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Germplasm conservation and breeding advancement in seed spices: An absolute overview

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Abstract
Seed spices "High-value low volume crops" are the most remunerative commodities of the arid and semi-arid regions of India. This group of spices is confined to crops like coriander, cumin, fennel, fenugreek, ajwain, nigella, dill, celery, anise, caraway etc. India is the world leader in seed spice production, consumption and export has to go a long way in the overall development of these crops and their growers. The germplasm of a crop species includes landraces, primitive cultivars, released varieties, genetic stocks with known desirable attributes and wild and weedy relatives of the cultivated species. None of the seed spices is native to India, but the continuous natural selection and creative human selection in a wide range of agro-climatic regions and different cultures led to enormous morphological and genetic diversity in India. In India, attention on improvement of these crops came very late after independence, in 1975 AICRP started and in the year 2000 NRCSS was established.

Keywords: seed spices; genetic improvement; germplasm conservation; selection

Introduction

Annuals whose dried fruits or seeds are consumed as spice are classified as seed spice and are well distributed over different agro-climatic regions in India. The major belt spreads from semi-arid to the arid region covering a large area in Rajasthan and Gujarat. In India Rajasthan and Gujarat acclaimed as "Seed Spices Bowl" for large scale commercialization of seed spice. These two states together are responsible for more than 80 per cent production in the country. Haryana, Bihar, Uttarakhand, Punjab, M.P., U.P., Orissa, Tamil Nadu Karnataka and West Bengal also produce one or more of seed spices at a significant amount. Our ancestors must have valued the medicinal importance of seed spices, with limited diversity available these crops have sustained the natural course for times immemorial. Seed spices are the golden wealth of arid and semiarid region of the country being most remunerative crops per unit time, space and resource utilized. In India, attention on improvement of these crops came very late after independence, in 1975 AICRP started in the year 2000 NRCSS was established.

Cultivation of seed spices has been started from the dawn of history in India. Country relishes the highest position in the world as it is bestowed with great biodiversity. The seed spices were first introduced from the Mediterranean and Central Asian region to India during ancient time. Ten seed spices are grown at a viable rate, though total twenty types of seed spices are noticed in India. Seed spices are classified into a major and minor group of seed spices. The crops namely coriander, cumin, fennel and fenugreek, are fallen under major group whereas, ajowan, dill, nigella, celery and anise dictate as minor one (Table 1). The seed spices mentioned above are dicotyledonous and most of them belong to family Apiaceae except fenugreek and nigella, which are from family Fabaceae and Ranunculaceae, respectively. Mediterranean region, South Europe and Asia are the primary growing centre for seed spice. Though seed spices are grown in larger areas in India and are exported to many other countries, none of them is native to India except ajwain and Indian dill [1].

Indian biodiversity is packed with the extensive number of landraces of seed spice crops. A major proportion of the country's agro-biodiversity is under farming community incarceration and Indian farming systems followed inherited conventional system. Although nowadays due to frontier cultivation in Agro-system, natural habitats going to endangered state. Development of improved cultivars has improved production and productivity of seed spices but has endangered the accumulated diversity among traditional cultivars of these crop species. Conservation of germplasm of seed spices is of profound importance for sustaining production.

Table 1: Major Seed Spice's germplasm at different centers in India

Sl. No	AICRP Centres	Coriander		Cumin		Fennel		Fenugreek
		I	E	I	E	I	E	I E
1	RAU. Jobner	649	112	313	10	185	8	325 12
2	GAU, Jagudan	70	18	173	7	284	20	48 2
3	TNAU. Coimbatore	205	-	-	-	-	-	262
4.	APAU, Guntur	230	-	-	-	-	124	-
5	RPAU. Dholi	102	-	-	-	40	-	103
6.	IGAU, Raigah	20	-	-	-	-	-	13
7.	NDAU, Kumarganj	29	-	19	-	15		17
8.	CCSHAU. Hissar	76	-	-	-	65	-	65
9.	NRCSS. Ajmer	255	18	126	8	238	19	200 2

Note: I- Indigenous: E- Exotic

Germplasm Maintenance

Proper maintenance of germplasm should take care of the important aspect of maintaining the genetic structure of the original sampled population. To achieve this objective, two criteria need to be fulfilled. The breeding system must be controlled, which involves prevention of outcrossing with other entries and the second, to reduce the effect of natural selection in an environment other than the original one [2]. Mode of reproduction determines genetic structure as well as the pattern of ecotypic differentiation and appropriate maintenance procedure [3]. In self-pollinated crops, the precise gene and genotypic composition of the population are preserved in the absence of selection, whereas cross-pollinated crops mandate controlled pollination techniques for their maintenance. Reproduction behaviour of umbelliferous seed spices is studied and elaborated [4, 5, 6].

Coriander is an andromonoecious crop and is a highly cross-pollinated crop. Even though it is a cross-pollinated crop, there is no inbreeding depression observed even after three generations of selfing [7]. Up to 60 per cent cross-pollination was observed in closely spaced plants [8]. Therefore, gene bank accessions need to be isolated from each other for genetically identical reproduction of an accession. If sufficient field area is available, isolation can be achieved by providing 80 m distance between accessions. In most of the cases, several accessions to be maintained is large and therefore, isolation of accessions has to be achieved by technical tools such as pergamin bags. It may reduce fruit set considerably. Alternatively, if there are only a few seeds, then isolation cabins can be used for successful reproduction of populations. Cumin and fennel are also cross-pollinated crops, bees being the major pollinator. Maintenance of these crops germplasms can be achieved by barriers, which can prevent bee movement. Fenugreek is a self-pollinated crop and hence its maintenance is easy as compared to other seed spices. The accessions can be maintained by selfing using appropriately sized butter paper bags and avoiding contamination during threshing of individual accessions.

Seeds should be harvested at maturity from plants to ensure optimum viability. Seed spices have remarkable resistance to high temperature, but for long-term storage, the drying temperature should not exceed 40° C. Therefore, seeds harvested from plants have to be dried, preferably under the shade, to appropriate moisture depending on the storage condition. Care should be taken to ensure that seeds are free from weeds, foreign particles, pests and diseases during processing.

Germplasm Conservation

Conservation of Plant Genetic Resources for their sustainable use is important and can be achieved by two approaches namely (i) in *situ* conservation and (ii) *ex situ* conservation.

***In-situ* Conservation**

Seed spices are annual and are propagated through seeds. Thus in-situ conservation is the economical method. Under normal storage conditions, the viability of seed spices seeds remains satisfactory for two years. Fresh seeds, therefore, have to be produced every third year. All of the seed spices except fenugreek are cross-pollinated and pollination is brought about mainly through bees. Thus, 1 to 1.5 m long muslin cloth cages are used as bee barriers. In each cage, several plants caged are 5 in fennel, dill and ajwain, whereas, 7-10 plants in cumin and coriander. The number is certainly small to regenerate the full spectrum of genetic variability of individual accession but is enough for maintenance of large germplasm by overcoming the problem of genetic drift [6].

An alternative strategy is to form gene pools based on agro-morphological traits of the accessions. A limited number of non-competitive gene pools can be formed by grouping the germplasm accessions based on important traits like maturity and habit. These gene pools can then be maintained as composite populations by random mating among accessions of each group in poly cross blocks maintaining proper isolation. This approach is successfully adopted in coriander where four composites are developed based on maturity and habit of accessions [9].

In situ conservation refers to the conservation of genetic resources within their natural habitat. It can be of two types namely conservation in a genetic reserve area and on-farm conservation. Among seed spices, the vegetatively propagated species of black cumin (through underground bulbs) which grow in wild stale in high altitudes of Kashmir, Himachal Pradesh and Uttarakhand, the conservation in the two basic approaches *in situ* and *ex-situ* conservation-has its objectives, advantages and disadvantages, these methods should not be viewed as alternatives or confirming each other but rather as being complimentary. Biodiversity of a crop could be conserved through a "complementary conservation strategy" involving more than one method, which can be complementary to each other [10].

Table 2: Seed Standard for Storage of Seed Spices (Teao, 1985)

Parameters	**Preferable Standards**
Seed moisture content	3-7 per cent (Base collection) and 8-10 per cent (Active collection)
Sample size/accession	3000-4000 seeds (fenugreek) 4000-12000 seeds (all seed spices except fenugreek)
Viability monitoring interval Regeneration	10 years (Base collection) and 5 years (Active collection)
	Minimum population of 100 plants/accession

Germplasm Characterization

Germplasm characterization furnishes proper data on proper recognition of accessions and basic information to promote its utilization in plant improvement if it is carried out in the systematic approach. There is the assemblage of a sizeable germplasm collection of different seed spices crops at NRC of seed spices and centres under A1CRP on Seed Spices. For characterization, descriptor list of ten seed spices crops *viz.* ajowan, anise, celery, caraway, coriander, cumin, dill, fennel, fenugreek and nigella has been published [1], so that information related to different accessions may be recorded uniformly by scientists, crop curators and breeders associated with seed spice germplasm management in the country.

Germplasm Evaluation

Germplasm evaluation is essential for superior productivity and eases utilization of plant genetic resources. Different components such as crop duration, resistance to biotic and abiotic stresses and quality of products also need to to be assessed. In seed spices, quality characters need special attention on account of their export value. Germplasm materials available at different centres are evaluated and

utilized for crop improvement. on conventional breeding successfully issued through selection from the germplasm and this process accomplish with releasing of fifty-two improved varieties in seed spices (coriander-18, cum in-5, fennel-10, fenugreek-14, Ajowan [2], Dill [2], Kalongi [1] at research station under the AICRP network Evaluation status of existing genetic resources of seed spices in India as per major thrust areas and further their utilization are given in Table 1. Existing germplasm collection of seed spices at various centres in the country possesses limited variability particularly in ajwain, fennel and cumin. There is a lack of genetic resources with high volatile oil content in seeds and resistance to biotic and abiotic stresses. Promising genetic stocks with potential genes are needed to be identified and utilized in the crop improvement programme. Validation of accessions identification at biochemical and molecular levels using RFLP, AFLP and RAPD is also attaining parallel importance.

Documentation of germplasm evaluation and characterization of seed spices is necessary for sustainable use of genetic resources of seed spices and availed data was catalogued crop-wise for use by breeders, geneticists, biotechnologists and other users.

1. Aphids and stored grain pests, powdery mildews, quality degradation due to microbial load during storage, lack of information on postharvest techniques particularly storage methods for seed spice crops arises a challenging situation in commerce and create hindrance for effective utilization of seed spices germplasm.
2. Most of the available germplasm exists in the form of traditional/local varieties and have been subjected to natural selection for local adaptation. The germplasm exits in the form of complex gene mixtures. Proper sampling and regeneration are essential to recover and maintain a full range of genetic variability for further utilization in the seed spices crop improvement programme.
3. Cultivable germplasm collection possesses a limited variability. Strong and stable resistant sources are not available against biotic and abiotic stresses due to high exploitation of clonal multiplication. Value-added germplasm collection requires value addition. Collections in respect of spices oil and oleoresins, suitability to rainfed conditions, tolerance to frost, resistance to diseases and insect-pests are the probable way to achieve the previous goal. Dual-purpose lines of coriander and fenugreek *i.e.* both for leaves and seeds are to be isolated. There is a need for collaborative exploration in Mediterranean regions (Morocco, Algeria, Libya, Egypt, Tunisia) and adjoining parts of Mediterranean sea, Iran, Iraq, Russia and Europe.
4. Collections made are unspecified, without proper cataloguing at field level as well as the maintenance site. Breeders develop improved varieties through collections causes biasness for superior types.
5. Survey and germplasm collection of ajowan, dill, celery, nigella, aniseed and caraway are neglected by the researcher. Collection, conservation and utilization of minor seeds need to be exploited, though they are under-exploited spices crops.
6. Morpho-agronomic attributes of seed spice biodiversity need serious attention for conservation, chemical and biochemical traits, resistance against biotic and abiotic stresses, and promising stocks with potential and rare gene combinations isolated are also sensitive site seeking prioritization.

Varieties released

Table 3: Coriander

SI No.	Variety	Pedigree/ Parentage	Av. yield (kg/ha)	Essential oil %	Duration (days)	Salient features
1	Guj. Cor.1	Selection from germplasm	1100	0.35	112	Suitable for early sowing, erect plant, round bold grains, moderately tolerant to wilt and powdery mildew
2	Co.1	Selection from Koilpatti local	440	0.27	110	A variety with small statute plant, suitable for rainfed areas and greens and grains, small grain
3	Co.2	Reselection from culture P2 of Gujarat	520	0.40	90-100	A dual-purpose variety, suitable for saline, and alkaline and drought-prone areas seeds oblong, medium.
4	Co.3	Reselection from Acc.695 of IARI, New Delhi type	650	0.38-0.41	85-95	A dual-purpose variety, good yielder, medium-sized grains, suitable for both rainfed and irrigated condition, *rabi* well as *Kharif* season. Field tolerant to powdery mildew, wilt and grain mould.
5	Co(CR).4	Reselection from germplasm ATP77 Guntur collection	600	0.4	65-70	Early maturing variety suitable for the both rainfed and irrigated condition; grains oblong and medium; field tolerant to wilt and grain mould
6	Guj.Cor.2	Reselection from Co.2	1450	0.40	-	Semi spreading type, suitable for early sowing. moderately tolerant to powdery mildew, grains oblong, lodging and shattering resistant.
7	RajendraSwathi	Pure line selection from Muzaffarpur collection	1300	0.65	-	Medium-sized plant with fine, aromatic round grains, suitable or intercropping, field tolerance to aphids
8	Sadhana	Mass selection from local Alur collection	1025	0.20	95-110	A dual-purpose, semi-erect variety; Suitable for rainfed condition field tolerance to whitefly, mites and aphids.

						A mid-late variety withstands moisture stress, responded well o input management under optimum moisture level.
9	Swathi	Mass selection from Nandyal germplasm	855	0.30	82-85	Plants medium size semi-erect type, early maturing variety, suitable for rainfed condition, and late sown season. Field tolerant to whitefly, moderately tolerant to disease. Suits well o the areas where the soil moisture retentiveness incomparably less, being early maturity, it escapes powdery mildew disease.
10	CS 287	Reselection from Guntur collection	600			Early maturing, suitable for both rainfed and irrigated condition. Field tolerant to wilt and grain mould.
11	Sindhu	Mass selection germplasm, Warangal local	1000	0.40	100-110	Oval medium breakable grains, suitable for rainfed areas, tolerant to wilt, powdery mildew as well as drought condition, medium duration.
12	Hisar Anand	Mass selection from Haryana collection	1400	0.35	-	A medium-tall dual-purpose variety, oval medium-sized seeds, wider adaptability to different soil conditions, Resistant o lodging due to spreading habit.
13	Hisar Sugandh	Mass selection from indigenous germplasm	1400	-	-	Suitable for irrigated conditions, resistant to stem gall diseases.

Table 4: Cumin

SI. No.	Variety	Centre which developed	Year of release	Pedigree/ Parentage	Av. yield (kg/ha)	Essential oil %	Crude fibre %	Salient features
1	Mc.43	Spices Research Station, GAU, Jagudan, Gujarat	1952	Selection from germplasm	580	2.7	15.5	Plant spreading, grains bold lustring withstand lodging and shattering, moderately tolerant powdery mildew
2	Guj. Cumin 1	Spices Research Station, GAU, Jagudan, Gujarat	1983	Selection from local germplasm (Vijaypur -5)	550	3.6	14.25	Plants bushy and spreading, grains bold, linear-oblong; Withstand shattering and lodging, moderately tolerant to wilt, powdery mildew and blight.
3	RZ-19	SKN College of Agriculture, RAJAU, Jobner, Rajasthan	1988	Recurrent selection from UC.19	500	-	-	Erect plant, bold, lustrous grain, tolerant to wilt and blight suitable for the late sowing season.
4	Guj. Cumin 2	Spices Research Station, GAU, Jagudan, Gujarat		Pure line selection from M2 irradiated seeds from MC-43	620	4	22.1	Bushy plant, good branching habit, grains bold, medium-sized, lustrous grain, tolerant to wilt and blight suitable for the late sowing season
5	Guj. Cumin 3	Spices Research Station, GAU, Jagudan, Gujarat		Recurrent selection derived from W.German entry EC-232689	620	4.4	-	Bushy dwarf plant, fruit medium-sized, frost wilt resistant variety suitable for the winter season in limited Irrigation. Higher essential oil content, seed pungent with good aroma
6	RZ-19	Repeat	1988	Recurrent single plant progeny selection from Ajmer	560			Erect plant, pink flowers, bold, lustrous grain, grey pubescent, tolerant to wilt and blight suitable for the late sowing season
7	5-404	Spices Research Station, GAU, Jagudan, Gujarat	1952	Selection from local germplasm	350	*22*	7.7	An erect plant, medium-sized fruit, moderately tolerant to powdery mildew.
8	RZ-209	SKN College of Agriculture, RAJAU, Jobner, Rajasthan	1995	Recurrent single plant progeny selection from Jore	650	-	-	A variety showed some resistance with blight and wilt
9	RZ-223	SKN College of Agriculture, RAJAU,		Mutation breeding in	600	*3.0-3.5*	-	Wider adaptability, resistant to wilt, superior in yield and seed quality over

		Jobner, Rajasthan		UC-216				RZ-l9Plants bushy, semi-erect, long bold attractive seeds, medium duration.
10	Ac-01-167	NRC seed spices, Ajmer, Rajasthan	2005	Reselection from EC-243373	515	*3*	-	Bold seeds are resistant to wilt.
11	RZ-345	SKN College of Agriculture, RAJAU, Jobner, Rajasthan	2009	recurrent selection based on individual plant progeny (half sib) performance in accession 345	-	-	-	-
12	GC-4 (Gujarat Cumin-4}	Sardar krushinagar Dantiwada Agricultural University, Jagudan	2006	The Cumin variety JC-2000-72 is the selection from GC-3.	-	-	-	-
13	RZ-223	SKN College of Agriculture, RAJAU, Jobner, Rajasthan	2004	The variety has been developed through mutation breeding in UC-216	-	-	-	-
14	RZ-341 (UC-341)	SKN College of Agriculture, RAJAU, Jobner, Rajasthan		The variety has been developed through poly cross between high volatile oil content and low volatile oil content	-	-	-	-

Table 5: Fennel

SI. No.	Variety	Centre which developed	Year of release	Pedigree/ Parentage	'Av. Yield (kg/ha)	Essential oil%	Crude fibre %	Duration (days)	Salient features
1	PF-35	Sardar krushinagar DantiwadaAgricultural University, Jagudan	1973	Selection from local germplasm	1280		-		Plant tall and spreading moderately tolerant to leaf spot, leaf blight and sugary diseases
2	Co.1	Dept. of spices and plantation crops, HC &Rl, TNAU, Coimbatore, Tamil Nadu		Reselection from PF 35	570		-	220	Medium statured, diffuse branching, Suitable for Intercropping and border cropping with chilli and turmeric Suitable for drought-prone, waterlogged, saline and alkaline conditions
3	Guj Fennel 1	Sardar krushinagar Dantiwada Agricultural University, Jagudan	1984	Pure line selection from Vijaypur local	1695	*2.2*	-	158	Plant tall and bushy, early sowing and *rabi* crop, reasonably tolerant to drought, moderately tolerant to sugery disease, oblong, medium bold and dark green seeds.
4	Guj fennel 2	Sardarkrushinagar Dantiwada Agricultural University, Jagudan	1997	Pedigree selection from local germplasm	1940	2.4	-	159	Plants bushy, bold grains, rich In volatile oil and suitable for both rain-fed and irrigated condition
5	RF101	SKN College of Agriculture, RAJAU, Jobner, Rajasthan	2001	Recurrent half sib selection from local germplasm collection from Jobner	1400	1.9	-	150-160	Erred medium-tall nature, medium maturity type with long bold grains, most suitable for loamy and black cotton soil.

6	S-7-9	-	-	Selection	1100	12	24	210	A bushy plant with big umbel, moderately tolerant to blight.
7	Guj. Fennel ll	Sardarkrushinagar Dantiwada Agricultural University, Jagudan	2003	Selection based on individual plant -progeny performance from local germplasm	2489	1.98	-	148	A medium maturity type adapted to rabi season under irrigation; seeds medium bold.
8	RF125	SKN College of Agriculture, RAJAU, Jobner, Rajasthan	2003	Recurrent half sib selection Is an exotic collection EC 243380 from Italy	1700	2.5-3.0 (2-78)	-	110-130	Plants are short statue red with compact umbels and long bold seeds when presence, denser view of plants, tolerant to sugery disease green.
9	Hisar Sawrup	Dept. of Vegetable Crops, CCS, HAU, Hisar, Haryana	2004	Mass selection from indigenous germplasm of Haryana	1600	1.6	-	175-185	Plants grow upright, spreading, gives a bushy appearance. A late maturity type grain long and bold, resistant to lodging, no shattering of grains.
10	Azad Sanuf-1	C.S. Azad University of Agric. And technology, Kanpur, Uttar Pradesh	1996	Selection from germplasm	1500	2	-	160-170	Medium plants, resistant to blight and root rot diseases. Escapes attack of aphids due to early maturity, seeds are bold green.
11	Pant Madhurika	G.B Pant University of Agriculture and Technology, Pantnagar, Uttaranchal	2001	Pure line selection from local germplasm	-	-	180-185	110	Tall robust eruct plant with big umbels having bold seeds with green fine rings sweetly in taste, medium maturity.
12	GF-11 (Gujarat Fennel-11)	Spices Research Station, GAU, Jagudan, Gujarat	2004	Recurrent selection based on individual plant progeny performance.	-	-	-	-	-
13	RF143	SKN College of Agriculture, RAJAU, Jobner, Rajasthan		Recurrent selection from Individual plant progeny	1200	1.87	-	-	Medium tall and recommended for loamy and black cotton soils
14	AF-01-119 NRCSS-AF1	NRC seed spices, Ajmer, Rajasthan	2005	Recurrent selection from Individual plant progeny	1950	-	-	-	Medium maturity seed, bold, tolerant to blight
15	RF-205 (UF-205)	SKN College of Agriculture, RAJAU, Jobner, Rajasthan	2009	Recurrent selection based on individual plant progeny (half -sib) from the F2 generation of a cross between JF-25 x RF -125.					

Table 6: Fenugreek

SI. No.	Variety	Centre which developed	Year of release	Pedigree/Parentage	"Av. yield (kg/ha)	Seed protein %	Duration (days)	Salient features
1	Co.1	Dept of spices and plantation crops, HC &Rl, TNAU, Coimbatore, Tamil Nadu	1982	Evolved from TG-2356 introduced from North India	680	-	80-85	A quick-growing, dual-purpose, early maturing variety is tolerant to root rot disease. Seeds contain 21.7% protein-
2	Co 2	Dept of spices and plantation crops, HC &Rl, TNAU, Coimbatore, Tamil Nadu	1999	Selection from CF 390	480		85-90	Short duration dual-purpose variety, field tolerant to *Rhizoctonia* root rot disease, suitable for both *Kharif* and *rabi* season. Early maturity, short duration.
3	Rajendrakanti	Dept of Hort, Tirhut College of agriculture RAU, Dholi, Bihar	1988	Pure line selection from Reghunathpur collection	1300	9.5	-	Medium-sized bushy plant; early maturity, suitable for Intercropping in Kharif and *rabi* season, field tolerant to *Cercospora* leaf spot,

								powdery mildew and aphids.
4	RML1	SKN College of Agriculture, RAJAU, Jobner, Rajasthan	1990	Pure line selection from Nagpur local	1400	21	-	Vigorous semi-erect medium-sized moderately branched growth habit, medium-sized, bold and attractive typically yellow coloured grains, moderately resistant to root-knot nematode and powdery mildew and aphids
5	Lam sel.1	Dr.YSR. Horticultural University Horticultural Research Station, Lam L-trx-	1992	Selection from germplasm collection of Uttar Pradesh	740	53	-	Dual-purpose varieties, early maturing, bushy type and medium height, more number of branches and green matter. When cultivated for green leaf purpose it gives an average green yield of 12 tonnes per hectare. Field tolerant to major pests and diseases.
6	HisarSonall	Dept of vegetable Crops, CCS, HAU, Hisar, Haryana	1994	Pure line selection from germplasm	1700	-	-	Tall and bushy vigorous growing variety, dual-purpose variety, late maturity (140-145 days), suitable for cultivation under Irrigated condition Moderately resistant to root rot and aphids.
7	HisarSuvarna	Dept of vegetable Crops, CCS, HAU, Hisar, Haryana	2001	Pure line selection from local germplasm	1600	-	-	A quick-growing, erect and tall, dual-purpose, medium maturity (130-140days), moderately resistant to *Cercospora* and powdery mildew, suitable for cultivation throughout the country.
8	HisarMadhavi	Dept of vegetable Crops, CCS, HAU, Hisar, Haryana	2001	Pure line selection from local germplasm of UP	1900	-	-	A quick-growing, erect and tall, dual-purpose, medium maturity (130-I40days), moderately resistant to powdery mildew and downy mildew. A variety with under adaptability suitable for both Irrigated and rainfed condition.
9	HisarMuktha	Dept of vegetable Crops, CCS, HAU, Hisar, Haryana	2001	Pure line selection natural green seed coated mutant line from UP	2000			A quick-growing seed type variety, medium maturity (135-I40days). Moderately resistant to powdery mildew and downy mildew. Erect and tall plants-Wide adaptability. Suitable for both Irrigated and rainfed condition.
10	RMt303	SKN College of Agriculture, RAJAU, Jobner, Rajasthan		Mutation breeding from variety RMt 1	1900			Medium maturity variety (145-150 days) seeds bold. with typical yellow colour Jess susceptible to powdery mildew
11	RMt 305	SKN College of Agriculture, RAJAU, Jobner, Rajasthan		Mutation breeding from variety RMt 1	1300			First determinant type, early maturing, wider adaptability, resistant to powdery mildew and root-knot nematodes. seeds bold, attractive and yellow, duration 120-125 days.
12	Guj. Methi 1	Spices Research Station, GAU, Jagudan, Gujarat	-	Recurrent selection based on pure line selection from J. Fenu 102	1864	-		The first variety from Gujarat released for the state, plant dwarf.

Table 7: Ajwain

SI No.	Variety	Centre which developed	Year of release	Pedigree/ Parentage	Av. yield (kg/ha)	Salient features
1	Gujarat Ajowan -1	Sardaikrushinagar Dantiwada Agricultural University, Jagudan		Selection form germplasm	2269	Non-shattering, mildly susceptible to powdery mildew and resistant to Insects, a late maturity (176 days) variety.
2	Pant Ruchika	G.B Pant University of Agriculture and Technology, Pantnagar, Uttaranchal	2001	pure line selection for local collection	600/800	Erect, bushy plant, seed light brown, and attractive; late maturing variety (170-175 days)
3	RFA-68	A.R.S. Substation, Udaipur Agricultural	-	Selection form local germplasm	900	A medium maturity variety, flowers in about 90 days takes about 150 days to mature.

		University, Chittorgarh. Rajasthan		grown in Pratapgarh area		
4	Ajmer Ajowan 1	NRC seed spices, Ajmer, Rajasthan	2004	Selection from Pratapgrah local NRCSS AA-61	1420	Plant tall, late maturity group (160 days), suitable for early and *rabi* sowing under Irrigated and limited available water conditions, seeds medium size, contains 3.4 % volatile oil.
5	Ajmer Ajowan -2	NRC seed spices, Ajmer, Rajasthan	2004	Selection from Gujarat local NRCSS AA-19	1280	A bushy plant, early maturing group (147 days), moderately tolerant to drought, seeds medium, 3.0 % volatile oil, moderately
6	Lamsel -1	PRS, ANGRAU, Guntur, Andra Pradesh	-	Mass selection	1000/1400	A tall early maturity (140 days) variety.
7	Lamsel-2	PRS, ANGRAU, Guntur, Andra Pradesh	-	Mass selection	1000/1200	A spreading bushy type with more braches, requiring more spading
8	Rajendra Mani	Dept of Hort, Timut College of agriculture RAU, Dholi, Bihar		NA	NA	NA

Future Perspective to Enhance the Use of Genetic Resources

1. A major proportion of the released varieties evolved through selection till today. Contemporary techniques using biotechnology oriented with molecular assisted plant breeding expertise are used to solve specific problems of biotic and abiotic stress resistance.
2. The first and foremost step to stop biopiracy of valuable germplasm of seed spices from India is stock-taking of biodiversity assets and precise annotation of text. Characterization of accessions at the biochemical and molecular level requires rigorous research this might be accomplished by employing different techniques like isozyme profiling, RFLP. AFLP and RAPD. Molecular characterization of commercially important accessions is required to uphold the recognition.
3. At National Gene Bank preservation of seed spices, germplasm accomplish with especial reference to National Active Germplasm Site, require attention for high prioritization.
4. Seed spices are still popular as under-utilized crops; as a result, serious attention has not been given towards germplasm collection, evaluation and conservation systematically. Plant diversity of major and minor seed spices in remote and tribal pockets needs consideration again. Their scope for collecting valuable landraces of such seed spice crops needs to be persuaded.
5. In India, diverse agro-climatic conditions offer good scope for the advancement of non-traditional seed spices (anise, caraway, celery, parsley and black caraway). This would make India a expand supplier of seed spices in world commerce. Methodical germplasm collection, evaluation and conservation of seed spices have better future vista for improvement.

Hybridization

In coriander, the selection is the commonly used breeding procedure and the crossing is non-existent. The stigma of coriander was receptive from the 3rd day to 6thday of anthesis indicating that artificial pollination on emasculated florets must be done repeatedly on 3rd and 4th day of anthesis. Pollen was viable for two days in the field. Fresh pollen cans bestow in an incubator at 25^{o}C for three weeks with 88% retention of viability. The emasculation of florets was carried out with the help of binocular loupe. Emasculation either in the morning before anthesis or previous day evening was found to be suitable. For demonstrating the technique, four parents were reciprocally crossed. Only three crosses were successful indicating the differences in combining ability of the parents. Mean success among the crosses was 23%, fruit set among the florets varied from 9.52-83.3% depending on the cross combination [11].

Mutations

Mutagenesis is an important tool to create variability in crops where the hybridization is difficult. However, the usefulness of any mutagenic agent depends on its ability to induce high-frequency of desirable changes as compared to undesirable ones. Hence, often it is necessary to assess the effectiveness and efficacy of mutagens for efficient and effective use. Small flower size and compound umbel lead to difficulties in creating variability of coriander. Studies on induced mutagenesis in coriander involving EMS and gamma rays are scanty. Mutagenic effectiveness and efficiency of gamma rays and ethyl methane sulphonate (EMS) were estimated in the genotype of coriander variety Swathi. The studies revealed that gamma rays were found to be more effective in inducing mutations than ethyl methane sulphonate (EMS). However, about mutagenic efficiency, EMS was more efficient than gamma rays. There was a progressive increase in mutation frequency of chlorophyll mutations with the increase in gamma rays and EMS doses. Synergistic effects were observed for increased mutation frequency in M2 generation in combination treatments of gamma rays with EMS. Both mutagenic effectiveness and efficiency were found to be higher at higher doses of both the mutagens. However, the trend was not observed in the case of efficiency measured based on injury. The possible reason for the increase in mutagenic efficiency and effectiveness with an increase in dose may be due to lower dose of mutagens used in the present investigation and less damaging effect of lower doses of chemicals on the genetic material [12].

Dry seeds of cumin (cv. RZ-19) were irradiated with 20, 30, 40, 50 and 60 kR gamma radiation using ^{60}Co to induce variability. The M1 generation was grown in the field and each plant was selfed and harvested for M2 seed. Ten M2 progenies per treatment were raised. Data on yield and yield components of 10 plants in each progeny and the control were recorded. Mean for plant height increased marginally at all rates in M2 whereas variance decreased except at 30 kR. The mean for branches per plant increased except at 20 and 60 kR. The mean and variance increased linearly for umbels per plant, umbellets per umbel, and seeds per umbel

while the mean for seed yield per plant and 1000-seed weight decreased with all rates of gamma radiation [13].

Cumin is an important spice crop of India mostly grown in Rajasthan. Apart from practical problems in emasculation and pollination, the conventional hybridization strategy is hampered due to non-availability of pure lines in cumin. RZ 19 was selected for the present study. Air-dried seeds of RZ 19 were subjected to γ rays at 200, 300, 400, 500, and 600Gy. M1 generation was raised from the treated seed by dibbling 400 seeds per treatment along with an untreated check. No specific morphological mutations were observed in this generation. Seeds harvested from each of the 125 self-pollinated and open-pollinated progenies were sown in single-row plots in RBD in the ensuing year along with control to rise M2 generation. Observations were recorded on important morphological traits. The progenies in each generation were screened for all possible mutations. Only albino [2] and chlorine [5] types were seen which did not survive beyond the seedling stage. 3 plants with white flowers were also observed in contrast to pink flowers in RZ 19. Higher estimates of GCV and PCV, heritability in radiation treatments than in control indicated induction of heritable variation. The linear increase in mean values along with the radiation gradient was observed for most of the characters. 300Gy and 400Gy are best doses which induced more mutations per dose; 200Gy dose was ineffective while 600Gy induced more of seed sterility [14].

Salient achievements

- ICAR-NRCSS is holding 2007 germplasm collection of various seed spices of which 620 are collected by the centre and 1387 are being deposited by other centres under NAGS (Table 1)
- Multi-location evaluation of cumin, coriander, fennel, fenugreek, ajwain and dill has been completed
- Minimal descriptors have been developed and published for all the seed spices by the centre. DUS guidelines have also been finalized for fenugreek and coriander
- Fenugreek Variety AFg-3 (27.26 % higher yield than the best check AM-1) has been identified at National level by AICRP on Spices in the year 2012
- Three varieties *viz*., AFg-4 (Fenugreek), AA-93 (Ajwain), AN-20 (Nigella) has been released for the Rajasthan State. Coriander variety ACr-1 is under pipeline for State release as a Stem Gall resistant variety
- Eleven cumin varieties have been identified by the centre for commercial cultivation and they are well adapted by the farmers (Table 4)
- Under resistance breeding in fenugreek two mutants AFg- M-3 and AFg-M-4 have been identified having resistance against powdery mildew
- Two unique mutants AFg-M-1 (rosette leaf type) and AFg- M-2 (vegetable pod type) have been identified in fenugreek
- Under recombination breeding in coriander and dill gene pools have been created and populations' improvement is underway, this is a novel approach taking advantage of natural recombination
- Molecular characterization of released varieties of cumin, coriander, fennel and fenugreek has been done using random and ITS primers.
- Sixteen gene sequences of fenugreek and cumin have been submitted to NCBI, USA database (Gene Accession numbers HM 176640-176649 for fenugreek and HM176650- HM176655 for cumin)

Footnotes

Seed spices are popularly used in different cuisine in India along with it also possess incredible pharmaceutical property. Seed spice contributes wealth to the Indian economy. Its cultivation could be improved by selecting superior and tolerant to resistant varieties for particular cultivation aims. Proper identification of superior clone and through germplasm conservation & genetic improvement cultivation could be improved.

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