials and methods

Nitrogen and plant density experiments

Two experiments on nitrogen and plant density effects were conducted in 1995 and 1996 at the experimental farm 'Pantanelli', Policoro, southern Italy (the farm is located on the Ionic coast, at 10 m asl and 40°N lat.).

In both years the study involved three plant densities and three different nitrogen applications for the comparison of yields in both field-sown and

transplanted plants. In 1995 both trials were planted on 5 May, while in 1996 transplanting took place on 22 April and sowing on 29 April.

Plant density trials were based on three plant populations (33, 50 and 100 plants / m^2) grown in single rows 10 cm apart and with 10, 20 and 30 cm within-row spacing, fertilized as side-dress with 100 kg / ha of N.

Fertilization studies were carried out with 100 plants / m and were based on three rates of nitrogen (0, 100 and 200 kg / ha). During the first year, urea was the N source, while in 1996 N was provided as ammonium nitrate and ammonium sulphate. Nitrogen was applied as side-dress on two occasions each year – 15 May and 6 June 1995, and 6 May and 5 June 1996 – for the transplanted and seeded fields, respectively.

All experiments received a broadcast of preplant soil-incorporated application of 100 kg / ha of P_2O_5. The experimental design was always a randomized block using four replications in 1995 and three replications in 1996.

Irrigation was provided as needed by overhead sprinklers. During 1995 and 1996 trials the total water volume supplied was about 2000 and 2500 m^3 / ha, respectively.

Harvest was made by hand with knives. There were four and two cuttings in 1995 and 1996, respectively. Plant material from each harvest was dried in a forced-air oven at 65°C for 48 hours to determine dry weight, fibre and nitrate content.

Saline water effect

The experiment on salinity level and seed germination was carried out in 1995 in a controlled environment (25°C germinator, 90% relative humidity, 16 / 8 hours day / night photoperiod).

Germination of seeds was done in embedded substrates with different salinity levels of water solution. Solutions were obtained with commercial salt (NaCl) and tapwater. Eleven treatments with ECw corresponding to 0.5, 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 dS / m were made.

Seeds, which had been kept in aluminium sealed envelopes at room temperature, were placed in Petri dishes, sealed with parafilm and covered with Whatman filter paper imbibed for 5 minutes with the different saline solutions.

'Beginning germination' was recorded as soon as seedlings had evident cotyledons (generally the 4th day after their inhibition). Germination was monitored every 2 days for 2 weeks and maximum germination percentage, average time of germination (ATG, days), germination precocity (days) – 10 (T_{10}), 25 (T_{25}), 50 (T_{50}), 75(T_{75}) and 90 % (T_{90}) – of total germinated seeds with normal seedling was calculated.

An experiment on the influence of salinity levels on some morphologic characteristics and yield of wild rocket was conducted during 1995-96 in pots at the greenhouses of the Agricultural Faculty of the University of Bari.

Wild rocket seedlings were transplanted, one in each pot, with a randomized block design replicated four times and six treatments were carried out: ECw equal to 0.5 (T_1), 4 (T_2), 8 (T_3), 12 (T_4), 16 (T_5) and 20 dS / m (T_6). Transplanting took place at the beginning of December.

Tapwater was used to irrigate the pots up to the end of February and later on water with the different salinity levels was used, obtained by adding commercial salt to tapwater. Watering volume was higher to meet the leaching requirement.

Five harvests were made between the end of March and the beginning of July.

Results

Nitrogen and plant density experiments

Plant density effects

Plant density has a significant influence on biomass and leaf marketable yields in both years.

Marketable yields, as an average of the number of cuttings and seasons, increased from 2742 to 3327 and 3710 and from 4648 to 5473 and 6752 g/m^2 for 33, 50 and 100 plants/m^2, respectively for the first cut and total yield. The dry matter was not significantly different from plant densities for both the first cut and the average of cuttings, but during 1996 it was higher at the first cut (Table 1). Biomass and marketable yields of direct-seeded crops, compared with transplanted ones, were always higher (Table 1).

Production decreased in both years from first to last harvest and in 1995, when four cuttings were taken, the yields of the last two were very low (Fig. 1).

Stems elongated very rapidly. On average they grew about 1 cm/day, and they were taller in seeded plants and in the second cut (Fig. 2).

Table 1. Effects of plant density and planting method on wild rocket (1995 and 1996 average)†

	Biomass (g/m^2)		Marketable yield (g/m^2)		Dry matter (%)		Stems (g/plant)	
	1st cut	Total	1st cut	Total	1st cut	Total	1st cut	Total
Plant density (no./m^2)								
100	4762 A	9124 A	3710 A	6752A	10.3 A	13.0 A	32.8 A	23.9 B
50	4228 B	7396 B	3327 B	5473 B	9.7 A	13.1 A	32.7 A	24.9 B
33	3466 A	6247 C	2742 C	4648 C	10.4 A	13.1 A	39.0 A	30.0 A
Season								
1995	4013 A	8790 A	3114 A	6329 A	9.2 B	13.1 A	39.8 A	26.4A
1996	4257 A	6689 B	3380 A	5057 B	10.9 A	13.0 A	31.1 A	26.2 A
Planting method								
Direct sowing	4520 A	7830 A	3535 A	5888A	9.5 A	12.1 B	38.0 A	25.8 B
Transplanted	3785 B	7348B	2990 B	5364 B	10.8 A	13.9 A	31.6 B	26.7 A

† Mean separation within column by SNK, *P*=0.01.

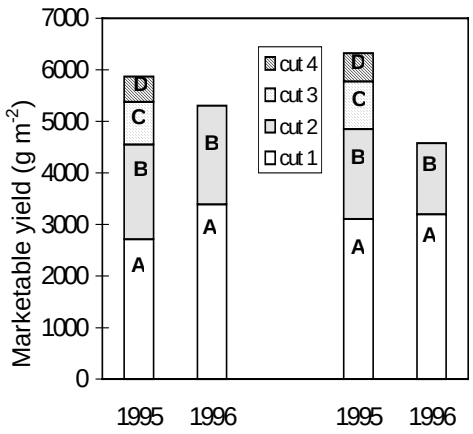

Fig. 1. Yield of wild rocket in successive cuttings for the plant density (left) and nitrogen rates (right) experiments. Values with different letters are significantly different at *P*=0.01 according to SNK.

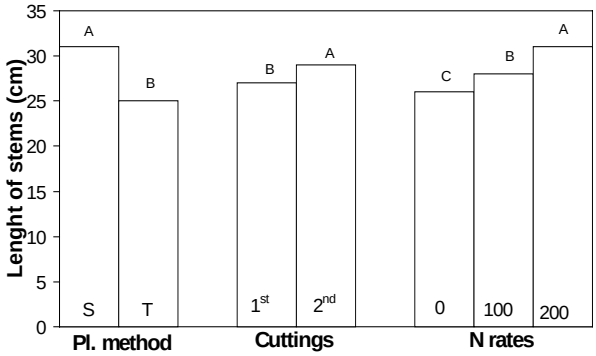

Fig. 2 Effect of planting method, time of cutting and nitrogen rates on length of stem of wild rocket in1996. Bars with different letters are significantly different at P=0.01 according to SNK.

Table 2. Effects of nitrogen rates, nitrogen source and planting method on wild rocket†

Treatments	Biomass (g/m^2)	Marketable yield (g/m^2)	Dry matter (%)	Stems (g/plants)
1995				
N rates (kg/ha)				
0	1435 A	13.2 A	19 A	–
100	2092 A	1492 A	12.9 A	19 A
200	2063 A	1475 A	13.7 A	18 A
Planting method				
Seeded	1859 B	1285 B	13.1 A	17 B
Transplanted	2230 A	1649 A	13.5 A	20 A
Cutting				
1st	3661 A	2719 A	9.6 C	26 A
2nd	2494 B	1832 B	12.7 B	21 B
3rd	1261 C	830 C	15.6 A	15 C
4th	760 D	488 C	15.2 A	13 C
1996				
N rates (kg/ha)				
0	3643 B	2419 B	14.4 A	17 B
100	3866 B	2636 B	13.6 B	18 AB
200	4245 A	2906 A	13.3 B	20 A
N source				
NH_4NO_3	4091 A	2755 A	13.8 A	19 A
$(NH_4)_2SO_4$	3746 A	2551 A	13.8 A	17 A
Planting method				
Seeded	4057 A	2720 A	13.3 B	16 B
Transplanted	3779 A	2586 A	14.2 A	20 A
Cutting				
1st	4664 A	3392 A	11.9 B	20 A
2nd	3172 B	1914 B	15.7 A	16 A

† Mean separation within column by SNK, *P*=0.01.

Effect of nitrogen fertilization

No yield response occurred in the 1995 trial while in 1996 the yields were slightly higher with 200 kg / ha of nitrogen. This response can be explained by the high soil fertility. In 1996, dry matter was lowered by nitrogen application and stems were heavier and taller (200 kg / ha) than those of the unfertilized plants (Table 2, Fig. 2).

There were no statistical differences between nitrogen sources for all the considered parameters.

During the 1996 experiments, the weight of leaves per plant was affected by the planting method. In the transplanted crop, it was higher in the nitrogen rates trial and lower in the plant density experiment (Fig. 3).

The stems per plant were heavier in the transplanted crop and with 200 kg / ha of nitrogen (Table 2). As always, yields were decreasing from first to last cuttings, and in the 1995 trial a linear trend was observed. In 1995, the fibre content of the unfertilized plants did not show any significant difference among cuttings: on average it was 9.3% in the first two cuttings and 7.6% in the last two.

Although wild rocket accumulates a large amount of nitrates – as much as other leafy vegetables such as lettuce, spinach and rocket salad (Ventrella *et al*. 1993; Santamaria *et al*. 1995; 1996) – no significant differences were detected between the two nitrogen sources and among the nitrogen rates. On average, nitrate content was 4000 mg / kg of fresh leaf weight.

The SO^{-}_{4} content (3412 mg / kg) was higher with ammonium sulphate than with ammonium nitrate (2771 mg / kg).

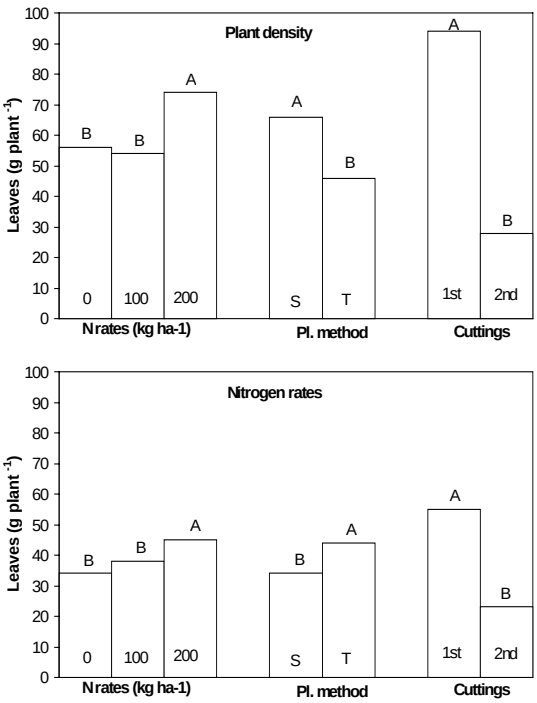

Fig. 3. Effect of plant density, planting method, time of cutting and nitrogen rate on weight of leaves of wild rocket in the two trials (top = 1995; bottom = 1996). Bars with different letters are significantly different at *P*=0.01 according to SNK.

Saline water effect

Salinity influenced significantly the different parameters taken into account.

Salinity and seed germination

Total germination decreased as salinity increased and varied between 62% for control and 22% for the most stressed treatment (20 dS/m). This decrease was significant compared with the control (ECw >10 dS/m (Fig. 4).

The ATG (Fig. 5) seemed to increase with higher salinity with values ranging between 4.5 (ECw=6 dS/m) and 6.2 days (ECw=20 dS/m).

Precocity germination values (Fig. 6) showed a steady upward trend (up to ECw=12 dS/m), increasing for ECw >12 dS/m and varying from 3.1 to 3.4, 3.3 to 3.9, 3.6 to 4.9, 3.9 to 6.0, 5.1 to 7.4 days for T_{10}, T_{25}, T_{50}, T_{75}, T_{90}, respectively, passing from the control to the most concentrated solutions.

Salinity and marketable yield

The increase of salinity caused a strong decrease of marketable yield of wild rocket.

The marketable yield ranged between 399 and 130 g/plant, passing from the control to the more stressed treatment (T_6) (Fig. 7). The yield reduction, compared with the control, was 10, 40, 49, 62 and 67% from T_2 to T_6 (Fig. 7), respectively.

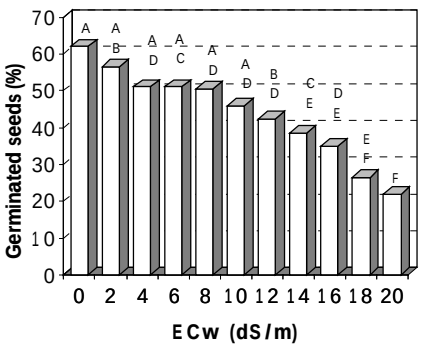

Fig. 4. Germinability of wild rocket seeds trend vs. ECw.

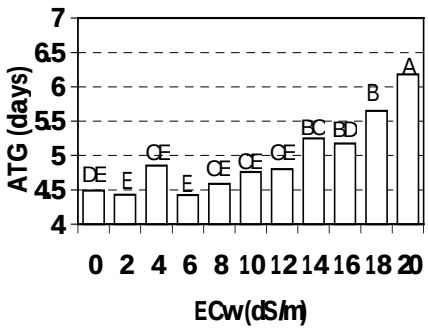

Fig. 5. Average time of germination (ATG) vs. ECw of wild rocket seeds.

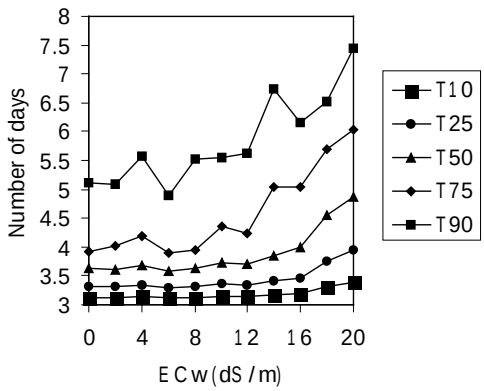

Fig. 6. Germination precocity trend vs. ECw of wild rocket seeds.

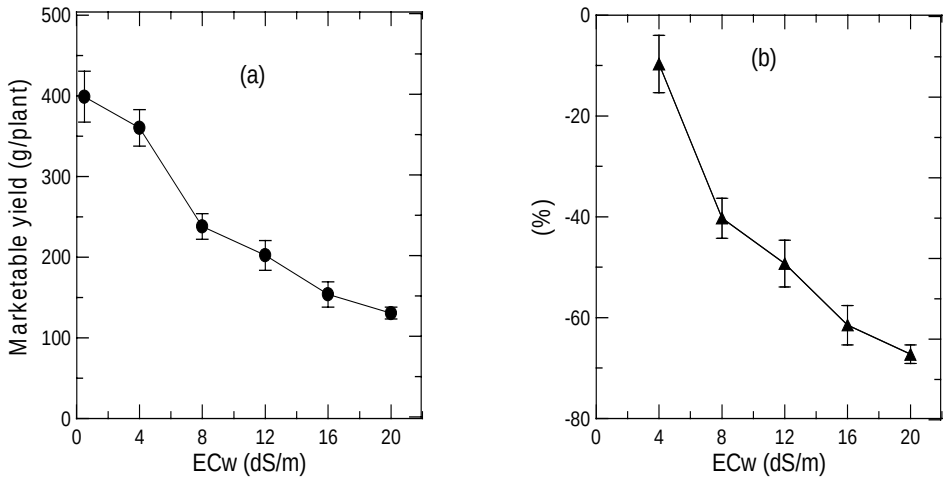

Fig. 7. Values ± SE (n=4) of marketable yield (left) and percentage decrease of this parameter compared with control (right) vs. ECw.

Conclusions

Wild rocket, very common in both uncultivated and cultivated areas in southern Italy, shows good adaptability to cultivation. However, because of its wildness it does not give higher yields with the increase of agrotechnical inputs.

The results presented in this paper give evidence that types and rates of nitrogen do not increase yields remarkably. This is due to the high soil fertility, and to the short biological cycle of wild rocket as reported by Bianco (1995).

Wild rocket tends to accumulate high levels of nitrates, which are also high in unfertilized plots, in agreement with results obtained on *E. vesicaria* (Ventrella *et al.* 1993).

Ammonium sulphate raised the sulphate content of leaves.

For maximum production of leaves it is suggested that wild rocket be grown at a plant density of 100 plant / m^2 or even more.

No definite response was observed when comparing results from direct-seeded fields and transplanted ones.

On average, the production of successive cuttings was lower and of inferior quality**,** but plant stands remain unchanged. We are inclined to conclude therefore that, in pedoclimatic conditions similar to those of our experiments, more than two cuttings per cultivation are not profitable.

Wild rocket seeds showed low germinability, but they are quite tolerant to salinity, showing a germination decrease significant only for ECw greater than 10 dS / m.

The increase of salinity caused a dramatic decrease in marketable yield of wild rocket. Furthermore, yield quality worsened with salinity increase due to evident leaf clorosis leaf thickening.

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II. Rocket in the World

Present status and prospects for rocket cultivation in the Veneto region *

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Areas of production and economic importance in the Veneto Region

Rocket is a herbaceous plant indigenous to the Mediterranean basin and western Asia and was cultivated and also highly appreciated by the ancient Romans. In recent years, in various Mediterranean countries, the area dedicated to its cultivation has grown with ever more interest. In Italy, thanks to its geographical position and mild climatic conditions, wild rocket can be found in many regions throughout the year, though in varying quantities. In the Veneto region, which has a surface area of rocket cultivation of approximately 130-150 ha, as well as in Campania, Latium, Apulia, Lombardy, Abruzzi and Sardinia, cultivation in both open fields and protected areas is increasingly growing, playing an important role, particularly with regard to autumn to spring harvests.

In Veneto the most extensive areas are situated in the province of Venice, Verona and Padova (Fig. 1) totalling over 120 ha, which can be divided as follows: 10-20% open fields and 80-90% protected areas. Total production is around 2400 t, of which over 90% is obtained from protected cultivation. Considering an average of 2.5 harvests for *Eruca sativa* and 1.3 for *Diplotaxis* spp., average production per hectare is around 16-18 t/ha and 19-21 t/ha respectively. The final product, packaged in different ways, is then principally sent to regional markets (Padova, Verona, Treviso, Venice and Vicenza), neighbouring regions' markets (in cities like Trieste, Udine, Milan, Brescia, Bergamo and Bologna) or directly despatched to supermarket chains (for example ALI, COOP, GS, INTERSPAR, La Rinascente, PAM, STANDA), whereas only a small quantity is exported abroad to Switzerland and Germany.

Type of soil and preparation

In favourable climatic conditions, *E. sativa* can be cultivated in almost any type of soil, provided there are no difficulties in working or preparing the soil, whereas calcareous soils are preferable for *Diplotaxis* spp.

At the outset of cultivation, careful attention must be paid to soil preparation, particularly in the case of direct sowing, which is one of the most important factors in ensuring its success. Generally, in open fields with medium-clay soils, ploughing should be 30-35 cm deep and carried out prior to the date of sowing or transplanting, above all when residues of a previous planting have to be interred. Subsequently, correct procedures to break up the clods must be carried out (either through harrowing and/or pulverizing), which should, however, not be excessive so as not to cause powder on the surface, which indicates the formation of a successive surface crust. In sandy soils, however, mechanical spading or pulverizing at 25-30 cm is carried out. Such practices are also reserved for cultivations in protected environments, but at a less shallow depth (20-30 cm).

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* This article has been published in Italian in the journal Colture Protette, issue no. 4 (1997). Photo credit for the figures in the text: Enzo Massimo.

When necessary, these steps can also be followed by further refining procedures (Fig. 2).

Sometimes soil preparation ends with the formation of ridges of various width (1-3 m), on which sowing by scattering or in rows or even transplanting can be carried out. This option is generally chosen when the farmer intends to obtain many harvests. In all cases, the levelling of the entire surface or of the turf in order to guarantee a more uniform depth of the seed planting is deemed very important. To avoid compressing the soil excessively, the formation of ridges, the levelling of the surface and sowing are carried out in one single operation. It is worth mentioning that, in view of the precision needed in all of the above operations, they should not be carried out until soil conditions are correct. Sometimes, particularly in the summer, this can be achieved by irrigating the field before commencing the work which, at the same time, also facilitates weed control ('false sowing') and maintains the soil water level at an optimum level to ensure fast and uniform germination as well as rapid emergence.

Sowing, transplanting and cultivation density

With regard to leaf production, direct sowing is generally the technique with which cultivation begins, although transplanting should not be excluded, especially when cultivation takes place during the autumn-winter period for *Diplotaxis* spp.

To obtain the best production results, it is often advisable to avoid intersuccession which, if practised for successive cycles, can favour parasitic damage. It is also inappropriate for rocket cultivation to follow beans or other species belonging to the Apiaeae, Cucurbitaceae and Solanaceae (Bianco 1995), while positive results have been observed in the Veneto region with regard to tomato, pepper, cucumber and zucchini production cultivated after it. These advantages were noted in sandy soils with a verified presence of gall-producing nematodes. This nematode-control capacity of rocket seems to be better when soil was previously ploughed. The above information has been accepted by the farmers who pay increasing attention to interannual rotation of rocket-Solanaceae or rocket-Cucurbitaceae.

The germination level in rocket seed is close to 85% with a reduction of 15-20% when seed is obtained from September to October (Fig. 3). Summer cultivation is practised above all in the Romagna region (Cesena), and rocket is always transplanted or sown in rows with distances constantly being widened to the point of reaching 40 cm between rows with plants 20-30 cm within rows.

For *E. sativa* ('cultivated rocket') sowing is carried out throughout the year by scattering or in rows. With the first method, ridges must first be prepared and 5-8 g of seed / m^2 (1.7-2.0 g in weight per 1000 seeds) are planted at a depth of 0.5-1.0 cm. For winter cultivation, or when seed germination is below 80%, the amount of seed increases by 20-30%. Sometimes, particularly with soft soils, a light rolling is carried out either after or during sowing (Fig. 4). Sowing in rows 3 cm apart is normally carried out by machine (a seed drill) (Fig. 5) using slightly less seed than that used for sowing by scattering; in this case emergence is more uniform and simultaneous (Fig. 6). Germination occurs approximately 24 hours after sowing during summer with temperatures around 25°C, whereas it occurs 2-3 days later in colder periods, when temperatures drop below 10-15°C. At this point, the importance of speed of germination and emergence should be highlighted, as both are very closely linked to weed control because of the high initial seed density (2000-3000 plants / m^2).

Fig.1. Distribution of rocket in the Veneto region of Italy.

Fig. 2. Making the field ready for sowing.

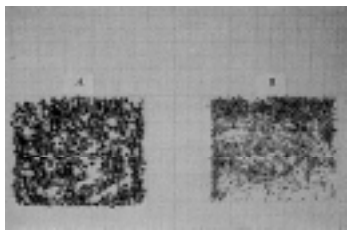

Fig. 3. Seeds of *Eruca sativa* (A) and *Diplotaxis* spp. (B).

Fig. 4 (right). Rolling/ flattening of soil.

Fig. 6. Even plant emergence in a field sown in rows.

Fig. 7. Transplanting cubes of compressed peat moved to simple soil.

Fig. 5 (left). Detail of a sowing machine.

Fig. 8. Transplanting cubes of compressed peat on mulched soil.

Fig. 9. Perforated hose sprinkler system.

Fig. 10. Irrigation bar in a protected environment/ greenhouse.

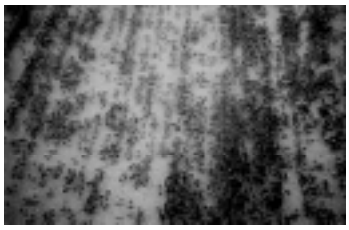

Fig. 11. Nonhomogenous plant emergence due to irregular water distribution/watering.

Fig. 12. Tunnel-shaped greenhouses covered with double EVA film.

Fig. 13. Plant Plane Hydroponics (PPH) system.

Fig. 14. Rock wool.

Fig. 15. Floating system (panels placed in the cultivation basin).

Fig. 16. *Eruca sativa* ready for harvesting.

Fig. 17. *Diplotaxis* spp. ready for harvesting.

Fig. 18. Detail of a sickle used in harvesting rocket.

Fig. 19. Harvesting operations.

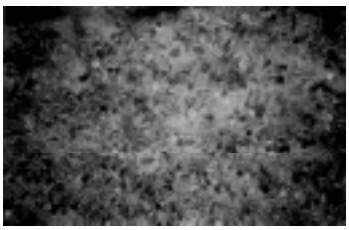

Fig. 20 (left). Cultivation after the first harvest.

Fig. 21 (right). Different leaf morphology in *Eruca sativa* from 1st to 2nd harvests (from left to right).

Fig. 22 (left). *Eruca sativa* ready for marketing.

Fig. 23 (right). *Diplotaxis* spp. ready for marketing.

Figs. 24-25-26. Various stages of the packaging process.

Fig. 27 (left). Damage caused by fungal attacks.

Fig. 28 (right). Damage caused by excessive watering in *Eruca sativa* cultivation.

Diplotaxis spp. ('wild rocket') is sown by scattering or in rows, particularly in greenhouses (protected environments) from April to September using the same methods as for the previous species. Of course, owing to the lighter seed weight (0.280-0.300 g per 1000 seeds), the quantity per surface unit is notably lower than the amount used for *E. sativa* and to obtain the same cultivation density, around 0.8 g / m^2 should be used. After sowing, the seeds are very rarely covered. Often, when scattered sowing is carried out by hand, flour and other material is mixed with fine sand and the seeds in order to make seeds visible on the soil and to improve homogeneity of distribution. Sowing in cubes of compressed peat (4 x 4 x 4 cm) or in alveolar containers of expanded polystyrene with 80-150 holes is always carried out in greenhouses to obtain seedlings for transplanting, in particular from autumn to late winter. In both cases the substrate is made up of equal parts of light and dark peat.

Eight to ten seeds per cube or alveolar container are used and are covered with a very thin layer of fine vermiculite and placed in germination greenhouses at a temperature of 20-22°C. In these conditions, germination takes place after approximately 2-3 days and transplanting by machine or more frequently by hand, either in open fields or in greenhouses, is carried out when plantlets have reached the stage of 3 true leaves (40-60 days after sowing) (Figs. 7, 8). Variable cultivation layouts from 20x10 cm to 20x15 cm are used for which 50-35 cubes / m^2 are needed and which offer the possibility of obtaining a cultivation density of 200-300 plants / m^2. In most cases, transplanting takes place into mulched soil with a 0.05 mm thick black or white film of polyethylene. With irrigation in sandy soils, a sprinkler providing 5-6 L m^{-1} $hour^{-1}$ of water or nutritive solution is placed under the mulching film in alternate rows (Fig. 9). Transplanting has certain obvious

advantages such as shortening the productive cycle, enhancing harvest precocity, improving the cleanliness and quality of product, as well as reducing problems associated with weed control.

This practice is limited by the rather high cost of the cubes of compressed peat (40-50 It. lire each, equivalent to US$ 0.034) and so, to reduce the costs, farmers tend to use the alveolar containers that do not, however, allow the same precocity in harvesting and the same efficient use of the cultivation environment.

Fertilization

Considering rocket's short biological cycle of leaf production and the speed with which nitrogen accumulates in the plant, it is now generally confirmed that it is not advisable to use more than 100 kg/ha of nitrogen in various forms (Bianco 1995). Preliminary results obtained from an experiment conducted in the Veneto region on a medium-muddy soil (Baggio and Pimpini 1995) confirmed the influence of nitrogen (0, 100, 200 and 300 kg/ha of N) in increasing production of the species examined, sown in an open field in three different periods (9 May, 15 June, 1 August) with the most interesting results obtained in response to 100 kg of nitrogen spread in the same way as ammonium nitrate. Similar results were also obtained in research conducted in southern Italy (Apulia region) with the same levels of nitrogen. When working in a protected environment and on a sandy soil, when several harvests are foreseen, the doses can even be doubled. With regard to rocket's phosphorus and potassium requirements, only approximate data have been gathered and it is widely believed that modest doses of both elements should be used. In Israel, in leaf breeding cultivations, 100 and 50 kg/ha respectively are used (Yaniv 1995), while for seed cultivation Jaugir *et al.* (1990) observed no increase in production when increasing doses of P_2O_5 from 20 to 60 kg/ha. Some Italian farmers recommend as optimum 50-60 kg/ha of P_2O_5 and 100-120 kg/ha of K_2O in sandy soils. Farmers in the region tend to follow the information provided in the literature, even though their practices vary according to the type of soils with which they work, which in different areas of cultivation can differ considerably [soils go from sandy (95-98% sand) in coastal areas to heavy soils (20-40% clay) in inland areas].

The above refers to the traditional distribution of solid chemical fertilizers and sometimes even organic ones. In recent years, however, fertigation (fertilization + irrigation) is becoming widespread among the more innovative farmers. For this procedure, particular attention is focused on improving the availability of nutritive elements, and the bicarbonates present in the water used are nearly always neutralized by adding nitric acid or phosphorus. The solution is made up of levels of EC varying between 1500 and 2500 nS/cm and pH 6.0-6.5, starting from water with an EC content between 350 and 1000 nS/cm. The relationship between the three principal macroelements varies according to the cultivation phases to which they belong and are as follows: 1.5-0.5-1.0 in the period leading from sowing or transplanting to the first harvests and 2.0-0.5-1.5 for successive regrowth. In this case, sometimes fertigation can be carried out with a solution consisting only of calcium nitrate (3-4 g/L).

Irrigation

Even though rocket adapts well to cultivation in arid soils, to improve the quality of production (for example, obtaining non-fibrous leaves), soil with a good availability of water is essential. Such a requirement is supported by numerous results obtained in irrigation tests carried out by various authors, particularly on

cultivations from seed [viz. studies on water with different saline concentrations, on soils found in conditions where water was increasingly more available, and with varying degrees of fertilization (see Bianco 1995)].

Having defined farming methods and requirements, it then follows that the choice of irrigation system must ensure a uniform distribution of water and, above all, must not cause leaf crushing or staining. The most widely used irrigation mechanisms are those with medium sprinkling capacity (120 L/hr) and medium range (3-5 m). To improve evenness of distribution, in some companies specialized in rocket cultivation and particularly where soils are heavy, low-capacity irrigation bars (10-15 mm/hr) on trolleys (Fig. 10) are increasingly being used. In this case, besides irrigation and fertigation, these structures can also be used for carrying out antiparasitic treatment.

It has been observed that rocket requires frequent watering to the point of complete immersion of the plantlets (Fig. 11). Most of the watering will be carried out immediately after sowing. In soils where a superficial crust is easily formed, it is best to decrease the volume of water and increase the frequency of watering up to full immersion. In the next phase, irrigation by sprinkling can cause serious damage to cultivation since, with the high plant densities used, the plants grow with very tender leaves that, having been wet for long periods, are easily prone to disease attacks, in particular to downy mildew. Considering that the ground is wet enough from previous watering, that the plant itself does not require large quantities of water and that the cycle between emergence and the first harvest is quite short in the period that goes from the complete spread of cotyledons and the first cutting, only one watering may be necessary, often just to ensure a supply of nutrients. Careful observation of the cultivation is an essential point of reference in judging whether further irrigation is necessary. Where there is a lack of watering during cultivation, plants with stunted growth, dark green colour and noticeable thickening of the leaves which emit a rather intense aroma are noted. Between one cutting and another fertigation with a watering volume equal to 20-30 m^3/ha is appropriate.

It should be remembered that rocket is less tolerant of excessive watering than of drought. However, it is always useful to pay particular attention to the latter, since as with other types of stress, drought may accelerate the flowering and jeopardize the good results of the whole cultivation.

Weed control

At present, only a small number of registered active herbicides for rocket are available, which do not, however, provide a wide range of action and a good degree of selectivity. Therefore, the fight against weeds during cultivation must be carried out by hand or by chemical, physical and/or agronomic means (if for prevention). In fact, the problem is particularly marked in the case of *Diplotaxis* spp. which, in unfavourable climatic conditions, has a fairly long germination emergence and growth period and thus allows weeds to take over the cultivation. This aspect is, however, less important for *E. sativa* since, as previously mentioned, it covers the soil very quickly and often the weeds are unable to grow. However, even in the cultivation of these species, above all when carrying out subsequent harvests between one regrowth and another, the presence of *Stellaria media* L., *Veronica* spp. and other weeds cannot be excluded during winter, while in the summer and with cultivation sown in rows, there is a fairly intense presence of *Portulaca oleracea* L., *Chenopodium album* L., *Solanum nigrum* L. and *Echinochloa crus-galli* (L.) Beauv.

Methods currently adopted for weed control range from 'false sowing' to the presence of mulch in the case of transplanted cultivations. It should always be borne in mind, however, that in the majority of cases, soils that are destined for rocket cultivation do receive different types of disinfestation before planting (e.g. by steam, pyrodisinfestation, Dazomet, methyl bromide) which, until now, have provided satisfactory results.

Cultivations in protected environments and on banks

As mentioned above, the majority of cultivations in the region are kept in protected environments throughout the year. The most widely used protective measures in 85-90% of cases are tunnel-shaped greenhouses with a volume of 1.5-4.0 m^3/m^2 per unit, covered with plastic material (Fig. 12). Occasionally, greenhouses with a volume of more than 4.0 m^3/m^2 with a glass covering can be seen. Sometimes tunnel-shaped greenhouses of medium to high volume and always those made of metal and glass are equipped with heating systems with warm-air generators, the air being piped through plastic tubes capable of guaranteeing a difference of 15-20°C between the outside and inside. Such practices are necessary to speed up the productive cycles during colder periods (end of autumn-beginning of spring), considering that optimum thermic values are reached at 22-24°C during the day and 16-18°C at night with an RH of less than 60%. During these periods, a cover weighing approximately 17-20 g/m^2 is spread over the cultivation to accelerate regrowth immediately after harvesting.

Covering materials used for tunnel-shaped greenhouses are made of polyethylene, polyvinyl chloride, ethylene vinyl acetate 0.20 mm thick, laid either singly or in double layers. In the latter case, room temperature or warm pressurized air is emitted between the two layers of plastic film which are placed 5-15 cm apart, thus creating an insulation layer that allows a better greenhouse effect, the formation of condensation on the inside layer and therefore making RH control easier. However, when the covering material is glass, and as greenhouses are not meant solely for rocket cultivation but are often also used for floricultural species, the type of covering material can also be slightly different (e.g. Hortiplus, U-Glass, double-layered). Occasionally, covers made of semi-rigid layers of polimetacrilate, polyester, PVC or polycarbonate are used.

The choice of greenhouse cover must be made paying particular attention to light characteristics insofar as they play an important role in the quality of production. In the case of protected cultivations, particularly during months of the year with poor natural light, episodes of aetiolation are frequent which in rocket manifests itself in the form of thinner surface leaves, light green colouring with elongated petiole, poor intensity of aroma, high nitrate content and poor shelf life.

Moreover, cultivation results are closely linked to a careful management of climatic parameters inside the greenhouse. To a certain extent, these can be controlled by openings which, besides temperature, help to avoid excessive RH values, which is particularly feared by producers of *E. sativa,* as the plant's conditions often favour severe attacks by downy mildew.

Fungal attacks (e.g. *Pithium* spp., *Phoma* spp., *Fusarium* spp., *Sclerotinia* spp. and others) also cause concern among rocket producers and, even moreso for those who only specialize in 'leafy vegetables' (e.g. lettuce, chicory and chard; this is a typical Italian production which consists of leafy vegetables harvested with scissors or by sickle) as they find themselves in a situation where large yearly successions are not foreseeable. For this and other reasons, research is being carried out to set up out-of-soil cultivation techniques, to allow for better planning of fast productive cycles,

typical of this type of production system, and also marketing. Moreover, out-of-soil cultivation leaves scope for improving the quality of production (e.g. aroma, colour and nitrate content), thanks to better management of the replenishment of nutrients.

At the research station Centro Sperimentale Ortofloricolo Regionale Po di Tramontana in Rosolina (Rovigo province, Veneto region) and in horticultural pilot companies, certain systems have been set up to investigate the most reliable cultivation systems with attention focused on prospects for mechanization.

The systems on which most attention is being focused are Plant Plane Hydroponics (PPH), Rock wool, Aeroponics and Floating system.

The following is a summary of information on these systems:

PPH: This is made up of a 3-5 mm thick layer of polyethylene of ca 100 g/m^2 in weight, placed on a plastic film and put on an inclined board on the ground (Fig. 13) or on suspended structures. Nutritive solution is distributed through a plastic handle with holes positioned in the uppermost part.

Rockwool: The substratum on which the plant grows its hypogeal part is a rock wool carpet 8 mm thick and 400-500 g/m^2 in weight, placed on supports directly on the ground or raised up (Fig. 14). The nutritive solution is spread with a 'flex and reflex' system.

Aeroponics: Support structures have to be built in steel or other material on which the polyethylene material weighing between 150-400 g/m^2 is fixed. Once ready for cultivation, they are used in two different ways. The first consists of placing it in a horizontal position over basins dug out of the ground or built up on them with cheap and easily adaptable material (e.g. boards recycled from the building industry). The internal part of the basins should always be insulated with plastic film. The second method consists of fixing together two structures (normally along the longest side) creating and preparing a triangular section to place on the support bench or on soil that has been carefully levelled off and covered with plastic film where it comes into contact with the structure. The nutritive solution is spread through a sprinkling system aimed directly at the root system.

Floating system: The system is essentially made up of expanded polystyrene panels or other lightweight water-repellent material, as containers for the substrate and to support the plant, and of cultivation basins 0.25-0.3 m deep for replenishment of water and nutritive solution. Conic holes are made in the 20-30 mm thick panel, of which the widest part of the holes (10 mm) are the side of the sheet that will be exposed to the light, and the narrowest (1 mm) are on the opposite side of the sheet, which will be in contact with the liquid. The holes, which cover the entire surface of the panels, are made 3 cm apart and are filled with various substrates (e.g. perlite, vermiculite, flakes of rock wool, etc.) on which sowing will take place.

This is followed by cultivation carried out in two possible ways. The first consists of floating the panel directly on the nutritive solution with which the cultivation basins have been filled. The second method consists of first sending the panel to germination cells, in order to accelerate this phase, and then after 24-36 hours, as soon as the rootlet has released itself into the sublayer, the panel is transferred to the cultivation basins (Fig. 15). It is obvious that the second option is most often carried out during periods in which temperatures do not reach the optimum level required for this important and delicate phase.

Knowledge acquired so far allows some conclusions on the above-mentioned systems to be drawn, which will, however, only receive a final assessment through future tests. It has been noted that with regard to the first three systems, only the rock wool seems to be particularly interesting, insofar as it could represent a new way of selling rocket which, having been sold in the market with its cultivation support, can be considered a 'live' product. Until now, the other two methods have instead proved to expose cultivation to excessive risks (for example, for even very brief periods (15 minutes) a failure in the nutritive solution's distribution mechanism can occur owing to only a slight availability of water to the system).

With regard to the floating system, as well as being that which currently gives the best production results from a quantitative and qualitative point of view (as it is a closed system), it also guarantees that the environment will be respected. Moreover, it is not difficult to run and may soon become automated or mechanized. Its functional characteristics show an easy adaptability to different climatic situations. In fact, the thermal conditions of the nutritive solution are less prone to rapid and consistent changes as is often the case with the soil. This aspect accelerates production by 7-10 days as well as causing an interesting reduction in the productive cycles.

Comparisons have been made of the effect of various nutritive solutions on the quality of taste, aroma, colour and nitrate content of rocket leaves. First results showed that the taste, aroma and intensity of leaf colour are closely linked to EC in the nutritive solution and it seemed that, with similar EC values, quality parameters can be subject to variation according to the type of ion that defines it. Moreover, different NO_3/NH_4 ratios, as well as the presence of chlorides and sulphates, can influence the reduction of nitrate concentration in the edible parts, as previously observed with lettuce by Malorgio *et al.* (1995).

Until now, nutritive solutions with a pH varying between 5.5 and 6.0 and EC between 1300 and 6000 nS/cm, have been used and it has been confirmed that, during a very reduced cultivation cycle, no correction of the initial values is necessary. This is only useful after the first harvest, when the level of the solution in the cultivation tanks needs to be replenished for subsequent harvests. After having corrected the pH and EC, the actual residue of the initial solution was used again for a further 10 successive cycles without any negative effects on the plant.

For all closed systems, the use of a sand filter is advisable to withhold biotic or abiotic impurities present in the nutritive solution, at least at the end of each cycle.

Harvesting, packaging and conservation of product

The harvesting of leaves can begin 20-60 days after emergence or transplanting according to the species used, the period, environment and market destination (Figs. 16, 17). Tests conducted by Haag and Minami (1988) clearly highlighted the appropriateness of harvesting no later than 34 days after emergence.

Taking advantage of the species' ability to regrow, after the first harvest it is possible to carry out a further 4-5 harvests at intervals of 10-20 days for *Eruca* and 1-3 times at 15-30 day intervals for *Diplotaxis*. Bianco (1995) suggests not continuing cultivation beyond the third harvest as a general rule, but the different pedoclimatic conditions may make prolonging the productive cycle economically viable. Combined production weight can vary between 15 and 25 t/ha according to the number of harvests made; as a good guess, the values given (Fig. 29) seem reliable.

Harvesting is mainly carried out by hand with the aid of a knife or sickle to which a collecting plate or other tool around 10 cm high is applied, in order to collect the leaves at the back of the blade (Fig. 18). This helps to facilitate the

subsequent packaging of the leaves (Fig. 19). Mechanical sickle bars which can speed up the process slightly are also available, but the leaf tissue is subject to slight crushing and quick oxidation at the cutting area, thus jeopardizing the quality of the product and its preservation. These negative aspects have so far prevented the spread of this interesting harvesting procedure. In the case of both mechanical and manual harvesting with a sickle, careful soil preparation before beginning cultivation must be carried out paying particular attention to eliminate even the slightest depression in the ground. During the first harvest, the leaves must be cut at least 0.5 cm above the cotyledons to avoid damaging the vegetative apex, thus allowing a quick and abundant regrowth (Fig. 20).

Leaf morphology of *E. sativa* varies greatly between harvests. In fact, at every regrowth, leaves tend to take on an increasingly lobate form (Fig. 21). The length varies between 5 and 8 cm at the first harvest and from 8 to 15 cm in subsequent harvests. As mentioned above, the number of harvests varies greatly; however, producers in the Veneto region are normally only able to carry out two harvests from summer cultivations because of the ease with which the plants, which are stimulated by the long period of daylight, rapidly show their flower racemes. During this period of cultivation, regrowth of new leaves occurs so quickly that within 7-10 days harvest can again take place. When crops are sown in autumn, 5-6 harvests can be made as the productive cycle carries on well into spring.

Diplotaxis spp. regrowth is far less rapid and intense and does not, therefore, allow more than 1 or 2 cuts to be made as the plants have a tendency to flower quickly. This occurs mainly when planting takes place during the spring-summer by direct sowing seeing as, in the case of transplanting in autumn-winter, it is possible to make up to 4 harvests. In all the harvests, the leaves must always be longer than 12-15 cm.

As far as quality characteristics of production are concerned, it is appropriate to mention that some markets prefer subsequent cuts to the first as the leaves are more consistent, aroma is more intense and the product preserves better. It also appears that leaves obtained from regrowth tend to improve in quality as cultivation density is reduced. In fact, after every harvest, when raking the soil to clean away residual leaves, some plants are inevitably uprooted and their removal favours regrowth. This modest thinning is probably responsible for the improved organoleptic characteristics of the leaves. In other markets, however, this situation may turn out to be a negative aspect, as only slightly fibrous, tender and crisp leaves with light aroma are preferred. The product depreciates when the small leaf petioles are excessively long compared with the leaf blades. Another problem encountered after the first harvest, in subsequent crops, is the production of leaves bearing petiole residues, when one would like to obtain a product only largely made up of blades. The petioles remain on the plant and can be a receptacle for plant diseases during the productive cycle and should, in any case, always be removed after harvesting, before the rocket blades are placed on the market.

Results of tests carried out by IRIPA in Venice have indicated that the best time for harvesting is the afternoon after the plant has been exposed to a fairly long period of sunlight. In fact, in this case, the leaves showed a much lower concentration of nitrates than those harvested in the morning. This is hardly surprising and, if anything, concurs with results reported by Malorgio *et al.* (1995) regarding lettuce grown in Nutrient Film Technique (NFT).

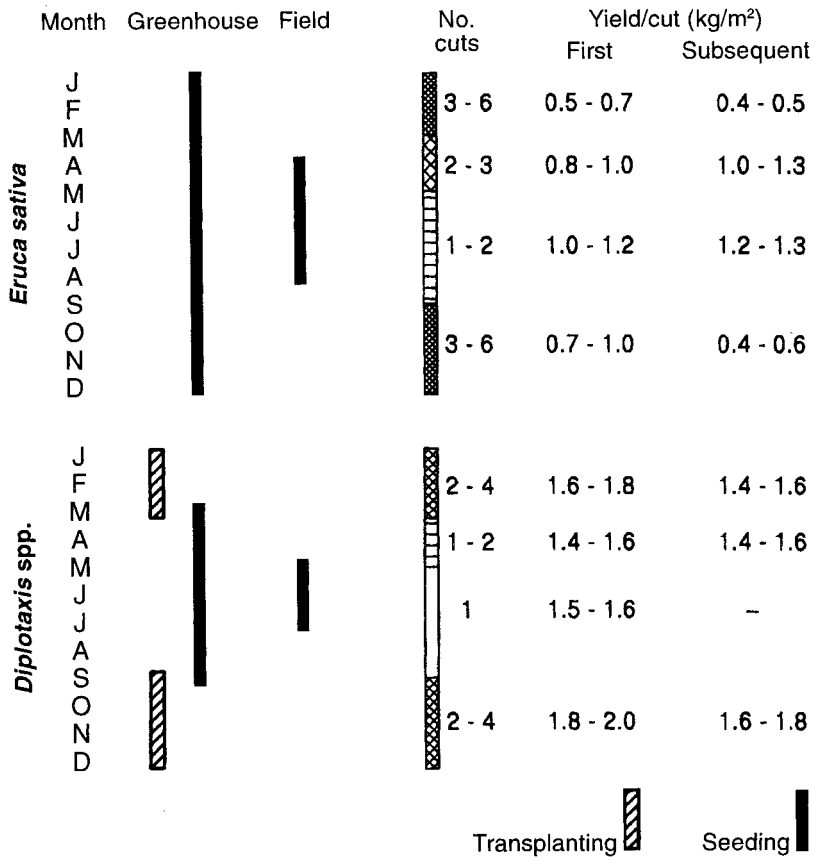

Fig. 29. Variation in yields of *Eruca sativa* and *Diplotaxis* spp. under different growing conditions.

Packaging takes place in different ways. *Eruca sativa* is marketed in rigid plastic packages 30x50x10 cm or 30x40x25 cm (Fig. 22). The first packages are able to contain, in a single layer, 1.5-2.0 kg of leaves placed 'upright', the second size packages containing 2.5-3.0 kg of leaves 'in bulk'; the placing of leaves in the containers is carried out directly in the field immediately after harvesting. *Diplotaxis* spp., however, because of their good preservation qualities and their resistance to feared diseases like downy mildew, are placed in 10-12 kg cases immediately after cutting (Fig. 23). Packaging is carried out later in appropriate premises with an automatic system capable of filling clear trays or bags of polyethylene with 100-150 g each (Figs. 24, 25, 26). Rocket packaged in this way is destined exclusively for supermarket distribution. Finally, it should be mentioned that this particular species is still sold in bunches of plants or leaves of 100-150 g in weight.

Post-harvest preservation criteria have not yet been backed by research results. It should be said that these procedures are carried out in an empirical way using knowledge available for similar types of vegetables, with particular reference to the '4th generation vegetables' which, thanks to their particular way of being packaged allow the product to be preserved quite effectively for up to 5 days after harvesting (Caponigro *et al.* 1996). For shorter periods and by packaging the product in a more traditional way, satisfactory results can be obtained by keeping the leaves in environments at 4-6°C and 60-70% RH.

Diseases and pests

The greatest worry is undoubtedly caused by fungal attacks which damage both epigeal and hypogeal parts of the plant, and whose effects are even more drastic when production takes place in a protected environment, where the temperature and RH often favour their growth.

In the cotyledon leaf phase, plantlets can be killed by *Fusarium* spp., *Pythium* spp. and *Rhizoctonia* spp. on which secondary rot can set in caused by *Botrytis* and/or *Sclerotinia* spp. (Fig. 27). *Alternaria* spp. can also attack leaf blades, petioles and hypocotyls. The most feared biotic agent of vegetable origin is without doubt peronospora (*Phytophthora brassicae* L.). These phycomycetes attack blades and small leaves causing more or less widespread discolouration, first yellowish and very quickly turning brown. In these parts, where there is a high level of humidity, a potentially whitish mycelium appears. This grows best in temperatures of 10-16°C and, when the leaves are wet, the cycle is concluded rapidly and the cultivation is lost within 1-2 days. In this regard, it is appropriate to mention that even in the case of slight damage, the product depreciates considerably. It should also be remembered that *E. sativa* is very sensitive to this disease, unlike *Diplotaxis* spp. which is fairly resistant to it.

In addition to these pathogens, attacks on leaves by some microlepidopters and aphids also have been reported, though so far causing limited damage.

Furthermore, over the last 2-3 years, a steady increase in the presence of *Liriomyza* spp. (phylominator fly) has been noted during the summer. These attacks could cause serious concern to the growers if not carefully controlled.

Finally, it is appropriate to mention that plants exposed to excessive watering in conjunction with low temperatures (4-5°C) tend to have reddish leaves, whereas, once exposed to higher temperatures, these turn yellow and this is accompanied by reduced growth, loss of aroma and preservation qualities (Fig. 28).

Conclusion

Examination of the situation regarding rocket cultivation in the Veneto region has shown that in recent years the species has played an ever-increasing role in the horticultural sector, to the point of becoming an independent activity within the sector. The continuous increase in the surface area occupied by rocket has led to an inevitable dynamism of the entire production/marketing network linked to the species. New directions have been taken in the choice of production techniques, considerable agronomic evolution has been reported, wider commercial market distribution has been attained and many possible new uses of the product have been identified to the extent that the conviction that the crop satisfies only certain market niches seems increasingly unfounded. As briefly outlined in this paper, a certain amount of enthusiastic expectation from the farmers seems justified. However, some considerations on the uncertainties of goals attainable in the near future also seem necessary. For example, because the majority of cultivation is carried out in greenhouses owing to an unfavourable climate, more detailed information should be made available with regard to cubic space, covering materials, ventilation openings and irrigation (with added nutrients/chemicals) corresponding to the total cultivation area employed.

From a strictly agronomic point of view, in view of the species' ability to adapt well, it can be confirmed that soil conditions do not generally cause problems. Most concerns lie in choosing the right variety of rocket, in view of the need for highly selective genetic material with regard to quality and quantity of production,

preservation, and resistance to the most common diseases, as well as being able to give consistent results in order to constantly satisfy market demand.

There is also a lack of results from appropriate research to dispel the many doubts regarding fertilization procedures for both open-air cultivations and protected cultivations. In this regard, besides the influence of nitrogen on the accumulation of nitrates in the edible parts, it would also be interesting to be able to specify the need for phosphorus and potassium as well as that of certain important microelements.

Irrigation has proved to be an efficient way of improving production quality and quantity, thus speeding up the production cycles. In this regard, it must be stressed that on the more efficient farms, low-capacity irrigation systems have already been installed for which the time of use and amount of watering must be identified, according to the needs of the plant.

Careful attention also must be paid to the appropriate use of a limited amount of plant protection products so as to offer a good-quality final product from a marketing and hygiene point of view. A very interesting and recent practice involves out-of-soil cultivation techniques as they guarantee good disease control, they produce a clean, homogeneous, pest-free product that is easy to manage and, thanks to good management of the nutritive solution, also is better from an organoleptic point of view. It is therefore very relevant to carry out specific research on this newly developed sector aimed specifically at addressing the many unsolved problems related to rocket cultivation.

Very special attention must be paid to harvesting methods, the packaging of the product according to the different market requests, and to preservation. Those directly concerned must pay better attention to studying mechanization throughout the various stages of cultivation, particularly to harvesting. At present, until better solutions have been found, it would be advisable to begin studies aimed at adapting the machinery already present for other types of cultivation that could also prove to be suitable for this particular type of plant. This would allow work to be carried out more quickly and precisely, to reduce farmers' labour and cut production costs, thus spreading cultivation over ever-wider areas. These aspects are of particular importance for out-of-soil cultivations, insofar as complete mechanization of the productive cycle would bring about great advantages that can be easily imagined.

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Status of rocket germplasm in India: research accomplishments and priorities

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Introduction

Rocket (*Eruca sativa* Mill), a member of the rapeseed and mustard group, is a minor oilseed crop of India. Its inedible, pungent oil, mainly used for industrial purposes, has a characteristic odour. Commonly known as 'taramira', it is a winter crop ('rabi') of drier areas in north and northwest India, grown either as a pure or mixed crop with other cereals, oilseeds and pulses. It is endowed with suitability to marginal lands having poor soil fertility, and is drought resistant, tolerant of biotic and abiotic stresses and has a fast-penetrating root system for moisture absorption from deeper soil profiles.

This allows its successful cultivation in uncongenial and hostile environments. Owing to its wider range in the time of sowing, it is the only alternative crop which if grown during the years of severe drought and late winter rains, would thrive and bear fairly good yield with ensured returns.

Rocket-seed oil is mainly used in industries as lubricant, soap-making, illuminating agent, in massaging, in medicines, for adulterating rapeseed/mustard oil and in cooking as salad oil. The oil cake is a source of cattle feed and manure. The young plants are used as salad, vegetable and as green fodder. Tender leaves are stimulant, stomachic, diuretic and antiscorbutic. Seeds are vesicant (Anonymous 1952).

Areas and production

In India, the chief rocket-growing states are Rajasthan, Haryana, Punjab, Madhya Pradesh and Uttar Pradesh. Rajasthan has the highest area and production of rocket. Cultivation of rocket in Rajasthan alone during 1993-94 accounted for more than 1.6 lakh/ha mainly under rain-fed conditions with a total production of 95 632 t (Anonymous 1994). The northwest region of the state constitutes more than 56% of the area under cultivation and contributes more than 52% of total production. Productivity of the crop is highly variable, from as low as 89 kg/ha in Bikaner district to as high as 1527 kg/ha in Dholpur district (Table 1).

Research accomplishments

Research priorities go hand in hand with demand. Since rocket lacks demand as an edible oil crop in India, so does its crop improvement programme/exploitation, irrespective of the fact that it offers good production potential in drier regions. The only variety of rocket released/identified is through direct introduction/selection (Ranga Rao and Ramachandram 1988).

Research accomplishments to date on various aspects in the area of genetic resources, crop improvement and management are summarized in the following.

Table 1. Area and seed production of rocket in different regions/districts of Rajasthan, India during 1993-94 (source: Anonymous 1994)

Region	District	Total crop area (ha)	Irrigated area (ha)	Avg. production (kg/ha)	Total yield (t/ha)
Bharatpur		15655	145	973	15231
	Alwar	2281	17	490	1118
	Bharatpur	3623	37	821	2973
	Dholpur	2537	40	1527	3875
	Swaimadhopur	7214	51	1007	7265
Bhilwara		5034	699	386	1943
	Bhilwara	2082	390	358	953
	Chittorgarh	2573	252	313	806
	Rajsamand	379	47	486	184
Jaipur		26927	1048	615	16553
	Ajmer	10981	602	638	7002
	Dausa	3432	32	885	3036
	Jaipur	10661	369	519	5538
	Jhunjhunu	309	25	534	165
	Sikar	1544	80	526	812
Jodhpur		42025	2888	639	26874
	Barmer	193	89	394	76
	Jaisalmer	410	155	263	108
	Jalore	1159	797	506	586
	Jodhpur	12777	115	802	10244
	Nagour	22265	1274	472	10501
	Pali	5136	378	1037	5325
	Sirohi	85	80	400	34
Kota		21654	265	512	11090
	Baran	530	16	596	316
	Bundi	2124	38	566	1202
	Jhalawad	30	4	100	3
	Kota	1424	22	505	719
Tonk		17546	185	504	8850
SriGanganagar		48449	1822	477	23101
	Bikaner	2528	361	89	226
	Churu	2046	14	282	576
	SriGanganagar	43875	1447	508	22299
Udaipur		1137	182	739	840
	Banswara	82	1	378	31
	Dungerpur	565	89	968	547
	Udaipur	490	92	535	262
		160881	7049	594	95632

Germplasm collection

Germplasm is the most valuable and essential raw material for any crop improvement programme. A wider genetic base thus assumes priority in breeding research aimed at developing new varieties with desired traits. This diversity encompasses native landraces, local selections, elite cultivars, promising exotic introductions and wild relatives of crops with specified traits.

The National Bureau of Plant Genetic Resources (NBPGR), New Delhi, has been entrusted with responsibility for the collection of germplasm through organizing region-specific crop-specific/multicrop explorations. However, not a single crop-specific exploration has been undertaken so far by NBPGR for rocket germplasm.

Nevertheless, germplasm has been collected from different parts of India during the explorations carried out either for the collection of germplasm of rapeseed and mustard or for other winter crops (Anonymous 1987a, 1988a, 1989-90; Kumar 1988; Chandel and Bhandari 1989). Rocket exhibited rich genetic variation in plant type, branching pattern, pigmentation, fruit habit, pod size, shape, grain size and colour (Chandel and Bhandari 1989). However, crop / region-specific exploration(s) for the collection of rocket germplasm have been undertaken at SKN college of Agriculture (Rajasthan Agricultural University), Jobner under an Indo-Swedish Project on Rapeseed and Mustard started in 1979 and later on under the All India Coordinated Research Project on Oilseeds - Taramira Unit commencing from 1987 (Sharma *et al.* 1991). In total, 650 collections of rocket germplasm have been made from different parts of India (Table 2). Variability for various qualitative and quantitative traits was observed in the collected germplasm. Information on the present status of these collections is, however, not available at present and there is a need to ensure that whatever collections of rocket germplasm have been made so far are properly evaluated, documented, conserved and available for utilization. If some of the collections have been lost in the process, efforts are to be made to recollect them.

In addition to locally found rocket diversity, three exotic accessions from Hungary [introduced in 1984 by NBPGR (Kumar 1988)] are also available.

Evaluation and maintenance

To enhance crop use, germplasm collected / introduced from different sources is usually evaluated in the field for various qualitative and quantitative traits. To make use of available germplasm in crop improvement programmes, it is necessary that germplasm traits are known on the basis of 2-3 years of evaluation at one or preferably more locations for a set of heritable characteristics. Accessions with desired traits so identified are then utilized as donor parents in developing new varieties (Rana and Singh 1992).

At Jobner, the rocket germplasm collected under an Indo-Swedish Project was evaluated for seed yield over 4 years (1979-83) (Sharma *et al.* 1991). Variability for various traits including seed yield was noted (Table 3). A number of accessions were identified as superior to the National check (T-27). Again, during the 1985-86 period, an evaluation of 399 new collections (the source of collection is not mentioned) indicated RTM-126 to be the highest yielder, followed by RTM-2, -7, -9, -13, -33, -75, -77, -95, -101, -108, -110, -115 and -118 which were superior to the National check (T-27). None of the collection was found to be free from important diseases such as downy mildew and Fusarium wilt, though a good number of these was tolerant to both (Table 4).

Because of the self-incompatibility of rocket, its germplasm maintenance is rather difficult. The collections are generally maintained by sib-mating, bud pollination and close inbreeding. Population improvement work on rocket was initiated at Jobner to preserve and enhance crop variability. These studies led to the constitution of two composite varieties through the random mating method using entries of a polycross (Sharma *et al.* 1991).

The two varieties are the following:

- JOB-TC-I: this was synthesized through random pollination in a polycross block among the seven selected progenies, viz. RTM-10-4, -9-11, -23-1, -23-4, -30-1, -29-14 and LDH-2-10. The performance of the composite was at par with the National check (T-27), having an oil content of 38.1%.

Table 2. Collection of rocket germplasm in India

Organization	Year of collection	Areas explored	No. of samples gathered
SKN College of Agriculture (RAU), Jobner	1980	Parts of Rajasthan	516
NBPGR	1982	Northern-western and central India	64
	1983	Jammu region, Madhya Pradesh, Kachchh region in Gujarat and Pune region	10
	1984	Semi-arid regions of Haryana	26
	1986	Northeastern Rajasthan	16
	1987	Southern Rajasthan	1
	1988	Southeast Rajasthan	1
	1989-90	Southeast and western Rajasthan	16
			650

Table 3. Variability in some agrobotanical traits in rocket germplasm evaluated at Jobner, Rajasthan (source: Sharma *et al.* 1991)

Trait	Range of variation	CV
50% flowering (days)	50.0 - 55.7	3.4
Maturity (days)	118.7 - 121.3	1.6
Plant height (cm)	49.4 - 84.0	16.5
No. of primary branches/plant	3.8 - 6.6	19.2
No. of secondary branches/plant	3.4 - 16.2	33.0
Pods/plant	59.2 - 181.8	22.8
Pod length (cm)	1.6 - 2.3	9.3
Seeds/pod	13.1 - 26.9	23.7
Seed yield/plant (g)	2.6 - 9.2	33.6
Oil content in the seed (%)	32.2 - 36.4	3.2

Table 4. Rocket accessions tolerant to downy mildew and *Fusarium* wilt as observed at Jobner, Rajasthan (source: Sharma *et al.* 1991)

Disease	Accessions
Downy mildew	RTM-2(I), -110, -127, -216, -228, -355, -360, -397 and -466
Fusarium wilt	JOB-TC-I, JOB-TC-II, RTM-2(I), -101, -112, -126, -360, -397, -461, -465, -466, -521, -522, -523, T-27 and TMH-52

- JOB-TC-II : the synthesis was initiated in the winter of 1980-81 during which 180 open-pollinated single plants were selected from 69 germplasm accessions. The progenies of these single plants were evaluated in the subsequent season and, out of these, 5 best-performing ones, viz. RTM-46-1, -82-3, -84-2, -99-2, and -100-3 were selected on the basis of their general performance, growth, fruit bearing, pod shape and size. The remnant seeds of these selected progenies were harvested and composited. Some promising accessions, viz. RTM-314 (a selection from Sri Ganganagar, Rajasthan), RTM-521 (a selection from the progeny of cross between T-27 and RTM-2), RTM-522 (a selection from the progeny of the cross between RTM-2 and -1) and RTM-523 (a selection from the progeny of the cross between T-27 and RTM-1) were developed also at Jobner (Sharma *et al.* 1991). A comparative performance of these two composite varieties with that of the National check (T-27) is given in Table 5.

Table 5. Performance of rocket composites at Jobner, Rajasthan (average of 3 years) (source: Sharma *et al.* 1991)

Variety	Maturity (days)	Seed yield (kg/ha)	Downy mildew incidence (%)
JOB - TC-I	146.0	823.0	45.4
JOB - TC-II	143.3	940.7	56.1
T-27 (check	151.5	824.8	50.2

Kumar (1988) reported that 427 accessions of rocket are being maintained by the Germplasm Unit of the Centre of All India Coordinated Research Project on Oilseeds. Several accessions of this collection are likely to be duplicates of material available at various cooperating research centres, where only working collections are kept. As a whole, 903 working collections in 1985-86 compared with 314 and 198 in 1983-84 and 1984-85, respectively, were maintained by cooperating centres.

RTM-439 recorded minimum days for maturity while the exotic accessions (EC 159505 and 159506) were the latest to mature but are high yielding. Accessions RTM-51 and -327 possessed maximum primary branches (15 and 18 respectively) and RTM-31, -92 and -327 possessed maximum secondary branches. The accessions RTM-78 and RTM were identified as the highest yielders (22.3 and 18 g, respectively) (Kumar 1988).

At Hisar, evaluation of 270 accessions of rocket led to the identification of several promising accessions (Anonymous 1991). On the basis of comparative performance of various accessions with the National check (T-27), 10 best-performing accessions were identified for each of the 12 traits observed (Table 6).

Table 6. Identification of 10 promising rocket accessions each for some agrobotanical traits at Hisar (source: Anonymous 1991)

Trait	Check (T-27)	Range in 10 promising accessions	Best promising accession
First flowering (days)	51	49 - 50	RTM-418
50% flowering (days)	63	59 - 60	RTM-448
Maturity (days)	141	137 - 140	RTM-44
Plant height (cm)	102	123 - 142	RTM-252
Primary branches	5	7 - 10	RTM-411
Secondary branches	15	22 - 24	RTM-441
Main shoot length (cm)	53	67 - 93	RTM-323
No. of siliques	22	34 - 43	RTM-418
Silique length (cm)	1.8	2.6 - 2.9	RTM-246
Seeds/silique	18	27 - 37	RTM-286
Seed yield/plant (g)	8.4	12.6 - 26.1	RTM-514
Oil content (%)	35	38.6 - 39.9	RTM-367

Conservation

The agricultural scenario, in India, is rapidly changing over time. Availability of high-yielding crops lures farming communities to shift to more profitable farming over the traditional one. This fact may lead to the partial or complete loss of some of the lesser-utilized crops such as rocket. Efforts are therefore needed to promote the use of these species as a means to safeguarding their genetic diversity.

The rejuvenation of cross-pollinated crops for maintenance is difficult and expensive. To avoid frequent regeneration and to check genetic drift, facilities have been developed for long-term conservation of germplasm at the National Gene Bank of the National Bureau of Plant Genetic Resources in New Delhi. Prior to

conservation, the germplasm is first tested for its germination percentage and moisture content is reduced to 5-6%. Samples meeting the minimum standards are sealed hermetically in laminated aluminium foil packets and kept in the module at –20ºC (Rana and Singh 1992).

According to IPGRI's recommendations, the sample size for long-term conservation should be made of a minimum of 12 000 seeds which correspond to about 50 g of seed for rapeseed and mustard group (IBPGR 1981). This figure should also be valid for rocket, owing to the closeness of these species to this crop. Periodic monitoring is done to monitor seed variability in genebank collections falling down to the 85% germination rate, when seed needs to be rejuvenated and restored.

Crop improvement

Rocket, though known for its wide adaptation, is poor in its yield potential. There could be various reasons behind this. Kumar and Yadav (1992) cited *inter alia* the following:

- Lack of attention from scientists in developing high-yielding, efficient and stable cultivars
- Cultivation of rocket is characterized by poor production technology and its planting takes place on neglected, marginal and submarginal lands
- Less stability of yield in fluctuating environments
- Physiologically inefficient plant type and poor yield potentials of cultivars
- Poor response of the cultivars to management practices.

Highlights of research carried out on rocket improvement are briefly summarized below:

- Some early maturing strains, viz. TC-4, -40, -52 and -59 maturing in 125-130 days, with better yield performance have been isolated (Yadav and Kumar 1983)
- TMH-24 and TRM-522 with higher seed yield have been identified as better suited to arid areas (Anonymous 1988b)
- Stable strains for yield and silique traits and some with general combining ability under salt conditions have been isolated (Kumar *et al*. 1986, 1988)

Response to abiotic stress

Research on the response of rocket to abiotic stress is briefly summarized here:

- Rocket has been found to possess twice as much frost tolerance as Indian mustard in terms of seed damage (Yadava 1976)
- In respect to seedling emergence, rocket was more salt tolerant than Brassicas at ECe 16 dS/m (Kumar 1990). Simultaneously, it showed less yield decline than Brassicas at ECe 10.5 dS/m (Anonymous 1987b).

Crop management

A brief highlight of major accomplishments and constraints in crop management is given below:

- Experiments have indicated that 3-5 kg/ha of seed is the best amount for optimizing yield production under varied soil moisture regimes (Yadava and Bhola 1977)
- Cultivation spacing of 30 x 15 cm has been found to be ideal for optimizing yield production in limited soil moisture conditions in Haryana, Uttar Pradesh and parts of Rajasthan (Anonymous 1982). However, under severe moisture

stress in western Rajasthan, wider spacing (45 x 15 cm) and delayed sowing have resulted in higher seed production (Anonymous 1988b)

- Fair rocket yields occur generally over a wider range of sowing dates; however, best yields are obtained when the crop is planted by mid-October (Yadava 1976; Maliwal 1985; Singh *et al*. 1985)
- Significant response to fertilization has been observed with a 30 kg/ha of N supply (Singh and Sharma 1981; Anonymous 1986a)
- Intercropping of rocket and chickpea (3:2) has proved most remunerative when compared with other combinations or sole cropping cultivations (Yadava 1976)
- Hand-weeding contributes to higher seed and slower yields (Anonymous 1986b)
- In terms of production potential and monetary gain, rocket has been rated the second most economic winter oilseed crop under limited moisture conditions (Kumar and Singh 1984; Singh and Sharma 1984) (Table 7).

Table 7. Production potential of winter crops under limited moisture conditions (source: Kumar and Singh 1984)

		Gross return/ha	
Crop	**Seed yield (kg/ha)**	**Rupees**	**US$**
Barley	1041	1960	55.21
Chickpea	586	1488	41.91
Indian mustard	1074	4400	123.94
Rocket	998	3162	89.07
Safflower	607	1565	44.08

Major constraints in rocket improvement are: the narrow genetic base for crop breeding programmes, difficulty in germplasm maintenance, limited knowledge on its genetics and its socioeconomic status.

In addition, the fact that rocket is usually grown on marginal lands and cultivated with poor management can also be perceived as a limiting factor to its diffusion to other more fertile areas.

Future thrusts

In spite of its wider adaptability to harsh and rustic environments, rocket is not widely accepted for enhancing the productivity of dry regions or as a source of oil and/or vegetable. Indeed it is rather underutilized and underexploited, being considered a minor oilseed crop in India. Taking into consideration that our need in rocket improvement programmes is to create a rich genetic resource base with desired traits in germplasm readily available to the breeders, we recommend that greater emphasis be laid on the following:

- Build up a good germplasm collection. This is the first and foremost activity to be initiated for both locally grown and exotic germplasm. Crop-specific collecting explorations are to be undertaken in those areas or regions not covered by previous missions or scarcely sampled.
- Efforts need to be made to promote the introduction of rocket as a vegetable crop in India.
- To have valid and consistent work on rocket, it is desirable that the collected/introduced germplasm be evaluated simultaneously at different locations. These evaluations should be made under a wider range of environmental conditions

using standard agronomic practices, during the same season and with specific and clear objectives.

- Action needs to be taken to eliminate duplicates in germplasm collections through the use of genetic or biochemical markers.
- Research should be initiated to identify and develop new varieties with desired fatty acid composition in order to enhance its exploitation as a source of edible oil crop.
- Crop improvement programmes are to be strengthened for developing physiologically efficient plant types, for the crop's better response to inputs, for stability in traits related to seed yield and crop management, for quality and quantity of seed oil content and for its greater adaptability and better performance in marginal/submarginal lands including saline and alkaline areas.
- There is a need to develop a set of region-specific package of practices to enhance the overall crop productivity and ensure higher economic returns when rocket is grown in pure or mixed stands taking into account prevailing environmental, biological and socioeconomic constraints.
- Efforts should be made to establish greater collaboration on germplasm conservation initiatives within the country: rocket germplasm maintained at different research centres and units should be sent to the National Gene Bank at NBPGR in New Delhi along with passport and evaluation data to ensure long-term conservation, avoid loss of material and provide greater availability to users.

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Traditions, uses and research on rocket in Israel

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Summary
Ten accessions of *Eruca sativa* were cultivated in Bet-Dagan experimental farm during the 1995-96 growing season. Physiological as well as chemical parameters were recorded. Special attention was given to the genetic diversity detected in the analyzed accessions and its relationship to their origin.

Introduction
The name rocket (*Eruca sativa*) is well documented in the old literature of the Holy Land. The identity of the plant was a subject of dispute among medieval as well as modern scientists. Most botanists and plant historians agree that the 'gargir' mentioned in the Talmud (5th-7th centuries) is the garden rocket. Our ancestors cultivated it both as a vegetable and for seed production. It is accepted that rocket corresponds to the Biblical 'oroth'. In the Book of Kings (II Kings 4: 39-40) in the Bible, it is said: "one of them went out into the field to gather 'oroth'". The plant is gathered near Gilgal, in the Jordan Valley, where the 'gargir' is very common. The local villagers or Bedouin collect it as a pot herb or wild salad. Since 'oroth' also appears as 'gargir' in the Talmud it can plausibly be identified with rocket (Zohari 1982).

According to Pliny, physician and botanist of the 1st century, a tea made from rocket seeds is used as an antihelmintic, i.e. to eliminate intestinal worms. From the Talmud we learn that it was used to treat eye infections. Our ancestors mentioned a decoction made from rocket seeds as an aphrodisiac and with the ability to increase semen.

Maimonides, a famous Jewish physician of the Middle Ages, indicated that seeds of *Eruca,* when eaten, stimulate saliva secretion, and Asaph Haropheh, another medieval physician, recommended the use of rocket to treat liver and stomach problems, kidney stones and for increasing milk flow in nursing mothers. In addition we also found in 13th century literature a mention of the use of rocket in biological control: rocket seeds were sown together with other vegetables to inhibit pest development.

Nowadays the Bedouins use fresh rocket leaves in salads, and rocket seeds as a substitute for mustard and as an aphrodisiac.

As part of the extensive effort to preserve the species of *E. sativa* we studied the biodiversity of native accessions of rocket and compared chemical and physiological properties with those of some European accessions.

Material and methods

Seed collection
Seeds of *E. sativa* were collected from the wild, as part of an ongoing large project of Cruciferae collection in Israel. These were collected during two expeditions led by two leading botanists. The following material was gathered:

- 'Mattatia' seeds were collected from two sites in the Jordan Valley, Saharo-Arabian region (see phytogeographical map of Israel of Plitmann *et al.* (1983) (Zohari 1996)
- 'Yair' seeds were collected from four sites in the Mediterranean region. At least three plants were collected from each site and seeds were kept separately for further research (Elber *et al.* 1989).

Oil quantity and fatty acid composition of the seeds were analyzed using the methods described by Yaniv *et al.* (1991).

Seed introduction

Four seed samples of *E. sativa* from different Botanical Gardens were sent to our genebank and used in cultivation trials, viz.:

- Accession No. 1/96 from Berlin Botanical Garden, Germany
- Accession No. 2/96 and 6/96 from Torino, Botanical Garden, Italy
- Accession No. 16/95 from Bari Botanical Garden, Italy.

Cultivation

Ten accessions (four introduced and six indigenous) of *E. sativa* were cultivated at the Bet Dagan Experimental Station. Each accession was replicated four times. Seeds of each accession were sown in 2.4 m^2 plots consisting of four rows, with 30 cm between rows. Basic fertilization was done at the time of soil preparation, at a rate of 100:100:50 N:P:K. Treflan (2.5 kg/ha) was used as a herbicide. Irrigation was applied until plantlets were fully established.

Plants were harvested at seed maturity during the month of May 1996 (8-26 May), some 150 days after emergence. Oil quantity and fatty acid analysis were conducted as described above (Yaniv *et al.* 1991).

Results and discussion

Data regarding the cultivation and the chemical analysis of the seeds are summarized in Table 1. In spite of uniform sowing and emergence dates, there is a significant variability in the onset of flowering and ripening. Both oil content in the seed (between 24 and 29) and content of major fatty acids varied. Data show similarity in oil composition across both foreign and indigenous material. This observation could indicate that the fatty acid profile of each *E. sativa* line is genetically controlled.

Table 2 presents data on the time required for flowering and ripening. There is a difference of 27 days between early and late flowering types, and a difference of 18 days between early and late ripening. It is interesting to note that the 'Yair' indigenous accessions (3, 20, 21, 22) are the earliest to flower and to ripen.

Table 3 shows data regarding oil content and the fatty acid composition in seed oils of 10 *E. sativa* accessions: oil content varied from 24.5 to 29.2%. The three top lines are European introductions. There is a genetic difference in oil content of seeds but this trait could be improved by selection and breeding.

Eruca sativa, as a member of the Brassicaceae family, contains erucic acid (C22:1), a unique fatty acid of seed oils. The content of erucic acid in the oil varies between 33% (in native Israeli material) and 47% (in the introduced accessions from Germany) (Table 3). In accessions characterized by high erucic acid, the level of linoleic (C18:2) and linolenic (C18:3) unsaturated fatty acids is reduced. These fluctuations indicate within the species in relation to a range of genetic diversity the geographical origin of the collected accessions.

Table 1. Cultivation and oil composition data of 10 accessions of *Eruca sativa* cultivated at the Bet-Dagan Experimental Station in 1995/96

Sowing date (in the field)	3 December 1995	
Emergence date	14 December 1995	
Flowering date	12 February - 11 March 1996	
Ripening date	8 May - 26 May 1996	
Oil (%)	24.5 - 29.2%	
Oil composition (fatty acids % from total oil):		
	Cultivated seeds	**Original seeds**
C 16:0	4.0 - 5.2	4.0 - 5.1
C 18:0	1.3 - 1.9	< 1 >
C 18:1	9.9 - 17.8	10.2 - 17.2
C 18:2	8.3 - 15.3	8.8 - 15.9
C 18:3	14.6 - 19.7	14.7 - 20.7
C 20:1	7.3 - 9.8	7.3 - 10.4
C 22:1	32.1 - 45.6	34.4 - 47.5

Table 2. Flowering and ripening times of 10 accessions of *Eruca sativa* cultivated at the Bet-Dagan Experimental Station in 1995/96

		No. of days from emergence to:	
Line no.	**Origin**	**Flowering***	**Ripening**[†]
1/96	Germany	77	163
2/96	Italy	73	163
6/96	Italy	71	163
16/95	Italy	88	163
14/96	Israel-(Mattatia)	74	163
18/96	Israel-(Mattatia)	70	163
3/96	Israel-(Yair)	66	146
20/96	Israel-(Yair)	66	145
21/96	Israel-(Yair)	62	145
22/96	Israel-(Yair)	60	145

[†] Values are average of four replications.

Table 4 compares the presence of mono-unsaturated fatty acids (oleic, C18:1; eicosenoic, C20:1; erucic, C22:1) with polyunsaturated ones (linoleic, C18:2; linolenic, C18:3). It is interesting to note that the four Israeli accessions collected in Yair (Mediterranean region) are very uniform in their fatty acid profiles (lines 3/96, 20/96, 21/96, 22/96). European introductions are different from these, although uniform too. The two native lines collected from the Jordan Valley are closer to the European group than to the other Israeli lines. There is a reciprocal correlation between the levels of monosaturated and polyunsaturated fatty acids in the seed oils. In a study done by our group on analysis of diversity of native *Sinapis alba* accessions, a genetic variability among eight accessions collected from two geographical locations was demonstrated by RAPD (Random Amplified Polymorphic DNA) markers (Yaniv *et al.* 1993; Granot *et al.* 1996). A genetic distance between accessions from the two locations was found. In addition, RAPD analysis revealed a genetic link between *S. alba* genotypes and their erucic acid content. These results emphasize the importance of preserving and documenting the genetic diversity within *E. sativa* species.

Table 3. Fatty acid composition in seed oil of *Eruca sativa* accessions (introduced or indigenous)

Access. no.	Origin	Oil (%)	Fatty acids (% of total content)						
			Palmitic C 16:0	Stearic C 18:0	Oleic C 18:1	Linoleic C 18:2	Linolenic C 18:3	Eicosenoic C 20:1	Erucic C 22:1
1/96	Germany	29.1	5.1†	1.3	15.1	8.3	14.7	7.4	44.7
2/96	Italy	28.7	4.9	1.4	16.7	10.3	14.6	7.3	42.8
6/96	Italy	27.8	4.8	1.6	15.2	9.4	15.2	7.6	43.3
16/95	Italy	28.8	4.8	1.4	15.9	9.5	15.1	7.6	43.3
14/96	Israel-(Mattatia)	27.8	4.7	1.4	17.8	9.4	14.9	7.5	42.4
18/96	Israel-(Mattatia)	27.8	5.2	1.4	16.9	9.6	14.9	7.4	41.7
3/96	Israel-(Yair)	24.8	4.1	1.5	9.9	14.1	19.7	9.8	37.0
20/96	Israel-(Yair)	26.2	4.0	1.9	11.4	14.0	18.8	9.4	36.3
21/96	Israel-(Yair)	25.6	4.2	1.8	11.5	14.8	19.2	9.6	35.2
22/96	Israel-(Yair)	25.5	4.0	1.9	12.6	15.3	18.9	9.4	33.4

† Numbers are average of 4 replicates.

Table 4. Comparison of the incidence in the presence of mono-unsaturated/polyunsaturated fatty acids in the seed oil of *Eruca sativa* accessions

Accession no.	Origin	Fatty acids (% of total content)	
		C 18:1 + C 20:1 + C 22:1	C 18:2 + C 18:3
1/96	Germany	67.2	23.0
2/96	Italy	66.8	24.9
6/96	Italy	66.1	24.6
16/95	Italy	66.8	24.6
14/96	Israel-(Mattatia)	67.7	24.3
18/96	Israel-(Mattatia)	66.0	24.5
3/96	Israel-(Yair)	56.7	33.8
20/96	Israel-(Yair)	57.1	32.8
21/96	Israel-(Yair)	56.3	34.0
22/96	Israel-(Yair)	55.4	34.2

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Rocket in Portugal: botany, cultivation, uses and potential

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Introduction

The name rocket is normally applied to a number of species belonging to the genus *Eruca* Miller and *Diplotaxis* DC. of the Brassicaceae family. The Mediterranean region and Western Asia are credited as centres of origin and domestication of these genera.

Rocket has an ancient use in Lusitania since it is reported to have been known by the ancient Romans before the birth of Christ. The market demand in Portugal, until a few years ago, was very limited and its utilization in traditional cuisine and medicine was limited to extensive harvesting from the wild by rural populations. Although its popularity as a market vegetable has increased recently in many European countries, in Portugal the commercial exploitation and production of this crop for salad started only a few years ago with the increased employment of rocket in the so-called 4th generation of vegetables. The actual Portuguese commercial production of rocket is basically destined to the supermarkets in United Kingdom and other northern countries like the Netherlands. In some big Portuguese supermarkets of Lisbon and Porto, rocket is also appearing more often.

The objective of this presentation is to give a brief description of the botany, cultivation, uses and potential of rocket in Portugal.

Botany

Eruca vesicaria (L.) Cav. subsp. *sativa* (Miller) Thell. and five species of *Diplotaxis* DC. – *D. catholica* (L.) DC., *D. vicentina* (Coutinho) Rothm., *D. virgata* (Cav.) DC., *D. viminea* (L.) DC. and *D. muralis* (L.) DC. – can be found in different regions of Portugal (Franco 1971). The geographical distribution of these species is presented in Figure 1. *Diplotaxis catholica* is the most widespread species in Portugal followed by *D. virgata*. The other species are very localized: *D. vicentina* is endemic in the southwest coast of Portugal, *D. muralis* was introduced in S. Miguel island of the Azores.

Diagnostic characters for *Eruca* include a conical, flattened, seedless beak with a minute stigma, and a silique that is rounded in section and has one-nerved valves. Seeds are small, ellipsoidal or flattened, and arranged in 2-3 rows. *Diplotaxis* have long siliques, papyraceous valves and minute ellipsoidal seeds arranged in two rows. An important character for diagnosis of *Diplotaxis* species is the presence or absence of 1-2 seeds in the silique beak.

According with Franco (1971) the main characteristics presented by the Portuguese rocket species are as follows:

1. *E. vesicaria* subsp. *sativa* (n=11), annual herbaceous plant 10-100 cm high; elongated branching stem; lower leaves lyrate-pinnatisect, all slightly fleshy, sparsely pilose, rarely glabrous with a characteristic fetid smell. Sepals 8-10 mm long; petals 15-20 mm long, at the beginning whitish and later yellow, violet veined; fruiting pedicels 3-4 mm long almost appressed to stem; siliques 12-25 mm long and 3-5 mm broad, valves firm with prominent midrib and a long (5-10 cm) ensiform and compressed beak.

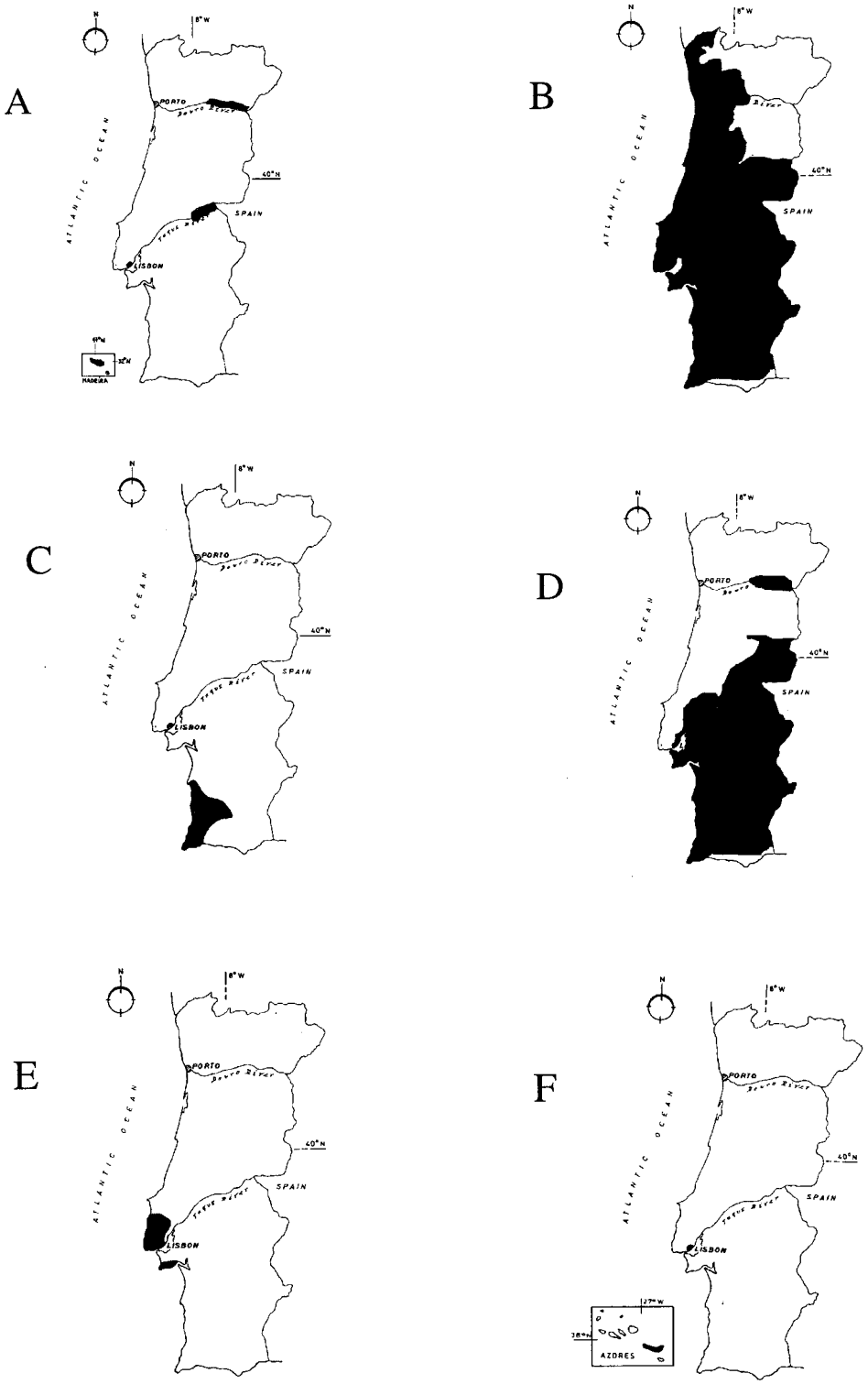

Fig. 1. Geographical distribution of *Eruca vesicaria* subsp. *sativa* (A), *Diplotaxis catholica* (B), *Diplotaxis virgata* (D), *Diplotaxis viminea* (E) and *Diplotaxis muralis* (F) (Franco 1971).

2. *D. catholica* (*n*=9), annual herbaceous plant 5-90 cm high; branching stem, glabrous or sparsely pilose at the base; leaves mostly basal pinnatisect or bipinnatisects. Sepals 3-4 mm long; petals 5-8(12) mm long, sulphur yellow; fruiting pedicels 5-20 cm long; siliques (14)20-35(45) long and 1.5-2 mm broad; beak 2-3 mm long sometimes with 1-2 seeds.
3. *D. vicentina* (*n*=10), annual or biennial herbaceous plant 15-30 cm high; very branching from the base; stem pilose at the base; leaves mostly basal, lower leaves thick, lyrate-pinnatiparted to pinnatisect with small lateral segments pilose in both pages. Sepals 2.5-3 mm long; petals 6-7 mm long, yellow; fruiting pedicels 6-10 mm long; siliques 14-20 mm long and 1.5-2 mm broad; conic beak 5-8 mm long.
4. *D. virgata* (*n*=9), annual herbaceous branching plant 30-90 cm high; stem pilose at the base; leaves mostly basal, lower leaves lyrate-pinnatisect or pinnatiparted with broad oblong or sublanceolated segments. Sepals about 3 mm long; petals 5-8 mm long, sulphur yellow; fruiting pedicels 10-15 mm long; siliques 15-50 mm long and 1-2 mm broad; beak 2-3 mm long.
5. *D. viminea* (*n*=10), annual herbaceous plant 5-30 cm high, glabrous or slightly glabrous; rosette leaves at the base of the stem, veined, lyrate-pinnatiparted with broad sub-entire segments, sometimes oblong-spatulated. Sepals about 2 mm long; petals 3-4 mm long, sulphur or citrus yellow; fruiting pedicels 5-10 mm long; siliques 10-25(40) mm long and 1.25-1.75 mm broad; beak 1-2 mm long.
6. *D. muralis* (*n*=21), annual or biennial herbaceous plant of 10-50 cm high, usually branching from the base; stem glabrous or sparsely covered with hairs at the base; rosette leaves, oblong, more or less sinuate-dentate to pinnatiparted. Sepals 3-4 mm long; petals sulphur yellow turning to violet, 6-8 mm long; fruiting pedicels with 7-15 mm long; siliques 20-45 mm long and 1.5-2.5 mm broad, glabrous with a fleshy, finely ribbed, tapering beak 2-3 mm long.

Besides *E. vesicaria* subsp. *sativa*, the Portuguese species with better agronomic interest are *D. muralis* and *D. viminea* both with rosette, thin and membranous green leaves. *Diplotaxis* species have a less sharp flavour than *Eruca*.

Cultivation and uses

Until few years ago rocket was not commercially cultivated in Portugal. Nowadays there is some cultivation of *E. sativa*, mainly in the southwest coast of Portugal, for exportation in sealed bags to the supermarkets of the United Kingdom, and in the central west coast for exportation mainly to the Netherlands. Both productions are used as a '4th generation' salad product, i.e. usually neatly prepared and sold in sealed bags after having been cleaned and mixed with other leafy vegetables. The export material consists of plantlets of *E. sativa* with 3-4 leaves. The cultivation is done almost all the year round (8-9 months), with successive sowing to provide successive harvests, mainly during autumn and winter. There is no commercial interest in the summer production for exportation. Cultural practices vary from grower to grower. Traditional growers, after preparation of soil, do a widespread seed sowing on large beds with high densities (10-15 g/m^2) and basically fertilize the crop with nitrogen in a manner similar to what is traditionally done in the case of turnip-green cultivation in Portugal. Usually, hand-weeding is not necessary. In the southwest coast, in farms managed by foreign technicians, a soil disinfection is performed by applying methyl bromide every 3 years to avoid weeds along with a dense seed row sowing (250 kg/ha) with rows placed 12-15 cm distant apart and

fertigation with a proper fertilizer mixture. Water deficits give rise to low-quality rocket. The tender leaves in both cases are hand-harvested by cutting them at the soil level. To facilitate emergence and uniformity, an agryl type cover is sometimes used.

Seed packages of introduced cultivars of rocket can also be found in some seed stores and are used by amateur growers.

Before its commercial cultivation, rocket was traditionally collected from the wild and used in some regions of Portugal as a vegetable or in traditional medicine.

The wild rocket (mainly *Diplotaxis* spp.) was and is traditionally consumed in Portugal. There are reports of the following recipes:

- raw in green salads mixed with lettuce and onions, seasoned with salt and olive oil; this salad can also include coriander or tomato but it is not so frequent
- simply boiled with salt, like the Portuguese do with turnip greens, to eat seasoned with olive oil with fish or meat
- boiled greens, finely chopped with flour, garlic, salt and olive oil, the Portuguese 'esparregado' that could also be made with turnip greens, spinach or a mixture of these vegetables
- rocket rice with onions and salt
- with a mixture of sheep / goat cheese
- fried with thin beef slices and wine
- in sauces or in meat stews.

Eruca is used in the Portuguese traditional medicine for various purposes: depurative, digestive, diuretic, tonic, stimulant, laxative and anti-inflammatory. For these properties it is recommended to fight asthenia and as a 'Spring restorer of health' for the disintoxication of the organism (Balmé 1978; Anonymous 1983). The plant is also used to treat greasy scalps and to prevent hair loss (owing to its properties to enhance hair regrowth). A lotion prepared by the addition of 30 g of edible burdock (*Arctium lappa* L.), 30 g of stinging nettle (*Urtica dioica* L.) and 30 g of rocket (*E. vesicaria* subsp. *sativa*) in one litre of water, boiled for 15 minutes, is a folk recipe recommended to enhance hair regrowth. Aphrodisiac properties for the plant have been reported since Roman times. It is also believed that *Eruca* has anti-inflammatory properties for colitis and is a good coadjutant in digestion. It also can be used as cough syrup because of its properties against phlegm, catarrh and hoarseness.

Furthermore, *Diplotaxis* is also mentioned to be stimulant, diuretic, and antiscorbutic, and the oil of its seeds is recommended to fight bronchitis and catarrh / phlegm since it is believed to be a fluidizer of bronchial secretions and to reduce inflammation of throat mucous membranes.

Crop potential and future

Until a few years ago the demand for rocket in Portugal was met by harvesting plants directly from the wild. Commercial cultivation of rocket for fresh leaves has started recently for exportation to the United Kingdom and to other northern European countries. In these growing areas local people are also starting to appreciate the crop, and in some famous Portuguese supermarkets of Lisbon and Porto, rocket is appearing more and more often on the shelves. Some amateur growers are also growing it, sometimes thinking that they are growing pungent turnip greens. Over the last few years, rocket is certainly increasing, and this is true especially for those sold in the form of small tender leaves. Having mentioned the market potentials in the country and outside, we can conclude that rocket seems to have a very good potential in Portugal. Much has to be done, however, in the area of research and market promotion. The success of rocket in Portugal does not depend much therefore

on the work of breeders but rather on market tendencies which are driven by market forces and trade organizations.

The production of rocket frozen leaves for 'esparregado' can be an interesting way to adapt this old vegetable to the modern consumer habits. Rocket can be consumed like spinach and turnip greens in 'esparregado' or in a mixture with those vegetables but has a different taste and texture that seems to be enjoyed by some consumers. The taste depends on the content of glucosinolates which is a genetically controlled trait and is influenced by plant age, soil and climatic conditions. The texture also depends on the age and size of the plants and cultural practices. These characteristics, important also in traditional markets, are of considerable importance when rocket has to be processed and sold in more sophisticated markets.

Taking these facts into account, a concerted action on germplasm collecting, evaluation of available diversity, research in cultural practices, industrial storage and freezing, and conservation of rocket genetic diversity is highly needed in Portugal for the sustainable utilization and commercial exploitation of rocket in the future.

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Marketing and utilization of rocket in Turkey

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Introduction

Rocket is grown for fresh consumption mostly in the southern and western parts of Turkey. Green fresh leaves are mostly used as appetizers with traditional Turkish foods like 'pide' (Turkish pizza) or 'kisip' (Turkish wheat meal), or to prepare fresh salads. Temperate and wet climates are appropriate to achieve high quality and acceptable yields. After harvest, rocket leaves are prone to microbial decay and should be immediately transported to the market. Low temperatures limit its growth and development. However, increases in temperature result in bleaching of leaves, and shoot and flower formation which decreases commercial value significantly. At appropriate temperatures, leaves can achieve a darker green colour and become more aromatic and pungent in order to meet different market requirements.

Vegetable production in Turkey

According to 1992 records, the total vegetable production area in Turkey is estimated to be 592 990 ha with about 17 467 920 t of production (Anonymous 1993). Vegetables consumed as shoots or leaves correspond to approximately 8% of this (1 419 638 t). The production of rocket is estimated to be 170 t. Furthermore, according to 1993 records, total vegetable production area is estimated to be 654 420 ha, with a production amounting to 16 818 636 t (Anonymous 1994). The proportion of leafy or shoot vegetables is recorded as approximately 9% with 1 433 670 t production, and that of rocket as 190 t. In fact, the values of 170-190 t provided for rocket production for both years do not reflect the reality of the rocket cultivation in the country, because a great amount of rocket is produced on small parcels and home gardens, which are generally not included in official records.

Mineral composition of rocket leaves is shown in Table 1. These data have been obtained from experiments carried out by the Ege University on rocket leaves to investigate the variation in mineral composition by plant age. These results are similar to those of Haag and Minami (1988), although some slight differences encountered could be attributed to different environmental conditions and cultural practices.

Table 1. Mineral composition of fresh rocket leaves at different ages (Esiyok, Oktay and Yagmur unpublished)

	Plant age (days after emergence)	
Mineral (mg/100 g fresh weight)	**20 days**	**50 days**
N	460	324
P	59	38
K	298	261
Ca	286	178
Mg	34	23
Cu	0.07	0.04
Fe	2.93	1.74
Mn	0.37	0.25
Zn	0.49	0.29
Na	11.2	6.95

Rocket marketing in Turkey

Rocket leaves that reach harvest maturity are cut 2 cm above the ground during the cooler hours of the day (late afternoon) and are placed in bundles (Fig. 1). Average bundle size varies between 50 and 100 g, according to the production. Bundles are placed in plastic or wooden boxes, or in large deep baskets for transport to wholesalers or local markets. Rocket is sold at greengrocers, in supermarkets or local markets (Fig. 2) at relatively high prices. Furthermore, rocket growers also sell their product directly to restaurants and bars. In this case, production and sale are mostly done on the basis of verbal agreements between farmers and buyers.

High quality and good economic returns are achieved at the first harvest. At successive harvests, yield and quality decrease, partly owing to an increasing presence of incised leaves which ultimately affects the economic value of the product.

Fig. 1 (above). Bundles of rocket leaves at harvest maturity.

Fig. 2. Rocket sales at an open-air market.

Utilization of rocket in Turkey

Rocket leaves sold as bundles are consumed fresh and green. Yellow leaves are discarded prior to consumption. It is prized for garnishing Turkish food specialities like 'pide' (pita=a Turkish pizza), 'kisir' (a Turkish wheat speciality made of rocket, tomato paste, hot paprika, lettuce, green onions, parsley, etc.), meatballs or fish. Rocket is even used as an hors d'oeuvre accompanied by alcoholic drinks (like Turkish raki).

Another way of consuming rocket is as a salad. Rocket leaves are cut into small pieces together with tomato, paprika, cucumbers, and green onions and mixed with some lemon juice and olive oil. Alternatively, rocket leaves can be mixed with lettuce, green onions and dressed with lemon juice and olive oil.

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III. International Cooperation

The second meeting of the Rocket Genetic Resources Network was held in Legnaro, at the Faculty of Agriculture of the University of Padova, Italy. It was attended by the following persons: Monserrat Aguade', D.C. Bhandari, Ferdinando Branca, Luigi Filippo D'Antuono, Carmelinda De Santis, Hamdy El-Doweny, Dursun Esiyok, César Gomez-Campo, Gerrit Hey, Ruth Magrath, Juan Martínez-Laborde, Stefano Padulosi, Domenico Pignone, Ferdinando Pimpini, João Silva Dias, Gianfranco Venora and Zohara Yaniv.

Padulosi and Pignone chaired the meeting.

The meeting consisted of two parts: during the first part, a general overview of past accomplishments of the Network was presented along with a discussion among participants of ongoing and future initiatives for rocket. The second part was entirely devoted to the revision of the final draft of the *Eruca* spp. descriptor list.

Part I: Network activities

Germplasm survey, collecting and exchange

- Gomez-Campo will collect wild *Eruca* in Spain and Morocco (during 1997);
- El-Doweny will send samples of the two Egyptian rocket varieties to Pignone for conservation in the Bari genebank (by January 1997);
- Silva Dias will survey the cultivation and uses of rocket in Portugal (during 1997);
- Yaniv will send to Pignone seed samples of wild *Eruca* material she has collected in Israel for safe conservation in the Bari genebank;
- D'Antuono and Pimpini pointed out that it would be useful to survey the cultivation of rocket in the Veneto as well as other Italian regions (e.g. Marche and Emilia Romagna regions – in the latter D'Antuono reports the presence of both *Diplotaxis muralis* and *D. tenuifolia*). It is therefore recommended that collecting missions be launched in these areas (Padulosi to investigate with Pignone the possibility that CNR might carry out these explorations);
- It was suggested to send samples of *Diplotaxis* material (herbarium and seeds) gathered in Italy and elsewhere to Martínez-Laborde to obtain proper taxonomic identification (**attention ALL**);
- The University of Catania is planning to collect rocket germplasm in Sicily and Branca agreed to send duplicates of the material that will be gathered to Pignone for conservation (during 1997);
- Esiyok will send samples of rocket accessions collected in Turkey to Pignone (by March 1997).

Germplasm conservation

- Pignone will continue to look after the germplasm collection of cultivated rocket deposited in Bari. In this regard he announced that the Germplasm Institute has agreed to include the rejuvenation and multiplication of rocket in its working plan for 1997. This decision will be beneficial for the seed increase of rocket accessions and thus enhance the possibility of germplasm exchange among rocket users.
- Gomez-Campo will continue to be responsible for the wild *Eruca* and *Diplotaxis* material. He intends to regenerate some old unpreserved accessions in 1997. He pointed out that frequent germplasm regeneration is not advisable and an equilibrium between good conservation and regeneration should be always maintained in genebanks. Rocket species are outbreeders and therefore they need

to be kept in isolation; such isolation leads inevitably to inbreeding depression and has a negative effect on the genetic structure of the material. Therefore, the group recommends doing less regeneration and whenever possible go back to the original site of collection in order to contribute to seed increase. *Ex situ* conservation is always required to ensure a constant seed availability. With regard to the size of the sample to collect, it was suggested that a reasonable collecting sample for rocket would be made by collecting seeds from at least 40-50 plants, whenever of course these populations would allow to do so. Concerning the seed viability of rocket seeds, two facts have been highlighted by Gomez-Campo: rocket seeds have a natural post-harvest dormancy of usually 2 months (this can be broken by using giberrelic acid), and genebank management of rocket seeds has demonstrated that these have a relatively long life in long-term storage conditions (after 25-50 years of storage these seeds are likely to still maintain a good germination).

- Pimpini announced his planned trip to Argentina some time in 1997. He volunteered to bring back from this country some samples of rocket seeds cultivated / and or wild for safe conservation in Bari.
- Several Network members indicated their interest in carrying out some agrobotanical characterization work. It was pointed out that the availability of the germplasm material represents a major constraint for promoting these activities. A strong recommendation was therefore made for a greater effort in the area of germplasm multiplication in the various genebanks (**attention ALL**).

Database

Pignone reported on the Rocket Database that has been developed at the Germplasm Institute. A suggestion to add to the DB the columns Local Name and Geographical Distribution was made (**attention Pignone**). It was also stressed that proper identification should be made before the material is listed in the DB. Yet, it was noticed that material listed in the DB might have been wrongly identified in the past by previous collectors. The recommendation was made to seek the opinion of experts (e.g. Gomez-Campo, Martínez-Laborde) whenever there is uncertainty on identification of material; however, such uncertainty should always be stated in the DB.

The need to have a standardization of the names used in the DB (**attention Pignone**) was expressed. To meet these requirements and to implement the recommendation in a consistent way it was decided to circulate the DB to all Network members and seek their comments. This procedure will allow colleagues to update the DB by adding further information on genebank holdings not previously included (**attention Padulosi, Pignone, ALL**). The possibility of putting the DB on the Internet will be investigated (**attention Pignone**).

Evaluation

- Venora expressed keen interested in collaborating in the area of cytogenetics of *Eruca* and *Diplotaxis* species. There are several taxa whose karyotype is still unknown, and owing to the extremely small dimension of their chromosomes such identification is a very difficult task. Venora intends to multiply the material received by Gomez-Campo (via IPGRI) in collaboration with Branca (**attention Venora, Branca**);
- De Santis, in collaboration with De Leonardis and Zizza of the University of Catania, will continue working on the carpological characterization of rocket.

Palynological analyses also will be carried out pending the availability of material (**attention Padulosi, Gomez-Campo, Pignone**);

- Branca is interested in carrying out rocket evaluation for salinity through anther culture. To this end, Magrath suggested that Branca contact her lab to obtain the protocols set up in Norwich, for carrying out anther culture in *Brassica* species (**attention Branca**);
- The antinematode activity discovered in rocket is of great interest for some Italian institutions. In Israel there have been a number of investigations on this topic, with some promising results. Pignone will contact Yaniv to discuss possible collaboration in this area of common interest (**attention Pignone**).

Information dissemination, public awareness

- Participants strongly recommended the establishment of a Rocket Newsletter. This newsletter could be made available on the Internet (**attention Padulosi, Pignone**) and circulated as hard copy. Such a medium would be very useful to promote exchange of information, ideas and promote collaboration among all people interested in rocket and at the same time raise the profile of the Network. The newsletter could be the vector of useful and practical information among users: *inter alia* it may contain data on the period of rocket cultivation in each country, characteristics of rocket varieties from different countries, market information, food recipes made with rocket (maybe a different one for every issue?), create awareness of the agronomic technique required for successful rocket cultivation (i.e. material should be free from nitrates), etc.;
- D'Antuono noted that rocket material already has been evaluated by private seed companies in Italy and elsewhere, so contacts with these companies should be promoted to gain a greater knowledge in this domain. In this regard Network members have been requested to pass on to Padulosi the address of any seed firm currently working on rocket for a follow-up (**attention ALL**).

Next Network meeting

The invitation from Turkey to host the next Network meeting was enthusiastically received by all participants. Dr Esiyok confirmed the offer after having consulted his colleagues of the Ege University in Izmir. It is suggested to hold the meeting toward the end of May 1998.

Part II: Descriptors list for *Eruca* spp.

The final draft of the *Eruca* DL was discussed during the meeting. Further amendments have been made to this version and will be incorporated by Padulosi. The document will be sent to Prof. Gomez-Campo, Drs Martínez-Laborde and Pignone for a final perusal before its submission to IPGRI's Publication Committee (**attention Padulosi**).

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