PROJECT ON UNDERUTILIZED MEDITERRANEAN SPECIES

Rocket Genetic Resources Network

UNDER UTILIZED MEDITERRANEAN SPECIES

Report of the First Meeting
13-15 November 1994
Lisbon, Portugal

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International Plant Genetic Resources Institute
IPGRI

The International Plant Genetic Resources Institute (IPGRI) is an autonomous international scientific organization operating under the aegis of the Consultative Group on International Agricultural Research (CGIAR). IPGRI's mandate is to advance the conservation and use of plant genetic resources for the benefit of present and future generations. IPGRI works in partnership with other organizations, undertaking research, training and the provision of scientific and technical advice and information, and has a particularly strong programme link with the Food and Agriculture Organization of the United Nations. Financial support for the agreed research agenda of IPGRI is provided by the Governments of Australia, Austria, Belgium, Canada, China, Denmark, France, Germany, India, Italy, Japan, the Republic of Korea, the Netherlands, Norway, Spain, Sweden, Switzerland, the UK and the USA, and by the Asian Development Bank, IDRC, UNDP and the World Bank.

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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Contents

Introduction

The Rocket Genetic Resources Network

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This gathering represents the first meeting of the Rocket Genetic Resources Network, an informal group of persons who have decided to join efforts and share research findings in order to promote better conservation and use of rocket. The Network was formally established during a meeting organized by IPGRI in Valenzano, Italy, in March 1994, which was well attended by participants from several Mediterranean countries.

This initiative was launched by IPGRI's project on Underutilized Mediterranean Species (UMS), which is being supported by the Italian Government through the Ministry of Foreign Affairs. The project wishes to give a contribution toward better conservation of the valuable heritage in agro-biodiversity harboured in the Mediterranean region. This wealth is largely untapped despite the fact that it contains species of large popularity and of recognized potential. Apart from rescuing the germplasm diversity of these species the project aims also at saving the traditional knowledge related to the cultivation and use of these crops and promoting collaboration among institutions and organizations in the region.

Rocket is an ancient crop, very popular among the Romans as it is today in most pizzerias of Rome. Its popularity as a food crop is probably due to the spicy hot taste of its leaves which are used as garnish to flavour salads, snacks and a large variety of meals. The economic potential of rocket is steadily increasing thanks also to the introduction in the market of the so-called 4th Generation vegetables, i.e. those leafy vegetables which are marketed after cleaning, leaf cutting and packaging which contribute to a longer shelf life. Rocket is also used in many ways other than as food: oil from *Eruca* plants is widely used in India; plant parts are used in the traditional pharmacopoeia for various purposes (depurative, diuretic, emollient, tonic, stimulant, laxative, anti-inflammatory) and oil and leaf extracts have been found to be an effective insect repellent, thus suggesting a possible use in the biological control of crop pests.

Most of the market demand for rocket is met today using a very limited number of varieties. This is a result of the lack of adequate germplasm collecting and conservation initiatives done on this crop in the past. Another source of supply for the market is represented by the extensive harvests carried out in the wild, which unfortunately is made with no concern for those naturally occurring populations. The networking initiative is a mechanism of cooperation aiming at safeguarding the diversity of rocket germplasm, while at the same time providing a wider genetic base for its exploitation.

The goals of the Network will be reached through common actions in the area of germplasm collection, conservation and documentation. Research investigations will be also carried out to better characterize the crop for its major agrobotanical and biochemical traits. A common database for the crop is being established and will contain relevant information on rocket accessions available in genebank collections worldwide. This centralized system will be of great help to breeders and users, facilitating their work of crop improvement and boosting the use of the crop. A descriptors list is under development and will contribute to enhancing the management of rocket genetic diversity.

Some of the papers included here present preliminary results of initiatives already started by the Network members. They provide general information to the reader and highlight actions regarded as a priority, which will receive greater attention by the Network.

Preliminary report on major activities initiated within the framework of Network activities

Activities conducted in Israel

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Introduction

Israel is known for the wealth of its plant species. Within a small geographical area, four different phytogeographical regions exist, contributing to a wealth of flora (Fig. 1; Plitman *et al.* 1983):

1. Mediterranean region: 350-1000 mm annual rainfall; dry summers, temperate winters.
2. Irano-Turanian region: 100-400 mm rainfall; very hot summers, very cold winters; semi-arid, typical of central Asia.
3. Saharo-Arabian region: 0-150 mm rainfall; extreme dryness - arid and desertic.
4. Sudanian penetration with tropical vegetation: below sea level; this is the northern limit of this region.

The genus *Brassica* and many wild allies seem to have originated in the Mediterranean region, adapted to conditions of mild winters and dry summers (Zohary 1966).

The following is a description of the biodiversity of *Eruca* and *Diplotaxis* species in Israel and experimental data regarding evaluation of native germplasm of *Eruca* as a potential agricultural crop and a source of seed oils.

Biodiversity of *Eruca* and *Diplotaxis*

Eruca sativa (rocket). Annual or perennial herb. Flowering: February-April. Fairly tall plants. Region: mainly Mediterranean, but also Irano-Turanian and Saharo-Arabian. Habitat: ruins, fences, on soils rich in nitrogenous matter.

Diplotaxis erucoides. Annual. Flowering: February-May. Region: Mediterranean. Very common. Habitat: fields, roadsides. Can form white flowering carpets.

D. tenuifolia. Perennial herb. Plants up to 70 cm tall. Flowering: March-July. Region: Mediterranean and Irano-Turanian. Very rare. It was introduced from Europe between the years 1930 and 1940 and became acclimated in the Judea Mountains, close to Jerusalem. Known as a medicinal plant in Italy. Used for the treatment of digestive, respiratory, urogenital, vascular and nervous disorders, metabolic disturbances such as diabetes and hypercholesterolemia, and as a sedative (de Feo *et al.* 1993).

D. viminea. Annual. Very small. Flowering: February-May. Region: Mediterranean. Rare. Habitat: fields and roadsides.

D. harra. Annual or perennial plant. Region: Saharo-Arabic. Leaves and stems are usually very hairy. Very common in the deserts and forms yellow flowering carpets in season. Known in folk medicine for its antibacterial and antifungal properties. The same uses are reported in Egypt (Shabana *et al.* 1988).

D. villosa. Annual. Flowering: April-May. Region: Irano Turanian. Rare. Habitat: Deserts. Found mainly in the eastern part of the Jordan Valley.

D. acris. Annual. Flowering: January-April. Region: Saharo-Arabic. Very common in hot deserts and sometimes forms violet or pink flowering carpets in season.

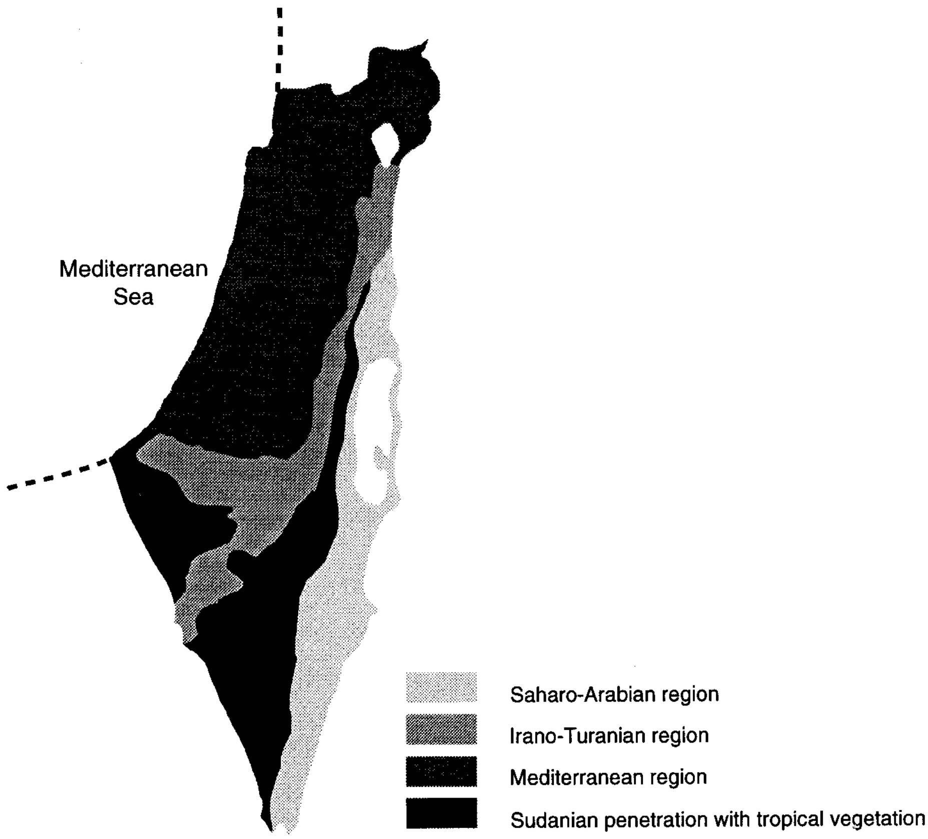

Fig. 1. The phytogeographical regions of Israel

Rocket: Examination, evaluation and uses

Materials and methods

1. Seed collection

Seeds of *E. sativa* were collected from the wild in the spring of 1989, as part of a large project of Cruciferae collection in Israel during the years 1987-1992. Plants of *E. sativa* were found at Nahalat Yehuda, which is located a few kilometers from the seashore in the center of Israel: Long. 13°05'; lat. 15°38'; alt. 40 m. Light soil, surrounded by orange plantations (Elber *et al.* 1989).

Three plants were collected from this site and seeds were kept separately and analyzed for oil quality and fatty acid composition using commonly practised methods (Yaniv *et al.* 1991). The data are presented in Table 1.

2. Cultivation

As part of a large-scale experiment designed to test the agricultural potential of native collected Cruciferae, seeds of two accessions of *E. sativa* were cultivated at the Bet Dagan Experiment 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 seedling establishment.

Observations were made on percent germination, plant vigour, plant uniformity, days to flowering and ripening, and seed yield. Seeds were analyzed for oil content and fatty acid composition using common methods (Yaniv *et al.* 1991).

3. Cultivation under stress conditions

Seeds of *E. sativa* collected in Israel (accession Nahalat Yehuda) were cultivated at the Ramat HaNegev Experimental Station, during the 1991/92 growing seasons. Two water irrigation lines were used, one with nonsaline water and the other with saline water. The two lines were parallel to each other, with 12 mm between them. Plots were sown perpendicular to the irrigation lines. Five treatments were used:

1. Dry = plants were cultivated 3-5 m away from the nonsaline water source;
2. Control = plants were irrigated with nonsaline water;
3. Center = plants were irrigated with a mixture of saline and nonsaline water;
4. Saline = plants were irrigated with saline water;
5. Dry + Saline = plants were cultivated 3-5 m away from saline water.

Each treatment was replicated four times. The plants were harvested in April 1992. The following parameters were recorded: plant height (cm), number of pods/plant, 1000-seed weight, yield/plot, percent oil and percent erucic acid.

Results

1. Cultivation at the Bet Dagan Experimental Station

Eruca sativa accessions collected at Nahalat Yehuda were cultivated at the Bet Dagan Experiment Station in order to evaluate their agronomic potential, as well as their seed oil quality and quantity. Tables 1 and 2 summarize the results. Germination did not exceed 65%, typical of the germination rate of wild species. Vigour and uniformity of the plants could be improved. However, the yield potential of 300 g/2.4 m^2 is promising. Oil quantity is 28-29%. The fatty acid profile indicates 37-38% erucic acid, which makes this oil an industrial, rather than edible, one. If the industrial oil market expresses interest, *E. sativa*, with 29% oil, could be considered as a possible source. A much better source is native *Sinapis alba*, as described previously (Yaniv *et al.* 1993).

2. Effect of salt and drought stress on yield parameters

Table 3 summarizes the results of salt and drought stress regimes on yield parameters of *E. sativa* cultivated at the Ramat HaNegev Experimental Station during the 1991/92 growing seasons. All yield parameters were affected by salt irrigation and drought. A decline was observed in plant height, number of pods/plant, 1000-seed weight and yield/plot. However, the quantity of oil and the content of erucic acid in the seeds were not affected by the stress. The yield obtained — 1500 g per plot under saline conditions — is remarkable, and shows salt tolerance of *E. sativa.*

These trials will have to be repeated in order to obtain a better evaluation of salt and drought tolerance of *E. sativa.*

Table 1. Yield parameters of native *E. sativa* cultivated at Bet Dagan

Sample	Germination (%)	Vigour*	Uniformity*	Days to		Plot yield (g/2.4 m^2)
				Flow-ering	Ripe-ning	
Cultivated 1	50	5-6	6-7	68	153	333
Cultivated 2	65	5-6	6-7	67	148	292

* On a scale of 1-9: 1 = very low; 9 = very high.

Table 2. Comparison between fatty acid composition of *E. sativa* seeds collected in the wild at Nahalat Yehuda and cultivated at Bet Dagan

Sample	Fatty acid composition (% oil)						
	C16:0	C18:0	C18:1	C18:2	C18:3	C20:1	C22:1
Wild*	—	3.1	11.6	13.5	18.7	9.3	38.9
Cultivated** 1	28.9	3.5	14.2	14.6	12.5	15.2	38.1
Cultivated 2	28.0	3.5	14.3	14.3	12.5	15.0	37.3

* Averages of three accessions collected.
** Averages of four replications.

Table 3. The effect of irrigation with saline water on yield parameters of *Eruca sativa*

Irrigation regime	Plant ht. (cm)	Pods/ plant	1000-seed wt (g)	Yield/ plot (g/2.4 m^2)	Oil (%)	Erucic acid (%)
Dry	159	218	2.00	900	21.8	39.0
Control	195	515	2.20	1500	23.0	36.5
Center	198	512	2.20	1450	22.8	38.3
Saline	164	394	1.80	1500	21.1	33.8
Dry + Saline	118	323	1.70	740	20.2	36.6

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Work conducted by the Istituto di Orticoltura e Floricoltura of the University of Catania, Sicily

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The species has been considered in recent years in diversification programmes of the vegetable production within Mediterranean areas, which have used species cultivated in other cultivated environments or those taken directly from the wild.

For rocket species (*Eruca sativa* L., *Diplotaxis muralis* and *D. tenuifolia*), the research activity consisted of identifying areas in which the species were widespread and in gathering, characterizing and preserving their germplasm material. Assessment of cultivation was also done using three lots of commercially available seeds of *E. sativa* provided by as many seed companies.

This activity has led to the identification of various sites in Sicily where the presence of rocket species was widespread, and the subsequent gathering of its germplasm.

With regard to the research involving assessment of *E. sativa*'s adaptability to cultivation, the experimental factors considered were the cultivation environment (greenhouse and open air), plant density (50, 100 and 200 plants/m^2), and harvesting method (single or repeated).

Cultivation began in December 1993. Protected cultivation yielded about 34 t/ha of leaves, which is 70% higher than those harvests done in the open air. In relation to simultaneous harvests of plants, 50 days after sowing in open air and 70 days in a cold greenhouse, the yield was respectively 9.2 and 23.2 t/ha. Higher yields were recorded with repeated harvesting (45.2 t/ha); in a cold greenhouse (five harvests, about 100 days after sowing) and 30.6 t/ha in open air (harvesting twice about 90 days after sowing).

In relation to plant density the yield increased up to 200 plants/m^2 both in open field (23.3 t/ha) and in greenhouse (42.9 t/ha).

In conclusion *E. sativa* demonstrated good adaptability both in open air and a greenhouse. Yield can be considered quite high, and is particularly so if one considers that our research results were obtained using seedlots that, although commercially available, are not highly qualified genetically. Owing to the ever-increasing demand for rocket all year round it would be interesting to study the effects of sowing periods on harvest timing and their interaction with the various cultivation techniques that affect production.

Collection and conservation of rocket genetic resources: the Italian contribution

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At the Valenzano preliminary meeting the Istituto del Germoplasma (IdG) and the Volcani Centre (VC) took the responsibility of surveying which collections of rocket genetic resources were available and determining the level of their characterization. This task was achieved by contacting several institutions. The VC made contact with major genebanks (IPK, FAL and USDA/GRP). The IdG carried on a bibliographical survey to assess which groups had recently published papers on *Diplotaxis*, *Eruca* or related species. To these institutions a questionnaire was sent in order to gather information. The questionnaire is shown in Box 1 and a list of the organizations to which it was sent is given in Table 1.

Fewer than half of the consulted institutes answered. Nevertheless, the results were quite encouraging (see Table 2). From analysis it appears clear that rather large collections of *Eruca* are held at IPK, FAL, USDA/Iowa and IdG. It appears also possible that large segments of these collections might be duplications; therefore a screening programme needs to be carried out in order to define the real entity of the genetic resources available. A large collection of *Diplotaxis* is present in Madrid, curated by Prof. Gómez-Campo, and a few samples are also available at other centres, the largest of which is curated by Prof. Quiros in California.

The results presented here are to be considered only as preliminary, since the questionnaire is still being distributed; for example, it will also be distributed to the colleagues participating in the *Brassica* workshop. It is likely that more samples will be provided by minor collections. Moreover, colleagues of the Komenskeho University, Bratislava, Slovakia, indicated their availability to collect *Diplotaxis* seeds from their area.

In southern Italy, both *Diplotaxis* and *Eruca* are present in the spontaneous flora. *Eruca* appears to have a more limited distribution than *Diplotaxis*. Wild *Eruca* stands have been observed in the area between Matera and Gravina di Puglia and cultivated local types are present in most of Basilicata, with the exception of the inner mountain areas and the coastal belt. *Eruca* flowers earlier than *Diplotaxis* in southern Italy; most flowering takes place in April-May. The preferred habitats for *Eruca* appear to be dumps and roadsides. It is possible in spring to drive literally between two rows of *Eruca* plants, especially in the less disturbed areas. *Eruca* appears to be absent from the districts of Bari, Lecce, Brindisi and Taranto. The preliminary impression is that these two genera, at least for the species of our interest, are not sympatric. Exploration and collection of *Eruca* resources are scheduled to take place during the spring of 1995 in several areas of Basilicata.

Diplotaxis is, instead, extremely widespread in all Apulia. In Italy several species are present, the most widespread being *D. erucoides*, which is not within the scope of our network. Possibly two species of interest are the most frequent, *D. tenuifolia* and *D. muralis*. The former has an erect aspect and large, fleshy leaves, while the latter tends to be a procumbent type and has slender leaves. The two types can co-occupy the same areas. Besides their distinctive morphology, the flower characters are very similar; in fact, from detached flowers it is almost impossible to distinguish the two types. Therefore a more detailed study on their classification could be highly beneficial, in order to establish whether the two types are in fact two different taxa.

Both types have a pungent taste, which makes them extremely appreciated for the preparation of salads. Prof. Bianco gave us a comprehensive picture of the utilization of *Diplotaxis* in southern Italy and in Apulia in particular. *Diplotaxis* tends to flower later than *Eruca*. Flowering starts in late May and continues for the whole summer and autumn. It is not infrequent to observe flowering plants even in late December. Some samples of *D. tenuifolia* have been collected in a few locations near Bari and Lecce (Apulia, Adriatic coast) and near Metaponto (Basilicata, Ionian coast). Other collections are scheduled for 1995. Collections of both *Diplotaxis* and *Eruca* are now considered priority for the IdG.

Questionnaire on conservation, study and use of rocket circulated to several institutions

1. Does your organization hold any germplasm material of *Diplotaxis* and/or *Eruca* species?
  1.1 If so, could you provide the following information?

2. Has the material been collected directly by your organization or has it been received as a donation from another institution?

3. Could you provide passport data on this material including the collector's original identification number?

4. Has this material been characterized/evaluated?
  4.1 If so, for which traits?
  4.2 Is this information available?

5. Do you rejuvenate/multiply routinely this material?
  5.1 If so, do you take any measures to prevent cross-pollination from taking place?

6. Would you be able to send a sample for each of those accessions held in your collection to the Germplasm Institute? (We would need at least 1 gram for each accession.)

7. Does anyone in your organization conduct research on these species, and if so could you indicate the area of such investigations?

8. Are you aware of any other person/organization in your country also involved in research activities on these species?
  8.1 If so, could you provide contact addresses?

At the IdG we also have carried on some preliminary cytological experiments in *Diplotaxis* to assess which techniques are best for cytological studies in these taxa. The preliminary results are encouraging. In the future we plan to carry out characterization of both *Diplotaxis* and *Eruca* genomes by means of differential chromosome staining using DNA-specific stains and *in situ* hybridization experiments using DNA probes from *Brassica* and *Arabidopsis*. The possibility of starting these studies is subject to the availability of proper human resources.

Table 1. Institutions to which the questionnaire was sent, ordered by country

Country	Contact person	Institution	City
Canada	Dr McVetty PBE	Allelix INC	Georgetown
Canada	Dr Warwick SI	Biosyst. Res. C. Agric. Canada	Ottawa
Canada	Dr Keller WA	Plant Res. C. Agric. Canada	Ottawa
Finland	Dr Sovero M	Dept. Biology, U. of Turku	Turku
France	Dr Chevre AM	INRA Stat. Amel. Plantes	Le Rheu
France	Dr Delcasso DC	NRS, U. of Perpignan	Perpignan Cedex
Germany	Dr Heyne FW	I. Pfl.bau Pflzucht U. Gottingen	Gottingen
India	Dr Dayal N	Dept. Botany, Ranchi U.	Ranchi
India	Dr Chatterjee G	Pl. Mol. Cell. Genet. Bose Inst.	Delhi
India	Dr Batra V	Dept. Botany, U. of Delhi	Delhi
India	Dr Batra A	Dept. Botany, U. of Rajastan	Jaipur
India	Dr Agnihotri A	Biotech. Div. Tata En. Res. Inst.	New Delhi
Japan	Dr Hinata K	Fac. Agric., Tohoku U.	Sendai
Slovakia	Dr Ferakova V	U. of Komenskeho	Bratislava
Spain	Dr Martinez-Laborde JB	Dept. Biol. Veg., ETSIA U. Polit.	Madrid
Spain	Dr Sobrino-Vesperinas E	Comp. Esp. Cultivos Oleaginosos	Madrid
Sweden	Dr Sundberg E	Pl. Breed., Swed. U. Agr. Sci.	Uppsala
USA	Dr Quiros CF	Dept. Veg. Crops, UCLA	Davis
USA	Dr Williams PH	Plant Pathol., U. of Wisconsin	Madison
USA	Dr Ahloowalia BS	Agrigenetics Adv. Sci. Co.	Madison

Table 2. Number of accessions and kind of activity on rocket collections around the world

Genus	Institution	Country	Contact person	No. access.	Coll-ected	Donations	Evalu-ation	Regen-erated	Research	Available
Diplotaxis	CLBRR	Canada	SI Warwick	—	Y	Y	Y	Y	Y	Y
Diplotaxis	IPK Gatersleben	Germany	H Knupffer	5	—	Y	—	—	—	—
Diplotaxis	U. of New Delhi	India	KR Shivanna	—	—	Y	Y	Y	Y	Y
Diplotaxis	CNR-Germplasm	Italy	D Pignone	2	Y	—	—	—	Y	—
Diplotaxis	U. of California	USA	CF Quiros	12	Y	—	—	—	Y	Y
Eruca	IPK Gatersleben	Germany	H Knupffer	24	Y	Y	—	—	—	—
Eruca	FAL, Braunschweig	Germany	L Seidewitz	86	—	—	—	—	—	—
Eruca	NAGRF	Greece	A Zamanis	—	—	—	—	—	—	—
Eruca	TERI, Delhi	India	A Agnihoteri	—	—	Y	—	Y	—	—
Eruca	Volcani Centre	Israel	M Manoah	—	—	—	—	—	—	—
Eruca	CNR-Germplasm	Italy	D Pignone	32	Y	—	—	—	Y	—
Eruca	HRI Wellsbourne	UK	A Pinnegar	27	—	Y	—	Y	—	Y
Eruca	USDA, Iowa	USA	—	157	—	—	—	—	—	—
Eruca	CGC, Wisconsin	USA	PH Williams	—	—	—	—	—	—	—

Preliminary results of agronomic trials on rocket conducted by the ESAV (Agency for the Rural Development of the Veneto Region)

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Objectives

In the framework of the collaborative activities of the Rocket Network, the ESAV Po di Tramontana Station, in collaboration with the University of Padova, Italy, has commenced some research work on rocket. The aim of these activities is to investigate the agronomic requirements for rocket cultivation in an area representative for northern Italian regions.

The objectives of the trials are to evaluate the yield response under three different sowing times and using four different nitrogen fertilizer concentrations. Another aim of the work is to monitor the nitrate concentration in the leaves resulting from the various concentrations of nitrogen applied. This latter part of the study is still underway and is being investigated by the analytical laboratory of the Agronomy Institute of the Faculty of Agriculture, University of Padova, Italy.

Materials and methods

The trial was conducted in the experimental fields, which are characterized by a medium type of lime soil, with an alkaline reaction. The soil can be considered well balanced in nutrients.

The experimental scheme adopted is that of randomized blocks with four repetitions, on which four nitrogen levels have been applied (0, 100, 200, 300 kg/ha) and three sowing dates were used (9 May, 15 June and 1 August 1994). The nitrogen fertilizer, in the form of ammonium nitrate, was applied as follows: one-third at sowing, one-third 20 days later and one-third one month later.

The sowing of the trial parcels (1 m^2 of surface) was done using seeds from *Diplotaxis* species (found on sale in the market) in quantities equivalent to 1.5 g/m^2. Seeds were sown within 1 cm of soil depth, in rows 20 cm apart, applied in continuous rows and without tilling operations.

The vegetative material was removed from the plots at the stage when the leaves had reached full maturity and before flowering induction. This material was then placed into a drying chamber to obtain the dry matter at 65°C for 48 hours.

Preliminary results and discussion

The preliminary information obtained shows a significant interaction between productivity and sowing dates. It seems clear that, in northern Italian conditions, sowing in the first part of May will mean a higher number of cuts (5 vs. 3 or 2 obtained from other sowing dates) corresponding to an increase in yield productivity of 40 and 60%, respectively.

Further preliminary conclusions could be drawn in regard to the interaction between sowing date and nitrogen fertilization. On average, productivity was reduced on the fertilized plots; at the same time no substantial differences existed among all the fertilized plots.

In regard to the concentration of nitrogen, it is interesting to look at the yields accumulated at the different harvests and from the different sowing dates (Figs. 1, 2 and 3). Until the third harvest and for all three sowing dates, the productivity increased and was almost constant for all the four plots in comparison. It is also clear that there seems to be a prevailing effect of the 100 kg/ha rate compared with the unfertilized control. The increase in yield is clearly visible starting from the third harvest of the first sowing date.

The statistical analyses did not show significant differences in the results, as the variability within the blocks was relatively high. We believe that this might be due to the lack of adequate agronomic techniques, which the investigation wishes to study and improve.

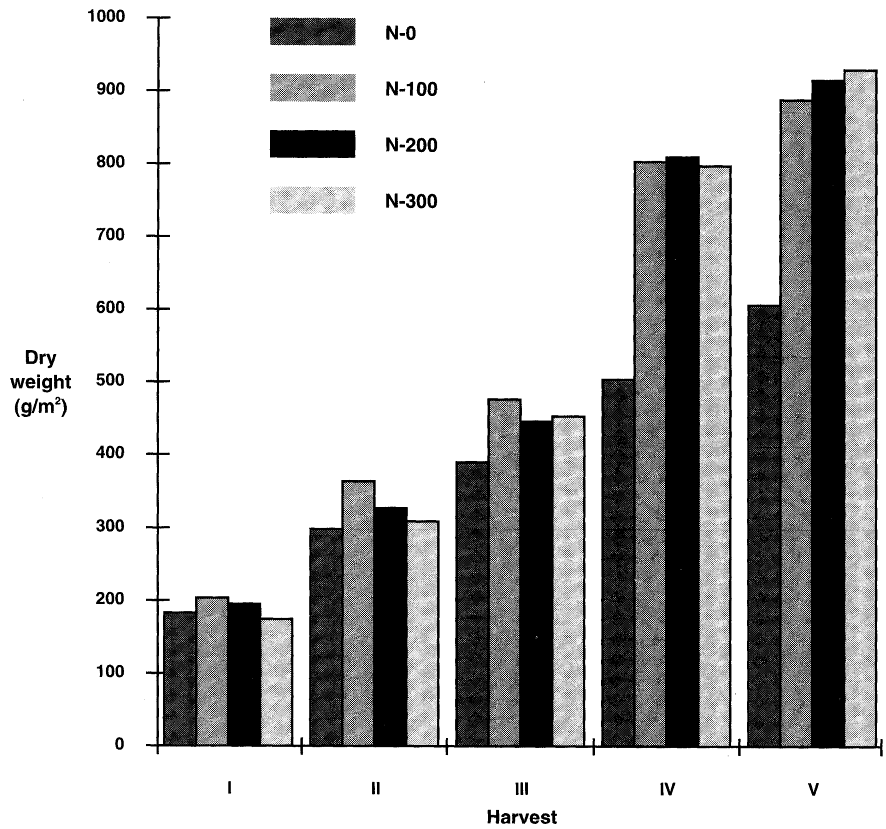

Fig. 1. Cumulative dry matter yield of *Diplotaxis* spp. from first sowing

Conclusions

On the basis of these preliminary results we will direct the next step of our investigation toward the characterization of the best sowing date which would fall within a period that would be best for an early harvest. The results suggest that a rate of 100 kg/ha of nitrogen fertilizer should be sufficient to ensure a good yield. This preliminary conclusion is to be confirmed, however, after having compared it with results obtained from the analyses of the presence of nitrates in the leaves.

It seems also opportune to reconsider the type of nitrogen to use in rocket cultivation, as it might be that the ammoniacal form present in the ammonium nitrate used became available to the plant at different periods, which resulted in different production responses.

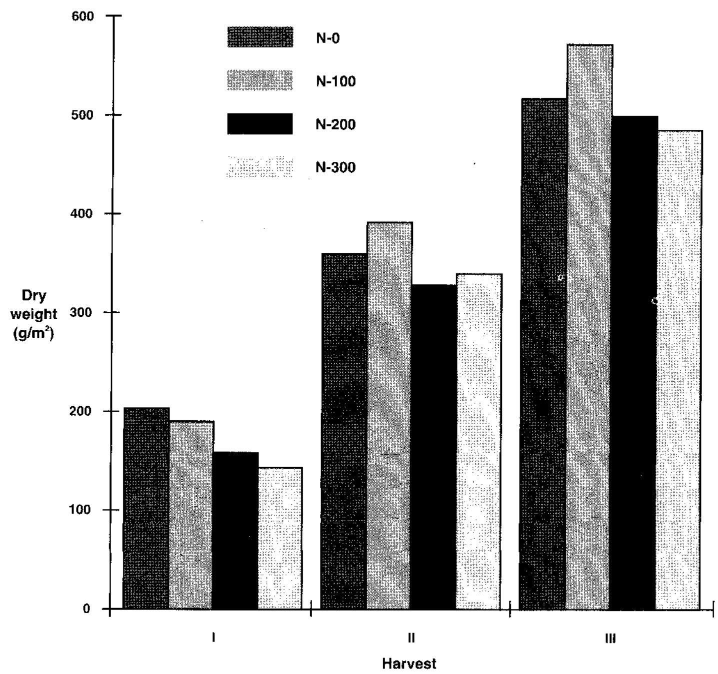

Fig. 2. Cumulative dry matter yield of *Diplotaxis* spp. from second sowing

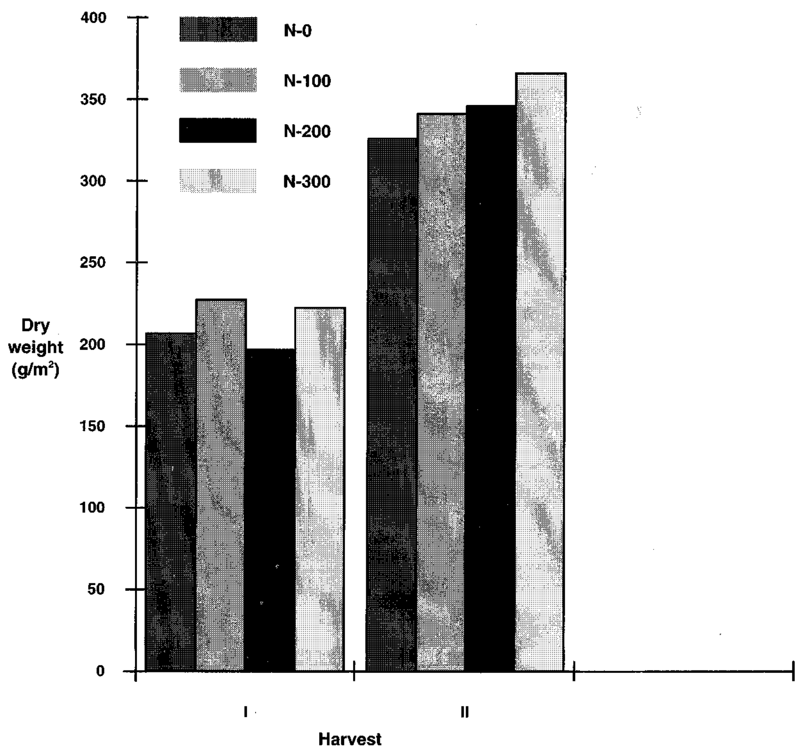

Fig. 3. Cumulative dry matter yield of *Diplotaxis* spp. from third sowing

Preliminary results from cytogenetic investigations aiming at characterizing the karyotype of *Eruca* and *Diplotaxis* species

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In Southern Italy rocket for human consumption is generally picked from the wild. *Diplotaxis* plants are much more frequent than *Eruca* and the two genera have different time and spatial distribution: *Eruca* is more frequent in inner areas and young plantlets are available from the spring whereas *Diplotaxis* is more frequent along coastal zones and has a longer life span (young plants can be found from early spring throughout late fall).

Two species of *Diplotaxis* are reported to be more commonly found and used, namely *D. tenuifolia* and *D. muralis*. The former is a diploid taxon, the latter is an allopolyploid species derived from the hybridization occurred between *D. tenuifolia* and *D. viminea*. The morphological differentiation between these two species is striking (Fig. 1): *D. tenuifolia* is characterized by smaller though erect and robust growth habitus with fleshy and crispy leaves, whereas *D. muralis* has more slender leaves and stems, and procumbent, almost bushy, growth habit. Consumers have a slight preference for *D. tenuifolia* which is reported to have a better flavor and a better consistency of the edible parts.

In some environments both taxa are present and grow interspersed; nevertheless no putative hybrids are generally observed in those areas. An interesting finding in this respect has been the one made by the Germplasm Institute of Bari near Metaponto, in Basilicata region, southern Italy where these two species were growing close to each other. Flower buds and seeds from both taxa were collected in order to allow cytological examination. The purpose of this collection was to investigate *D. tenuifolia* and *D. muralis* genomes in order to verify if any adaptive chromosomal rearrangements had occurred in these two species.

Young flower buds proved to be a better source of metaphase than root tips. The metaphase preparations were stained with DAPI and observed with a fluorescence microscope. The chromosomes of *D. tenuifolia* appeared to be rather small, similar to those of other Brassicaceae. The chromosome number observed was $2n$=22 in all examined individuals. The karyotypic analyses were rather difficult since chromosomes did not show differential reaction to DAPI (Fig. 2), hence, chromosome identification could only be made by using morphometric indices. Different investigation methods might, however, be pursued for seeking better identification of these chromosomes.

A very interesting and intriguing result came from the cytological examination of some individuals of *D. muralis* from Metaponto: the chromosome number observed in this material was in fact $2n$= 22. This result is unexpected since the chromosomal number reported for this taxon has been always $2n$=4x=42. Moreover, no spontaneous hybridization between the two taxa has been reported so far in the literature. At this moment, considering the preliminary stage of these investigations, no plausible explanation is possible. As a working hypotheses, however, it could be suggested that a certain degree of introgression might have taken place from *D. muralis* into natural populations of *D. tenuifolia*, thus conferring those peculiar morphological traits observed in those individuals. The absence of a detectable hybridization at cytological level may be an indication that the introgressed population may have rearranged their chromosomes and hamper therefore the establishment of ‘orthodox’ hybrid individuals.

Further studies are necessary to better evaluate these populations from Metaponto and a multidisciplinary approach, such as a combination of cytogenetic, molecular and biochemical analyses, will be highly desiderable if human resources are available.

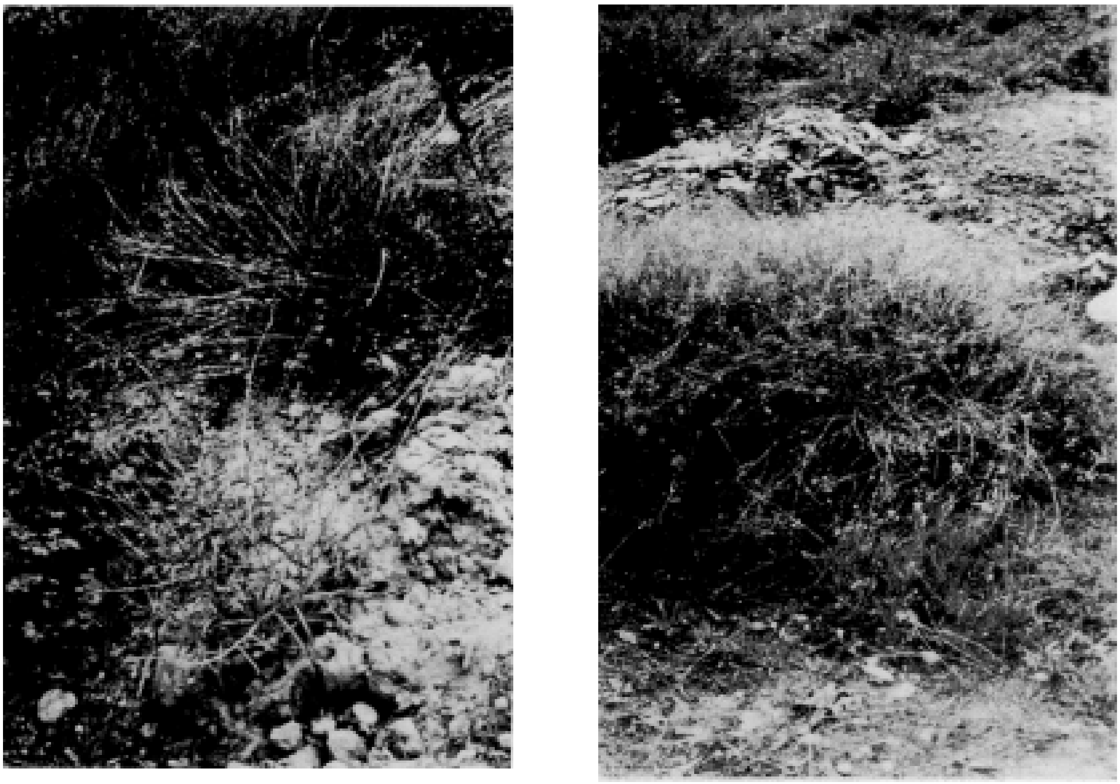

Fig. 1. Distinct morphological differences exist between *Diplotaxis tenuifolia* (left) and *D. muralis* (right)

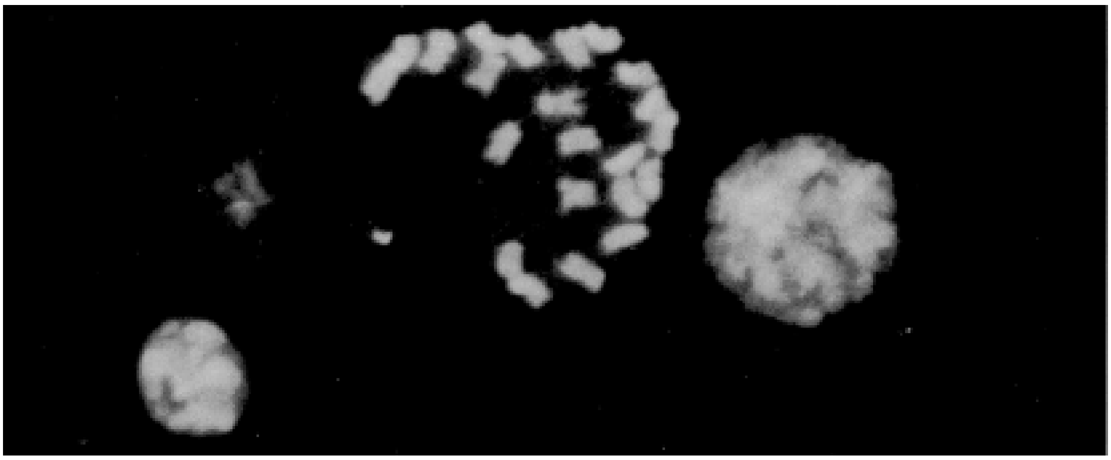

Fig. 2. Metaphasis chromosomes of *Diplotaxis tenuifolia*; 2*n*=22 in all examined individuals

Workplan of the Network

First meeting of the Rocket Genetic Resources Network

The first meeting of the Network was held among representatives of various institutions from Israel, Portugal, Spain, Egypt, Turkey, Greece and Italy. The informal gathering represented an opportunity for re-addressing issues related to the conservation and utilization of rocket that had been previously brought up at the Valenzano meeting.

After listening to the preliminary results of those activities that had already started in the framework of the Network collaborative initiatives, participants discussed and agreed to continue their commitment to furthering conservation and utilization of both *Eruca* and *Diplotaxis* species in the Mediterranean region, area of speciation, domestication and major use of this underutilized crop.

Following is the workplan of these activities that will be carried out during the period 1994/95. Activities are being grouped under major items: viz. exploration and collection, multiplication and exchange of material, database, descriptors list, evaluation activities and other activities (mainly follow-up contacts). It is the intention of the participants to present findings and review the Network's activities during the next meeting of the Group, which should take place in late 1995 or early 1996.

Exploration and collection

D. Pignone has distributed to the Group members a copy of the collecting form that is being used at the Germplasm Institute of Bari, Italy. It has been recommended that the Group use this form whenever gathering germplasm accessions.

1. The Germplasm Institute of Bari, Italy (D. Pignone) will be exploring/collecting *Eruca* and *Diplotaxis* species in the following areas:
   - islands of Pantelleria and Linosa (Sicily Channel, Italy). The expedition will take place before the end of November 1994;
   - Pollino Mountain area (Basilicata region, Italy), some time before the end of 1994;
   - surroundings of the Germplasm Institute's field stations of Valenzano, Metaponto, Lecce and Cerignola), aiming at sampling wild populations of *Diplotaxis*. Collection expected to be carried out before the end of November this year.

2. The Agricultural Research Centre, Cairo, Egypt (M. Salah) will collect material of rocket (two varieties of *Eruca sativa* will be targeted) in Egypt. Areas in which the cultivation of rocket is reported to be rather popular (along the coast of the Red Sea, in the Upper Egypt region and in oases scattered in the desert) will be targeted.

3. S. Pais, J. Silva Dias and H. Cotrim (Portugal) will collect wild and cultivated rocket in the southeast region of Portugal. Attention will be paid to surveying the use of cultivated rocket in the country.

4. Z. Yaniv will collect rocket germplasm material in Israel (mainly wild species).

5. V. Bianco will collect additional rocket material from Puglia region, Italy.

Multiplication/exchange of material

The Germplasm Institute of Bari agreed to serve as a depository of germplasm material of rocket (cultivated and wild) that will be collected/provided by group members. D. Pignone will act as a coordinator within the group for the safe deposit and exchange of these materials to group members. The Germplasm Institute will multiply rocket germplasm starting from this fall using a newly established greenhouse in order to ensure that genetic integrity within the material is maintained. Owing to the limited space available, multiplication will involve a limited number of accessions. Z. Yaniv will assist D. Pignone in the multiplication of the germplasm and to this end she will seek the cooperation of the Israeli Gene Bank located at the Volcani Center.

1. M. Salah will acquire samples of the marketed varieties of rocket and send them to D. Pignone for conservation and distribution.

2. Y. Tuzel will contact, on behalf of the Group, the Izmir Gene Bank in Turkey to request samples of rocket germplasm deposited there and send them to D. Pignone.

3. UPM of Madrid and The Germplasm Institute of Bari agreed to exchange duplicates of *Eruca* and *Diplotaxis* accessions conserved in their respective genebanks.

4. V. Bianco will provide D. Pignone with samples of the two varieties of rocket available in his institute.

Rocket database

D. Pignone will contact the manager of the *Brassica* DB (Theo van Hintum) in the Netherlands to obtain a copy of the information available on rocket as well as to seek suggestions for building the rocket database. The rocket database will be similar to the *Brassica* one but it will be developed using a dBASE programme instead of the Oracle programme. Additional items in the database might be added / removed in order to meet the *Eruca/Diplotaxis* descriptors requirements.

Rocket descriptors list

During the meeting a close look at the IPGRI *Brassica* descriptors was made and a first draft of rocket descriptors was developed based on them. S. Padulosi will send to the Network members a print of the first draft of the agreed descriptors list in order to gather further comments and suggestions. There was strong support for having a descriptors list limited to *Eruca* species. An introductory part in the descriptors could provide, on the other hand, general information on the taxonomy of rocket including *Diplotaxis* species. A suggestion came from the group regarding the usefulness of indicating in the descriptors list those characters which are considered to be essential for a basic characterization of rocket germplasm. Also stressed was the importance of having an introductory part dealing with the utilization of rocket (including names in different languages) in order to facilitate an awareness of the consumption of the crop in different countries.

Evaluation activities

Members of the group presented reports of various evaluation activities that started after the Valenzano meeting. These activities will be continued and additional projects have been added to them as follows:

1. V. Bianco will be working on:
   - analyses of nitrate accumulation in the leaves
   - evaluation of nutritional value in rocket varieties
   - post-harvest physiology
   - studies on the possibility of freezing rocket leaves
   - tolerance to salt stress.

2. M. Salah will be working on:

- water stress on rocket
- chemical constituents in seeds and leaves of rocket
- agronomical aspects of rocket cultivation.

3. Z. Yaniv will continue to study the following:
   - chemical characterization of rocket material
   - the biological properties of rocket oil (e.g. nematicide potential)
   - osmotic stress in rocket and adaptability to dry areas.

4. D. Pignone will be focusing his activities on:
   - agrobotanical characterization of the germplasm material using the descriptors list
   - development of standard karyotypes for the three species of major interest to the Group (*Eruca sativa, Diplotaxis tenuifolia* and *D. muralis*)
   - attempts to localize repeated DNA sequences through *in situ* hybridization technique.

5. J. Dias, S. Pais and H. Cotrim will work on the following:
   - evaluation for pest resistance in populations of wild *Diplotaxis* from Portugal
   - studying the presence of glucosinolates in rocket (i.e. study their role in the process of iodine fixation).

6. S. Warwick will work on:
   - developing techniques of DNA-DNA *in situ* hybridization using the whole genome in order to trace specific chromosomes in interspecific hybrids
   - natural hybridization and gene flow between cultivated *Brassica* and wild *Diplotaxis* species (in collaboration with Seguin-Swartz).

7. Y. Tuzel will start working on thioglycosides in rocket (compounds responsible for the pungent taste in rocket).

8. UPM (Dolores Sánchez-Yélamo) will start working on isozyme characterization in *Eruca* species; the investigation will use wild material first but other sources, included cultivated material, will be analyzed as well in the future.

Other activities

1. Contacts will continue with the Mediterranean Agronomic Institute of Chania (MAICh) in Crete, Greece, regarding the possibility of supporting part of a PhD thesis of a Greek student at the germplasm laboratory in Bari (D. Pignone and G. Stavroulakis from MAICh).

2. S. Padulosi will contact F. Branca of the University of Catania concerning the follow-up of rocket evaluation activities that have started there.

3. S. Padulosi will contact E. Marconi of the Nutrition Institute of Rome, Italy to investigate possible cooperation between the Institute and the University of Bari on nitrate presence in rocket.

4. S. Padulosi will follow up with Pimpini/Baggio from the Veneto region on the agronomic evaluations being carried out at ESAV.

Thematic presentations

An introduction to the diversity of rocket (*Eruca* and *Diplotaxis* species) and their natural occurrence within the Mediterranean region

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The name rocket *sensu stricto* is normally applied to members of the genus *Eruca*. This genus is classified in the tribe Brassiceae within the family Brassicaceae or Cruciferae.

Defining characters for *Eruca* include a conical, flattened, seedless beak with a minute stigma, and a siliqua with valves rounded in section, one-nerved. Seeds are small, ellipsoidal or flattened, and they are arranged in 2-3 rows.

Four species are commonly recognized within this genus (see Table 1). Three of them are local in the Maghrebian countries (Morocco, Algeria or Tunisia) while only *Eruca vesicaria* has a wider distribution (circummediterranean in the widest sense) and it has been further introduced in other countries and continents.

Table 1. Species described for genus *Eruca* Miller

Species	Distribution	Chromosomes (*n*=)
Eruca setulosa Boiss. & Reuter	Tunisia, Algeria	?
Eruca loncholoma (Pomel) O.E. Schulz	Morocco, Algeria	?
Eruca pinnatifida (Desf.) Pomel	Algeria, Morocco	11
Eruca vesicaria (L.) Cav.	Mediterranean, Macaronesian and Irano-Turanian regions	11

Table 1 also shows chromosome numbers for two species where it is known. Both have 2*n*=22.

At present, and in our opinion, the most conspicuous taxonomic problems in *Eruca* involve the establishment of the proper position of *E. setulosa* and *E. loncholoma*, as well as the differentiation between the infraspecific taxa under *E. vesicaria* (subspecies *vesicaria*, *sativa* and *longirostris*).

Eruca loncholoma and *E. setulosa* are perhaps too close in their characters to the members of Section Brassicaria in the genus *Brassica*, so that they might well become members of this Section in the future, once they are studied more closely. So far, only scarce herbarium material is now available.

The situation for those subspecies described under *E. vesicaria* needs detailed studies. The characters used to differentiate subsp. *vesicaria* and subsp. *sativa* are too feeble (leaf shape and persistence of the calyx) and they show a continuous reticulate variation. The persistence of the calyx in herbarium specimens, for instance, largely depends upon the moment of collection, so that the ascriptions to subspecies in herbarium specimens are nearly chaotic. The most characteristic subsp. *vesicaria* populations grow in central to southeast Spain, where they are uncommon and probably suffer introgression by dominating subsp. *sativa* types.

A similar situation in the southwestern Mediterranean area occurs with subsp. *longirostris*, defined by the relative length of its beak and pod. Perhaps better defined is subsp. *lativalvis*, from Algeria and Libya.

As for *E. pinnatifida* (sometimes also considered a subspecies of *E. vesicaria*) it is very distinctive by its large size (up to 1 m high), compressible stem and long siliqua stalks.

Very similar uses to those of *Eruca* can be recorded for some species of *Diplotaxis*, but in this case the name rocket is only locally applied, obviously by extension. *Diplotaxis* is a large genus (Table 2) with long siliquas, papyraceous valves and minute ellipsoidal seeds arranged into two rows. Its geographic distribution is mostly circummediterranean, with maximum variation in the west. At least 16 species are single-country endemics, often very local. Others have become widespread weeds.

Table 2. Species described for genus *Diplotaxis* DC.

D. acris	*D. gracilis**	*D. siettiana**
*D. assurgens**	*D. griffithii*	*D. siifolia*
*D. berthautii**	*D. harra*	*D. simplex*
*D. brachycarpa**	*D. hirta**	*D. tenuifolia*
*D. brevisiliqua**	*D. ibicensis**	*D. tenuisiliqua*
D. catholica	*D. ilorcitana**	*D. villosa**
*D. cretacea**	*D. muralis*	*D. viminea*
*D. decumbens**	*D. nepalensis**	*D. virgata*
D. erucoides	*D. ollivieri**	*D. vogelii**
*D. glauca**	*D. pitardiana*	

* Single-country endemics.

Chromosome number can be *n*=7 (*D. erucoides*), *n*=8 (*D. brevisiliqua*, *D. ibicensis*, *D. ilorcitana*, *D. siettiana*), *n*=9 (*D. assurgens*, *D. berthautii*, *D. brachycarpa*, *D. catholic*, *D. tenuisiliqua*, *D. virgata*), *n*=10 (*D. siifolia*, *D. viminea*), *n*=11 (*D. pi-tardiana*, *D. cretacea*, *D. simplex*, *D. tenuifolia*, *D. acris*), *n*=13 (*D. harra*, *D. glauca*, *D. gracilis*, *D. hirta*) and *n*=21 (*D. muralis*), the last considered to be an amphidiploid. For other species, this number is unknown.

An important character for diagnosis is the presence or absence of 1-2 seeds in the siliqua beak.

In a recent comprehensive thesis by Martínez-Laborde (1988), three subgenera are recognized. Subgenera *Diplotaxis* and *Catocarpum* both show seedless beaks and they might probably include the most interesting species from an applied point of view. Subgenus *Rhynchocarpum* is divided into three sections which correspond with the basic chromosome numbers *n*=7, 8, 9.

Reference

Martínez-Laborde, J.B. 1988. Estudio sistemático del género *Diplotaxis* DC. (Cruciferae, Brassiceae). Unpublished Ph.D. Thesis. Universidad Politécnica de Madrid, Escuela Tecnica Superior de Ingenieros Agronomos, Madrid, Spain.

New taxonomic views within *Eruca* and *Diplotaxis* genera in the light of hybridization and molecular findings

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Cruciferae or mustard family

Contains ca. 3500 species and 350 genera, and is subdivided into 4-19 tribes. Tribe Brassiceae is one of the few natural groups.

	No. tribes
Bentham and Hooker (1862)	10
Prantl (1890)	4
Hayek (1911)	10
Schulz (1936)	19
Janchen (1942)	15

Tribe Brassiceae

Contains ca. 217 species and 52 genera; 25 genera are monotypic. The last taxonomic monograph was by O.E. Schulz (1919, 1923, 1936). There are six subtribes:

Brassicinae Hayek
Moricandiinae Hayek
Raphaninae Hayek
Cakilinae (DC.) O.E. Schulz
Vellinae Hayek [includes Savignyinae Hayek]
Zillinae DC.

Note: The Brassicinae is defined primarily on the basis of elongated (siliquose) dehiscent fruits, presence of median nectaries and usually seeded beaks. Although morphologically quite distinct from subtribes Cakilinae, Vellinae and Zillinae, its separation from the Raphaninae and Moricandiinae is less clear. Current generic circumscriptions within the subtribe Brassicinae have also been considered to be highly artificial by many taxonomists, with generic delimitation based primarily on only one or two morphological traits.

Subtribe Brassicinae

Ten core genera with chromosome numbers n=7, 8, 9, 10, 11, 12, 13.

1. *Brassica*
2. *Coincya*
3. *Diplotaxis* (28 species)
4. *Eruca* (3 species)
5. *Erucastrum*
6. *Hirschfeldia*
7. *Raphanus*
8. *Sinapis*
9. *Sinapidendron*
10. *Trachystoma*

Brassica Coenospecies[1]

Definition

On the basis of chromosome number and crossing ability, Harberd (1976) defined the *Brassica* coenospecies as "the group of wild species sufficiently related to the six cultivated species of *Brassica* to be potentially capable of experimental hybridization with them."

To date, there are 45 diploid cytodemes or crossing groups and six amphidiploid taxa described for *Brassica* coenospecies The coenospecies corresponds closely to the taxonomic subtribe Brassicinae, with the inclusion of *Raphanus* and *Enarthrocarpus*. Taxa included within a cytodeme have a single diploid chromosome number, are generally fully interfertile, and essentially cross-sterile with other cytodemes. Inter-cytodeme F_1 hybrids are usually obtained via embryo rescue and tend to exhibit extensive meiotic irregularities. However, the existence of six naturally occurring inter-cytodeme hybrids has been reported, *Diplotaxis muralis* being one of them.

Taxonomy[2]

1. *Diplotaxis tenuifolia* (*n*=11) cytodeme
(includes *Diplotaxis tenuifolia D. cretacea, D. simplex* [Sobrino Vesperinas 1988])

Genus: *Diplotaxis*
Species: *tenuifolia* (L.) DC.
Auth source: Reg. Veg. Syst. Nat. 2:632 (1821)

Genus: *Diplotaxis*
Species: *simplex* (Viv.) Spreng.
Auth source: Syst. Veg. 2:914 (1825)

Genus: *Diplotaxis*
Species: *cretacea* Kotov
Auth source: Klokov *et al.*, Ukr. Bot. Zhurn. 3:17 (1926)

2. *Diplotaxis muralis* (*n*=10+11) cytodeme

_ Parent ×	_ Parent
D. viminea (*n*=10)	*D. tenuifolia* (*n*=11)

Genus: *Diplotaxis*
Species: *muralis* (L.) DC.
Auth source: Reg. Veg. Syst. Nat. 2:634 (1821)
Subspecies: *ceratophylla* (Batt.) Martínez-Laborde, Bot. J. Linn. Soc. 106:69 (1991); ssp. *muralis*

3. *Diplotaxis viminea* (*n*=10) cytodeme

[1] From Warwick and Black 1993b.

[2] From Warwick 1993a.

Genus: *Diplotaxis*
Species: *viminea* (L.) DC.
Auth source: Reg. Veg. Syst. Nat. 2:635 (1821)

4. *Eruca* spp. (*n*=11) cytodeme
(includes *E. vesicaria*, *E. sativa*, *E. pinnatifida*)

Genus: *Eruca*
Species: *vesicaria* (L.) Cav.
Auth source: Descr. Pl. 426 (1802)
Subspecies: *pinnatifida* (Desf.) Emb. & Maire: Jahandiez & Maire, Cat. Maroc 1004 (1941)
sativa (Mill.) Thell., Ill. Fl. Mitteleur. 4(1):201 (1918)
vesicaria

Synonyms for taxa included above:

Genus: *Eruca*
Species: *pinnatifida* (Desf.) Pomel
Auth source: Nouv. Mat. Fl. Atl. :367 (1875)
Synonym: *Eruca vesicaria* ssp. *pinnatifida* (Desf.) Emb. & Maire

Genus: *Eruca*
Species: *sativa* Mill.
Auth source: Gard. Dict. ed. 8(1) (1768)
Synonym: *Eruca vesicaria* ssp. *sativa* (Mill.) Thell.

5. *Eruca*: Perennial members (presumed separate cytodeme status)

Genus: *Eruca*
Species: *loncholoma* (Pomel) O.E. Schulz
Auth source: Engler, Bot. Jahrb. 54 (Beibl. 119):56 (1916)

Genus: *Eruca*
Species: *setulosa* Boiss. & Reut.
Auth source: Boiss., Diagn. Pl. Orient. ser. 2, 5:26 (1856)

Chromosome numbers[3]

Species	*n*=	Authority
Diplotaxis tenuifolia (L.) DC.	11	van Loon and de Jong (1978)
	11	Gómez-Campo and Hinata (1980)
	11	Natarajan (1981)
	21?	An_ev (1981)
	11	Martínez-Laborde (1988)
Diplotaxis cretacea Kotov	11	Gómez-Campo and Hinata (1980)
Diplotaxis simplex (Viv.) Spreng.	11	Gómez-Campo and Hinata (1980)
Diplotaxis muralis (L.) DC.	21	Gómez-Campo and Hinata (1980)
	21	An_ev (1981)
Diplotaxis viminea (L.) DC.	10	Gómez-Campo and Hinata (1980)
Eruca vesicaria (L.) Cav.	11	Gómez-Campo and Hinata (1980)
	11	Gómez-Campo (1980b)
ssp. *pinnatifida* (Desf.) Emb. & Maire	11	Gómez-Campo and Hinata (1980)
ssp. *sativa* (Mill.) Thell.	11	Gómez-Campo and Hinata (1980)
Reported as *E. sativa* Mill.	11	Sikka and Sharma (1979)
Reported as *E. sativa* Mill.	11	Al-Shehbaz and Al-Omar (1982)
Reported as *E. sativa* Mill.	11	Lan (1986)

Hybridization data[4]

Intercytodeme hybridization between *Diplotaxis tenuifolia*, *D. muralis*, *D. viminea* and *Eruca* spp. and other members of the tribe Brassiceae. Symbols: D? - the direction of the cross is not known; Rs - the reciprocal cross has been successful; Rt - the reciprocal cross has been tried and not been successful; SEXL - hybrid was obtained sexually; OVAR - hybrid obtained with ovary culture; OVUL - hybrid obtained with ovule culture; EMBR -hybrid obtained with embryo culture; and PROT - hybrid obtained via protoplast fusion.

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[3] From Warwick and Anderson 1993.

[4] From Warwick and Black 1993a.

Parental combinations (_ × _)	Cross type	Reference
***Diplotaxis muralis* (*n*=21)**		
D.m. × *Brassica juncea*	PROT	Chatterjee *et al.* 1988
D.m. × *Brassica napus*	Rt,SEXL	Salisbury 1989
	SEXL	Ringdahl *et al.* 1987; Fan *et al.* 1985
Brassica oleracea × *D.m.*	Rt,S / EMBR	Harberd and McArthur 1980
D.m. × *Brassica rapa*	Rt,S / EMBR	Harberd and McArthur 1980
	Rt,SEXL	Salisbury 1989
	PROT	Hinata and Konno 1979
D.m. × *Diplotaxis harra* (as *D. crassifolia*)	Rt,S / EMBR	Harberd and McArthur 1980
Diplotaxis tenuifolia × *D.m.*	SEXL	Sobrino Vesperinas 1988
D.m. × *Erucastrum gallicum*	Rt,S / EMBR	Harberd and McArthur 1980
D.m. × *Sinapidendron frutescens*	Rt,S / EMBR	Harberd and McArthur 1980
***Diplotaxis tenuifolia* (*n*=11)**		
D.t. × *Brassica elongata*	Rt,S / EMBR	Harberd and McArthur 1980
D.t. × *Brassica juncea*	Rt,SEXL	Salisbury 1989
D.t. × *Brassica nigra*	Rt,SEXL	Salisbury 1989
D.t. × *Brassica oleracea*	Rt,S / EMBR	Harberd and McArthur 1980
D.t. × *Brassica rapa*	Rt,SEXL	Salisbury 1989
D.t. × *Coincya rupestris* (as *H. leptocarpa*)	Rt,SEXL	Salisbury 1989
D.t. × *Diplotaxis muralis*	SEXL	Sobrino Vseperinas 1988
D.t. × *Diplotaxis simplex*	SEXL	Sobrino Vesperinas 1988
Diplotaxis viminea × *D.t.*	Rt,S / EMBR	Harberd and McArthur 1980
D.t. × *Erucastrum virgatum*	Rt,S / EMBR	Harberd and McArthur 1980
D.t. × *Hirschfeldia incana*	Rt,S / EMBR	Harberd and McArthur 1980
***Diplotaxis viminea* (*n*=10)**		
D.v. × *Diplotaxis tenuifolia*	Rt,S / EMBR	Harberd and McArthur 1980
***Eruca vesicaria* ssp. *pinnatifida* (*n*=11)**		
E.p. × *Brassica repanda*	SEXL	Sobrino Vesperinas 1988
***Eruca vesicaria* ssp. *sativa* (*n*=11)**		
E.s. × *Brassica juncea*	PROT	Sikdar *et al.* 1990
E.s. × *Brassica napus*	PROT	Fahleson *et al.* 1988; Sundberg and Glimelius 1991
E.s. × *Brassica oleracea*	Rt,S / EMBR	Harberd and McArthur 1980
	OVAR	Matsuzawa and Sarashima 1986
E.s. × *Brassica rapa*	EMBR	Agnihotri *et al.* 1988
	OVAR	Matsuzawa and Sarashima 1986
Brassica rapa × *E.s.*	Rt,S / EMBR	Harberd and McArthur 1980
E.s. × *Raphanus sativus*	D?,SEXL	Dayal 1987

D?,OVAR Matsuzawa and Sarashima 1986

Life history and geographical distribution of *Diplotaxis*[5]

Diplotaxis tenuifolia — widespread in Mediterranean, Europe, N. Africa
Diplotaxis cretacea — endemic in Baltic Region
Diplotaxis simplex — N. Africa
Diplotaxis muralis — widespread in Mediterranean, Europe, N. Africa
Diplotaxis viminea — widespread in Mediterranean, Europe, N. Africa.

Species: *Diplotaxis tenuifolia* (L.) DC.
Life/Form: perennial, suffrutescent
Ecology: coastal, plains, montane to 1100 m; beaches, dunes, chalk hills, rocky slopes, crevices in rocks; weedy in roadsides and waste places, fields, crevices in walls; sandy and chalky soils
Geography:[6]
Europe: Albania [E], Austria [E], Balearic Islands [E], Baltic [A], Belgium [E], Bulgaria [E], Corsica [E], Crimea [E], Czech / Slovak Reps. [E], Denmark [A], Faeröe Islands [A], France [E], Germany [E], Great Britain [A], Hungary [E], Italy [E], Malta [E], Netherlands [E], Norway [A], Poland [E], Romania [E], Sardinia [E], Sicily [E], Spain [E], Sweden [A], Turkey [E], Yugoslavia [E]
Africa: N Algeria [A], N Morocco [A?]
ME / WAsia: Anatolia [E], Armenia [E], Georgia [E], Lebanon / Syria [E]
Americas: Argentina [A], Canada [A], United States [A]
Aust / Asia: Australia [A]
Phytogeo: Euro-Siberian, Mediterranean

Species: *Diplotaxis cretacea* Kotov
Life/Form: annual, biennial
Ecology: hills of river basin (Donets R.); bare chalky slopes
Geography:
Europe: W-central Russia [E], NE Ukraine [E]
Phytogeo: Euro-Siberian

Species: *Diplotaxis simplex* (Viv.) Spreng.
Life/Form: annual
Ecology: semi-arid to arid subdesert coastal, plains, hills to 1100 m; beaches, sandy plains, steppes, dry pastures, dry stream beds

[5] From Warwick 1994.

[6] The symbol [E] after the names of countries or areas indicates where endemism of the species has been suggested in the literature or, if not specifically stated, where we believe endemism can be reasonably assumed. The symbol [E?] indicates that a species has been reported, but that its endemic status is not certain. The symbol [A] indicates that the species is known to be either recently introduced, adventive and / or has become naturalized following natural spreading from such introductions. [A?] indicates that a species would have [A] status, but its presence has not been confirmed.

Geography:

Africa: N Algeria [E], N Libya [E], SW Morocco [?], Tunisia [E]
ME / WAsia: N Egypt [E]
Phytogeo: Saharo-Sindian

Species: *Diplotaxis muralis* (L.) DC.
Life/Form: annual, biennial, rarely perennial, herbaceous
Ecology: non-arid to semi-arid low valleys, plateaus, rarely hills; pastures, open woodlands and brush; weedy in roadsides and waste places, fields, crops, vineyards, gardens, oases; clay, sandy, peaty and chalky soil
Geography:
Europe: Adriatic [E], Albania [E], Austria [A], Balearic Islands [E], Belgium [A], Bulgaria [E], Corsica [E], Crimea [E], Denmark [A], France [E], Germany [E], Great Britain [A], Greece [E], Hungary [E], Ireland [A], Italy [E], Malta [E], Netherlands [A], Poland [E], Romania [E], Sardinia [?], Sicily [?], Spain [E], Sweden [A], Switzerland [E], Turkey [E], Yugoslavia [E]
Atlantic: Azores (S. Miguel) [A]
Africa: N Algeria [E], N Libya [?], N Morocco [?], South Africa [A], Tunisia [E]
Americas: Canada [A], United States [A]
Aust / Asia: Australia [A]
Phytogeo: Euro-Siberian, Mediterranean

Species: *Diplotaxis viminea* (L.) DC.
Life/Form: annual
Ecology: coastal, plains, hills; dry plains, rubble; weedy in roadsides and waste places, fields, crops, gardens, vineyards; sandy, chalky, often damp, rich soil
Geography:
Europe: Aegean [E], Austria [A], Balearic Islands [E], Bulgaria [E], Crete [E], Crimea [E], Cyprus [E], France [E], Germany [A], Greece [E], Italy [E], Malta [E], Netherlands [A], Portugal [E], Romania [E?], Sardinia [E], Sicily [E], Spain [E], Turkey [E], Yugoslavia [E]
Atlantic: Azores [E?]
Africa: N Algeria [E?], N Morocco [E], Tunisia [E?]
ME / WAsia: Anatolia [E], Egypt [E], Israel / Jordan [E], Lebanon / Syria [E]
Phytogeo: Euro-Siberian, Mediterranean

Life history and geographical distribution: *Eruca* [7]

Eruca vesicaria
ssp. *vesicaria* — S Spain, Balearic Islands, North Africa
ssp. *sativa* — widespread in Mediterranean, widely introduced
ssp. *pinnatifida* — S Spain, N Africa, Algeria, Morocco, Tunisia
Eruca loncholoma — N Africa, Algeria, Tunisia
Eruca setulosa — N Africa, Algeria, Morocco

[7] From Warwick 1994.

Species: *Eruca vesicaria* (L.) Cav.
Life/Form: annual

Ecology: coastal, plateaus, montane to 2600 m; wild, cultivated, and weedy escape; beaches, steppes, dry pastures, dry stream beds, rubble; weedy in roadsides and waste places, fields, crops, oases, palm and olive groves; sandy, chalky, loam, or saline soils

Geography:

Europe: Adriatic, Aegean, Balearic Islands [E], Bulgaria, Corsica, Crete, Crimea, Cyprus, France, Greece, Hungary, Italy, Portugal, Romania, S Russia, Sardinia, Sicily, Spain [E], Switzerland, Turkey, Yugoslavia (subsp. *sativa* widely naturalized and also cultivated in Europe)

Atlantic: Canary Islands (all except Gran Canaria, Palma), Madeira (Madeira, Porto Santo)

Africa: Algeria [E], N Chad [E], Ethiopia, Libya [E], Morocco [E], South Africa, Sudan, Tunisia [E]

ME / WAsia: Afghanistan, Anatolia, Armenia, Azerbaijan, Bahrain, Egypt [E], Georgia [E], NW India, Iran, Iraq, Israel / Jordan, Kuwait, Lebanon / Syria, Oman, NW Pakistan, Qatar, Saudi Arabia, Turkmenistan, United Arab Emirates, Yemen

Americas: Canada [A], Mexico [A], United States [A]

Aust / Asia: Australia [A], China [A], Mongolia, New Zealand [A]

Phytogeo: Mediterranean, Irano-Turanian (Saharo-Sindian, Euro-Siberian). Native range of subsp. *sativa* is uncertain.

Species: *Eruca loncholoma* (Pomel) O.E. Schulz

Life/Form: perennial, herbaceous, caespitose

Ecology: plateau, montane to 2300 m; esparto-grass steppes, high meadows, fields, stony pastures

Geography:

Africa: NE Algeria [E], W Tunisia [E]

Phytogeo: Mediterranean

Species: *Eruca setulosa* Boiss. & Reut.

Life/Form: perennial, herbaceous, caespitose

Ecology: non-arid montane to 1600 m; high fields, meadows, stony and clay pastures; calcareous soils

Geography:

Africa: NW Algeria [E], NE Morocco [E]

Phytogeo: Mediterranean

Chloroplast DNA molecular studies [8]

1. Clear separation of genera and species in the Brassicinae into two lineages: (i) Rapa / Oleracea Lineage and (ii) Nigra Lineage.

2. All three *Eruca* subsp., *Diplotaxis tenuifolia*, *D. muralis* and *D. viminea* were assigned to the Rapa-Oleracea lineage (Fig. 1).

[8] From Warwick and Black 1991, 1993b; Warwick and Black 1992.

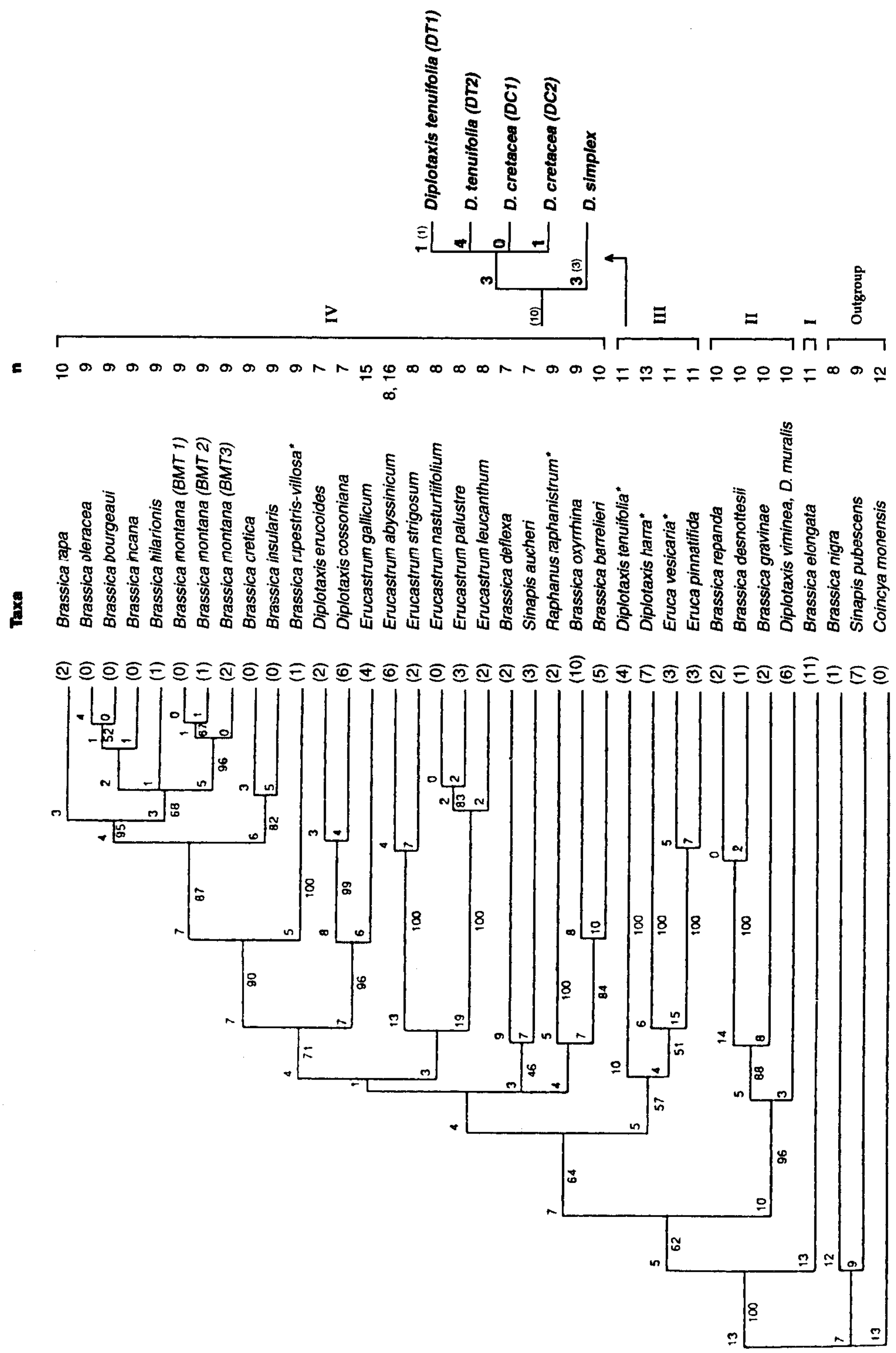

Fig. 1. Majority-rule (50%) consensus tree for the Rapa-Oleracea lineage in subtribe Brassicinae according to findings of Warwick and Black (1993b); numbers shown above branches are branch lengths and numbers below are % probability values; an asterisk (*) indicates the inclusion of additional taxa; Roman numerals I-IV denote major groups

3. Some molecular evidence that the rockets shared a common ancestor. In most of the most parsimonious trees in the phylogenetic analyses, the taxa *D. tenuifolia* complex, *Eruca* spp. formed a monophyletic group with *D. harra* (Clade III, Fig. 1). *Diplotaxis viminea* was in a separate clade (Clade II).

4. Studies of the maternally inherited chloroplast DNA confirmed that *D. viminea* was the maternal parent of *D. muralis*. No mutational differences in 870 restriction site (characters) were observed between two species.

5. Molecular studies confirmed the monophyletic origins for:

    1. *Diplotaxis tenuifolia* cytodeme
       - *Diplotaxis tenuifolia** cpDNA clade, included *D. tenuifolia*, *D. cretacea* and *D. simplex* (Fig. 1 Insert).
       - *D. tenuifolia* and *D. cretacea* were most similar and distinguished from *D. simplex* by 9 mutational differences.

    2. *Eruca* cytodeme
       - *Eruca* cpDNA clade included all three subspecies of *Eruca vesicaria*.
       - No differences were detected in the chloroplast DNA of *E. vesicaria* subsp. *vesicaria* and subsp. *sativa.*
       - Chloroplast genomes of *E. vesicaria* (above two subspecies) and the third subspecies *pinnatifida* were quite distinct (total of 18 mutational differences).

Characteristics of rocket *Diplotaxis* species

See Table 2.

Key to subspecies of *Diplotaxis muralis* [9]

Racemes with 5-10 (-21) flowers; petal limb obovate; siliquae with gynophore 0.2-0.6 mm and beak 2-3 mm (Europe).. subsp. *muralis*

Racemes with 15-47 flowers; petal limb oblong; siliquae with gynophore 0.6-0.9 mm and beak 1.3-2.4 mm (NE Algeria, NW Tunisia) .... subsp. *ceratophylla*

Note: According to Martínez-Laborde (1991) further recognition of infraspecific taxa in Europe is not supported. "The notable amount of morphological variation displayed by *Diplotaxis muralis* has led to the description of many infraspecific taxa, almost all of them corresponding to European material, mainly on the basis of differences in plant size, growth habit or flower size (considered to be unstable characters)."

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[9] From Martínez-Laborde 1991.

Table 2. Characteristics of rocket (*Diplotaxis*) species

D. tenuifolia	*D. cretacea*	*D. simplex*	*D. muralis*	*D. viminea*
Erect, Leaves mostly cauline	Erect Leaves mostly cauline	Decumbent, spreading Leaves mostly basal	Decumbent, spreading Leaves mostly basal	Decumbent, spreading Leaves mostly basal
Perennial, suffruticose at base	Annual or biennial, herbaceous	Annual herbaceous	Annual or biennial, herbaceous	Annual or biennial, herbaceous
Leaves glaucous, more or less fleshy	Leaves glaucous, more or less fleshy	Leaves ?	Leaves green, thin, membranous	Leaves green, thin, membranous
Foetid when crushed	Foetid when crushed	Foetid when crushed	Foetid when crushed	Not foetid when crushed
Entire to pinnatifid	Pinnatifid-bipinnatifid			
Petals 8-15 mm, vivid, sulphur yellow	Petals 7-9 mm, yellow	Petals 7.5-10 mm, pale yellow	Petals 4-8 mm, vivid sulphur yellow turning ± brown-violet	Petals 3-4 mm, pale yellow
Stamens fertile	Stamens fertile	Stamens fertile	Stamens fertile	Outer stamens sterile
Gynophore 1-2 mm	Gynophore 0.5-1 mm	Gynophore 0.3-0.8 mm	Gynophore 0.2-0.9 mm	Gynophore 0.1-0.3 mm
		Valves obtuse or acute Not emarginate at apex	Valves truncate Subemarginate at apex	

Translation of Schulz's classification (from Latin)

Eruca
Key to species

1. Root annual. Stems more or less leafy. Petals markedly veined with few, distinct veins at wide intervals. Siliques gradually tapering to a fairly wide bveak; valves almost nerveless.
   a. Sepals caducous, the outer sepals hood-shaped at the apex, the inner sepals blunt. Anthers blunt. Beak broadly ensiform.
      [i Lower leaves not forming a rosette, their terminal lobe larger than the other lobes. Ovary 13-40 ovuled .... 1. *E. sativa* [= *E. vesicaric* ssp. *sativa*]
      [ii] Lower leaves rosette-forming; their terminal lobe smaller than the other lobes. Ovary 40-50 ovuled .... 2. *E. pinnatifida* [= *E. vesicaria* ssp. *pinnatifida*]
   b. sepals covering younger fruit for a long time, all sepals hooded apically. Anthers somewhat acute. Beak narrowly ensiform .... 3. *E. vesicaria* [ssp. *vesicaria*]

2. Root perennial. Stems scapose. Petals indistinctly veined with fine, close veins. Siliques abruptly tapered to a slender beak; valves finely net-nerved.
   a. Sepals ca. 1 cm long. Petals intensely violet throughout, 16.5 mm long. Beak compressed, almost half as long as the valves .... 4. *E. setulosa*
   b. Sepals 3.5-4 mm long. Petals pale yellow, violet-purple at the apex, 5.5 mm long. Beak tetragonal, about one-quaarter as long as the valves .... 5. *E. loncholoma*

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Rocket, an ancient underutilized vegetable crop and its potential

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Origin and geographical distribution

Under the name of rocket are grouped a number of species of the Brassicaceae family belonging to *Eruca* Miller and *Diplotaxis* DC. genera. *Eruca* (from the Latin 'eruca' of doubtful etymology; suggested to be derived from 'uro' or 'urere' = burn, for the acrid taste of leaves; others from the Greek 'ereugomai'). *Diplotaxis* (from the Greek words 'diplos' = double and 'taxis' = row, referring to the seeds placed in double rows in the siliqua).

The *Eruca* plant was sacred to Priapo, god of the generation and fruitfulness identified in Italy as the god Mutinus Tutinus, an ancient Roman divinity. It has been mentioned by Plinio, Columella and Dioscoride Pédanio in their scripts on Roman culinary habits because of the peculiar taste of its leaves.

In the language of flowers, the rocket means deceit or swindle (Bremmes 1988).

The Mediterranean region and Asia are credited as centres of origin and domestication (Zeven and de Wet 1992). *Eruca sativa* has a wide distribution as a weed in cornfields, flax fields and on waste ground, along roadsides under sun-exposed and dry environments. It can be found also in Turkey (Lyle 1974), the Crimea, the Caucasian area and Siberia (Bush 1970), Afganistan and Western China (Bennett 1970), Switzerland and Belgium (Bonnier 1934), Slovenia (Cerne 1992), Portugal (Polurein and Smythies 1973), South Africa, the USA and Australia (Nuez and Bermeyo 1992). The presence in the three last countries is probably linked to the crop's earlier introduction from Europe and to its escape from those fields where it had first been planted. In the USA the crop was introduced around 1854, probably brought by European emigrants who settled in that country.

Eruca sativa is grown as a vegetable and as a cold weather oilseed crop to produce jamba oil. As an oilseed crop it is cultivated mainly in India, up to the western Himalayas (records from up to 3500 m a.s.l.) but also in Iran, Afganistan, Pakistan and Ethiopia (Baldrati 1950; Chopra *et al.* 1956; Bennett 1970; Vaughan 1970; Bush 1970).

The leaves are eaten raw in salads or cooked in various culinary preparations, and are grown or gathered from wild plants in Egypt (where it is very popular and the production can be considered the largest in the world), Northern African countries, Italy, Turkey, Greece, Spain, Sudan, Ethiopia, Somalia, Jordan, Israel, Slovenia, Japan, Brazil, Argentina, the USA, Australia, the Caucasis area, and in several countries of Northern Europe.

Taxonomy

Rocket has often raised controversies among workers concerning its taxonomical identity. Several synonyms have been used over the years to refer to it; below is one of the latest reviews provided by Hanelt (1986) for the classification of *E. sativa* and by Bush (1970) for *D. tenuifolia* and *D. muralis*.

***Eruca sativa* Mill., Gard. Dict. ed. 8 (1768) n. 1**

- *Brassica eruca* L., Sp.Pl. (1753) 667
- *Eruca foetida* Moench, Methodus (1791) 256
- *Brassica turgida* Pers., Syn. 2 (1807) 207
- *Eruca oleracea* J. St.-Hil., PL. France 4 (1809) 22
- *E. ruchetta* Spach, Hist. nat. vég. 6 (1838) 355
- *E. cappadocica* Reut., Cat. Horti Genève 1857 (1858) 2

- *E. glabrescens* Jord., Diagn., esp. nouv. 1, 1 (1864) 193
- *E. lativalvis* Boiss., Fl. or. 1 (1867) 396
- *E. longirostris* Uechtr. in Österr. Bot. Zeitschr. 24 (1874) 133
- *E. vesicaria* (L.) Cav. var. *genuina* Rouy et Fouc., Fl. France 2 (1895) 63
- *E. eruca* (L.) Aschers. et Graebn., Fl. Nordstdt. Flachld. (1898) 362
- *E. vesicaria* (L.) Cav. var. *sativa* (Mill.) Thell., Fl. adv. Montp. (1912) 260
- *E. vesicaria* (L.) Cav. spp. *sativa* (Mill.) Thell. in Hegi, Ill. Fl. Mitte-Eur. 4, 1 (1918) 201.

***Diplotaxis tenuifolia* (L.) DC., Regen. veg. syst. nat. 2 (1821) 632**

- *Sisymbrium tenuifolium* L., Cent. Pl. 1 (1755) pl. 18, Amoen. Acad. 4 (1759) 279
- *Eruca perennis* Mill., Gard. dict. ed. 8 (1768) no. 3
- *Arabis sylvestris* Scop., Fl. carn. ed. 2, 2 (1772) 32
- *Sisymbrium acre* Lam., Fl. fr. 2 (1778) 520
- *Eruca tenuifolia* (L.) Moench, Methodus (1794) 257
- *Brassica tenuifolia* (L.) Fries, Novit. fl. suec., ed. 2 (1828) 209

D. tenuifolia (L.) DC. var. *integrifolia* is distinguished by its single, dentate leaves.

***Diplotaxis muralis* (L.) DC., Syst. II (1821) 634 et Prodr. I (1824) 222; N. Busch in Fl. cauc. crit. III, 4 (1908) 260**

- *Sisymbrium murale* L., Sp. pl. (1753) 658
- *Brassica muralis* Shmal'g., Fl. I (1895) 80.

According to Pignatti (1982) *D. muralis* is a hybrid between *D. tenuifolia* and *D. viminea* (L.) DC. Both species are diploid, but *D. tenuifolia* has $2n=22$, while in *D. viminea* $2n=20$. *Diplotaxis muralis* is a fertile allotetraploid species ($2n=42$). Bonnier (1934) referred to the existence of another race called *D. intermedia* Schur. bearing many characters typical of *D. muralis* and *D. tenuifolia*. In addition he reported a hybrid between *D. muralis* and *D. tenuifolia*.

The genus *Diplotaxis* groups many wild relatives of crops belonging to the genus *Brassica* thus representing a potential source of genes for plant breeding programmes involving brassicas. On the basis of cytological, morphological, flavonoid isozyme and seed protein evidences, it was suggested that *D. muralis* ($n=21$) is an amphiploid species derived from the combination of *D. tenuifolia* ($n=11$) and *D. viminea* ($n=10$). Recently, Mummenhoff *et al.* (1993), by isoelectric analyses means of the polypeptide composition of ribulose-1,5-bisphosphate carboxylase/oxygenase subunits, have supported the putative amphiploid origin of *D. muralis*. Nuclear-encoded small subunits also can be used to indicate *D. tenuifolia* and *D. viminea* as parental species, whereas the chloroplast-encoded large subunits serve to identify *D. viminea* as the maternal parent.

Other edible less important rockets are:

- ***Eruca pinnatifida*** (Desf.) Pomel (Synon. *Brassica pinnatifida* Desf); *E. sativa* Mill. var. *pinnatifida* (Desf.) Coss.; *E. sativa* Mill. spp. *pinnatifida* Desf. Batt.; *E. aurea* Batt.; *E. vesicaria* (L.) Cav. spp. *pinnatifida* (Desf.) Emb. & Maire).
- ***Diplotaxis erucoides*** (L.) DC. (Synon. *D. valentina* Pau, *Sinapis erucoides* L., *Sisymbrium erucoides* Desf., *Brassica erucoides* Boiss.). Languages: a) French: fausse roquette, roquette blanche, roquette sauvage; b) English: white wall rocket; c) German: rauchen-doppelsame; d) Italian: ruchetta violacea.
- ***D. crassifolia*** (Rafin.) DC. (Synon. *D. pendula* Presl., *D. hárra* Boiss., *D. hárra* Boiss. var. *crassifolia* DC.; *Pendulina crassifolia* Willk.).
- ***D. duveyrierana*** Coss. (Arabic: hárra; Tuareg: azezzega; Temahac: tâneéfait; Twaitian: Al-Kashain).
- ***D. griffithii*** Hook.
- ***D. sieberi*** Presl.

The findings of some specific compounds in the seeds of *Eruca* and *Diplotaxis* species can help to distinguish the different species. In particular, the seed extracts of *E. sativa* seem to contain sinapine-O-b-D-glucopyranoside, while isoferuloylcholine has been identified in *E. sativa, D. erucoides* and *D. tenuifolia*. Sinapin contributes 10% to the total phenolic choline esters in seeds of *E. sativa,* 69% in those of *D. tenuifolia* and 78% in those of *D. erucoides* (Bouchereau *et al.* 1991).

Wild and cultivated rocket are called different names in the Mediterranean basin and elsewhere, a fact that indicates the popularity of these plants (Table 1).

Morphology, biology and breeding

Morphology

Diplotaxis tenuifolia (Tribe: Brassiceae; Section Catocarpum)
Perennial, stem erect, up to 80 cm high, branching, leafy, coarse and woody at base, dispersely covered in lower part with retrorse hair; leaves oblong, long, glabrous, pinnatipartite or pinnatisect, with lanceolate-linear or linear more or less dentate to entire lateral lobes, and a long, dentate or pinnatifid terminal lobe. Raceme elongating in fruit. Sepals glabrous, 5-6 mm long; petals 7-12 mm long, gradually tapering into a claw, yellow. Ovary with 50-150 ovules; siliques sparse, 25-50 mm broad (1.8) 2-3 mm, style 1-2 mm long, fleshy; pedicels glabrous, 15-40 mm long. Seeds very small 5000-5500 in 1 g of yellow brown or mustard color. Type specimen deposited in London (Bush 1970).

Diplotaxis muralis (Tribe: Brassiceae; Section Anocarpum)
Annual or biennal, with stem up to 70 cm high, usually branching from base, dispersely covered, mostly with spreading, somewhat retrorse, hairs in lower part; leaves oblong, more or less sinuate-dentate to pinnatipartite, with lanceolate lobes, sparingly pilose along petioles and veins. Sepals 3-4 mm long; petals yellow, 6-8 mm long, obovate, abruptly tapering into a claw; siliques 25-50 mm long, 2-2.5 mm broad, glabrous, with a fleshy, finely ribbed tapering beak, 2-3 mm long, and a distinctly 2-lobed stigma; pedicels 5-20 mm long (in lower part of plant some fruiting pedicels attain a length of 60-80 mm); seeds yellow-brown, about 1 mm long, 0.5-0.75 mm broad, short-elliptic. Type in London (Bush 1970).

Eruca sativa (Tribe: Brassiceae)
Annual, stem erect, branching up to 80 cm high. Lower leaves are lyrate-pinnatisect, all leaves slightly fleshy, sparsely pilose, rarely glabrous with a characteristic odour. Sepals 9-12 mm long; petals 15-22 mm long, obovate-cuneate, whitish or sulphur-yellow, violet- or brown-veined, sometimes slightly emarginate; fruiting pedicels rather stout, almost appressed to stem. Ovary with 12-50 ovules. Siliques ovate-oblong or oblong, compressed, not torulose, 2-3 cm long; valves firm, with prominent midrib; beak 5-10 cm long, ensiform, compressed; seeds biseriate, are of varying shade of colour from yellow-green to brown, and vary in length from 1.7-3 mm. The weight of 1000 seeds is equal to 2 g. Type in London (Bush 1970).

Table 1. Common names of rocket in various languages and idioms

Language	Common name
Afganistan, Iran	mindau, indau
Arabic	harra, dgirgir
Danish	mursennep†
Dutch	wilde kool, rakette, rokette, rubbe, krapkol, mosterdzaad*, wild raket*, muurdubbelkruid*, zandkool*, muurzandkool†, wild-mostaard-zoad*
English	rocket, hedge rocket, garden rocket, salad rocket, bladder eruca, drant, roman rocket, sand rocket†, wild rocket*, annual wall rocket†, annual rocket*
French	roquette, rokette, eruce, ruce, roquette de muraille†, roquette jaune*, diplotaxe des murs†, diplotaxe à feuilles menues, herbe-puante*, salade de vingt-quatre heures
German	rauke, dünnblattriger, doppelsame, weissesenfrauke*, raukette,mauer-rampe†, stinkrampe*, mauer-doppelsame†, feinblättriger doppelsame*, ackerrampe†
Indian (Bengali)	shwetsursha
Indian (Hindi)	taramira, seoha
Indian (Punjab)	assu, jamba, tara, usan
Indian (Sanskrit)	bhutanghna, daradharsha
Italian	ruca, ruchetta (is diminutive for ruca), rughetta, rucola dei muri†, erba diavola†, rucola selvatica*, salterelli†
Italian (Roman)	rughetta, rughetta selvatica*
Italian (Apulian)	rucoletta, r'cuacce, ruca*, ruc'*, ròcl, rùchele, ruche
Italian (Neapolitan)	arùcula, arucolo, eruca, ruca, ruchetta, rucola di Spagna, arucola or aruca di montagna*, aruca servaggia*, rugolo
Italian (Sicilian)	aruca, arùcula, ruca
Japanese	kibana-suzushiro, piao-êrh-ts'ai
Norwegian	mursennep†
Portugese	eruca, rúcula, fedorenta, pinchão (Brazil)
Russian	mindau
Russian (Tartaric)	solobur
Spanish	rúcula, roqueta, jaramago amarillo†
Spanish (Castillan)	oruga, oruga comun, eruca, roqueta comun
Spanish (Catalan)	ruqueta
Swedish	mursenap†
Turkish	roka

* Specifically referring to *D. tenuifolia.*
† Specifically referring to *D. muralis.*

Biology and breeding

Poliploidy and politeny have been observed by Viegi *et al.* (1976). The seed is formed from bitegminal and crassinucellar ovule. The testa is comprised of epidermis with mucilage subepidermis of 1 or 2 layers, and a supporting layer. The first 3 layers are formed from the outer tegument, while the fourth is derived from the inner tegument. An aleurone layer is formed by the endosperm and characteristic primary and secondary nettings are present on the testa (Lamba and Arora 1981).

The core of basal body (subhilar tissue) is directed toward the antiraphe side in the region of the micropyle. The tissues of the median tier proliferate to a comparatively greater extent and the inner tier, which is formed by the augumentation of middle layers of the inner tegument, is well developed at only one side of the core. The outer epidermis of the median tier forms an oblique V-shaped fold, and the 3 tiers of the basal body appear quite asymmetrical (Prasad 1977).

Dry seeds show a high resistance to damage from gamma irradiation (Gomez-Campo and Delgado 1964).

As the siliquae dry up, the various tissues contract differently owing to differential wall thickenings: a force of tension is established, which pulls apart the valves, the stomatal tissue breaking down, with notches and replum-siliquae wall junction open. The fruit dehisces by four longitudinal clefts which separate the two valves from the replum which seeds are attached to. The split goes from the bottom of the valves to the base of the break, above which there is no stomial tissue. Dehiscence is further aided by absence of fibrous layer in the region of the replum (Arora and Lamba 1980).

Investigations in the stomatal apparatus of seedlings show that the stomatal density is 77% higher in cotyledons and 46% higher in abaxial side of the first leaves; moreover, stomata on the first leaves were smaller than those on the cotyledons (Zeleny and Resnickova 1985).

The stomata and pollen grains of tetraploid plants are bigger than those of diploid plants (Labana *et al.* 1977).

Pollination is entomophylous. Free (1970) reports that insect pollination is essential for high seed yield, and describes flower behaviour in respect to visits from bees. Flowers open in the morning and remain so for about 3 days. Soon after anthesis, anthers dehisce toward the style, the latter being either long or short. Nectar is not available until flowers have opened enough for bees to reach it through gaps between the petals. By introducing honeybee colonies into the crop, a higher seed yield is obtained (25 to 117 kg for each colony). Flowers that have been kept isolated do not produce seeds. Only 7% of bagged flowers and self-pollinated flowers produce seeds compared with a success of 98% in those flowers that had been cross-pollinated.

Auxin applied at flower-bud stage increased the total number of seeds formed (Maini and Sandhu 1959).

Fifty *E. sativa* accessions have been investigated for 11 yield components. Compared with other traits, estimates of heritability and genotypic and phenotypic coefficients of variation were found to be higher for secondary branches/plant, siliqua length, seeds/siliqua and 1000-seed weight characters. Seed yield showed high heritability. In both early and late-sown crops, seed yield was significantly, positively and more or less consistently correlated with number of siliquae on the main shoot and number of siliquae/plant. Secondary branches/plant and number of main-shoot siliquae had the highest direct positive effects on yield (Yadav and Kumar 1984b).

Studies on traits of the siliqua traits were conducted by Kumar *et al.* (1986) on 15 *E. sativa* accessions grown in five different environments. Significant genotype × environment interactions were found for three traits, but not for siliqua length character.

Research conducted on seeds from Turkey, using unopened or freshly opened flowers prior to anther dehiscence, revealed that all plants were highly self-incompatible, 90% showed nonreciprocal compatibility, and a high proportion of reciprocal interplant incompatibility was also recorded (Verma and Anuradha 1985).

In *E. sativa*, treatment of stigma with concavalin A or phytoaematoagglutinin before pollination was effective in overcoming the sporophytic self-incompatibility (Sharma *et al.* 1985).

In diallel crosses of 10 cultivars of *E. sativa*, general and specific combining ability values were found to be significant in seed yield / plant and for other eight related characters, 1000-seed weight and siliqua length not being among those. The best general combiners were Ludhiana Comp-1 for seed yield / plant, length of main shoot and number of siliquas on the main shoot (Yadav and Yadava 1987).

Other investigations (Kumar *et al.* 1988) have revealed that pod length and number of primary branches / plant on both normal (pH 7.5) and alkaline (pH 9.0) soils seem to be mainly the result of nonadditive gene effects. Main shoot length and seeds / plant were influenced by additive effects on normal soil and by nonadditive effects on alkaline soil.

In an I_2 generation of *E. sativa* (ES55) were found plants bearing low, mid and high protruding stigma type and exerted stile respectively in the proportion of 9, 24, 26, 22 and 19%. The normal distribution curve obtained for style length suggested a continuous variation of this trait due to its possible polygenic control. To ensure cross-pollination, long-styled types with protruding or emergent stigmas could be used in breeding programmes. Also, since F_1 breeding requires selection of individuals homozygous for the *S* allele within families of bud-selfing origin, selection can be performed simultaneously for *S* allele homozygotes and long emergent styles (Verma 1985).

After crossing a variant of *E. sativa* with deep serrated leaves with a normal-leaved type, the F_1 showed the normal leaf shape as dominant character, and in the F_2 a 3:1 segregation ratio for normal to deeply serrated leaves was obtained (Singh 1975).

In a cross between *Raphanus sativus* and *E. sativa* only three plants from 110 pollinations were obtained; these were intermediate in morphology, but the leaf and floral characters of *E. sativa* were dominant. Hybrid plants did not set seeds when pollinated by either parent but four seeds were produced by selfing (Dayal 1987).

Diploid hybrids were obtained when *Brassica napus* was crossed as the female parent with *D. tenuifolia* and *E. sativa* (Heyne 1977).

Male sterility is controlled by two recessive genes (Verma 1984).

To protect *E. sativa* cultivations in field conditions from visits of *Apis florae*, applications of ketones were made; ketones proved to be a useful repellent, the repellency effect lasting for several hours (Gupta 1989).

According to Bennett (1970) *E. sativa* is an extremely polymorphic species and explorations in the mountainous areas of Bokhara and Northern Afganistan have revealed the existence in the same locality of many forms with no marked prevalence of any of them. In Bokhara, however, most of the populations exhibit certain distinct character combinations more frequently than others. There, some characters are absent altogether, and character-complexes of an adaptive value have become more or less fixed by selective pressure. In populations from Kashgar, Western China, certain typical character-complexes are commonly present, while other forms have been eliminated. In those populations genetic variance was rather low and character correlation was high.

Different species and ecotypes of rocket are often associated with a variety of pungent flavours and leaf succulence. This fact would suggest the presence within its genepool of a wide variability which provides the breeder with adequate genetic material for pursuing successful crop improvement programmes on the species.

Preliminary works conducted in Germany have suggested that the crop contains sufficient genetic diversity for allowing breeding programmes to increase seed and oil yield successfully (Seehuber and Dambroth 1984).

Cultivation

When other conditions are favourable *E. sativa* can be grown on any good soil, but for *Diplotaxis* species, calcareous soil is preferred. To obtain better yields it is advisable that rocket crops do not follow beans and species belonging to Apiaceae, Cucurbitaceae and Solanaceae families.

Chickpeas intercropped with *E. sativa* grown as oilseed gave 0.84 t/ha (Singh and Singh 1988).

Crop propagation and germination

Eruca sativa and *Diplotaxis* species can be propagated by seeds or through transplants. When grown for leaf production, *E. sativa* does not usually need transplants, although they might be sown in protected environments and transplanted in spring or summer. Seeds should be sown at 0.5-1 cm depth, in rows 15-20 cm apart; within the row, the final stand should be 5-10 cm apart. Following this procedure some 3 kg/ha of seeds are usually required. For seed production rows of 40 cm apart, with plants 20-30 cm within row, are used. In germination (which is epigeal) at least 10°C are needed and the emergence takes place within 6-8 days. In Puglia and Basilicata region (southern Italy), *Diplotaxis* is cultivated both in field (one farmer is reportedly growing more than 2 ha) and greenhouse conditions. In fields of larger farms, transplants are made using flats filled with peat-lite seedling medium, and plant spacing is lower than that of *E. sativa.* In the greenhouse, plants raised in cells of larger volume are more easily marketed (this can happen as early as 40 days after sowing).

On *E. sativa* some studies on seed germination, plant spacing and *in vitro* multiplication have been conducted.

Soaking of seeds of *E. sativa* in 0.5 and 1% potassium nitrate, 10 and 100 ppm indol acetic acid or water for 1-48 hours was carried out in order to determine the best soaking method; soaking in water for 6 hrs gave the highest germination; moreover, this was seen to be positively influenced by evening sowings (Oswal and Sharma 1975).

In the cotyledons, during the germination period, the total content of oil triglycerides gradually decreases, while that of the erucic acid increases (Sukhija and Bhatia 1972).

Rocket seeds have been germinated also in various concentrations (0 to 10%) of aqueous extracts of sorghum stubble: a light decrease in germination was observed when concentrations were higher than 4% (Narwal *et al.* 1990).

Seed germination and plant survival rates have been found to be higher in diploid than in tetraploid plants of *E. sativa.* The growth of tetraploid accessions was slow in early stages, but was similar to that of diploid plants at maturity. Tetraploid plants have larger seeds although they gave lower seed yields than the diploids (Labana *et al.* 1977).

Seed germination increases after applying fungicides during seed storage as this reduces losses due to seedborne fungi such as *Aspergillus flavus, A. niger, A. funegatus, Alternaria alternata* and *A. flavus* (Gupta and Saxena 1984).

Steroidal lactones such as withaphysanolide extract from leaves of *Whitania obtusifolia* Dun and *Physalis augulata* L. applied at the rate of 30 ppm to seed of *E. sativa* strongly inhibit seed germination (Modawi *et al.* 1985).

Sowing date and plant spacing

Sowing date is very important in the cultivation of rocket for seed production purposes. In India, seed yield from cultivations sown on 1 October was 0.81 t/ha, 90% higher than that obtained in cultivations sown at the end of November (Singh and Singh 1985). Delaying sowing dates decreased seed protein production, oil contents and yields. Row spacing had nonsignificant effects on sulphur protein or oil contents of seed (Singh and Rajput 1993).

Trials conducted by Maliwal *et al.* (1984) in India with cv. T-27 gave the highest seed yield. Here, among six dates of sowing falling between 25 September and 9 December, the highest yield (1.1 t/ha) was obtained from those planted on 10 October.

In a trial carried out in Turkey on *E. sativa* grown in rows 30, 40 or 50 cm apart, 5 cm within the row, crop yield and most yield components were unaffected by row spacing, but seed weight was highest when using a 30-cm spacing (Kara 1989).

Seed yields of 0.82, 0.75 and 0.69 t/ha and seed oil contents of 33.9, 32.9 and 32.8% were observed in cultivation having inter-row spacing of 30, 45 or 60 cm respectively. Seed oil contents decreased with the increase of the intra-row spacing, going down from

35% (with no thinning) to 31% (with 30 cm spacing) (Maliwal and Mundra 1990).

Seed yield of *E. sativa* decreased progressively when sowing was delayed for 15 days but was not affected at the spacing of 10, 15 or 20 cm between plants in rows 30 or 45 cm apart (Singh *et al.* 1985).

Seed yield could vary from 0.30 to 0.73 t/ha and oil from 96 to 244 kg/ha. Annual variations could be due to differences in the amount and distribution of rainfall; no differences due to seed rate and sowing time were noted (Singh *et al.* 1970).

Harvest index in 25 cultivars of *E. sativa* sown on three dates and with 0 or 15 g/ha of N varied among cultivars, increased with a delay in sowing and was higher without than with nitrogen (Yadav and Kumar 1984a).

Micropropagation

Various media and growth regulators have been studied to obtain protoplast regeneration followed by plantlet production through organogenesis and through somatic embryogenesis processes. Regenerated plantlets appeared normal and were diploid. The technique seems to offer potential for protoplast fusion experiments to be used for introgressing desirable traits, such as stress tolerance, from *E. sativa* into cultivated *Brassica* species (Sikdar *et al.* 1987).

Cotyledonary leaves of *E. sativa* cv. T27, TMH46 and TMH48 were cultured in Murashige and Skoog medium supplemented with NAA, BA and kinetin in various combinations and concentrations. Best results were obtained with 2 mg/L of BA or kinetin and a low level of NAA. Highest regeneration frequencies (9.8%) were observed in T27 (Parkash *et al.* 1989).

Cotyledonary nodes from 2-week-old seedlings cultured on Murashige and Skoog medium, with the addition of different combinations of cytochinins and auxins, formed multiple shoots and roots. Flower buds bearing normal corollas were induced on the plantlets (Amla and Dhingra 1991).

By means of ovary culture, two embryos obtained through the hybridization of *E. sativa* with *Brassica campestris*, 11 of *E. sativa* with *B. oleracea* and eight of *E. sativa* with *Raphanus sativus* have been rescued (Matsuzawa and Sarashima 1986).

In a study aimed at the use of tissue culture for genetic improvement, immature embryos showed organogenesis from the hypocotyls and a few produced somatic embryos on the lower surface of the cotyledons. Subculture of the responsive embryos resulted in meristem proliferation and formation of many shoots that rooted and could be transferred into soil (Ahloowalia 1987).

Fertilization

Considering the short biological cycle of rocket when grown for leaves and the fast way by which nitrogen accumulates in the plant, it has been estimated that the nitrogen rate for this crop should never be higher than 100 kg/ha.

Kheir *et al.* (1991) have carried out, in Egypt, fertilizing experiments with *E. sativa* (cv. Balady); in those trials nitrogen was applied at the dose of 60 kg/ha in two split doses as ammonium sulphate and ammonium nitrate or urea. In addition foliar applications of sodium molybdate, manganese sulphate or a mixture of micronutrients containing 1.0% Fe, 0.5% Mn, 0.25% Zn and 0.1% Cu were employed. Highest yields were obtained with application of N as ammonium nitrate. The nitrate concentration was reduced by foliar application of the micronutrients and by harvesting in late afternoons compared with early morning pickings.

Ventrella *et al.* (1993) carried out experiments growing *E. sativa* in controlled environments and using nutrient solutions; five rates of KNO_3, two levels of continuous temperature (10 and 15°C) and two levels of irradiance (200 and 400 mmol m^{-2} s^{-1} PPFD, photosynthetyc photon flux density) obtaining four °C-PPFD combinations (10-200, 10-400, 15-200 and 15-400). To reach marketable maturity, plants treated with 10 and 15°C took 65 and 52 days, respectively. When plants were grown under 200 instead of 400

PPFD conditions, at 10°C temperature, the growth cycle was 6 days longer, while with 15°C it was only 2 days shorter.

By varying the dose of KNO_3 from 0 to 0.4% in the nutrient solution, leaf fresh weight per plant linearly increased from 49 to 86 g and from 30 to 57 g (with 10-400 combinations). Leaf number/plant increased along with leaf fresh weight and ranged from a minimum of 12 to a maximum of 41 leaves. In the same experiment leaf dry matter content decreased only with the 10-200 combination (10.5 to 8.0%), whereas it did not show any change with 10-400, 15-200 and 15-400 combinations (11.6, 7.1 and 9.3%, respectively).

Nitrate concentration in leaf dry matter increased with increasing KNO_3 rates showing higher values with lower irradiance level. Higher temperature enhanced nitrate accumulation in leaves when plants were treated with both lower KNO_3 and lower irradiance. Higher irradiance increased nitrate-riductase activity which resulted in lower nitrate accumulation in leaves. On average, from 0 to 0.4%KNO_3, nitrate concentration in leaf dry matter increased from 4.9 to 7.0% with 15-200, from 0.9 to 9.2% with 10-200 and from 1.6 to 6.3% with 15-400 and 10-400.

With increased KNO_3, the total nitrogen accumulated in the leaves did not vary in plants grown under 15-200 and 15-400 conditions, while it dramatically increased under 10-200 and 10-400 conditions, respectively, from 100 to 250 and 180 to 475 mg N-Ntot/plant with 0 and 0.4% KNO_3.

When Jat *et al.* (1987) applied N rates from 0 to 45 kg/ha on cv. T27, ITSA and RTM2 of *E. sativa* grown as oilseed crop in India, the average seed yield increased from 0.94 to 1.41 t/ha, without differences among cultivars.

Irrigation

In order to obtain good tender leaves an adequate soil moisture is needed. As a cold weather crop *E. sativa* is well adapted to dry soils, although irrigation increases yields noticeably.

Eruca sativa grown for seeds on aridosols under dryland conditions in Haryana (India) produced 1.4 t/ha (Singh and Sharma 1984). A trial conducted in 1942 at Santa Maria Capua Vetere, near Caserta (Southern Italy), under rainfed conditions, produced a seed yield of 0.5 t/ha with a 30% oil content (Baldrati 1950).

Singh *et al.* (1992) conducted an experiment to study the effect of irrigation on seed yield of *E. sativa* in India. The highest yield and water-use efficiency was obtained with two irrigations at presowing and at plant branching stage, water use increasing with an increase in the number of irrigations (Table 2).

On aridosols, good and normal moisture levels increased the seed yield of *E. sativa* by 106 and 57%, respectively over suboptimal moisture level. Additional supply of 1 mm water gave 2.7-3.0 kg/ha more oil yield than the suboptimal level. The oil content in the seed was found to have a positive correlation with sulphur applications: rates of 30, 60 and 90 kg of S/ha gave 19.5, 31.8 and 32.2 higher yield than the control. Water-use efficiency was highest when soil moisture was good.

In a field trial *E. sativa* was irrigated with water having electrical conductivity of 1, 5 and 10 dS/m and SAR of 2, 4 and 20 or 30 applied at 50-80% depletion of the available moisture in the top 30 cm of soil. Irrigation with water having 10 dS/m slightly

Table 2. Irrigation, seed yield, water use and water-use efficiency in *E. sativa*

Water consumption (cm)	Seed (kg/ha)	Water use efficiency	
		(cm)	(ha/cm)
10 [1]	930	15.3	60.6

10+5 [2]	1150	18.1	61.1
10+5 [3]	990	20.8	47.8

[1] At pre-sowing stage.
[2] At presowing and branching stages.
[3] At pre-sowing and flowering stages.
(From Singh *et al.* 1992)

increased the seed yields compared with 1 dS/m, whereas irrigation at the depletion of 80% available moisture did not decrease yields (Des and Lal 1982).

The amount of oil produced by *E. sativa* seeds increased with the number of irrigations. It reached 19% of the seed dry weight when no irrigation was applied and 33% when three waterings were given. The erucic acid formed more slowly in drier conditions, but the oil composition was not affected by irrigation treatments (Sukhija *et al.* 1976).

In the arid area of Rajasthan, various water regimes gave similar seed yields (average 1.3 t/ha), but yields were higher by applying 25, 20, 15 kg/ha respectively of N, P_2O_5 and K_2O (Kanthaliya *et al.* 1990). In rainfed trials, yields of 1.2, 1.3, 1.4, 1.5 and 1.3 t/ha were obtained by applying 0, 15, 30, 45 and 60 kg/ha of N, respectively, whereas applications of 20 and 60 kg/ha of P_2O_5 had no effect on yields (Jaugir *et al.* 1989).

Eruca sativa plants grown in sand culture were watered with saline solution to give stress levels of -0.03 (control), -0.3, -0.7 and -1.0 MPa; plants were sprayed twice with the auxin IAA at 50 ppm. In all stressed plants, growth was reduced whether plants were sprayed with IAA or not. As the level of salinization increased the Na, Ca, Mg, N and K concentration increased, while P, carotenoid and chlorophill *a* and *b* decreased (Salama *et al.* 1981).

In another experiment, *E. sativa* (cv. T27) was grown in pots which had been buried in the field and water-stressed conditions were created at vegetative, flowering and pod-filling stages: water stress reduced shoot weight and seed yields (Pannu *et al.* 1992).

Singh *et al.* (1988b), studying the effect of exchangeable sodium percentage (ESP) on growth, yield and plant nutrient of *E. sativa*, found that the germination was delayed and decreased when ESP was higher than 44 and prevented when it was higher than 62. In addition the number of branches and siliquae/plant decreased with the increase of ESP. Increased ESP gave fewer plants and lower contents in the tissues of N, P, K, Ca, Mg, Fe, Zn, Cu and Mn and higher presence of Na.

Harvesting

Harvest of rocket leaves is done around 40-60 days after sowing. Harvest can span a period of 30 to 40 days, although for pursuing an economically convenient cultivation it is recommended to resow the crop after the third harvest.

In a trial carried out by the Istituto di Orticoltura Industriale of Bari (southern Italy), *D. tenuifolia* was sown there in April and four different N applications were applied (0, 100, 200 and 300 kg/ha). Harvests were done in June, July and August. The yield of marketable leaves was doubled by applying N applications (4.4 vs. 8.3 t/ha), with no significant correlation between increases and N rates. In this experiment the nitrate concentration in the leaves of the fertilized plants averaged 2600 mg/kg against 1600 mg/kg of the control, the dry matter being around 15%.

The weight of leaves of *E. sativa* harvested at 20, 27, 34 and 41 days after emergence increased until the 34th day; the root's weight doubled during the last week (Table 3).

Table 3. Yields of *E. sativa* at different plant ages

Plant age (days after emergence)	Dry weight (kg/ha)	
	Leaves	Roots
20	143	34
27	356	70
34	434	73
41	426	150

(From Haag and Minami 1988)

Leaf and seed composition

Compared with other leafy vegetables *E. sativa* appears richer in fiber, iron and particularly in Vitamin C, with comparable amounts of protein, carbohydrates, calcium and vitamin A (Table 4).

In 41-day-old plants, the concentration of Fe, Mn, Zn and Ca was found to be higher than in younger plants, whereas the presence of P, K, Mg, B, Cu and S was not significantly different in plants of various ages (Table 5) (Haag and Minami 1988).

Seedlings of *E. sativa* yielded the alkylthiocyanate (4-methylthio)(butylthiocyanate) after receiving hydrolysis of the glucosinolate glucoerucin (Schlüter and Gmelin 1972). This compound also has been found in mature plants (Cole 1976).

Because of the importance of *E. sativa* as an oilseed crop, many studies have been conducted on seed and oil composition.

In the seed the content of carbohydrates (expressed in % of dry weight), fat, protein, crude fiber, ash, Ca, P and Fe are equivalent to 37.1, 33.7, 19.0, 7.1, 3.2, 0.94, 0.20 and 0.04 respectively (Sindhu Kanya and Kantharaj Urs 1989). Work done by Polacchi *et al.* (1982) reported values of the content of water, protein, total lipid, total carbohydrates, ash and kcal being as 6.3, 17.8, 28.8, 44.4, 2.7 and 484 respectively.

According to Pathak *et al.* (1973), oil content is negatively correlated with protein content.

In five accessions of *E. sativa* grown in Idaho, USA, during the spring-summer period, with 75 kg/ha of N, the average seed yield, oil contents and 1000-seed weight were 1.2 t/ha, 29% and 2.5 g respectively (Auld *et al.* 1993).

Bhatia and Sukhija (1971) analyzed the total fatty acid content of three cultivars of *E. sativa* harvested at 10, 20, 30 and 40 days after flowering (DAF). Oil content ranged from 1.8 to 2.2% at 10 days, but increased markedly at 10-20 DAF (24 to 29%), after which there was only a slight increase at maturity (29 to 35%). Erucic acid level increased rapidly from 4 to 6% of the total fatty acid content at 10 DAF from 24-36% at 30 DAF and 32-44% at maturity.

Table 4. Chemical composition and energy value of edible portion of rocket and other leaf vegetables (average figures from various authors)

Element and components	Unit	Rocket	Dandelion	Swiss chard	Lett-uce	Spin-ach
Energy value	(kcal)	23	44	17	15	23
Water	(%)	91	87	95	94	91

Protein	(g / 100 g)	2.6	3.1	1.3	1.4	3.0
Lipids	(g / 100 g)	0.3	1.1	0.1	0.2	0.5
Carbohydrates	(g / 100 g)	3.9	3.7	2.8	2.2	1.8
Fiber	(g / 100 g)	0.9	0.4	0.5	0.6	0.5
Calcium	(mg / 100 g)	309	316	67	45	102
Phosphorus	(mg / 100 g)	41	65	29	29	60
Iron	(mg / 100 g)	5.2	3.2	1.0	1.2	3.5
Sodium	(mg / 100 g)	—	76	130	10	52
Magnesium	(mg / 100 g)	46	36	70	13	60
Potassium	(mg / 100 g)	468	440	538	247	547
Thiamin (Vit. B1)	(mg / 100 g)	—	0.19	0.0	0.1	0.1
Riboflavin (Vit. B2)	(mg / 100 g)	—	0.17	0.2	0.2	0.3
Niacine (Vit. B3)	(mg / 100 g)	—	0.8	1.8	0.3	0.5
Vit. A (retinol equiv.)	(mg / 100 g)	742	992	354	186	569
Vitamin C	(mg / 100 g)	110	52	24	20	53

Table 5. Mineral composition of plants of *E. sativa* of different ages

Mineral (mg/100 g fresh weight)	**Plant age (days after emergence)**			
	20	**27**	**34**	**41**
N	448	556	422	364
P	46	45	42	45
K	468	403	459	456
Ca	140	151	157	197
Mg	41	38	37	39
S	44	39	41	32
B	0.53	0.38	0.37	0.35
Cu	0.19	0.18	0.16	0.19
Fe	7.84	8.02	9.86	13.89
Mn	0.29	0.29	0.30	0.59
Zn	1.06	1.03	0.78	2.06

(From Haag and Minami 1988)

The period of maximum oil synthesis in the *E. sativa* seeds was 10-20 DAF which coincides with a considerable increase in erucic acid-rich triglycerides with a concomitant decrease in partial glycerides, sterol esters and hydrocarbons and free fatty acids. Only a slight change in lipid composition at later stages has been observed (Sukhija and Bhatia 1972).

In ground, defatted seeds of *E. sativa* cv. Baladi, the crude protein content was 31%

and the most important proteins were those corresponding to 10-38 kDa. Main amino acids found were glutamic acid, aspartic acid, leucine and proline (Salama and Hussein 1992).

Erucic acid is the most abundant in seed fat total acids (amounting to more than 40%). It is followed by 6; 9; 11; 13-octadecenoic acids ($C_{18:1}$), a and g-linoleic acid ($C_{18:2}$) and 9, 11, 13, 15-eicosanoic acid ($C_{20:1}$) (Hilditch and Williams 1964; Sindhu Kanya and Kantharaj Urs 1989) (Table 6).

Table 6. Unsaturated and saturated component acids of seeds of *E. sativa* of various origin

Origin	**Acids (% by weight)**						
	C_{16} monoene	**C_{18}**			**C_{20} monoene**	**C_{22}**	
		oleic	**lin.**	**len.**		**erucic***	**diene**
Unsaturated							
India	1.5	24	9	7	12	38	0.5
Bulgaria	—	36	12	6	—	41	—
USA	0.2	18	10	12	10	43	—
	C_{14}	**C_{16}**	**C_{18}**	**C_{20}**	**C_{22}**	**C_{24}**	
Saturated							
India	—	4.5	———	5	———		
USA	trace	4.0	1	0.9	0.1	1	

* Docos-13 enoic acid
(From Hilditch and Williams 1964)

Isothiocyanates (corresponding to about 1% of the weight of *E. sativa* meal) are formed as products of enzymatic hydrolysis of glucosinolates and are responsible for the pungency of the seed oil. The main glucosinolate (138 mmol/g of dry meal) is glucoerucin (4-thiomethyl 3-butenyl glucosinolate). By enzymatic hydrolysis the compound produces 4-thio-methyl-3-butenyl-isothiocyanate which by having two sulphur atoms is responsible for the strong pungency of the oil (Sindhu Kanya and Kantharaj Urs 1989).

Seeds are essentially free of sinapin (Kerber and Buchloh 1982).

Utilization

The young leaves of *E. sativa* and *Diplotaxis* spp. are used mainly for the distinct, piquant and spicy flavour whereas the flowers are used as a garnish. The seeds of *E. sativa* are used mainly for the production of a semidrying oil (jamba oil), illuminant oil, for edible purposes (particularly in India) as a substitute for mustard (Arietti 1965; Uphof 1975; Vaughan 1970; Facciola 1990). Older leaves which are too piquant to be consumed rough can be pureed and added to sauces and soups (Facciola 1990).

Baldrati (1950) mentions that in Fano (central Italy) seedlings of *E. sativa* with 2 or 4 leaves with cotyledonary leaves still present are sold in the market. These tender leaves are used to prepare a delicate salad named ‘persichina’.

In southern Italy *Diplotaxis* spp. have been used as food for a long time, but nowadays their popularity is increasing remarkably. This is so true that many restaurants offer in their menus many dishes having rocket as a main ingredient. A list of old traditional Apulian recipes along with some new ones which can be tasted in famous restaurants throughout Italy are provided in Table 7.

Interesting trials on mid-term storage and on best technologies required to freeze *E. sativa* and *Diplotaxis* spp. are being planned at the Istituto di Orticoltura Industriale, (CNR), Bari, Italy.

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

Rocket is used in the traditional pharmacopeia for various purposes: antiphlogistic, astringent, depurative, diuretic, digestive, emollient, tonic, stimulant, laxative, stomachic, anti-inflammatory for colitis, antiscorbutic and rubefacient (Arietti 1965; Uphof 1968; Ellison *et al.* 1980; Ambasta *et al.* 1986; Anonymous 1988, 1991).

An infustion at 4-8% is used against itchings, 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 inflammations (Anonymous 1988) and to cure catarrh and hoarseness (Mascagno 1987).

Oil and leaf extracts showed also a good potential as insect repellents. In particular, the mucilaginous seeds of *E. sativa* appeared to be promising as biocontrol agents for the larvae of the insect *Culex quinquefasciatus* Say. and *Aedes aegypti* L. (Sharma and Wattal 1982).

Oil of *E. sativa* proved effective against insects such as *Perkinsiella insignis, Sogata striatus, Sogatella longi-furcifera, Toya attenuata* and *Peregrinus maidis* feeding on rice (Khan and Khan 1985).

In the Spanish province of Cordova *E. sativa* is used in experiments to feed larvae of *Artogeia rapae* L. (*Pieris rapae*): 96% of the larvae are reported to have been killed (Haeger *et al.* 1987). Moreover, leaf extracts containing glucosinolates from *E. sativa* had an adverse effect on the survival and development of nymphs, adult lifespan, reproductive period and fecundity of the mustard aphid *Lipaphis erysimi* Kalt. (Narang and Atwal 1986).

In addition *E. sativa* was found very suitable as a test plant in a rapid bioassay to detect the presence of lenacil and oxyfluorfen in the soil (Parente 1994).

Seed meals for animal and poultry have a limited value because of the presence of bitter-tasting glucoerucin (Sindhu Kanya and Kantharaj Urs 1989).

Table 7. Italian recipes having rocket among the ingredients

Italian name of recipe	Ingredients
Insalata di rucola (da sola o mista)	Green salad alone or in mixture (misticanza) with other vegetables
Pomodoro, mozzarella e rucola	Tomatoes, mozzarella cheese, rocket
Bruschetta	Toasted bread, tomatoes and rocket
Bruschetta con mozzarella e rucola	Toasted bread, mozzarella cheese, rocket
Fave alle sette insalate	Broad beans, olives, onions, rocket, pepper in vinegar, eggplant in olive oil, boiled chicory and tender tendrils of grapevine
Quagghjariedde	Sheep meat, wild vegetables, tomatoes, olive oil, salt
Ruchetta e pecorino	Pecorino (sheep's / goat's) cheese, rocket
Risotto alla rucola	Rice, rocket
Risotto, gamberetti e rucola	Rice, shrimps, rocket
Gamberetti e rucola	Shrimps, rocket
Spaghetti, gamberetti e rucola	Spaghetti, shrimps, rocket, salted garlic
Spaghetti e rucola	Spaghetti, rocket, salted garlic or tomato sauce, cheese, olive oil
Orecchiette, patate e rucola (bandiera)	Orecchiette pasta, potatoes, rocket, tomatoes
Rucola saltata in padella	Rocket sautéed with garlic and olive oil
Insalata di mare con rucola	Sea salad, grana cheese, rocket
Grana e rucola	Grana cheese (like Parmesan cheese), rocket
Branzino alla rucola	Bass fish, rocket
Anguille alla rucola	Eel, rocket
Carpaccio di carne cruda e rucola	Very thin liced raw lean veal, balsamic vinegar and rocket
Carpaccio di pesce spada e rucola	Swordfish, rocket
Carpaccio di cernia e rucola	Stone bass fish, rocket
Carpaccio di orata e rucola	Daurade, rocket
Straccetti alla rucola	Thin beef slices fried with rocket
Frittata di rucola	Rocket, grated cheese, eggs, salt
Preboggion	Mixed cooked vegetables (i.e. rocket, borage, common sow-thistle)
Patate ruchetta e pasta	Potatoes, rocket, pennette pasta, garlic, tomatoes (peeled), basil, parsley, olive

	oil
Pancotto e ruca	Rocket, slice of stale bread (boiled), potato, garlic, olive oil
Rucola con pancetta	Rocket, bacon, garlic, salt and pepper
Rucola lessata	Rocket, olive oil lemon
Cavatelli o strascinati	Home-made pasta, fresh tomato sauce and rocket
orecchiette con la rucola	Tomato sauce, olive oil and rocket
Cicatill e rùchele	Rocket, dumpling made from potato
Fainelle, patate e rucola	Rocket, home-made pasta, potato
Frisedde ncapunate	Rocket, fresh tomato, roasted bread (`friselle'), sweet basil, wild majoram or italian oregano, salt, olive oil

Pest and diseases

A number of insects are recorded to attack rocket plants. In Italy the rocket flea beetle (Pollini 1991), *Philaenus spumarius* on *Diplotaxis* spp. (personal observation); in Cyprus *Asphondylia* spp.; in the USA (Oklahoma and Idaho), where a breeding line (K-841) was seriously damaged by the mustard aphid, *L. erysimi* (Amiad and Peters 1992) and several cultivations were attacked by *L. erysimi* and *Brevicoryne brassicae* aphids and by flea beetles (*Phyllotreta* spp.) (Auld *et al.* 1993) and in Spain where the butterfly pierid, *Artogeia rapae* L. (*Pieris rapae*), also caused damages (Haeger *et al.* 1987).

In India the infestation of *Myzus persicae* (Sulzer) on nine cultivars of *E. sativa* averaged 77-78% without any significant difference among them; none was resistant to aphids (Singh *et al.* 1988a).

Colonies of *M. persicae* and *Macrosiphum euphorbiae* could be mantained on a single plant for about 3 months. Aphids from colonies maintained on *E. sativa* for 4 years did not lose their ability to transmit viruses.

In Italy the incidence of the aphid *M. persicae* on *E. sativa* was significantly higher when the crop was sown in late November than in October.

Regarding the type of diseases recorded on rocket plants in Italy, we should mention the presence of the rust, *Albugo candida* (Pers.) Kun. (Pollini 1991). Inoculation of rocket plants with *A. candida* or *A. candida* + *Peronospora parasitica* increased both respiration and peroxidase enzyme activity (Saxena and Rai 1987).

Alternaria brassicae appears on pods as small, blackish, circular lesions which eventually cause the death of the pod (Prasada *et al.* 1970). Sharma and Gupta (1985) isolated *A. brassicae* and *A. brassicicola* (Schew.) Wiltshire from air spora and phylloplane throughout the growing season of *E. sativa* ; *A. brassicicola* is transmitted by seeds (Gorini 1979). In India root and foot-rot disease induced by *A. alternata* (Fr.) Keissler, *Erysiphe convolvuli* and *Fusarium oxysporum* (8-10% of plants damaged) have been reported (Seharan *et al.* 1985; Gupta 1988). Furthermore, out of 121 accessions of *E. sativa* screened for *F. oxysporum* only 3 were found tolerant and 18 moderately tolerant (Gupta and Dubey 1988).

One-month old plants of *E. sativa* artificially inoculated with a strain of *Xantomonas campestris* did not develop the disease (Gandhi and Parashar 1977).

Some viruses are reported to occur on *D. erucoides* and *E. sativa*, the latter being the natural host for the turnip mosaic virus which causes leaf distortion and stunting (Feldman and Garcia 1972).

In Italy, in the Lazio region, a mosaic virus on plants of *E. sativa* was discovered, which is responsible for blisters and discolouration of the perinerval veins (Quaquarelli and Gallitelli 1983).

In Northern Italy (Turin area), *E. sativa* plants were found bearing severe crinkling, chlorosis and stunting and occasional necrosis, caused by a strain of radish mosaic virus (RaMV) (Milne *et al.* 1980). In India, Verma *et al.* (1969) reported the presence of a virus on *E. sativa*, which seemed to be a mutant strain of the radish mosaic virus, causing considerable damage to the crop.

When tested with the antiserum prepared from a local tomato isolate, *E. sativa* was found to be infected by tomato yellow leaf curl gemini virus (Abdel-Salam 1991).

Diplotaxis erucoides was found as an important reservoir host of plant pathogenic viruses such as pelargonium zonate spot virus (PZSV) cucumber mosaic, cucumovirus, tobacco rattle tobavirus (in symtoms-free plants), turnip mosaic potyvirus and radish mosaic comovirus (in symptomatic plants) (Lupo *et al.* 1991).

Crop potential

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 growing in backyard gardens together with basil, sage and other condiment herbs in a traditional way. Wild types of rocket can be easily spotted in Italian vegetable marketplaces where they are often being supplied directly by the peasants. In the last few years the plants coming from cultivation are increasing remarkably, especially those sold in the form of small tender leaves and called 'ruchetta da taglio', although they are less appealing to some consumers, being less aromatic than the wild forms.

The appearance on the markets of the so-called '4th generation' of vegetables, i.e. those vegetables that are neatly prepared and sold in sealed plastic bags after having been sorted, cleaned and trimmed, could have a positive impact on the commercialization of minor vegetables, including rocket. This type of packaging does in fact enhance the shelf life of the product which deteriorates fast in marketplaces when no protection is provided for reducing wilting of leaves.

In Italy rocket has indeed a very good potential. As a matter of fact, the price of *Diplotaxis* species present in major Italian wholesale markets is being quoted daily and the most important Italian daily newspaper specializing in economic matters (Il sole 24 ore) reports the daily price of rocket at the wholesale market of Milan. The average price for the first seven months of 1993 was 3.0, 2.6, 3.3, 3.2, 2.4, 1.8 and 1.5 USD (1 USD is equivalent to 1650 Italian lira).

The prices of rocket of the 4th generation, sold as packaged products ready to be used as salads in some supermarkets of Rome (Italy) during September 1993, were as follows (Anonymous 1993):

Supermarket	**Weight of package (g)**	**Price ($/kg)**
PAM	110	12.0
GS	200	9.0
Standa	100-125	11.4

The potential of *E. sativa* also has been stressed by the Californian Farmers' Association which gives an indication of which crops need more research attention (Brown and Valenzuela 1992).

Germplasm collections

Despite such popularity, rocket germplasm is scarcely represented in Mediterranen genebanks. A limited number of accessions are in fact stored at the Italian Germplasm Institute of Bari, Italy, and in some *Brassica* collections like the one held at the University of Madrid (ETSIA), Spain.

Rocket germplasm is also being maintained in some botanical gardens. *D. tenuifolia* can be found in the botanical gardens of Palermo, Pisa, Siena, Padova, in Italy; in Paris, France; in Meise, Belbium; Leipzig, Germany; Cluj-Napoca, Romania. Accessions of *D. muralis* are maintained in the botanical gardens of Lucca, Italy; Paris, and Meise, whereas *E. sativa* is in those of Palermo, Pisa, Madrid, Meise, and Zalek (former Jugoslavian Republic) and *D. crassifolia* at Palermo and Egypt, Cairo.

The existence of practices of massive harvests of rocket material from the wild (viz. the case of the Apulia region) indicates that genetic erosion is actually taking place in its natural habitat. Yet the fact that rocket can be found easily in the wild cannot justify any irresponsible overexploitation of its diversity.

Some concern is also arising from reports of recent germplasm-collecting missions launched in Italy which have noted that landraces are being gradually replaced in the country by new cultivars marketed by seed companies (Hammer *et al.* 1992). In fact in Italy, besides the *E. sativa* seeds which have been commercialized for a long time, recently many seed firms (e.g. SAIS, Ingegnoli, Perega, Magda, etc.) have started to sell seeds of *Diplotaxis* species.

A concerted action on conservation of rocket genetic diversity is highly recommended for ensuring a sustainable utilization of the species and allowing future generations to continue to use these valuable resources which have been kept alive and highly appreciated all along by our ancestors.

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Conservation and utilization of rocket in Mediterranean countries

Rocket growing in Turkey

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Summary
Although *Eruca* and *Diplotaxis* spp. are included in the native flora, *Eruca sativa* is the cultivated form in Turkey. It is grown as a salad crop and the leaves are harvested as greens. Owing to the fact that the consumption rate is high all over the country, it is planted all the year around.

Introduction
Rocket is an appetizing vegetable that is freshly consumed as green salads. It is rich in minerals and vitamins. The stem, which at the early growth stage is rosette-shaped with a high number of leaves, is herbaceous and greatly branched. Leaves are long and oval in shape and the border of the leaf is either pieced or plain and green in colour.

As the duration of the rocket is very short, it is grown continuously. Daylength and light intensity cause the rocket to grow and flower quickly. Therefore, short-day growing is recommended. Rocket needs large amounts of water and high relative humidity. Water deficits and low relative humidity give rise to low quality in rocket.

It is important that the rocket to be sold at market have healthy, green leaves and be harvested before shooting and flowering. Since rocket is consumed as a fresh vegetable, it is not stored. Rocket can, however, be easily stored in plastic bags at +5°C for 4-5 days.

Vegetable production in Turkey
In Turkey, according to the figures of 1992, total vegetable grown area is 592 990.2 ha, and the production is 17 467 920 tons (Table 1). Most of the vegetable production comes from fruit-bearing vegetables (85%) such as tomato, pepper, onion, aubergine and cucumber. It is followed by, in decreasing order, leafy or stem vegetables, leguminous vegetables, roots, bulbs and tuberous vegetables and others.

Among the leafy or stem vegetables, there are no values for rocket production prior to 1992. Although the production in 1992 was 170 tons it may not reflect the real value because production is realized on small parcels many times during the year.

Culture of rocket
It is planted all the year round. The leaves are harvested for about a month in summer (growing in warm temperatures shortens the period by 30 days but causes the leaves to be bitter and pungent), and 45-60 days in winter (low temperatures delay the harvest).

There are no commercial cultivars; there is only one cultivated form of *Eruca sativa.* Growers provide the seeds through the seed companies or leave the plants for seed production in spring (they leave the plants for flowering from 15 February until 15 May).

Seeds (5 g/m^2) are sown into the beds 1 m wide by 3 m long at intervals, in order to provide successive harvests (Figs. 1 and 2). The growers use ammonium nitrate and animal manure for fertilization. The other unique cultural practice is pest control against *Phyllotreta cruciferae.*

Table 1. Vegetable production (tons) in Turkey

Vegetables	1990	1991	1992
Leafy or stem	1 419 700	1 394 000	1 419 638
Cabbages	575 000	560 000	585 000
Black cabbages	124 000	124 000	117 000
Artichoke	10 000	11 000	10 000
Celery	12 000	11 000	9 000
Head lettuce	60 000	75 000	85 000
Leaf lettuce	126 000	120 000	110 000
Spinach	160 000	160 000	153 000
Leek	340 000	320 000	310 000
Garden orach	8 700	8 000	11 500
Purslane	4 000	5 000	5 000
Dill	—	—	268
Parsley	—	—	20 000
Mint	—	—	2 200
Rocket	—	—	170
Cress	—	—	1 500
Leguminous	560 000	566 000	583 132
Fruit-bearing	13 958 000	14 931 000	14 864 000
Root, bulb and tuberous	451 000	478 900	531 630
Other	68 020	68 020	69 520
Total	16 456 720	17 437 920	17 467 920

From Anonymous 1993.

The plants are harvested by cutting them at the soil surface level and then binding them into bundles for marketing (Figs. 3 and 4). The yield of rocket is estimated as 30 to 40 bundles / m^2.

Fig. 1. Seeds of *Eruca sativa* are sown into beds 1 m wide by 3 m long at intervals, to provide successive harvests

Fig. 2. The plants are harvested by cutting them at the soil surface level and then binding them into bundles for marketing

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Rocket cultivation in Egypt

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An introduction to the classification

The following information on rocket classification was extracted from 'Student's Flora of Egypt' 2nd. edn. Cairo University.

English name: rocket or garden rocket
Arabic name: gargir
Scientific name: *Eruca sativa* Mill.
Systematic position
(according to Engler)
Subclass: Angiospermae
Class: Dicotyledoneae
Subclass: Archichlamideae
Group: Dialypetalae
Order: Rhoedales
Family: Cruciferae
Genus: Eruca
Full taxonomic name
of species: *Eruca sativa* Miller (syn. *E. vesicaria* (L.) cv. spp. *sativa* Miller Thell.).

Rocket is an annual plant very common in Egypt and completely naturalized from cultivations. It has lyrate leaves, parted or more or less hispid. Flowers are typically of a cream colour and pods are somewhat inflated. In Egypt it is common in the Nile region, in oases, along the Mediterranean shores and in the Sinai area.

A number of types can be found in Egypt, viz. Mediterianes, Nubica, *lativalvis*, *longirostris* and *oblongifolia*. Mediterianes is characterized by lyrate leaves, parted, more or less hispid, whiteish-yellow flowers with fruit somewhat inflated. It is cultivated widely in lower Egypt where it is present also as an escapee. Nubica is characterized by simple dentate leaves, thick globers, flowers of a lemon-yellow colour, fruits of a narrow cylinder shape. It is cultivated in the upper Egypt region, and is present there also as an escapee. Subsp. *lativalvis* (Boiss.) has coss leaves, binnatisect with very narrow lobes. It is a rare variety and can be found only in the Nile valley and in the Delta region. Subsp. *longirostris* (Vechtr.) Rovy differs from all the previously mentioned types because of its pods, only 3 mm broad, characterized by a very long beak (6-10 mm); it is also a rare variety and can be found in the Nile Valley and along the Red sea (El-Qoseir area). Subsp. *oblongifolia* Pasq. is characterized by simple leaves, dentate, thicker and glabrous; flowers are lemon yellow; it is a rare variety and is present in the Nile Valley, occasionally found as an escapee.

Rocket cultivation

Rocket is a popular crop in Egypt and it is consumed widely in the country. It is grown in urban lands near cities and in villages. It is estimated that the area grown with rocket in the country in 1993 was 4500 acres (1821 ha). A suitable environment has mild weather conditions with somewhat low temperatures (13/20°C day/night). Short days are favourable to obtain leaf production. Higher temperatures (18/25°C) and long days (14 hrs) result in bolting and early flowering.

Rocket is grown all year round in Egypt; however, the best time for its cultivation is autumn and winter. In summer the plants should be harvested when they are still small and before they commence bolting. Cultivation of an acre (0.4 ha) of land requires 4-8 kg of seeds of rocket depending on the system of cultivation that is adopted. The crop is usually grown in fertile soil of medium texture. Sandy soil with application of enough fertilizer is also suitable to its cultivation.

The preparation of the soil for the cultivation consists in ploughing the soil twice, adding organic manure and leveling it into basins with dimensions of 2x2 m or 3x2 m or into ridges 1 m wide.

Sowing is done by broadcasting the seeds in the basins and covering them with soil. Sometimes soil is drilled in rows 15-20 cm distant apart, seeds are placed in the rows, which are being then covered and irrigated.

Irrigation for rocket takes place according to weather conditions and prevailing temperatures. In summer time, irrigation is applied at 5-day intervals, whereas in autumn and winter it is applied at 10 and 15-day intervals, respectively.

Plants are thinned in early stages. Fertilization takes place according to the following practices: a first application of green manure takes place during soil preparation at the rate of 10-15 m^3, a second one is carried out 2-3 weeks later by adding 50-100 kg of ammonium sulphate, and at each harvest the latter quantity of fertilizer is also applied.

Weeding is usually by hand. Harvests made in autumn and winter take place 6 weeks after sowing and consists of cutting the tops of the plants and leaving the roots, thus facilitating the vegetative regrowth in the plant.

The following 3-4 harvests are carried out at 4-week intervals. In summer, plants are uprooted 3 weeks after sowing.

The yield in autumn and winter reaches 4-6 t/acre (10-15 t/ha). Usually 3-4 harvests are made, thus 12-24 t/acre (30-60 t/ha) is the estimated production of a cultivation of an acre per year. Total production of rocket in Egypt in 1993 was equivalent to 38 800 t.

For seed production the soil preparation is different from the one used for leaf production. In this case ridges are usually made 60 cm apart, sowing is in September or October and the seeds are sown on 2 rows of each ridge at 10-15 cm apart. Two harvests of the vegetative growth are taken, than plants are left there until the flowering stage in March and seed production is carried out finally in May.

Utilization

In Egypt leaves are consumed raw as salad. Leaves are used whole or are shredded, consumed alone or mixed with tomatoes, cucumber and onions. Rocket used in Egypt lacks the pungent taste that characterizes — and is particularly appreciated by — varieties used in other Mediterranean countries (such as Italy). In the local pharmacopeia it is believed that rocket has a number of important curative properties as a coadiuvant in digestion, to control diabetes and against phlegm. The plant is also believed to prevent hair loss and to have aphrodisiac properties. The retail price of a kilogram of fresh rocket leaves in Egypt is around 0.12 USD (in 1994).

Diversity and use of *Eruca* germplasm in Greece

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Cultivated rocket (*Eruca sativa* Miller) is a vegetable of limited distribution and use in Greece today. It was, however, cultivated there from ancient times as its cultivation has been reported by Theophrastus. It was called 'Euzomon' by the ancient Greeks, meaning 'with good juice' and was classified among the vegetables that permit successive seedings throughout the year.

Today rocket is a peculiar and luxury salad vegetable served with certain dishes or on certain traditional festivities. It is grown near large cities, mainly in villages around Athens and Thessaloniki, in Kriti, certain Aegean and Ionian islands and particularly on the island of Kerkyra (Korfu) where it is associated with certain Easter dishes. However, detailed official data on areas of cultivation, areas and production are not available. Unofficial estimation of the quantities of rocket sold through the central vegetable market of Thessaloniki gives a daily input of 100-150 kg.

Local landraces are cultivated for commercial production and they are produced by a few experienced farmers. Introduced varieties are used in small quantity packaging by amateurs and are predominantly French or Italian.

A closely related species, *Eruca longirostra*, considered to be the wild progenitor of the cultivated species, is widely destributed in Greece. It was reported in the beginning of the century as particularly abundant near Athens where it was used as feed for goats (favouring milk production). The plant is also rich in nectar and is respected as a good bee feeder.

Other related species, *Diplotaxis muralis*, *Diplotaxis viminea* and *Diplotaxis tenuifolia*, were also reported in earlier floras as being widely distributed in Greece. However, no recent ecogeographical studies on the distribution of *Eruca* or *Diplotaxis* are available.

Contacts with the Department of Vegetable Crops and the Department of Taxonomy and Systematics of the University of Thessaloniki have shown the existing gaps in scientific knowledge on these species. Any program on the collection and exploitation of this germplasm must take this weakness into account and organize, as a first step, a rough survey of the country to assess the existing genetic diversity and potential of the crop and the related wild species.

Germplasm of wild rocket in the Madrid-UPM seed genebank

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The classical procedure for obtaining wild rocket seeds from botanical gardens' Index Semina had several disadvantages which are now being rapidly corrected as long-term conservation procedures are becoming common in many gardens.

The Madrid UPM seedbank is not linked to any garden, but it is specialized in crucifer seeds and has used these reliable conservation methods at least since 1966.

Eruca has never been a special priority, but nonetheless it has been routinely collected in many occasions (49 accessions). Only for 12 of these have we found it convenient to put the samples under long-term storage conditions (Tables 1 and 2). Although this number is small, it is interesting to note that it includes accessions from seven different countries.

Table 1. Germplasm of wild *Eruca* accessions in Madrid (UPM)

Under long-term preservation procedures (-10°C and 3.5% moisture)	12
Only at +5°C	37
Total	49

Table 2. Germplasm of wild *Eruca* seed samples in long-term preservation at Madrid (UPM)

Accession no.	Species	Origin
1471 - 68	*E. pinnatifida*	Ksabi, Midelt, Morocco
1813 - 70	*E. pinnatifida*	Djelfa-Bou Saada, Algeria
887 - 66	*E. vesicaria*	Jumilla, Murcia, Spain
1796 - 70	*E. vesicaria*	Marnia, Orán, Algeria
3061 - 74	*E. vesicaria*	Alcalá de Henares, Spain
3604 - 75	*E. vesicaria*	Venta Caballos, Zaragoza, Spain
3750 - 75	*E. vesicaria*	Ruins of Persépolis, Irán
4757 - 77	*E. vesicaria*	Arenas S. Juan, C. Real, Spain
6424 - 84	*E. vesicaria*	North of Sousse, Tunisia
7314 - 86	*E. vesicaria*	Cap Bon, Tunisia
7322 - 86	*E. vesicaria*	Athalassas, c. Nicosia, Cyprus
7368 - 86	*E. vesicaria*	Cagliari, Sardinia, Italy

Further collection in Spain would be of considerable interest because it could lead to a number of accessions of *E. vesicaria* subsp. *vesicaria*, whose odoriferous potential seems to be stronger than for subsp. *sativa*. It could be also used as an alternative green crop for the control of nematoda in sugar beet cultures. Furthermore, such collections could help to elucidate some pending taxonomic problems through proper studies on living material.

The Maghrebian countries also offer unique opportunities to collect wild *Eruca* germplasm. As for other genera (for instance Moricandia) the center of genetic variation lies there, and only single well-defined types have escaped to become weedy inhabitants of the circummediterranean world. The species *E. loncholoma* and *E. setulosa* (never collected) and possible variation within *E. pinnatifida* are challenges to be added to the wide existing diversity of *E. vesicaria* infraspecific taxa and ecotypes.

In the meantime, it might be wise to regenerate some stored material of special interest, which is kept in seedbanks without much care for obtaining long lifespans. Table 3 lists some suggestions in this respect for the UPM bank. Material from Spain (15 accessions) has been omitted because it would be easier for us to undertake direct recollection instead.

Table 3. Germplasm of wild *Eruca* accessions of interest for regeneration

Accession no.	Origin
1501-68	Tamri, Morocco
5884-81	Gral. Acha, Argentina
1837-70	W. Setif, Algeria
6035-82	Akrokorinthos, Greece
1942-71	Mograr, Algeria
6215-83	E. Turgutlu, Turkey
1963-71	Mostagnam, Algeria
6322-83	Magheri, Crete, Greece
3734-75	Quasr-el-Shirin, Iran
6355-83	Ano Vianos, Crete, Greece
3778-75	Chalus, Iran
6451-84	E. Gafsa, Tunisia
4680-77	E. Gafsa, Tunisia
6456-84	Gafsa / Feriana, Tunisia
4681-77	SW Feriana, Tunisia
6468-84	N Bou Saada, Algeria
4687-77	S Sedrata, Algeria
6504-84	E Ain Beida, Algeria
4713-77	El Aricha, Algeria
6612-84	Capri, Italy
5539-80	Jbel Siroua, Morocco
7537-86	El Kelah, Morocco

Note: Unpreserved samples; only those collected after 1980 may be expected to germinate.

As for the genus *Diplotaxis* (often used in the same way as *Eruca*), we refer the reader to our seed catalog of crucifers. Most species have been collected and their seeds are now available for distribution. Further action could involve the collection of some missing species and also of the infraspecific diversity of those considered more interesting from the practical point of view. Cape Verde islands, the East Mediterranean region and the Maghrebian countries might be the main areas of focus.

Appendix I. Programme

First working meeting of the Rocket Genetic Resources Network

13 November 1994

Morning session

Introduction

Joint session with ECP / GR Brassica Working Group	
Welcome address	Monteiro, Gusmão
ECP / GR Phase V	Frison
ECP / GR Brassica Working Group	Gustafsson
IPGRI project on Underutilized Mediterranean Species and the Rocket Genetic Resources Network	Padulosi

Taxonomy of rocket

An introduction to the diversity of rocket (*Eruca* and *Diplotaxis* spp. and its natural occurence within the Mediterranean region	Gómez-Campo
New taxonomic views within *Eruca* and *Diplotaxis* genera in the light of hybridization and molecular findings	Warwick

Diversity and uses of rocket in Mediterranean countries

A survey on rocket diversity and use across the region (key words: genetic diversity, wild, cultivated, uses, production, constraints, pests, diseases, agronomy, marketing)

Italy (mainland)	Bianco
Italy (Sicily)	Branca
Greece	Stavropoulos
Portugal	Pais / Dias / Cotrim
Israel	Yaniv
Spain	Gómez-Campo

Afternoon session

Diversity and uses of rocket in Mediterranean countries (continued)

Egypt	Mohamedien
Turkey	Tuzel
North America	Warwick

Collection and conservation of rocket genetic resources

Status of national collections of rocket

Areas that should be targeted for collecting rocket wild / cultivated diversity with higher priority

Collecting activities carried out in 1994 and / or planned for 1995

In situ conservation

Role of NGOs in on-farm conservation

Italy	Pignone / Branca
Greece	Stavropoulos
Turkey	Tuzel
Israel	Yaniv
Egypt	Mohamedien
Spain	Gómez-Campo

Portugal — Pais / Dias / Cotrim

14 November 1994

Morning session

Descriptor list

General discussion among participants on the development of a descriptor list for rocket (participants to come with comments on the IPGRI *Brassica* descriptor received by mail)

Definition of a minimum descriptor list for rocket

Regeneration/distribution of germplasm

A plan for concerted action by the Network on acquisition, regeneration, multiplication and exchange of rocket genetic diversity — Pignone, Yaniv

Database on rocket

Discussion on the format for the DB on rocket — Pignone

Afternoon session

Evaluation activities

Preliminary reports on activities in each country

Israel (chemical evaluation)	Yaniv
Italy (agronomic trials)	Baggio / Padulosi
(adaptability studies)	Branca
(cytogenetics)	Pignone

Future plan for Network activities

Activities to be carried out by the network and possible recommendations to pass on to the ECP / GR *Brassica* Working Group

15 November 1994

Morning session

Election of a chairperson for the Rocket Network

Project proposal to the EU

Participants to propose a project and ways to possibly fit it into the context of a wider *Brassica* proposal

Afternoon session

Interaction with ECP/GR Brassica Working Group/International Collaboration

Joint session with ECP / GR	
Access to genetic resources	Frison
Status of *Brassica* Genetic Resources in the USA	Astley
Workplan of the Rocket Genetic Resources Network	Chairperson
Workplan	ECP / GR
Presentation of the ECP / GR Brassica Working Group report and discussion	

Session for participants from EU countries

Preparation of the EU proposal

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