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Cumin cultivation: Present status and future prospects

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Abstract
Cumin is an important spice crop, having good medicinal properties. It is grown predominately in the arid and semi-arid regions of the world. This paper deals with the comprehensive study of nutritional value, cultivation practices, botany morphology, and the varietal characteristics of different varieties of cumin crop. The current scenario and status, of area, production, and productivity in India during 2010 to 2019 has been reviewed to identify the various factors affecting cumin productivity and production. It was found that the area and production of cumin in India increased by 60% and 28% respectively. While cumin export has been increased by 464% in terms of quantity between 2010 and 2019, there is huge potential to increase productivity by managing all the constraints. Therefore, the major challenges and thrust areas were reviewed in this paper. It was found that the further research is needed in the areas of plant breeding as well as biotechnological interventions, seed quality standards, seed priming, and pelleting. Moreover, there is an urgent need to improve weed management practices. In addition, the level of mechanization needs to increase by developing innovative small tools and machineries.

Keywords: cumin, cumin cultivation practices, cumin production, cumin productivity, research challenges

Introduction
Cumin (*Cuminum cyminum* L.) is an important spice crop, belongs to the *Apiaceae* (Umbelliferae) family, Cumin seeds are known for their aroma and medicinal use (Banerjee and Sarkar, 2003; Hassanzadehdelouei *et al*. 2013) [9, 24]. It is seasonal crop grown in *Rabi* season. It is grown as inter crop under both the rainfed and irrigated conditions after the *Kharif* crops like jowar, green gram, cowpea, and maize. The cumin crop is grown mainly in two states of India viz., Gujarat and Rajasthan. The Rajasthan state covers largest area 6.72 lakh ha under cumin cultivation whereas; Gujarat state has highest production 3.19 MT of cumin crop in the year 2018-19 (Indiastat, 2020) [28]. Cumin crop is a cash crop and it gives good net returns profit with proper management. Therefore, farmers are interested to cultivate this crop. However, the cumin crop is very sensitive to weather conditions and requires improved agronomic practices and management to get quality seeds and good yield.
Limited information and literature are available regarding cumin cultivation practices. Moreover, available information in the research papers is in staggered forms. Therefore, there is an urgent need to compile the information on cultivation practices. Thus, a review was conducted to collect the information related to cumin crop. This paper is related to the information about botany and morphology, nutritional and medicinal properties of cumin crop. Moreover, the scenario and status of cumin production and export is also thoroughly discussed. The important varieties and general cultivation practices of cumin crop with growth parameters of important varieties have been also reviewed. Research challenges and major thrust area for future research are also covered in this paper.

Botany and morphology of cumin plant
The cumin is a small bushy plant grown annually. It has thin stem having 3 to 5 cm diameter and height of 20 to 30 cm. It has a throne less branched stem of greenish colour at early stage and greyish colour at maturity (Hussein and Batra, 1998) [26]. Cumin plant flourishes large number of small pink or white colour flowers at same level with equal length of stalk. The fruit of cumin is similar to cremocarp grows from lower ovary. The fruits are light brown or greyish in colour and ovate or fusiform in shape. The fruit of cumin is termed as seeds but the real seeds are come out by breaking the fruit wall at the time of germination.

Cumin seeds are dry and capsuled shaped and split into two fragments with just one seed having a grooved wall at maturity stage. The seeds are curved lengthwise and brownish in colour similar to other members of *Apiaceae* family but more resemble to caraway seeds (Chandola *et al*. 1970) [11]. It has wide range of medicinal properties (Singh *et al*. 2017) [58].

Nutritional value and medicinal properties of cumin crop

Among the seed spices cumin is a high-quality source of various nutrient, vitamins and minerals (Table 1). Many people around the world do not get enough iron in their daily diet. As a result, iron deficiency is one of the most common nutrient deficiencies, affecting nearly 20% of the world's population and up to 10% of people in the wealthiest nations (Levi *et al*. 2016) [36]. Cumin seeds are naturally high in iron, one teaspoon of ground cumin contains 1.4 mg of iron, or 17.5 percent of the RDI (Reference Daily Intake) for adults (Ancuceanu *et al*. 2015) [5]. It is also a good resource of manganese as per the ratings of the World's Healthiest Foods, which improve the haemoglobin in the human body and for boosting the immune system.

Table 1: Nutritional composition of cumin

Cumin seeds (Nutritional value per 100 g)					
Sr. No.	**Nutrient**	**Value / 100 g**	**Sr. No.**	**Nutrient**	**Value / 100 g**
1	Energy	1500-1700 kcal	13	Folate (Vit B9)	10-11 µg
2	Carbohydrates	42-46 g	14	Vitamin B12	0.001-0.002 µg
3	Sugars	2-2.5 g	15	Vitamin C	7.5-8.5 mg
4	Dietary fiber	9-11 g	16	Vitamin E	3-4 mg
5	Fat	21-24 g	17	Vitamin K	5-6 µg
6	Saturated	1-2 g	18	Calcium	930-932 mg
7	Protein	16-18 g	19	Iron	65-67 mg
8	Water	7-9 g	20	Magnesium	360-370 mg
9	Vitamin A equiv.	62-64 µg (7%)	21	Phosphorus	490-510 mg
10	Riboflavin (Vit. B2)	0.3-0.35 mg	22	Potassium	1750-1800 mg
11	Niacin (Vit. B3)	4-5 mg	23	Sodium	160-170 mg
12	Vitamin B6	0.4-0.45 mg	24	Zinc	4.5-5.5 mg

Source: Sowbhagya *et al*. 2008; Sowbhagya, 2013 [59, 60]; DHC (2020) [17] www.diethealthclub.com

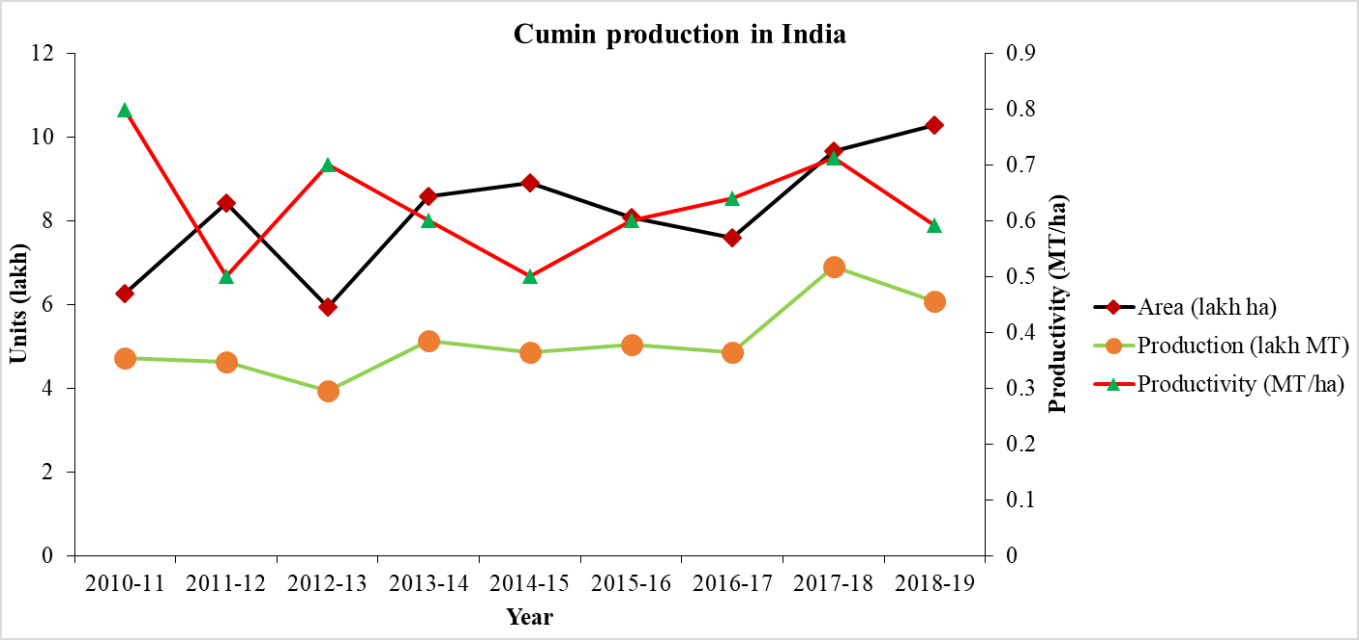
It has several medicinal properties, used for treatment of stimulant, carminative, stomachic, astringent and constructive in diarrhoea and dyspepsia (Malhotra & Vashishtha 2008) [39]. It is also used to treat fever, nausea, vomiting, abdominal discomfort, edoema, and puerperal disorders (Johri, 2011 [30]; Deepak, 2013 [15]; Mnif and Aifa 2015 [42]). Dried cumin seeds are significant in terms of nutritional value and health benefits because they contain volatile oil (5-7%), fat (20-24%), protein (9-11%), fibre (10-12%), and free amino acids (Sowbhagya, 2013) [60]. Cumin seed oil is used as multifunctional luminescent paints or in topical clothing ointment. It has been used in the treatment of mild digestive disorders as a carminative and eupeptic and astringent in bronco pulmonary disorders and as a cough remedy, as well as an analgesic (De *et al*. 2003) [14].

Cumin is a good source of minerals too such as copper and zinc, as well as vitamins like B-complex, riboflavin, thiamine, niacin and antioxidant vitamins such as A, E and C (Bettaieb *et al*. 2011) [10]. It serves as an active reservoir for a variety of bioactive compounds with therapeutic applications (Hajlaoui *et al*. 2010 [23]; Johri, 2011 [30]). The shoots of cumin plant are good source of metabolites, fatty acids, phenolic compounds and amino acids. All of these properties reveal the plant's therapeutic potential while also providing valuable information about metabolic responses to salinity stress (Pandey *et al*. 2015) [51].

Cumin essential oil has high antibacterial activity against *Klebsiella pneumoniae* in vitro (Derakhshan *et al*. 2008) [16], and cumin aqueous/solvent extract has been shown to restrict the growth of a variety of pathogenic microorganisms (Iacobellis *et al*. 2005 [27]; Gachkar *et al*. 2007 [22]; Hajlaoui *et al*. 2010 [23]). The earlier studies indicate that cumin essential oils have considerable toxicity against various insect pests of stored food, and it can prevent food spoilage, due to the anti-bacterial and anti-*Aspergillus* property of this plant (Tunc *et al*. 2000 [64]; Iacobellis *et al*. 2005 [27]; Chaubey, 2008 [12]; Abdelgaleil *et al*. 2009 [1]; Hajlaoui *et al*. 2010 [23]; Oroojalian *et al*. 2010 [50]; Mohammadpour *et al*. 2012 [43]; Yeom *et al*. 2012 [66]; Ziaee *et al*. 2014 [68]).

Scenario and status of cumin production in India

India is the leading nation in the world under area, production, consumption and exporter of cumin since year 2010. The area, production and productivity of cumin crop in India from 2010 to 2019 has been represented in the graph (Fig. 1). In 2018-19 the area under cumin crop was 10.27 lakh ha. Its production and productivity were 6.08 lakh MT and 0.59 Mt/ha, respectively.

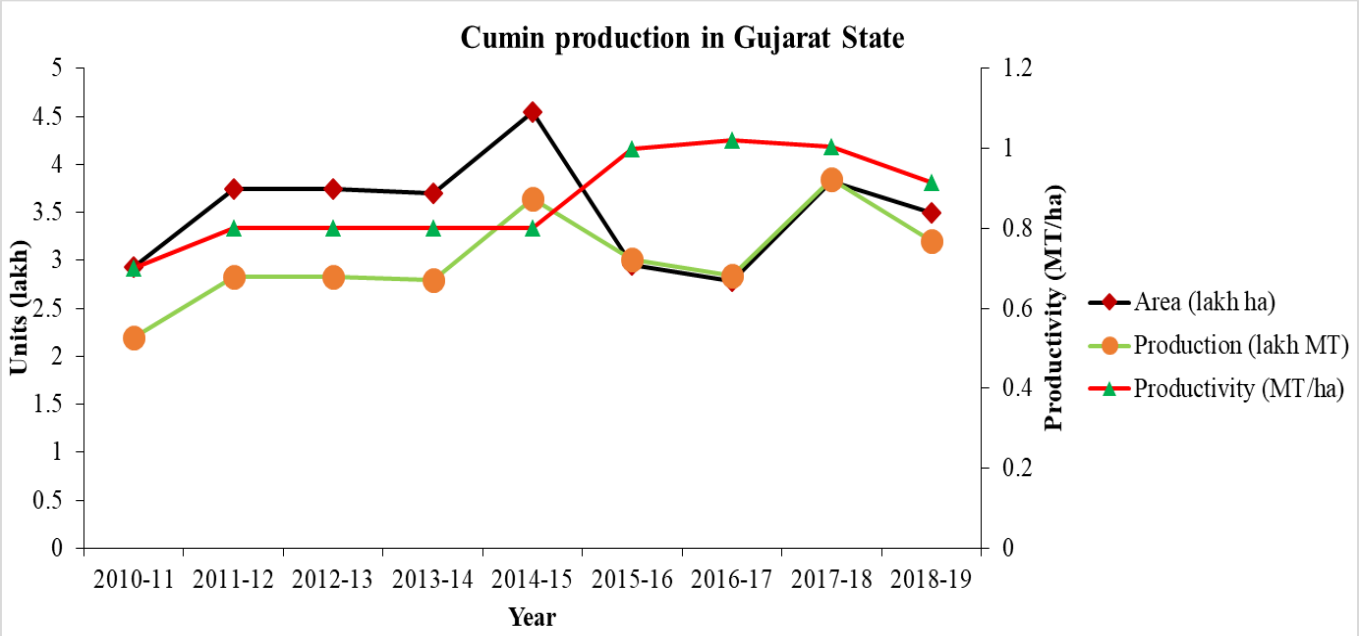


Source: Indiastat (2020) [28] www.indiastat.com

Fig 1: Area, production and productivity of India from 2010 to 2019

The production constantly increased from 2010 and it was recorded maximum in the year of 2017-18 (6.8 lakh MT). While, in the year 2019, it was reduced by 0.82 lakh MT. The overall production has increased up to 28.54% in between period of 2010 to 2019. The area sown under cumin cultivation has been increasing since the year 2010. The overall area of cumin cultivation is increased by 60% and production by 28% during the last decade. However, the productivity has decreased from 0.8 (2010) to 0.6 (2019) MT/ha in last ten years.

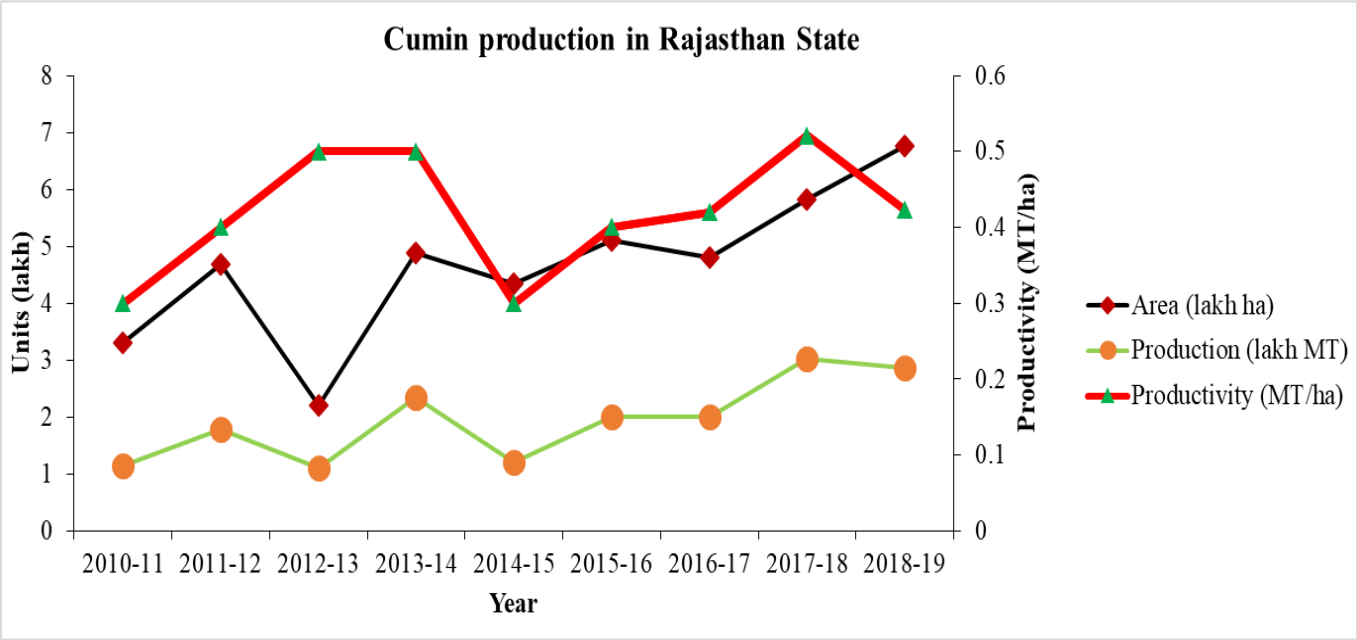
Two states (Rajasthan and Gujarat) of India have played major role in cultivation and contribution of cumin crop production. Gujarat has been the leading state of cumin production in India from 2010 to 2019. Gujarat was having highest productivity of 1.04 MT/ha in 2018. The production and area under cumin cultivation, in Gujarat has increased by 45.66% and 20.33% respectively, from year 2010 to 2019 (Fig. 2).



Source: Indiastat (2020) [28] www.indiastat.com; DOH (2020) [19] https://doh.gujarat.gov.in/index.htm

Fig 2: Area, production and productivity of Gujarat from 2010 to 2019

Whereas, in case of Rajasthan, the cumin production was highest in the year 2017-18 which is 3.02 lakh MT cultivated over an area of 5.81 lakh ha (Fig.3).



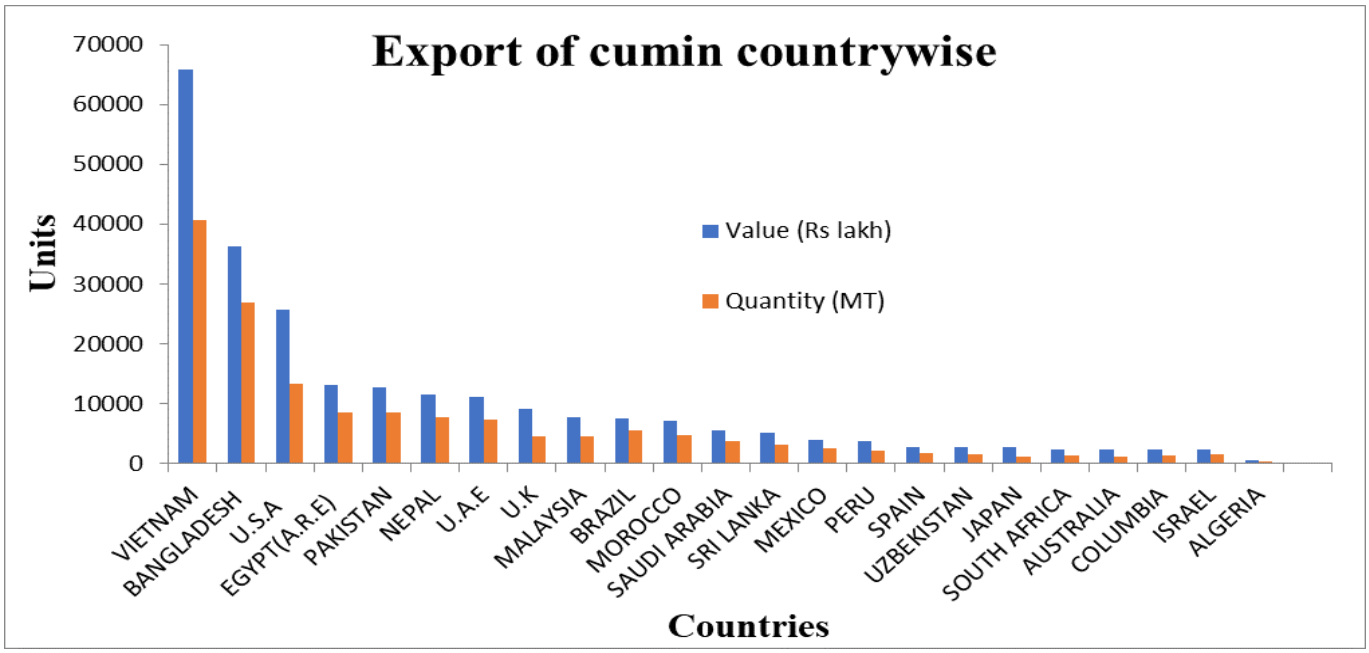
Indiastat (2020) [28] www.indiastat.com; DOA (2020) [18] www.agriculture.rajasthan.gov.in

Fig 3: Area, production and productivity of cumin in Rajasthan from 2010 to 2019

The production of cumin crop in Rajasthan has increased by 150% and area by 104% since 2010. The productivity has increased from 0.3 to 0.5 MT/ha from 2010 to 2018, while it slightly decreased in 2019 from the previous year.

Export status of cumin crop

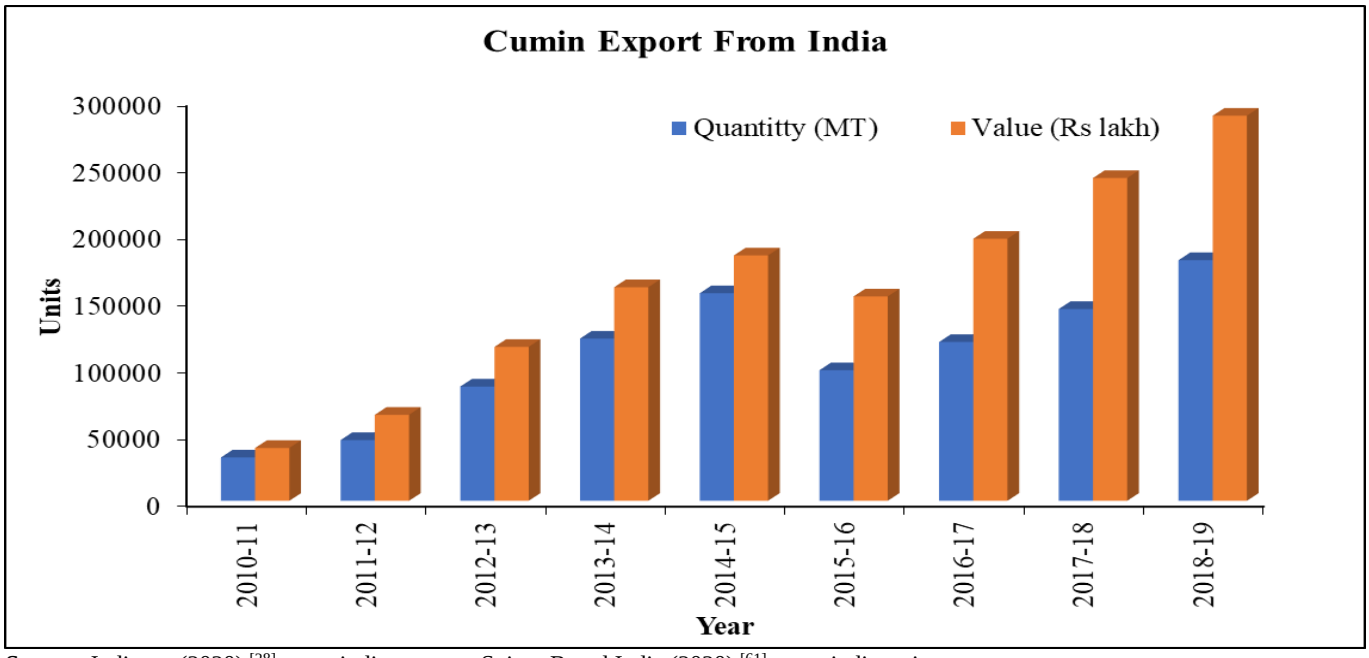
The cumin is being exported from India to nearly 81 countries among which 23 countries, shown in the graph, had highest demand (Fig. 4). The cumin exported during 2018-19 was maximum for Vietnam having demand of 4.05 lakh tonnes in terms of quantity and INR 659.02 crore in terms of value. After Vietnam, higher demand of cumin was seen in Bangladesh, USA, Egypt, Pakistan, Nepal, UAE, respectively in that order.



Source: Indiastat (2020) [28] www.indiastat.com; Spices Board India (2020) [61] www.indianspices.com

Fig 4: Export value of cumin country wise from 2018-2019

Fig. 5. shows that the cumin export has increased by 454% in terms of quantity nearly (1.4 tonnes) and 628.5 percent high in value nearly (INR 2488.82 crore) from the year 2010 to 2019.



Source: Indiastat (2020) [28] www.indiastat.com; Spices Board India (2020) [61] www.indianspices.com

Fig 5: Export of cumin from India to different countries during 2010 to 2019

The continuous increase in export of the cumin may be due to globalization and free trade policy. That has created high demand of Indian seed spices in the global market. Consequently, interest of the farmers for more profit popularized the cultivation of this crops.

Important varieties

The yield of cumin crop depends on improved varieties as well as good agronomic practices. The list of improved varieties of cumin for major growing region in India are shown in Table 2.

Table 2: Characteristics and important features of cumin varieties

Sr. No.	Variety name	Institution / organization (Released by)	Maturity days	Yield q/ha	Essential oil (%)	Salient features
1.	RZ-19	RAU, SKN College of Agriculture, Jobner, Rajasthan	120-140	5-6	1.66	It was developed through recurrent single plant progeny selection from local collection of Kekri (Ajmer). The plants are erect in growth behaviour, bears pink coloured flowers and bold grey pubescent grains. It is tolerant to wilt and blight and is suitable for late sowing season.
2.	RZ-209	RAU, SKN College of Agriculture, Jobner, Rajasthan	140–150	6.5	4.0	It was developed through recurrent single plant progeny selection in a local collection from Ahore (Jalore). The plants are erect in growth behaviour, bears pink coloured flowers and bold grey pubescent grains. It is tolerant to wilt and blight diseases.
3.	RZ-223	RAU, SKN College of Agriculture, Jobner, Rajasthan	120-130	6.0	3.23	It was developed through mutation breeding in UC-216. The plants are bushy, semi-erect and long bold attractive seeds; it has wider adaptability. It is resistant to wilt and blight diseases, superior in yield and seed quality over RZ-19.
4.	RZ-345	RAU, SKN College of Agriculture, Jobner, Rajasthan	120-130	6.07	3.83	The variety has been developed through recurrent selection based on individual plant progeny performance in accession 345. The plants are bushy and semi-erect with long and bold seeds, attractive, higher volatile oil content with lesser infestation of wilt, blight and powdery mildew. This variety is most suitable for Rajasthan and Gujarat.
5.	RZ-341	RAU, SKN College of Agriculture, Jobner, Rajasthan	120-130	4.5	3.87	The variety has been developed through polycross between high volatile oil content vs. low volatile oil content. The plants are bushy and semi-erect with long and bold seeds with lesser infestation of wilt, blight and powdery mildew and also have high volatile oil contents.
6.	GC-1	SDAU, Jagudan, Gujarat	105-110	7.0	3.6	The variety has been developed from local germplasm. The plants are bushy and spreading with pink flowers, grains bold, linear oblong, withstands shattering and lodging. It is moderately tolerant to wilt, powdery mildew and blight. It is suitable for Gujarat and Rajasthan.
7.	GC-2	SDAU, Jagudan, Gujarat	100	7.0	4.0	This variety has been developed through pure line selection. The plants are bushy with good branching habit, grains bold, medium sized, lustrous grain. It is moderately tolerant to wilt and blight and is suitable for late sowing season.
8.	GC-3	SDAU, Jagudan, Gujarat	100	7.0	3.3-4.0	This variety has been developed through selection from exotic line. The plants are bushy dwarf with good branching habit and attractive grains with fruit medium sized. It has higher essential oil content and seed pungent with good aroma. It is also resistant to wilt and frost, suitable for winter season with limited irrigation.
9.	GC-4	SDAU,	100	8.7-	4.2	This variety has been developed through selection from GC-3. This is very popular

		Jagudan, Gujarat		12.5		variety of cumin because of its resistant to *Fusarium* wilt and higher yield performance.
10.	Mc.43	SDAU, Jagudan, Gujarat	110-115	5.8	2.7	The plants of Mc.43 are semi spreading, grains bold lustring and it can withstand lodging and shattering. It is moderately tolerant to *Fusarium* wilt, *Alternaria* blight and powdery mildew
11.	Ac-01-167	Ajmer Rajasthan	110-140	5.15	3.5-4.0	This variety is suitable for limited available water condition. Its bold seeds are resistance to *Fusarium* wilt.

Source: (Anandaraj *et al*. 2007; Parashar *et al*. 2014; Verma *et al*. 2018; Dar *et al*. 2019) [4, 52, 65, 13]

The table shows the details about the maturity days, yield capacity, essential oil content and salient features of various varieties of cumin grown all over India. The growth season of cumin crop depends on varieties, which normally ranges from 100 to 150 days and essential oil content varies from 1.6 to 4.2%. The yield of cumin also varied, with the varieties; in the range of 4.5 to 12.5 q/ha (Table 2). The table covers the information about varieties RZ-19, RZ-209, RZ-223, RZ-345, RZ-341, GC-1, GC-2, GC-3, GC-4, Mc-43 and AC-01-167. The table shows that the variety RZ-209 requires 140 to 150 days to mature which is highest among all the varieties. It is also shown that the highest yielding variety is GC-4 having yield potential of 8.7-12.5 q/ha. The highest essential oil content was also found in the variety GC-4 having an amount of 4.2%.

General cultivation practices of cumin crop

Cumin is a drought-tolerant crop and generally grown in the tropical or subtropical region. The seed emergence starts at 2 to 5°C whereas, optimum temperature required for germination is 20 to 30 °C. The Mediterranean climate is most suitable for its growth. Climate fluctuations play crucial role during growing phase of plant, such as at low temperatures the colour of leaves changes into purple, whereas at higher temperatures the growth period may reduce and early maturity is achieved which results in ultimately low seed yield. At the flowering and fruiting stage high humidity can cause damage to crop due to incidence of diseases such as powdery mildew and blight. The soil condition also plays significant role in productivity of crop. The most suitable soil for cumin cultivation is sandy to loamy soil with proper drainage, adequate aeration and high oxygen availability. The preferred pH range of soil is 6.8 to 8.3 (Lal *et al*. 2018) [34]. Cumin seedlings are highly susceptible to salinity. The proper and improved cultivation practices can increase the production and productivity of the crop. It can also save the resources such as seeds, fertilizers, pesticides and insecticides and it can also help in reducing the labour. The cumin cultivation includes following unit operations (shown in Fig. 6.), and their improved method is also explained below:

Fig 6: Cultivation practices of cumin crop

(a) Land preparation

The land required for cumin should be levelled and well pulverized. The land should be well prepared for better germination of seeds and growth of plant. A total of 3-4 ploughing is required. The first ploughing should be done by soil turning plough followed by 2-3 ploughing with harrow to bring the soil to a fine tilth. At the time of sowing there should be good moisture in the soil for better germination of seed (Lal *et al*. 2014) [35]. In light soils it is achieved by 3-4 ploughings and planking with traditional plough or tractor mounted tillers. In weedy fields, ploughing at least once with mould board plough is desirable. Rotavators are better option to create well pulverized seedbed. For levelling bullock drawn plank or tractor mounted scraper are generally used (Alam, 2007) [2]. Due to undulating land in the cumin growing areas, the fields are not uniform and results non uniform seed. Solution to this problem is to use laser leveller followed by ploughing using MB plough and rotavator. This provides well pulverized and levelled land.

(b) Seed treatment

After the land preparation, seed treatment is next important operation for the cumin cultivation. The seed treatment of cumin seeds before sowing can improve the germination of seedling and save the crop from severe decease and pest attack. There are two seed treatment methods suggested by Malhotra and Vashishtha (2010) [40] and Lal *et al*. (2014) [35] to improve the germination of cumin seed. Malhotra and

Vashishtha (2010) [40] suggested that with the use of bio inoculant *Azospirillum* or *Azotobactor* and seed priming for 8 hours followed by shade drying before sowing improves germination. Whereas, Lal *et al*. 2014 [35] suggested that the seed treatment with Bavistin (2.5 g/kg) and *Trichoderma viride* (4 g/kg) and drying in shade in an airtight container for some hours before sowing improves germination percentage. Mahajan *et al*. (2012) [38] found that seed priming increase the seed germination by 26% and pre-sowing seed treatment with *T. harzianum*, ethephon and *A. versicolar* increased the emergence by 23%, 20% and 18.46% respectively, as compared to the control. It was also found that application of seed treatment reduces the chances of attack of disease. The control of wilt and cumin blight disease can be done by the seed treatment with *T. asperilium* and Bavistin (Trivedi *et al*. 2019) [63].

(c) Sowing

The optimum sowing period for cumin crop is mid November to starting of December but in India, at most of the place's cumin crop is sown from October to starting of December month and harvested in month of March. While, in Syria and Iran, it is sown from mid-November to mid-December (Rahimian, 1991) [54] and it is harvested in June to July (Mollafilabi, 1992 [44]; Mollafilabi, 1998 [45]; Rahimian, 1991 [54]). These seed rate of 12 to 15 kg/ha is considered ideal for healthy crop standing (Faravani, 2004) [21]. The optimum depth of sowing is 1-2 cm and plant density are approximately 120 plants/m^2 (Omidbigi, 1999) [49]. Cumin sowing can be done by two methods namely broadcasting method and line sowing. Broadcasting method is extensively adopted method by farmers in which beds are formed and seed is scattered manually on the beds. Thereafter, seeds are covered through thin layer of soil using a rake (Aminotojari, 1993 [3]; Zare Faizabadi, 1994 [67]). Whereas, in line sowing method, it is sown in shallow furrows at a spacing of 20 to 25 cm. These furrows are made using hooks. Seeds are then put in these furrows, and covered with a thin layer of soil. This method offers more benefits over the broadcasting method for intercultural operations. Currently, the cumin sowing is mostly done by broadcasting method. It causes non uniform germination and interruption in intercultural operations. Along with, it is time consuming and high labour-intensive job. Therefore, to overcome these problems levelling before sowing with the help of laser leveller in undulating fields can be done. Thereafter, sowing with seed cum fertilizer drill can be done for maintaining the proper plant density that can results a uniform germination of seeds.

(d) Irrigation

After sowing, the first operation is to provide moisture to the soil for proper germination of seeds. The water requirement of crop is 335 mm, throughout the crop cycle (Khajehpour, 1986) [32]. Irrigation should begin immediately after sowing and continue at 8-10 days intervals. The first irrigation should not be heavy; otherwise, it would result in uneven distribution of germination (plants). The emergence of seedling starts after second irrigation which is given at 10 days after the first irrigation. Though, if the temperature at daytime is high or there is a dry spell, an additional irrigation may be required after 4 to 5 days for complete germination. Later, based on weather conditions and soil type, the frequency of irrigation should be kept between 20 to 30 days. It was found that irrigation plays crucial role at the time of flowering to seed filling stage (Karimi, 1989) [31]. Hence, proper irrigation is to be given during this time period. The final irrigation should be slightly heavy at the time of seed formation to supply moisture at maturity stage.

The irrigation management is important for proper and uniform germination. Irrigation management using sprinklers specifically in undulating areas of western Rajasthan had played a significant role in increasing yield and quality (Ravindran *et al*. 2006 [55]; Sundaria *et al*. 2014 [62]). Introducing the modern methods of irrigation such as micro irrigation, drip system and sprinkler system, improves the water use efficiency and saves water for healthy crop production.

(e) Fertilizer application

The optimal nutrient requirement should be met by applying the appropriate amount of fertiliser. During land preparation, application of 15-20 tonne/ha of FYM should be given as basal dose. Thereafter, recommended fertilizer dose is 30 kg Nitrogen (N) and 20 kg Phosphorus (P_2O_5) per ha (Karimi, 1989 [31]; Ehteramian, 2002). Nitrogen can be applied in single dose at 30 days after sowing (DAS) or in two equivalent doses at 30 and 60 DAS (Hornok, 1992) [25]. It was found that the split applications of fertilizers as per recommendations had enhanced the nutrient use efficiency with increased yield level (Ravindran *et al*. 2006) [55]. From last several years farmers apply fertilizer through broadcasting method, which require more amount of fertilizer and results in unequal distribution of fertilizer. So, if fertilizer should be applied through modern irrigation tools such as drip fertigation technique that can help in increasing the nutrient use efficiency and improve the soil health.

(f) Weeding

After, irrigation and fertigation, weeding plays an important role in increasing the productivity. Therefore, proper weeding should be done at right time. The first weeding and hoeing should be performed 30 to 40 DAS or when the plants have reached at height of 4-5 cm. If weeds reappearance occurs, another 1-2 hoeing and weeding will aid in better crop growth. The Zeeri (*Plantago pumile*) is a significant weed in cumin, morphologically it is similar to cumin plant, it is distinguishable only at flowering stage, to avoid contamination of seeds. Hand weeding is the only possible solution for this weed. The control of weed can be done by soil solarization technique during field preparation, whereas application of pre-emergence herbicides can also be effective but this type of herbicide requires adequate soil moisture.

Application of pre-emergent herbicide such as Penimethalin @ 1.0 kg/ha or Terbutryn @ 0.5–1.0 kg/ha which provides effective weed control (Dar *et al*. 2019) [13]. Later, for post emergence weed control, oxadiargyl 6 percent EC @ 60 to 75 ml/ha in 500 litres of water at 15 to 20 days is recommended for healthy crop growth. This is effective over many types of weeds such as *Cyperus difformis*, *Rumex spp*, *Eclipta alba*, *Chenopodium album* and *Cyperus iria*. Pendimenthalin and oxadiargyl had shown significant impact in reducing crop-weed competition and cost of cultivation (Meena *et al*. 2013; Sundaria *et al*. 2014) [41, 62]. Generally, the application of herbicides is done manually or by knapsack sprayer, so there is possibility to introduce the power sprayer for weed control.

(g) Diseases and pest attack

The cumin crop is more prone to diseases which reduce the

growth of crop. High relative humidity favours fungal diseases infection. Early-sown crops are more susceptible to disease than late-sown crops. There are three major diseases of cumin crop namely wilt, powdery mildew and blight. Fusarium wilt is seed or soil borne disease; it needs specific soil temperatures for epidemics to develop. It can reduce yield upto 80% (Dar *et al*. 2019) [13]. Whereas, powdery mildew disease can cause severe yield losses in early development stage due to poor seed formation. While, at later stage it can cause discoloured tiny seeds. The blight disease appears as brownish spots on leaves and stems. The disease is more susceptible to cloudy weather and after flowering stage. The seed treatment by Captan @ 2 g/kg seed can be effective in controlling these diseases. The foliar application spray of crop two times with Zineb @ 300 g/100 litter of water is also effective for these diseases.

Along with, disease the insects attack also hampers the productivity of cumin crop. Aphid (*Myzus persicae*) is an important insect, which attacks mostly at flowering stage. This insect feeds on plant sap from tender parts and flowers. The plant becomes yellowish in colour and formation of seed is reduced as well as quality of the produce is also degraded. Aphid can be controlled by spray of Rogor @ 1 ml/litre of water. Other major pests include mites, which regularly invade crops and feed mostly on young leaves; the infestation is more intense on young inflorescences. Disease and pest management by integrated approach using both bioagents and pesticides are effective in management of wilt, blight, powdery mildew and aphid which cause most devastating biotic stresses in cumin crop (Israel and Lodha, 2004 [29]; Khare *et al*. 2014 [33]; Lodha and Mawar, 2014 [37]). There is need to develop varieties with multiple resistances to disease and pests such as wilt, blight, powdery mildew and aphid for future.

(h) Harvesting and threshing

The crop is ready for harvesting from February to end of March, in most parts in India. The crop is harvested when it turns yellow, leaves fall down, and seeds turn light greyish brown. The cumin crop matures in 90-140 days (Balandari, 1994) [8]. The plants are harvested with hand tools such as sickle. However, attempts have been made in recent years to modify available harvesters for this purpose (Rahimi, 1993) [53]. After harvesting, threshing is done by threshers or done manually. In manual method, the crop is beaten on smooth surface. Other method is by running tractor tyre on the crop. Both manual methods are time consuming, and losses are too much high. After harvesting and threshing, cumin seeds are dried in sun up to moisture level of 8.5-9%.

Growth parameters of important varieties

Plant yield depends on the interaction between the genotype and environment. Cumin yield is directly dependant on various yield attributing traits like plant height, fruiting branches, umbel per plant and seeds per umbellate. The quantitative data of different traits for each variety was observed over different locations of Rajasthan (Anonymous, 2018a) [6] (Table 3). Table 3 covers quantitative data of growth parameters such as plant height, number of primary and secondary branches, umbel per plant, umbellate per umbel, seed per umbellate and yield for the varieties GC-1, GC-3, GC4, RZ-19, RZ-209, RZ-341 and RZ-345. It can be helpful for identification of variety and selecting particular variety as per the requirement. The plant height plays vital role in plant growth and development at early growth stage, which helps in supressing the weed, maintain moisture and increase input use efficiency. Fruiting branches and umbel per plant leads toward the increase grain yield per plant ultimately grain yield potential.

Table 3: Important growth parameters of cumin varieties in different district of Rajasthan

Variety	Plant height (cm)	No. of primary branches	No. of Secondary branches	Umbel per plant	Umbellate per umbel	Seed per umbellate	Yield kg per ha
GC-1	26-28	10-12	14-16	28-31	4-6	4-6	450-600
GC-3	26-27.50	10-12	15-17	31-33	5-7	5-7	600-700
GC-4	28-30	11-13	15-18	29-32	5-6.5	4-5	650-800
RZ-19	28-30.50	10-12	17-20	34-37	5-6	5-6	750-850
RZ-209	27-29	8-10	10-12	25-27	6-8	5-6	300-450
RZ-341	27-29	9-12	15-17	30-32	4-6	5-7	700-800
RZ-345	25-27	8-11	15-18	25-27	4.5-6.5	6-7	300-400

Source: NRCSS (2016) [47] annual report; Anonymous (2018b) [7]; NRCSS 2016 [47] www.nrcss.res.in

Research challenges in cultivation of cumin crop to enhance production and productivity

There are various challenges, and potential areas for study and improvement in cumin crop since its actual potential has yet to be achieved. The need of the hour is to have strategies to sustain this crop on Indian land for harnessing maximum profit for the poor and marginal farmers of the arid and semi-arid areas of the country (Singh and Solanki, 2014) [57]. The important points are briefly described in the following section:

- Currently, the criteria of commercial seed production are not developed appropriately; therefore, farmers face the problems of quality seed. There is a challenge for standardization of minimum seed standards and follow the recommended isolation distance which is more than 400 metres.
- The existing varieties are low yielding and susceptible to biotic and abiotic stresses. Only GC-4 variety is wilt resistance with highest yield. Therefore, no other varieties are available to cope up the diseases as well as give higher yield in cumin crop. There is major challenge for plant breeder and pathologist to develop multiple resistant varieties including for biotic and abiotic stresses to reduce the ongoing monovarietal cultivation of GC-4. There is also need to focus on searching the resistance source from germplasm accession for blight disease. Along with it, solution for the emerging problems such as yellowing and reddening in cumin crop is also to be found by the researchers (NRCSS 2012) [46].
- As cumin is a minor crop, the study of the genetics and inheritance of complex traits (yield, quality, disease and pest) in this crop is very limited. Because, the main focus of plant breeders is for improvement in the major crops such as rice, wheat, to fulfil the food demand of growing

population. Therefore, there is need to emphasis on initiation of pre-breeding and recombination breeding by improving methods of manual emasculation and pollination in cumin crop.

- The sowing of cumin crop is mainly done through manually by broadcasting method. It causes more seed wastage and non-uniform germination. Therefore, sowing of crop through seed drill can help in reduction in wastage of seeds and also proper placement of seeds can maintain uniform germination. At some places sowing is done by seed drills but these drills are not especially designed for cumin seeds so there is wastage of seed and proper maintenance of spacing was not there. Hence there is need to develop a specific seed drill for cumin seed.
- Weed management is the major problem in dense cumin crop (broadcast method) and as the crop is mostly sown on undulating land, hence there is even more challenge to develop techniques for weeding to replace manual weeding. There is also need to develop a cultivar with herbicide tolerant.
- Agriculture engineers face big challenge to design the harvester due to the low cutting height and high shattering loss in the crop because cumin seeds are delicate in nature and require very less force to detach. Therefore, this is a major challenge for plant breeders to increase cutting height and develop variety with resistance to shattering through different breeding programme.
- There are no threshers specifically designed for cumin crop. Threshing of cumin crop is done either manually or on available threshers, which have low efficiency and time consuming. The greater challenge for engineer to increasing the efficiency of available thresher and design new thresher with high efficiency.

Major thrust areas for future research

The development of unique technologies to avoid the unnecessary costs, minimise labour drudgery for farmers, and boost production of cumin are the main thrust areas of research. The following are some of the important thrust areas: (Singh and Solanki, 2014; NRCSS-Vision 2050) [57, 48].

- Major research work is needed to study the role of pollinators, new pollinators can be developed and pollination management can be done.
- Further research work is also required to develop the field quality standards specifically isolation distances required for quality seed production. The instruments/equipment can be designed to judge the quality parameters.
- Biotechnological interventions are required to understand the crop genomics and developing the resistant/tolerant (resistance to biotic and abiotic stresses and tolerant to disease and pests) varieties for upcoming future.
- Plant breeder should focus on development of tall verities of cumin, which may facilitate higher cutting height for mechanical harvesting. As the cutter bar at very low height does not perform well and prone to in contact with stone and soil clods which will reduce the life of cutter bar.
- Focus on priming and pelleting of the seeds is required, because of the inherent problem of delayed germination which needs to be rectified by priming. Moreover, pelleting that can increase the seed size making it suitable for sowing with seed drill. Seed drill can be easily developed for pelleted seeds.
- More research work is needed to develop better weed management modules using post emergence herbicides through different power sprayer. Variable rate and spot specific sprayer can be developed to apply herbicides in effective and economic manner.
- Studying the crop-based properties to develop harvester. Selection of suitable variety which can resist the cutter bar vibration without shattering loss.
- Threshing of cumin crop to be studied on various threshers mechanism to find the most efficient thresher. A novel thresher can be developed for cumin crop.

Conclusion

Among the seed spice cumin is an important crop and plays key role in human nutrition. This paper has covered the information related to importance of cumin crop in India, its important varieties and general cultivation practices of the crop. The paper also covers the scenario and status of cumin crop from 2010 to 2019. It indicates that there is increase in production and area under cumin cultivation from 2010, but still there is huge potential to improve the productivity. Whereas, the export of cumin is increased from 2010 to 2019. This increase in export may due to the increase in area under cumin cultivation and emphasis given to cultivation of high yielding varieties such as GC-4 having yield potential of 8.5 to 12.5 q/ha. However, still there is need to improve cultivation practices to increase the productivity at its actual potential. Moreover, it was found that the major constraints are lack of quality seeds, multiple resistance varieties and unavailability of farm machines namely suitable seeders, weeders, harvester and thresher for the cumin crop. The review also includes information about the challenges and major thrust areas in this crop that can helpful in achieving the goal of higher productivity and improving the farmers level of standard.

References

1. Abdelgaleil SA, Mohamed MI, Badawy ME, El-arami SA. Fumigant and contact toxicities of monoterpenes to *Sitophilus oryzae* (L.) and *Tribolium castaneum* (Herbst) and their inhibitory effects on acetylcholinesterase activity. Journal of Chemical Ecology 2009;35:518-25.
2. Alam A. Production, development, quality and export of seed spices. National Research Centre on Seed Spices 2007, 1-11.
3. Aminotojari A. Enhancing quality of cumin for export. Institute of Standard and Industrial Research, Khorasan, Iran 1993, 30p.
4. Anandaraj M, Parthasarathy VA, Shiva KN, Johny AK. Production, development, quality and export of seed spices. National Research Centre on Seed Spices 2007, 350-71.
5. Ancuceanu R, Dinu M, Hovaneţ MV, Anghel AI, Popescu CV, Negreş S. A survey of plant iron content-a semi-systematic review. Nutrients 2015;7(12):10320-51.
6. Anonymous. Annual Report of NRCSS, Ajmer 2018-19 2018a, 29p.
7. Anonymous. Directorate of Agriculture 2018b, www.indiastate.com
8. Balandari A. Botanical characteristics of local population of cumin in Iran. Scientific report, Iranian Scientific and Industrial Research Organization, Khorasan Center 1994.
9. Banerjee M, Sarkar PK. Microbiological quality of some retail spices in India. Food Research International

2003;36:469-74.
10. Bettaieb I, Knioua S, Hamrouni I, Limam F, Marzouk B. Water-deficit impact on fatty acid and essential oil composition and antioxidant activities of cumin (*Cuminum cyminum* L.) aerial parts. Journal of Agricultural and Food Chemistry 2011;59:328-34.
11. Chandola R, Mathur S, Anwer M. A serious weed of cumin crop "zeeri" (*Plantago pumila* Wild.). Science and Culture 1970;36:168-69.
12. Chaubey MK. Fumigant toxicity of essential oils from some common spices against pulse beetle, *Callosobruchus chinensis* (Coleoptera: Bruchidae). Journal of Oleo Science 2008;57:171-79.
13. Dar EA, Mehdi M, Ahmad M, Bhat FN, Hussain N, Hussain M *et al*. Cumin: The Flavour of Indian Cuisines-History, Cultivation and Uses. Chemical Science Review Letters 2019;8(29):129-35.
14. De M, De AK, Mukhopadhvay R, Banerjee AB, Micro M. Antimicrobial activity of *Cuminum cyminum* L. Ars Pharmaceutica 2003;44:257-69.
15. Deepak. Importance of *Cuminum cyminum* L. and *Carum carvi* L. in traditional medicaments - a review. Indian Journal of Traditional Knowledge 2013;12:300-07.
16. Derakhshan S, Sattari M, Bigdeli M. Effect of subinhibitory concentrations of cumin (*Cuminum cyminum* L.) seed essential oil and alcoholic extract on the morphology, capsule expression and urease activity of *Klebsiella pneumoniae*. International Journal of Antimicrobial Agents 2008;32:432-36.
17. DHC. Healthy Diet for Prevention of Various Diseases 2020. www.diethealthclub.com
18. DOA. Directorate of Agriculture 2010-2020. www.agriculture.rajasthan.gov.in 2020.
19. DOH. Director of Horticulture 2010-2020. https://doh.gujarat.gov.in/index.htm 2020.
20. Ehteramian K. Effects of nitrogen level and date of sowing on yield and yield components of cumin in Koshkak area of Fars province. M. Sc thesis, Shiraz University 2002.
21. Faravani M. Survey on treatment of seed amount, transplanting time of black zeera from nursery to field with best cultivation practices. Iranian Journal of Pharmaceutical Research 2004;2:65.
22. Gachkar L, Yadegari D, Rezaei MB, Taghizadeh M, Astaneh SA, Rasooli I. Chemical and biological characteristics of *Cuminum cyminum* and *Rosmarinus officinalis* essential oils. Food Chemistry 2007;102:898-904.
23. Hajlaoui H, Mighri H, Noumi E, Snoussi M, Trabelsi N, Ksouri R *et al*. Chemical composition and biological activities of Tunisian *Cuminum cyminum* L. essential oil: A high effectiveness against *Vibrio* spp. Strains. Food and Chemical Toxicology 2010;48:2186-92.
24. Hassanzadehdelouei M, Vazin F, Nadaf J. Effect of salt stress in different stages of growth on qualitative and quantitative characteristics of cumin (*Cuminum cyminum* L.). Cercetări Agronomiceîn Moldova 2013;46:89-97.
25. Hornok L. Cultivation and processing of medicinal plants. Academic Kiado, Budapest 1992;45:26-77.
26. Hussein M, Batra A. In vitro embryogenesis of cumin hypocotyl segments. Advances in Plant Sciences 1998;11:125-28.
27. Iacobellis NS, Locantore P, Capasso F, Senatore F. Antibacterial activity of *Cuminum cyminum* L. and *Carum carvi* L. essential oils. Journal of Agricultural and Food Chemistry 2005;53:57-61.
28. Indiastate. Socio-Economic Statistical Data and Facts About India from 2010 to 2020. www.indiastate.com 2020.
29. Isarel S, Lodha S. Factors influencing population dynamics of *Fusarium oxysporum* f. sp. *Cumini* in the presence and absence of cumin crop in arid soils. Phytopathologia Mediterranea 2004;43:3-13.
30. Johri RK. *Cuminum cyminum* and *Carum carvi*: An update. Pharmacognosy Reviews 2011;5:63-72.
31. Karimi P. Chemical analysis of essential oil of umbelifereae family, Tabriz University, Thesis of Doctor of Pharmacy, Iran 1989.
32. Khajehpour MR. Principle of Crop Production. Jehad-e-Daneshgahi of Isfahan University of Technology 1986.
33. Khare MN, Tiwari SP, Sharma YK. 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 2014;4(1):1-8.
34. Lal G. Scenario, Importance and Prospects of Seed Spices: A Review. Current Investigation in Agriculture Current Research 2018;8:49-62.
35. Lal G, Saran PL, Devi G, Deepak RR. Production technology of cumin (*Cuminum cyminum* L.). Advances in Vegetable and Agronomy 2014;1:223-31.
36. Levi M, Rosselli M, Simonetti M, Brignoli O, Cancian M, Masotti A *et al*. Epidemiology of iron deficiency anaemia in four European countries: a population-based study in primary care. European Journal of Haematology 2016;97(6):583-93.
37. Lodha S, Mawar R. Cumin wilt management- a review. Journal of Spices and Aromatic Crops 2014;23(2):145-55.
38. Mahajan SS, Kumawat RN, Mertia RS. Organic seed production of cumin (*Cuminum cyminum* L.) with foliar application of Panchgavya and plant leaf extracts in arid western Rajasthan. International Journal of Seed Spices 2012;2:19-26.
39. Malhotra SK, Vashishtha BB. Package of practices for production of seed spices. Book, Publisher Director, National Research Centre on Seed Spices, Ajmer 2008, 3-19p.
40. Malhotra SK, Vashishtha BB. Possibilities of mechanization in seed spices. Production, Development, Quality and Export of Seed Spices 2010, 28-30p.
41. Meena SS, Singh B, Lal G, Mehta RS, Singh R, Aishwath OP *et al*. Scientific production technology of minor seed spices brings cheers to farmers. Indian Journal of Horticulture 2013;58(6):42-45.
42. Mnif S, Aifa S. Cumin (*Cuminum cyminum* L.) from traditional uses to potential biomedical applications. Chemistry and Biodiversity 2015;12:733-42.
43. Mohammadpour H, Moghimipour E, Rasooli I, Fakoor MH, Alipoor AS, Shehni MS *et al*. Chemical Composition and Antifungal Activity of *Cuminum cyminum* L. Essential Oil from Alborz Mountain against *Aspergillus* species. Jundishapur Journal of Natural Pharmaceutical Products 2012;7(2):50-55.
44. Mollafilabi A. Effects of date of sowing and row spacing on yield of cumin. Scientific report, Iranian Scientific and Industrial Research Organization, Khorasan Center 1992.

45. Mollafilabi A. Effects of rate nitrogen on physiological indices of growth and yield components of cumin. Proceedings of 5th Iranian Crop Science Congress, Karaj, Iran 1998.
46. NRCSS. Seed Spices Newsletter NRCSS, Ajmer, India. www.nrcss.res.in 2012.
47. NRCSS. Annual Report, 2015-16, NRCSS, Ajmer, India. www.nrcss.res.in 2016.
48. NRCSS Vision. (2050). NRCSS, Ajmer, India. www.nrcss.res.in
49. Omidbigi R. Approaches for production and processing of medicinal plants. Behnashr Publishing Company, Astan Ghods Razavi, Iran 1999.
50. Oroojalian F, Kasra-Kermanshahi R, Azizi M, Bassami M. Phytochemical composition of the essential oils from three *Apiaceae* species and their antibacterial effects on food-borne pathogens. Food Chemistry 2010;120(3):765-70.
51. Pandey S, Patel MK, Mishra A, Jha B. Physio-biochemical composition and untargeted metabolomics of cumin (*Cuminum cyminum* L.) make it promising functional food and help in mitigating salinity stress. PLoS One 2015;10(12):15-18.
52. Parashar M, Jakhar ML, Malik CP. A review on biotechnology, genetic diversity in cumin (*Cuminum cyminum*). International Journal of Life Sciences and Pharma Reviews 2014;4:17-34.
53. Rahimi M. Chemical control of weeds in cumin. Scientific report, Iranian Scientific and Industrial Research Organization, Khorasan Center 1993.
54. Rahimian MH. Effects of date of sowing and irrigation on growth and yield of cumin. Scientific report, Iranian Scientific and Industrial Research Organization, Khorasan Center 1991.
55. Ravindran PN, Babu NK, Shiva KN, Kallupurackal JA. Advances in Spices Research "History of Achievements of Spices Research in India Since Independence. Agrobios (India), Jodhpur, Rajasthan 2006, 994p.
56. Singh B, Parashar, Madhuri, Jakhar ML, Malik CP. A review on biotechnology, genetic diversity in cumin (*Cuminum cyminum*). International Journal of Life Sciences and Pharma Reviews 2014;4:17-34.
57. Solanki RK. 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 2014.
58. Singh RP, Gangadarappa HV, Mruthunjaya K. *Cuminum cyminum* – A popular spice: An updated review. Pharmacognosy Journal 2017;9(3):1-5.
59. Sowbhagya HB, Sathyendra RBV, Krishnamurthy N. Evaluation of size reduction and expansion on yield and quality of cumin (*Cuminum cyminum*). Journal of Food Engineering 2008;84:595-600.
60. Sowbhagya HB. Chemistry, technology, and nutraceutical functions of cumin (*Cuminum cyminum* L): An overview. Critical Review in Food Science and Nutrition 2013;53:1-10.
61. Spices Board India. Spices Board Statistics 2010-2020. Kochi, India. www.indianspices.com 2020.
62. Sundria MM, Mehriya ML, Rathore BS, Choudhary BR. Cumin (*Cuminum cyminum* L.) sustainable production technology in Rajasthan. Agricultural University, Jodhpur, Rajasthan 2014, 29p.
63. Trivedi V, Sasidharan N, Patel DA. Effect of pre-sowing seed treatment on seed emergence and yield parameters in cumin (*Cuminum cyminum* L.). International Journal of Seed Spices 2019;9:73-76.
64. Tunc I, Berger BM, Erler F, DaglI F. Ovicidal activity of essential oils from five plants against two stored-product insects. Journal of Stored Product Research 2000;36:161-68.
65. Verma AK, Singh R, Choudhary S, Lal G. Cultivation of Dollar Earning Cumin Crop for Higher Income. Acta Scientific Agriculture 2018;23:46-48.
66. Yeom HJ, Kang JS, Kim GH, Park IK. Insecticidal and acetylcholine esterase inhibition activity of *Apiaceae* plant essential oils and their constituents against adults of German cockroach (*Blattella germanica*). Journal of Agricultural and Food Chemistry 2012; 120(3):765-70.
67. Zare Faizabadi A. Cumin in Khorasan. Annual seminar, Faculty of Agriculture, Ferdowsi University of Mashhad 1994.
68. Ziaee M, Moharramipour S, Mohsenifar A. MA-chitosan nanogel loaded with *Cuminum cyminum* essential oil for efficient management of two stored product beetle pests. Journal of Pest Science 2014;87:691-99.