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RECENT ADVANCES IN SEED SPICES RESEARCH – A REVIEW

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ABSTRACT

India dominates in the world seed spices trade because of the intrinsic qualities. National Agriculture Research System has contributed for providing needed technology backup and further promotion programs under horticulture mission have fuelled the growth. Concerted efforts have been made for utilization of plant genetic resources in seed spices crops and more than 102 varieties of coriander, cumin, fennel, fenugreek, ajowan, dill, nigella, anise, celery have been developed. Recent contributions are development of a wilt resistant variety of cumin (GC-4) and stem gall resistant variety of coriander (NRCSS ACr1). The other important varieties identified for release are for ajowan (NRCSS AA1, AA2), dill (NRCSS AD1, AD2), nigella (NRCSS AN1), anise (Ani 1), celery (A Cel 1), fennel (NRCSS AF1) and fenugreek (AFg 1, 2, 3). Standardization of hybridization techniques, evolving high yielding varieties with high quality using recombination breeding, marker assisted breeding for tolerance to stresses are the important areas need attention. Suitable package of practices including optimum sowing time, seed rate, nursery management, transplanting, spacing, intercultural practices and weed management has been standardized for different seed spices crops and agro-climatic conditions. A good response of sprinkler and drip irrigation system for efficient water use in fennel, fenugreek, coriander, cumin, ajowan, dill and nigella has been reported. Fertigation requirement in coriander, fennel, fenugreek, dill needs to be standardized to improve the nutrient and water use efficiency together. Disease and pest management by integrated approach using both bioagents and pesticides have effectively managed wilt, blight, powdery mildew, downy mildew and aphids. A value chain of major seed spices from field to plate was developed under NAIP which included all the parameters of production, protection, post-harvest handling, processing, value addition, product development, marketing, trade and export.

Keywords: Seed spices, genetic enhancement, integrated nutrient management, water productivity, plant protection, good processing practices

INTRODUCTION

Seed spices, an important segment of spices group, plays a significant role in the economy of arid ecosystem. Seed spices contribute about 50% of total area and 20% of production of spices in the country. Presently 16.50 lakh ha of area is under seed spices cultivation with a production of 11.83 lakh tonnes annually (2015-16). Seed spices are mainly cultivated in the states of Rajasthan and Gujarat and it also has sizeable area in the states of Madhya Pradesh, Uttar Pradesh, Andhra Pradesh and Karnataka (DASD, 2016; Malhotra, 2016). Out of 17 seed spices are grown, coriander, cumin, fennel and fenugreek are pillars of economic importance. Ajwain seed, dill seed, celery, nigella and poppy seed too contribute a considerable share. The volume of spices exported increased from 350,363 metric tons in 2005-06 to 893,950 metric tons in 2014-15 (Saxena *et. al.,* 2015). In the export basket of spices, seed spices (raw) account for about 30% of total volume and 19% of total foreign exchange earnings. During 2014-15, India exported 270,150 metric tons of raw seed spices valued at Rs 2815.60 crores. Among seed spices, cumin alone is the highest export earner with an export of 155,500 MT valued at Rs 1838.20 crores (Saxena et al 2015, DASD, 2016). There has been increasing demand of seed spices and importing countries look at India as a consistent source. India dominates in the world seed spices trade because of the intrinsic qualities. National Agriculture Research System has contributed for providing needed technology backup and further promotion programs under horticulture mission have fuelled the growth (Malhotra, 2014). In the National Agriculture Research System for seed spices crops, NRC Seed Spices, AICRP Spices and State Agricultural Universities, has contributed substantially by enriching germplasm, developing high yielding varieties; technologies for increasing the production and productivity; combating pests and pathogens to reduce crop

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losses, secondary agriculture etc. Recent advances in seed spices research and development have been described here.

Genetic enhancement

The germplasm collection available at National Research Centre on Seed Spices, Ajmer, consists of 1990 accessions in coriander, 499 in cumin, 625 in fennel and 989 in fenugreek (Malhotra, 2010; Malhotra, 2013). The genetic resources of seed spices have been evaluated for stress tolerance, high volatile oil content and also proper harvest stage for enhancing the quality. Concerted efforts have been made for documentation, conservation and utilization of plant genetic resources in seed spices crops and important traits identified are given here (Table1).

Table 1: Seed spices genetic resources identified with important traits

S.No.	Crops	Genetic resources with important traits
1	Coriander	Wilt (ACr -01-250), stem gall (ACr -01-256), dual Purpose (leaf and seed) (Acr-01-256)
2	Cumin	Wilt resistance (AC-01-3, AC-01-167), drought tolerance (AC-01-3), high oil content (AC-01-167)
3	Fennel	Ramularia blight (Sel 01-87), high oil content (Sel 01-119), early season (Sel 01-119),
4	Fenugreek	Downy mildew (AM-01-10), root rot (AM-01-10), early & large podded (AM-01-35), dual Purpose (leaf and seed) (AM-01-35)
5	Ajowan	Powdery mildew (AA-01-19, AA-01-61), high oil content (AA-01-19), drought tolerance (AA-01-19, AA-01-61), early and bold seeded (AA-01-61)
6	Dill	Powdery mildew (AD-01- 32), high oil content (AD-01- 32), drought tolerance (AD-01- 6) dillapiole toxin less (AD-01-43)
7	Nigella	High essential oil (AN-01-1)

(Malhotra, 2013; Malhotra, 2010; Malhotra and Vijay 2003, Malhotra, 2005)

Many high yielding varieties of different seed spices crops (about 102 varieties) have been developed for different regions and have been adopted for cultivation by many farmers. Cumin wilt and blight, stem gall in coriander are the major challenges which drastically reduce its production and productivity. A cumin variety, GC-4 has resistance to wilt but is susceptible to blight. Till date no resistance source to cumin blight is available. Cumin is also very susceptible to frost and none of the genotypes is reported to be resistant to this stress. Occurrence of Stem Gall disease in the coriander has been major problem resulting in drastic reduction in yield and quality of coriander. Recently NRCSS has developed stem gall tolerant variety i.e NRCSS ACr-1 (Ajmer Coriander-1) which has been reported highly tolerant and released for cultivation in affected areas (Malhotra et al 2016). In fennel, no tolerant varieties against blight and gummosis are available. Breeding programmes for disease resistance, higher yield, and stability in performance (Chaudhary and Malhotra, 2000), high volatile oil and active ingredients and earliness in seed spices have been identified as important attributes for increasing production and quality. Hence research developments through breeding needs to be strengthened. Five varieties consisting of two ajowan (NRCSS AA1, AA2), two dill (NRCSS AD1, AD2) and nigella (NRCSS AN1) and detailed in Table2 (Malhotra and Vashishtha, 2004). It was also revealed that Coriander NRCSS ACr 1; Fennel NRCSS AF1; Ajowan NRCSS AA1; Dill NRCSS AD1 and Nigella NRCSS AN 1 out yielded their performance with essential oil content of 0.42%, 1.6%, 3.4%, 3.5% and 0.7%, respectively (Malhotra et al 2009). A new variety of Anise, NRCSS Ani 1 with high essential oil (3.2%) and anethole content (89.6%) have been developed, offers a potential nutraceutical value (Malhotra, 2012).

Agro-techniques and integrated nutrient management

The agro-techniques are highly site specific and vary for different crops. Suitable package of practices including optimum sowing time, seed rate, nursery management, transplanting, spacing, intercultural practices and weed management has been standardized for different seed spices crops for realizing the optimum potential of improved varieties in the different agro-climatic conditions (Malhotra and Vashishtha, 2007; Malhotra and Vashishtha, 2005).

Table 2: Varieties identified by NRCSS for commercial cultivation

Crop	Varieties	Average yield (kg/ha)	Remarks	Reference
Fenugreek	AFg-3	2595	1.79 % diosgenin	Krishnakumar *et. al.,* (2014a)
	AFg-1	2700	Bold seeded	
	AFg-2	1800	Small seeded	
Coriander	ACr-1	1250	0.5% essential oil, stem gall resistant, Dual purpose	
Fennel	AF-1	1900-2500	1.6 % essential oil	
Ajwan	AA-1	500-1400	3.4 % essential oil, rainfed and irrigated condition	AICRPS (2004); Malhotra and Vashishtha (2004); NRCSS (2013); Malhotra (2013), Krishnakumar *et. al.,* (2014b)
	AA-2	500-1200	3.0 % essential oil rainfed and irrigated condition	
Dill	AD-1	1470	3.5 % essential oil, European type	
	AD-2	1460	Indian type	
Nigella	AN-1	800	High yielding	
Anise	AAni-1	730	3.2 % essential oil	AICRPS (2006); Malhotra (2012a); Krishnakumar *et. al.,* (2014b)
Celery	ACel-1	800	2.4 % essential oil	

The production technologies for coriander, cumin, fenugreek, ajowan, fennel, nigella, caraway summarized in Table 3 (Malhotra, 2012b-g) have been described along with information on production and trade, main uses in food and cosmetics, functional properties and quality aspects. The production technology for off season cultivation has also been worked out for leafy coriander, 15th October sown crop with application of 60kg N ha^{-1} and foliar spray of NAA 25ppm at 30 DAS yielded maximum green leaf production (Meena and Malhotra, 2006, Meena *et al* 2007). Use of *Azospirillum* + 50% nitrogen+ 5t farm yard manure ha^{-1} produced higher seed yield of coriander (Malhotra et al 2006). Influence of sheep manure, vermicompost and biofertilizers on productivity of cumin (Mehta *et. al.,* 2012), coriander (Mehta *et. al.,* 2011), fennel (Mehta *et. al.,* 2012) and dill (Meena *et al* 2007) have been worked out. Application of irrigation at IW/CPE ratio 1 along with weed control by pre-emergence application of Pendimethalin @ 0.75 kg ha^{-1} + inter-culturing at 40DAS is beneficial for realising better growth and productivity of fenugreek (Mehta et al 2010) and at 18 days interval with 30 kg N+20 kg P_2O_5/ha at 25x10 cm crop geometry high yield of cumin was received (Mehta *et. al.,* 2014). Nutrient uptake study in important cultivars of cumin revealed highest uptake of N, P, S and micronutrients in GC 4 (Aishwath and Malhotra, 2013). Fenugreek is also a good soil renovator and reported to fix 48% of its total N_2 during the growing season (Pawar *et. al.,* 2012). Fertilizer requirement for Indian horticulture, including seed spices have been earlier reviewed (Malhotra and Srivastava, 2015).

Germination Improvement

Among seed spices particularly *Apiaceae* family crops have been reported to exhibit poor crop stand due to slow germination, dormancy and sudden shift in climate from optimum to abnormal. Optimum temperature requirement and depth of sowing for different seed spices crops as standardized is given in Table 4 (Malhotra and Vashishtha, 2007). To help seeds germination, certain measures can be employed for improvement by overcoming dormancy and also through plant growth regulators. The seed spices crops have been reported to have less dormancy problem, except for celery, having photo-dormancy and seeds only germinate after fulfillment of light requirement. Thus in case of celery, shallow sowing should be done to allow the contact with sunlight. Furthermore, coriander seed botanically schizocarp should be rubbed for splitting into two parts called mericarp before sowing, not only shall improve germination but also give birth to two plants. The soaking of seeds has helped hastening the germination process in most of the seed spices crops. Soaking of seeds in water 8-12 hours in coriander, fennel, ajowan and 18-24 hours in cumin and dill before sowing followed by drying in shade, improves germination by leaching out of chemical inhibitors such as coumarins commonly found in the seeds of *Apiaceae* family seed spices (Malhotra and Vashishtha, 2007). Pre-soaking of seeds before sowing can also activate the enzymes and hormones and thereby can improve the germination. Seed primed with KH_2PO_4 (1%, 36hr.), PEG (10 and 20%, 36hr) showed more than 75% increase in germination over non-primed seeds of cumin (Saxena et al 2008). Soaking of seeds in 2% KH_2PO_4 for two days before sowing gave maximum germination in ajowan (Singh et al 2008). Such primed seeds germinate early and uniformly by initiating physiological processes for quicker germination. The sprouted seeds in fenugreek, coriander, fennel, cumin and dill can be used for sowing and obtaining better, early and uniform germination level. Direct seeding is extremely difficult when seeds are very tiny as in ajowan, celery and parsley. To improve germination, tiny seeds may be pelleted by coating with clay. Pelleting makes planting easier and spacing more precise (Malhotra and Mehta, 2003).

Table 3: Sowing depth and spacing for seed spices crops

Seed spices crops	Maximum sowing depth (in cm)	Row x plant spacing (in cm)	Sowing time
Coriander	2.0-2.5	25-30 x 15	October- November
Cumin	1.0-1.5	22.5-25 x 10	Mid November– First week of December
Fennel	1.5-2.0	45-60 x 20-25	Early season: July (Nursery sowing) :August (Transplanting) Main season:Mid September- 7 October
Fenugreek	2.5-3.5 (Common Methi) 1.0-1.5 (Kasuri Methi)	25-30 x 10	Mid October- Mid November
Ajowan	1.0	30 x 20	Early season: July- August Main season: October
Dill	1.5-2.0	30-45 x 20	Early season: July- August Main season: October
Nigella	1.5-2.0	30 x 15	Mid September- Mid October
Anise	1.0-1.5	30 x 15	October
Celery	0.50-0.75	30 x 15	September- October (Nursery sowing) November- December (Transplanting)
Caraway	1.5	30 x 20	Mid October- Mid November

(Source: Malhotra 2012 b-g)

Application of plant growth substances in coriander have considerably helped in improving the seed germination, plant growth, flowering and seed setting. Early and higher germination was noticed by soaking coriander seed in solutions of GA_3 (50 ppm) or NAA (20 ppm) or IAA (10 ppm) or warm water for 12 hours. Soaking of seeds in cycocel solution at 50-100 ppm improves germination and enhanced seedling growth in fenugreek. The plant growth substances IAA, GA and ethephon were tried by Ortuno *et al.,,* (1999) and found that treatment of seed with GA (10^{-4} & 10^{-5}M) improved seed germination. Thomas (1994) revealed that florence fennel, seeds soaked for 4 h at 25^0C or for 24 h at 5^0C in GA 4/7 solution (100 mg/1) showed a higher germination percentage and increased rate of seedling emergence compared with untreated dry seeds when sown in compost at 25^0C. The application (foliar and seed) of plant growth regulators (ethephon, or GA_3) increased seed yield of cumin. The celery seeds are reported to possess thermo dormancy resulting in no or slow germination at temperature greater then 25^0 C. A seed soaking treatment at 10^0 C using growth regulators GA 4/7, and ethephon at 1000 ppm can over come this dormancy. Sunlight exposure improves germination percentages when the seeds are dormant; therefore it is advisable to sow seeds shallow to enhance light exposure in celery (Malhotra and Vashihstha, 2007).

Water productivity

Seed spices cultivation is confined to the areas where limited water is available for irrigation. Irrigation efficiency is to the tune of 30-35%, therefore only means to provide the water is effective management and enhancing the water use efficiency to the level of 80%. Therefore lots of initiatives were taken to apply water in such a manner which can provide maximum output. Productivity and quality of any crop is affected by availability of optimum level of irrigation during critical stages of growth. Use of appropriate irrigation method etc. can ensure water availability throughout the crop period and thus help in uniform growth and development of plants. A good response of sprinkler and drip irrigation system for efficient water use in fennel, fenugreek, coriander, cumin, ajowan, dill and nigella has been studied. Based on the yield performance it was revealed from the studies that fenugreek, dill and fennel responded better to both sprinkler and drip irrigation method with yield performance of 20.4, 11.4 and 17.3 q/ha under sprinkler and 21.1, 11.8 and 18.4 q/ha under drip irrigation system, respectively (Malhotra *et. al.,* 2009). It was also revealed that drip irrigation method of irrigation was suitable for fennel, fenugreek, dill and nigella whereas sprinkler irrigation was better for coriander, fenugreek, cumin and ajowan.

Table 4: Preferable temperature requirement and time taken to germination for seed spices

S. No.	Seed spices crops	Preferable temperature requirement for germination (^{0}C)	Time taken to germination (days)
1	Ajowan	18-20	10-12
2	Anise	15-20	10-12
3	Caraway	12-15	10-12
4	Celery	10-12	15-20
5	Coriander	14-20	10-12
6	Dill	16-22	8-10
7	Cumin	14-20	8-10
8	Fennel	16-18	8-10
9	Fenugreek	14-18	5-10
10	Nigella	20-25	8-10

(Malhotra and Vashishtha, 2007)

The drip method of irrigation was not suitable for cumin cultivation since it enhanced the occurrence of fusarium wilt and there was drastic decrease in yield. This study gives basic indications for further studies on each irrigation method which can be planned with combination of both sprinkler and drip irrigation methods or in solo. Till vegetative growth of seed spices, sprinkler can be tried and later, after flowering drip irrigation can be used. Since germination and crop stand is the problem in Apiaceous family crops, therefore in the initial stage of crop growth, one surface irrigation can be provided and for later irrigations switching over to sprinkler or drip can also be considered (Malhotra *et. al.,* 2009). Irrigation management using sprinklers specifically for cumin in undulating areas of western Rajasthan and drip systems in transplanted fennel had played a significant role in increasing yield and quality. Mulching and low pressure drip irrigation system in cumin and nigella whereas use of mini-sprinklers in low rising crops like cumin, kasuri methi and fenugreek have proved beneficial in achieving high water productivity (Sundria *et. al.,* 2014). Fertigation requirement in coriander, fennel, fenugreek, dill needs to be standardized to improve the nutrient and water use efficiency together.

Crop protection technologies

Diseases like wilt, blight and powdery mildew in cumin; wilt, powdery mildew and stem gall in coriander; blight and gummosis in fennel, and powdery mildew, downy mildew and mycoplasma-like organism (MLO) in fenugreek frequently attack and cause heavy loss to yield and deteriorate the quality of the produce. Disease and pest management by integrated approach using both bioagents and pesticides have effectively managed wilt, blight, powdery mildew, downy mildew and aphids which are the most devastating biotic stresses in majority of seed spices (Khare *et al.,* 2014, Khare *et. al.,* 2014, Lodha and Mawar 2014)**.** Concerted efforts are needed to evolve appropriate technology for their effective control or varieties which can tolerate or resist these diseases. Methodology developed and recommended by NRCSS, Ajmer for cumin wilt is application of mustard residue (2.5 t/ha) + mustard cake (0.5 t/ha) + neem cake (0.5 t/ha) as soil amendment with one irrigation during hot summer, application of *Trichoderma viride* or *A. versicolar* as seed treatment @ 10g/kg seed and soil application @ 2.5 kg/ha mixed with 50 kg of FYM at the time of sowing and adoption of soil solarization in combination with oil cakes has been found highly effective (Lodha and Mawar 2014; Malhotra 2016). Develop Good Agricultural Practices and or Integrated disease and pest management programme needs to be strengthened with the use of biocontrol agents for pest and disease resistance.

Good processing practices

There is obviously a high risk of contamination by dust and dirt occurring if the raw materials are laid out in the sun. The area used for drying crops in the sun should be on raised platform or concrete floor inaccessible to domestic animals and also dust contamination by wind is minimized. Precautions should be taken to prevent contamination by rodents, birds, insects and other animals during drying and handling in the open (Vashishtha and Malhotra, 2007). Solar and powered dryers protect against contamination and are thus strongly recommended. Fan driven dryers may suck in fine dust particles in dusty areas, therefore powered dryers may need a muslin filter over the air inlet. During storage it is necessary to take care of temperature and relative humidity. The studies are required to be conducted for ascertaining the suitable packaging media for storing the seeds of seed spices with better quality retained for longer period at suitable temperature ranges and RH levels for safe storage (Malhotra and Vashsihtha, 2005, Malhotra, 2016). To ascertain critical seed moisture level, packaging material and storage conditions viz. storage temperature, relative humidity for retaining the quality for a longer period. Value addition throws open ample opportunity in spices export. Cryogenic grinding not only retains the volatiles but enhanced the recovery by 33.9 % in GC 4 and 43.5 % in RZ 209 (Sharma et al 2016). The quality specifications for different fenugreek, ajowan, nigella, caraway, celery, fennel products such as whole seed, powdered seed, volatile oil, oleoresins and thymol production are reviewed (Malhotra 2012b-g). A value chain of major seed spices from field to plate was developed under NAIP which included all the parameters of production, protection, post-harvest handling, processing, value addition, product development, marketing, trade and export (Aglodiya 2014, Malhotra, 2016).

Conclusion

How to harness the potentiality and face the challenges are the points, which need to be addressed. The most important gaps needing attention are low-productivity, quality and pace in adoption of improved technology. The research approaches for addressing these problems are standardization of hybridization techniques for creation of variability and evolving high yielding varieties coupled with quality using recombination breeding; marker assisted breeding for resistance or tolerance to stresses particularly for heat, drought, frost, diseases and major pests; development of plant ideotype/s of seed spices based on physiology and biochemistry for obtaining sustainable yield in view of changing climate; precision farming for enhancing resource use efficiency particularly water and nutrients; standardization of production technology in accordance with Good Agricultural Practices based on mechanization of cultivation for clean and safe production and processing; development of organic production technology and novel biofertilizers based on location specific strains with high nutrient use efficiency and economic feasibility; pollination improvement for high seed set through apiculture; disease and pest forecasting models and integrated pest management techniques are the important interventions for pesticide residue management (NRCSS, 2015; Malhotra, 2016). The development has to be seen as an integrated approach, addressing important gaps, in harnessing the potential for seed spices development

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