Research Review Article

Indian Journal of Agricultural Sciences **85** (2): 151–6, February 2015/Review Article

Status of seed spices research and development in India

BALRAJ SINGH[1] and R K SOLANKI[2]

National Research Centre on Seed Spices, Tabiji, Ajmer, Rajasthan 305 206

Received: 1 January 2015; Revised accepted: 6 January 2015

ABSTRACT

The present paper reviews the research and development status of seed spices in India in the last seven decades. Seed spices are one of the important group of spice crops being cultivated in the arid and semi-arid region of the country. These crops are attaining importance day by day due to its aromatic and medicinal values, the present era is reflecting high International demand of Indian seed spices. The research achievements till date have been very concise for developing, numerous high yielding disease resistant or tolerant varieties, efficient production and protection technologies have also been developed during the period. Since 1930, we have gone long way in understanding the basic problems of these crops. The area of research have been focused mainly on designing packages to harvest more, production of better quality and consumer safe produce is yet to come. The ongoing compilation is a brief information of the milestones that has been bagged by the country's scientific and developmental team to sustain these crops. The problems and challenges in the cultivation of seed spices are enormous and each has to be answered with the changing climatic scenario in the time to come. New problems are also coming up in many of the seed spice crops. Cumin and coriander being the pre-dominant seed spice of the group needs more of the attention. The ongoing paper reflects the synchronized events that have happened in the country for seed spices research and development and also mentioning the significant achievements made and technologies which have shown considerable impact in sustaining these high value low volume crops under the hands of seed spice growers.

Key words: Development, India, Research, Seed spices, Status

Indian spices and spicy food is popular worldover from ancient time. Traders from across the world have visited our sub-continent for spices; nearly 76 spices are grown in India. Seed spices are annual crops whose seeds are consumed as spice, viz. coriander, cumin, fenugreek, fennel, ajwain, dill, anise, nigella, caraway celery etc. These seed spices make food tasty and luxurious, and also bear medicinal value. Interestingly, these crops are pre-dominantly grown in semi-arid and arid zone of the country having dry or wet cool weather conditions. Together the states of Rajasthan and Gujarat and parts of Madhya Pradesh can be called as the 'bowl of seed spices" contributing more than 80% of the country's annual production.

Seed spices possesses significant importance as domestic and export commodity. There has been a gradual rise in area and production of these crops, emphasizing more on the major crops like cumin, coriander, fennel and fenugreek a clear enhancement is visible both in area and production including productivity in the last 25 years (Fig 1). Coriander and cumin covers nearly 80 % of the seed spice area and production. In the last five years export of these commodities has gone high, but cumin export has bounced 144 percent high in terms of quantity nearly (1.21 lakh tonnes) and 191 percent high in value nearly (₹ 1 600 crore). This may be due to globalization and free trade which has created high demand of Indian seed spices. Consequently, interest of the farmers for more profit popularized the cultivation of these crops, effective dissemination of improved varieties and production technologies also guided the growers. In the recent times farmers have become enthusiastic to grow more seed spices to earn more profit due to high domestic and international demand.

In India, the research and developmental activities on seed spices started in the early years of the 20th century. After independence systematic research and developmental programmes happened in the country. A brief picture of the sequence of events that have happened in seed spice improvement can be summarized periodically as the preliminary phase (Year 1938-1970), systematic phase (Year 1971-2000) and advance phase (Year 2000 onwards).

The preliminary phase (Year 1938-1970)

Starting from the early years of the 20th century till 1970 scattered and scanty scientific research happened in India.During the period two pioneer reports came, identification of *Alternaria burnsii* Uppal, Patel and Kamat, causing *Alternaria* blight in cumin (Uppal *et. al.*

[1]Director, National Research Centre on Seed Spices (e mail: drbsingh2000@yahoo.com) and [2]Scientists (SS) (e mail: rks.iipr@gmail.com)

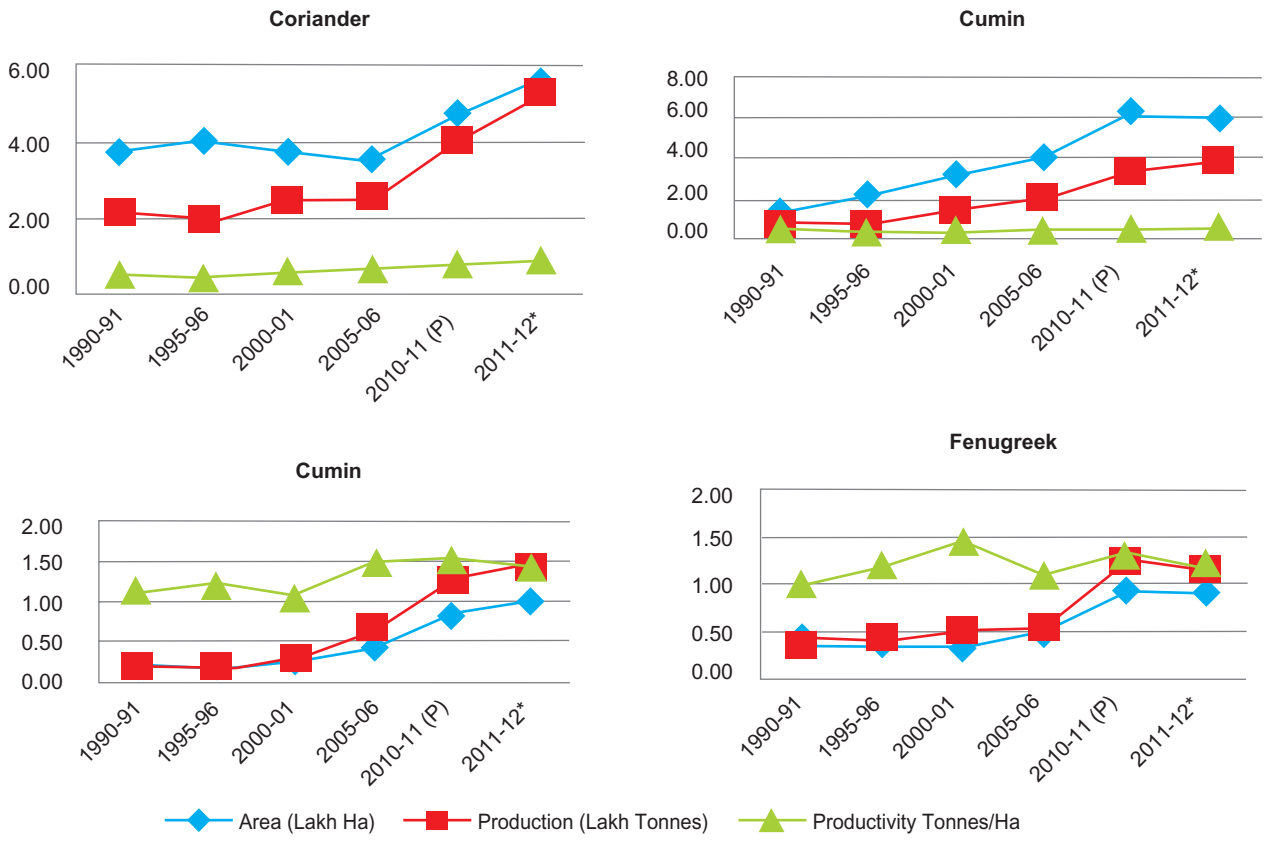

Fig 1 Area, production and productivity of major seed spices (1990 to 2012) of India

1938) and *Fusarium oxysporium* f.sp. *cumini* (Prasad and Patel 1963) causing *Fusarium* wilt in cumin. In 1951 Planning Commission of India constituted a committee to review and formulate research programme on neglected spice crops (Planning Commission of India, 2012-17).A "*Spices Inquiry Committee*" was formed which submitted its report in 1953, emphasising research to be focused on spices including coriander and cumin (Ravindran 2003). In 1961 committee was renamed "Indian Central Spices and Cashewnut Committee" (Ravindran 2003).In 1960, Spice Export Promotion Council was created and in 1966 Directorate of Arecanut and Spices Development was established at Calicut to look into various issues of spices promotion and export. Simultaneously, in early and mid 1960's some basic work at Indian Agricultural Research Institute, New Delhi;Regional Research Laboratory (RRL), Jammu; Central Institute of Medicinal and Aromatic Plants, Lucknow; SKN College of Agriculture, Jobner, Rajasthan; Centre for Spices Research, SDA University, Jagudan, Gujarat; GB Pant University of Agriculture and Technology, Pantnagar also started. Germplasms were collected from various parts of the country and were evaluated to know the extent of variability available. To broaden the genetic base, lines were introduced from other countries also. Exotic coriander was introduced from erstwhile USSR in 1969, *Anethum graveolance* (European Dill) was introduced from Europe by RRL, Jammu. Few classical research reports published during the period, Ramanujam *et al.* (1964) reported extent of cross pollination in coriander (25.02-50.04 %), fennel (82.2-91.4%), ajwain (70.05-77.83 %). Later Patel *et al.* (1966) reported 2-4.5 % cross pollination in cumin.Ramanujam and Tewari (1966) did some inheritance studies in coriander, Nene *et al.* (1965) tested various fungicides against stem gall which is a burning problem in coriander.These all efforts were happening at a low pace and were of less significance for the seed spice growers. Need was to have strong network programme on development of technologies to increase the production and productivity of seed spices.

Systematic phase (Year 1971-1999)

The efforts initiated in 1951 by the Government materialized with the establishment of All India Coordinated Spices and Cashew Improvement project (AICSCIP) in 1971. With that an era of systematic research on seed spices came into existence. The biggest milestone was achieved in 1975 when cumin, coriander, fennel and fenugreek were added in the AICSCI project by starting four new seed spices research centres, viz. at Coimbatore (Tamil Nadu), Guntur (Andhra Pradesh), Jagudan (Gujarat) and Jobner (Rajasthan). In 1986, two organizations came into existence, first, All India Coordinated Research Programme on Spices at Calicut from AICSCIP for research and second, Spice Board of India by merging Cardamom Board (1968) and Spice Export Promotion Council (1966) for promotion of export and implementation of various government schemes on spices including seed spices.

Table 1 List of superior genotypes/varieties identified/released in India

Crop	Developed from/by	Name of varieties and year of release (in parenthesis)	Total No
Cumin	Indigenous selection	S-404 (1952), MC-43 (1970), GC-1 (1983), RZ-19 (1988), RZ-209 (1995), RZ-345 (2008), GC-4 (2006)	10
	Exotic selection	GC-3 (2000)	
	Mutation	GC-2 (1992), RZ-223 (2004)	
Coriander	Indigenous selection	GCor -1 (1974), Co-1 (1977), Co-2 (1982), GCor-2 (1985), Rajendra Swathi (1987), Swathi (1988), Sadhna (1989), Co-3 (1991), CS-287 (1991), DH-5 (1993) Pant Haritima (1993), DWA-3 (1999), RCr-684 (1999), Co-4 (2002), RCr-480 (2006), Sudha (2006), APHU-Dhania-1 (2008), RCr-728 (2008), DH-206 (2008), RKD-18 (2012)	34
	Exotic selection	CIMPO-S-33 (1976), ACr-1 (2006)	
	Mass Selection	Swathi (1989), Sindhu (1991), Hisar Anand (1994), Azad Dhania-1 (1996), Hisar Sugandh (2001), Hisar Surabhi (2004),	
	Half Sib Selection	RCr-41 (1988), RCr-20 (1997), RCr-436 (2001), RCr-446 (2001), RCr-435 (2003)	
	Mutation	RCr-684 (1999)	
Fennel	Indigenous selection	S-7-9 (1956), PF-35 (1973), GF-1 (1984), Co-1 (1985), Azad Sanuf-1 (1996), GF-2 (1997), Pant Madhurika (2001), GF-11 (2003), Hisar Swarup (2004), RF-178 (2006), AF-1 (2006), RF-143 (2007), LFC-84 (2008)	16
	Exotic selection	RF-125 (2003)	
	Half Sib Selection	RF-101 (2002)	
	Recombination	RF-205 (2008)	
Fenugreek	Pureline selection in indigenous material	Co-1 (1982), Rajendra Kanti (1988), RMt-1 (1989), Lam Sel.-1 (1992), ML-150 (1994), Hisar Sonali (1994), RMt-143 (1997), Co-2 (1999), GM-1 (1999), Hisar Suvarna (2001), Hisar Madhavi (2001), Pant Ragini (2001), Azad Methi-1 (2001),Hisar Sugandh (2004), AM-1 (2005), AM-2 (2005), RMt-351 (2006), GM-2 (2006), Hisar Mukta (2006),HM-219 (2008), RMt-361 (2008), AFg-3 (2012), Rajendra Khushba, Pusa Early Bunching	26
	Mutation	RMt-303 (1999), RMt-305 (2007)	
Ajwain	Indigenous selection	GA-1, Pant Ruchika (2001), RPA-68, AA-1 (2004), AA-2 (2004), LamSel-1, LamSel-2, Rajendra Mani	08
Dill	-	GD-1 (1999), GD-2 (1999), RSP-11 (1999), AD-1 (2004), AD-2 (2004)	05
Nigella	Indigenous selection	Azad Kalaungi (1998), Pant Krishna (2001), Ajmer Nigella-1 (2004), Rajendra Shyama	04
Anise	Exotic material selection	AAni-1 (2005)	01
Celery	Selection	RRL-85-1, ACer-1 (2006)	02

Source: www.seednet.gov.in

Under the AICRP on Spices umbrella, research started on major aspects of seed spices, i.e. to develop good technologies and standardize package of practices for increasing the yield levels. More than 100 varieties of seed spice crops have been identified/released out of which more than fifty were identified during 1997-2006 period (Table 1). The present germplasm holding is of more than 2000 lines which are being maintained at various AICRPS centres (NRCSS-Annual Report 2013-14).

Crop improvement, production and protection technologies /recommendations which had a strong impact in changing the national seed spice scenario:

In the country significant work was done at various centres, the basic aim of the scientists was only to develop effective production technologies to enhance the yield potential of these crops. The work done was more on applied aspects looking to the major problems in seed spice cultivation. Despite varietal development, germplasm characterization was also done. Few significant achievements are mentioned below:

(i) More than 100 varieties have been developed, or identified (Table 1). Adoption of these high yielding disease resistant varieties, viz. Guj. Cumin-4 (First wilt resistance variety presently having maximum acreage), Raj. Coriander-40, RCr-435, RCr-436, Ajmer Cor-1, Guj. Cor-2, Guj. Fennel-11, Ajmer fennel-1, Raj. Fennel-101, RF-125, Raj Methi-305 (First determinate variety for synchronous maturity), RMt-301, Ajmer Methi-1, AM-2, Ajmer Ajwain-1, Ajmer Dill-1, Ajmer Dill-2 etc.have contributed significantly (Ravindran *et al.* 2006, www.seednet.gov.in, Kakani *et al.* 2013)

(ii) Sowing time and methodologyfor cultivation were standardized based on strong research programmes,

which provided optimum cardinal growth environment for cultivarsto realize high yield with better quality (Ravindran *et al.* 2006)

(iii) Weed management using pendimenthalin and oxadiargyl had shown significant impact in reducing crop-weed competition and cost of cultivation (Meena *et al.* 2013, Sundaria *et al.* 2014)

(iv) Split applications of fertilizers as per recommendations had enhanced the nutrient use efficiency with increasedyield levels (Ravindran *et al.* 2006)

(v) 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 (Ravindran *et al.* 2006, Sundaria *et al.* 2014)

(vi) 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 (Israel and Lodha 2004, Khare *et al.* 2014, Khare e*t al.* 2014, Lodha and Mawar 2014)

Advance phase (Year 2000 onwards)

Looking to the importance of these crops, Government strengthened the existing research set up by establishing a National Research Centre on Seed Spices under ICAR at Ajmer in the year 2000 with a mandate to address basic, strategic and applied research on seed spices. This was to add a pillar to the existing AICRP on spices. Multidisciplinary research work is being carried out at the centre.Besides doing basic work numerous technologies are being tested and developed which are under pipeline and can be helpful in sustaining seed spices cultivation in the country. The significant advancement made in the recent years at NRCSS and other centres are as-

(i) High yielding cultivars of seed spices and few unique varieties like extra early ajwain line AA-93 of 110 days suitable for cultivation on conserved moisture (Meena *et al.* 2014)

(ii) Intervention of raised beds in seed spices coupled with drip fertigation system for fennel, coriander, dill, ajwain and celery (Singh *et al.* 2013, Sundria *et al.* 2014)

(iii) Mulching and low pressure drip irrigation system in cumin, nigella etc. (Singh *et al.* 2013)

(iv) Use of mini-sprinklers in low rising crops like cumin, kasuri methi and fenugreek (Singh *et al.* 2013)

(v) Intercropping of seed spices such as fennel, coriander and ajwain along with carrot, cabbage, cauliflower (Lal *et al.* 2013)

(vi) Intercropping of seed spices in arid fruit orchards of ber and anola (Lal *et al.* 2013)

(vii) Cumin disease management using bioagents and scheduling of pesticides mancozeb, tabuconazole, propiconazole and karathane effectively controlled wilt, blight and powdery mildew (Meena *et al.* 2013)

(viii) Bio-rationales for control of aphids in seed spices (Meena *et al.* 2013)

(ix) Protected cultivation of seed spices to create more favourable environment for on-season and off-season crops specifically coriander (NRCSS Annual Report 2013-14)

(x) Study of honey bee abundance on crops of anise (*Pimpenella anisum* L.), dill (*Anethum graveolens* L.), nigella (*Nigella sativa* L.) and ajwain (*Trachyspermum ammi* Sprague) showed that bees were main pollinator of these crops. Among different honey bees visited on different seed spice crops, *Apis florea* L. was most abundant and active on these crop during entire flowering period. *Apis dorsata* L. and *Apis mellifera* L. were two other species found pollinating and foraging on these crops. Observation on relative abundance showed that *A. florea* was most active on ajwain followed by dill, anise and nigella. *Apis dorsata* was most active on nigella than dill, whereas *A. mellifera* preferred more on nigella and anise crops (Kant *et al*. 2013)

(xi) Post-harvest management, packaging techniques to retain the highest quality and aroma of the produce (Lal *et al*. 2013)

(xii) Cryo-grinding technology using liquid nitrogen to retain the aroma and flavour of seed spices (Saxena *et al*. 2013)

(xiii) Organic cultivation modules to harvest safe produce for fetching high returns from markets available in metro cities and developed countries (NRCSS Annual Report, 2013-14, Sundaria *et al.* 2014)

Research challenges and future areas of research

There are numerous challenges and future areas of research and development in seed spice crops. The need of the hour is to have strategies to sustain these crops on Indian land for harvesting maximum profit for the poor and marginal farmers of the arid and semi-arid areas of the country (Singh and Solanki 2014a).

(i) Seed replacement rate (SRR) of seed spices is very negligible, it needs to be increased by producing and supplying high quality seeds of improved varieties on top priority basis.

(ii) Cumin: Need more number of wilt resistant varieties in cumin similar to GC-4 to reduce the ongoing mono-varietal cultivation of GC-4, need of blight resistance source in cumin and answer to emerging problems like yellowing and reddening (Seed Spices Newsletter NRCSS)

(iii) Coriander: There is a need to develop varieties having high essential oil and stem gall resistance looking to the export and increasing severity of incidence of stem gall in major production areas of the country (Meena *et al.* 2013). An emerging problem of longitudinal root cracking in coriander also needs to be addressed (Unpublished data, NRCSS), further studies are underway as it was found in the year 2014 at farmers field.

(iv) Fennel: Need of dwarf varieties with high sweetness and resistance against ramularia blight, answer to problem of gummosis (NRCSS Annual Report 2012-13)
(v) Dill: Need of early and non-shattering varieties with high yield and quality
(vi) Initiation of pre-breeding and recombination breeding by developing methods of manual emasculation and pollination by overcoming the hurdles of flower size in these crops
(vii) Standardization of minimum seed standards, as our present understanding still could not answer that to what extent natural cross pollination is happening by air and insects in seed spices therefore, as in cumin the reported cross pollination is 2-18 % and the recommended isolation distance is more than 400 metres. Further research work is also required to standardize field standards specifically isolation distance required for quality seed production in different seed spices crops
(viii) Intervention of mulching, drip and fertigation in transplanted fennel and other crops to increase yield and per unit efficiency of time, labour and inputs
(ix) Nursery raising and transplanting techniques in crops like fennel, celery, dill, ajwain etc. needs to be standardised at high throughput levels for reducing total crop duration and strong initial plant-weed competition (NRCSS Annual Report 2013-14)
(x) Raising seed spices in protected conditions along with apiculture for increasing percent seed set, reducing biotic and abiotic stress and dependency on isolation distance for seed production
(xi) Priming and pelleting of the seeds of seed spice crops, as these crops have inherent problem of delayed germination which needs to be rectified by priming and moreover pelleting will increase the seed size making it suitable for sowing with pneumatic seeders. Few private players have launched their pelleted cumin product in the market, still we have to go a long way to introduce mechanized sowing in these crops
(xii) Identification of novel molecules of medicinal importance, quality profiling of the genetic resources available and enhancement of the value of the produce by identifying more and more of unique industrial important metabolites in these crops (Rathore *et al.* 2013)

Major thrust areas for future research

In the coming times, the major thrust area of research will be focused mainly on developing unique technologies for sustainability at both national and international levels (Singh and Solanki 2014b, NRCSS-Vision 2050)

(i) Major research work is needed to study the role of pollinators and pollination management in seed spices.
(ii) Further research work is also required to develop the field standards specifically isolation distances required for quality seed production of different crops but more specifically for cumin.
(iii) More research work is needed to develop better weed management modules in seed spices by using post-emergence herbicides.
(iv) Focused work on quality analysis of major and minor seed spices is also required looking to the high medicinal value of these crops.
(v) Focused work is needed to develop GAP standards for organic and non-organic seed spice cultivation both for domestic and international need
(vi) Biotechnological interventions are very much required to understand the crops genomics and for developing durable varieties for future
(vii) Major research is needed on pesticide residue management in seed spices.
(viii) Further work is also required for value addition in seed spices to increase the level of income from these crops

The review of past work done is an eagle view of all the activities that have happened. Numerous research has been published on various aspects of seed spice crop improvement, production, management etc. But summarising the whole in nutshell suggests that in the entire period of nearly seven decades we have not only attained self-sufficiency in seed spices but have achieved much in developing better technologies. Need is to have strong basic and strategic research plans for answering the emerging problems and also to tackle the already existing problems to deliver more efficient and sustainable technologies. Presently we are also exporting around 10 % of the annual produce from the country to various destinations in the world. But it is pertinent to mention here that demand of our seed spices is increasing day by day in developed and non-traditional countries. Therefore, there is need of more concerted efforts on front of research for producing safer and high quality seed spices through development of GAP standards and procedures for improvement in the existing production systems. Seed spice cultivation has become more of an enterprise rather than crop husbandry to meet global demand of raw, processed, value added and seed spice based herbal medicines.

REFERENCES

Anonymous. 2013. Annual Report of NRCSS, Ajmer 2012-13. pp 9.

Anonymous. 2014. Annual Report of NRCSS, Ajmer. 2013-14, pp 30

Anonymous. 2014. Annual Report of NRCSS, Ajmer 2013-14, pp 31

Anonymous. 2014. Annual Report of NRCSS, Ajmer 2013-14, pp 32

Isarel S and Lodha S. 2004. Factors enfluencing population dynamics of *Fusarium oxysporum* f. sp. *Cumini* in the presence and absence of cumin crop in arid soils. *Phytopathologia Mediterranea* **43**: 3–13.

Kakani R K, Ranjan J K, Solanki R K and Meena R S. 2013. Varietal wealth for higher profit. *Indian Horticulture* **58**(6): 6–9.

Kant K, Singh B, Meena S R, Ranjan J K, Mishra B K, Solanki R K and Kumar M. 2013. Relative abundances and foraging behaviour of honey bee species on minor seed spice crops. *International Journal of Seed Spices* **3**(2): 51–4

Khare M N, Tiwari S P and Sharma Y K. 2014. Disease problems in fennel (*Foeniculum vulgare* Mill) and fenugreek (*Trigonella foenumgraceum* L.) cultivation and their management for production of quality pathogen free seeds.*International Journal of Seed Spices* 4(2). 11–7.

Khare M N, Tiwari S P and Sharma Y K. 2014. Disease problems in the cultivation of I.Cumin (*Cuminum cyminum* L.) II. Caraway (*Carum carvi* L.) and their management leading to the production of high quality pathogen free seed. *International Journal of Seed Spices* 4(1): 1–8.

Lal G, Singh B, Mehta R S, Meena S S, Mishra B K, Singh R, Aishwath O P and Sharma Y. 2013. Scientific cultivation brings handsome return. *Indian Horticulture* **58**: (6) 13–6.

Lodha S and Mawar R. 2014. Cumin wilt management- a review. *Journal of Spices and Aromatic Crops* 23 (2): 145–55.

Meena R D, Kant K , Sharma Y K and Meena N K (2013) Healthy seed spices brings more returns. *Indian Horticulture* **58**(6): 36–40.

Meena S S, Kakani R K, Singh B, Meena R S, Mehta R S, Kant K, Sharma Y K and Meena R D. 2014. Ajmer Ajwain 93: An early maturing variety of ajwain developed at NRCSS for all ajwain growing areas. *International Journal of Seed Spices* **4**(2):91–3.

Meena S S, Singh B, Lal G, Mehta R S, Singh R, Aishwath O P and Meena N K. 2013. Scientific production technology of minor seed spices brings cheers to farmers. *Indian Horticulture* **58**(6): 42–5.

Nene Y L, Siddiqui I A, Kharbanda P D. 1965. Control of stem gall by fungicides. *Mycopathologia et Mycologia Applicata* 29(1) 142–4.

NRCSS Vision 2050. NRCSS, Ajmer, India

Patel R M, Patel R A and Ramanujam M (1966) Extent of natural cross pollination in cumin (*Cuminum cyminum*). *Indian Journal of Genetics and Plant Breeding.* **26**(1): 220–2.

Government of India. 2012. Twelfth Five Year Plan 2012–17. Planning Commission.

Prasad N and Patel P N. 1963. Fusarium wilt of cumin (*Cuminum cyminum* L.) in Gujarat State, India. *Plant Disease Report* **47**: 528–31.

Ramanujam S and Tewari V P. 1966. Inheritance of Plant Height in coriander. *Indian Journal of Genetics and Plant Breeding* **26**(2): 217–9.

Ramanujam S, Joshi B S and Saxena M B L. 1964. Extent and randomness of cross pollination in some umbelliferous spices of India. *Indian Journal of Genetics and Plant breeding* **24**(1): 62–7.

Ravindran P N. 2003. *Black Pepper: Piper nigrum*, p 526. CRC Press.

Ravindran P N, Babu N K, Shiva K N and Kallupurackal J A. 2006. Advances in Spices Research "History of Achievements of Spices Research in India Since Independence. Agrobios (India), Jodhpur, Rajasthan, 994 pp.

Rathore S S, Saxena S N and Singh Balraj. 2013. Potential health benefits of major seed spices. *International Journal of Seed Spices* 3 (2): 1–12.

Saxena S N, Rathore S S and Singh B. 2013. Value added delicacies of seed spices. *Indian Horticulture* **58**(6): 21–3.

NRCSS. 2012. Seed Spices Newsletter NRCSS, July-December 2012, **1**(1).

Singh Balraj and Solanki R K. 2014a. Status of research and development of seed spices in India. (In) *Proceeding of the* 3rd*International conference on Agriculture and Horticulture* organised by OMICS group at Convention Centre, Hyderabad from 27-29 Oct, 2014, pp 72.

Singh Balraj and Solanki R K. 2014. Seed spices research and development: A way forward. Invited paper presented in the Silver Jubilee Symposium on "*Strategic approaches on Horticulture Research and Development*- A Way Forward" organized by NAAS at NASC Complex, Pusa New Delhi from 26-27 Dec, 2014.

Singh R, Singh B, Lal G, Mehta R S and Sharda Choudhary. 2013. Drip fertigation technology is a boon for seed spices cultivation. *Indian Horticulture* **58**(6): 29–32.

Sundria M M, Mehriya M L, Rathore B S and Choudhary B R. 2014. Cumin (*Cuminum cyminum* L.) sustainable production technology in Rajasthan. Agricultural University, Jodhpur, Rajasthan, 29 p.

Uppal B N, Patel M K and Kamat M N. 1938. Alternaria blight in cumin.*Indian Journal of Agricultural Sciences* **8**:49–62.