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Assessment of Yield Gap and Remedial Measures in cumin

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Abstract

Cumin is the largest grown seed spice (7.14 lakh ha) and second largest grown spice next only to chilli (8.44 lakh ha) in India during 2022-23. The yield of cumin in India is 647 kg ha^{-1}; varies from district to district in Rajasthan (424 kg ha-1) and Gujarat (995 kg ha^{-1}). Yield difference in Gujarat and Rajasthan needs to measure to assess the existing yield gap (YG), factors responsible and appropriated remedial measures. The present study has tied to document this YG during 2006-07 to 2021-22 with possible reasons. In Rajasthan, study measures YG of 23% (115 kg ha^{-1}) at state level. In major cumin growing districts namely, Barmer (43%), Jaisalmer (31%), Pali (21%) and Jalore (21%) had YG of 214, 153,107 and 106 kg ha^{-1} respectively, over Nagaur during TE 2020-21. In Gujarat, at state level a YG of 17% (162 kg ha^{-1}) is found. Over Kutch, highest YG of 43% (417 kg ha^{-1}) is measured in Patan district, followed by Jamnagar (35%). Surendranagar, the largest cumin growing district of Gujarat, harvested 27% (264 kg ha^{-1}) lower yield than Kutch. Changes in climate, soil health, crop management, inputs use, extension services, farm mechanization, and post-harvest management etc. are main yield determining factors in a particular district. If the yield of the aforementioned major cumin-growing districts improves by 25% over the next five to six years, the country's current cumin acreage will yield an additional thirty-fivethousand tons of cumin.

Keywords: Cumin, yield gap, constraints and remedial measures, Gujarat and Rajasthan

Introduction

The primary component of seed spices are their seeds, which are utilized in whole, powder and value-added products, like curry powder, oleoresins, spice oil etc. India produces more than 20 different seed spices. Cumin, coriander, fennel, and fenugreek are large grown seed spices in the country. India is the world's largest producer, consumer and exporter of spices, producing11.26 million ton spices from 4.31 Mha area during 2022-23 (DASD, 2024). Seed spices contributes 38.56 and 16.24% area (1.66 Mha) and production (1.83 million ton) to total spices respectively, in this year. The average productivity of seed spices in the country has shown increasing trend in last two decades as result of R&D technologies developed and adopted in these crops by the different seed spice stakeholders. During 1980 to 2000, seed spice productivity was standing at 500 kg ha^{-1}, has doubled in next two decades reaching to 1029 kg ha^{-1} in 2016-17 and reached to 1102 in 2022-23. Seed spices occupies nearby 6% of horticultural acreage contributing 0.6% horticulture production in the country due to comparatively low productivity than current other horticultural crops even total spices. Therefore, there is need and scope to improve seed spice productivity employing all possible means especially bridging existing yield gap (Pagaria and Sharma, 2019; Kumar, 2021). The difference between the yield under optimum management and the average farmer yield is defined as yield gap grown in a certain location and cropping system (Evans, 1993, Van Ittersum and cassman, 2013). It is estimated by the difference between potential and average farmers' yields over some specified spatial and temporal scale of interest (Lobell *et al.*, 2009). Research on yield gaps is gaining attention to highlights management opportunities and potential extent of yield increase from current levels. This study evaluates YG in cumin, as it is high value crop to the farmers and second highest exchange earning spice (4194 crore) to the country next only to chilli during 2022-23.

Methodology

Gujarat and Rajasthan were selected in present study because both states only produces cumin in India. To study yield gap in above states district-wise area, production and yield information was compiled from Directorate of Economics and statistics website (http://aps.dac.gov.in/APY/Public_Report1.aspx), Agriculture statistics of Rajasthan and Gujarat published by respective states between 2006-07 and 2020-21.Based on the area top cumin growing districts in respective state were selected. Yield gap over state and top yielding district was measured, taking average yield during study period as potential yield. The average yield in respective chosen districts were taken as actual yield. Yield gap is calculated by subtracting achieved average yield from the potential yield (Lobell, Cassman, and Field, 2009).Efforts to mitigate disease impact and enhance productivity have

$$YG = \frac{Yp - Ya}{Yp} * 100$$

Where YG = Yield Gap

Yp = Potential Yield

Ya = Actual Yield

Results and discussion

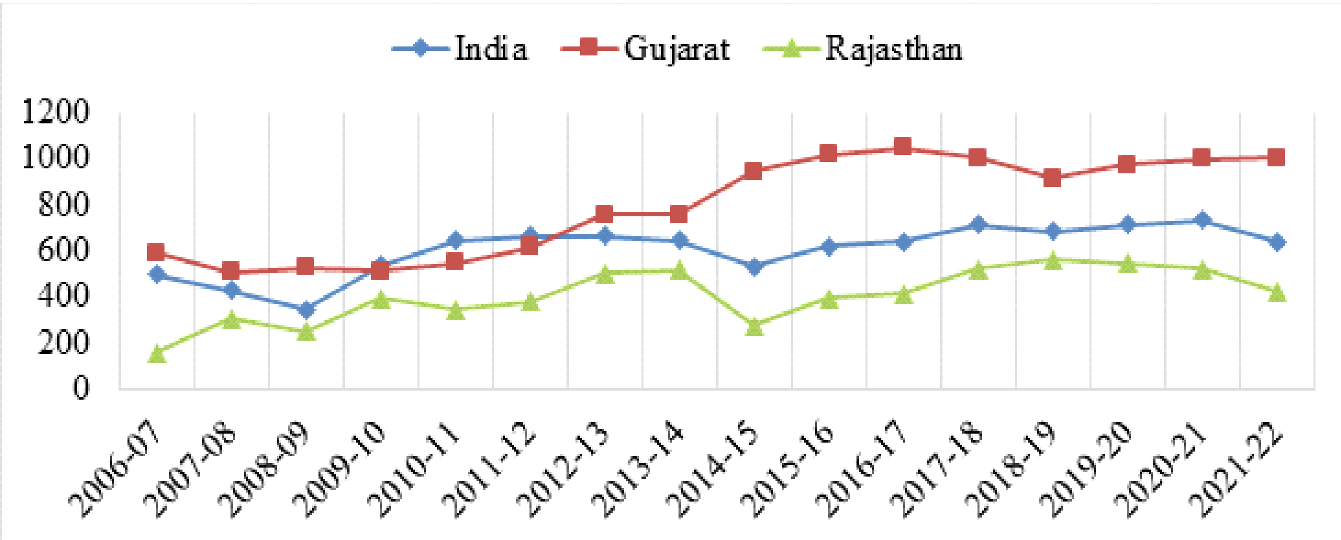
In India, cumin (*Cuminum cyminum*) is the second largest grown spice (7.14 lakh ha) next to chilli (8.44 lakh ha);and largest grown seed spice. It contributes 17 and 43% area share to total spices and seed spices respectively, during 2022-23. In export also it plays important role during 2022-23, 1.86 lakh tons of cumin worth Rs 4194 crore was exported, accounting for over 70% of global cumin trade and approximately 80% of global demand. It is mostly grown in the arid zone of Gujarat and Rajasthan under 2.76 and 4.36 lakh ha, producing 2.74 and 1.85 lakh ton cumin seed respectively. During study period its cultivation increased at CGR of 10.45% in Rajasthan, adding extra 4 lakh ha to cumin cultivation in the state. Area increased from 1.49 to 5.44 lakh ha; coupled with almost tripled yield enhanced from 158 to 424 kg ha^{-1}, resulting 16.33% growth in cumin seed production in the state. In the same period cumin acreage in Gujarat expanded only by 0.6 lakh ha, increasing from 2.59 to 3.22 lakh ha. Because of wider popularization of cumin cultivation in western Rajasthan its share in national acreage increased from 37 to 63% and production share increased from 12 to 42%. On the other hand, Gujarat share in area reduced from 64 to 37 and production share decreased from 77 to 57% during 2006-07 to 2021-22 (Graph 2). As expressed by higher instability index for cumin area and yield in Rajasthan its production was more volatile here than Gujarat (Table 1).

The average yield of cumin in Rajasthan (408 kg ha^{-1}) is almost half of Gujarat (795 kg ha^{-1}) during study period i.e. 2006-07 to 2021-22 (Table 1). Yield pattern in both the states followed similar trend till 2013-14 then after

Table 1. Area (lakh ha), Production (lakh ton) and yield (kg ha^{-1}) of cumin during 2006-07 to 2021-22

Particulars	India			Gujarat			Rajasthan		
	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield
TE 2010-11	5.43	2.84	509.40	2.77	1.47	529.87	2.35	0.79	331.74
TE 2021-22	10.77	7.54	695.23	4.31	4.26	991.32	6.45	3.26	498.54
2022-23	7.14	4.62	646.88	2.76	2.74	994.67	4.36	1.85	424.42
Average	7.40	4.68	606.41	3.28	2.69	795.02	4.20	1.86	407.66
CGR (%)	7.06	10.42	3.13	3.21	8.91	5.53	10.45	16.33	5.32
Instability	0.13	0.24	0.17	0.19	0.24	0.19	0.22	0.45	0.30

Note: TE represents triennial ending average.
Source: Based on data compiled from Dept. of Agriculture and Statics GoI and Agri. Statistics Rajasthan and Gujarat.

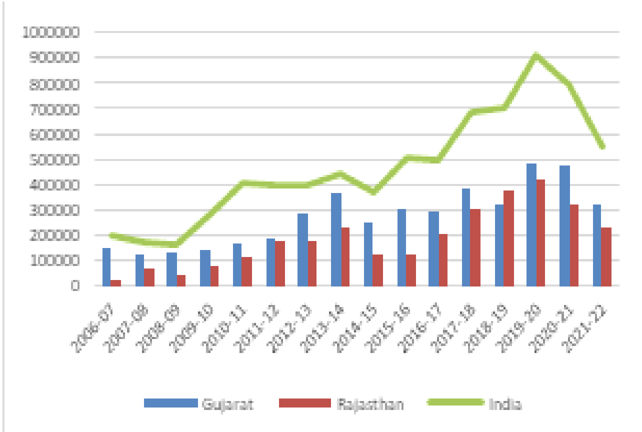


Graph 1: Yield (Kg ha^{-1}) of cumin in India during study period

yield difference in Gujarat and Rajasthan widens (Graph 1). The average low productivity in Rajasthan is because nearly one third of state cumin is grown in Barmer district alone where average productivity is only 210 kg ha^{-1} during TE 2010 and 287 kg ha^{-1} throughout study period (Table 2).

Cumin cultivation and Yield Gap in Rajasthan

Table 2, depicts the scenario of cumin cultivation in Rajasthan. Based on average area during 2006-07 to 2021-22; Barmer, Jodhpur, Jalore, Nagaur, Jaisalmer and Pali are the top cumin growing districts, jointly contributing 95.19 and 79.04% to states area and production during TE 2020-21. Comparatively lower share in production than area for above districts is because of comparatively lower yield levels in above major cumin growing districts. In above districts, highest growth in area (21%) and production (29%) was measured in Jaisalmer, followed by Jodhpur during study period. In Jaisalmer, cumin area expanded more than 12 folds, from 7 to 88 thousand ha



Graph 2: Area (left) and production (right) of cumin in Gujarat and Rajasthan

and yield enhanced from 147 to 414 kg ha^{-1}. As multiplicative effect production increased from 1 to 36 thousand ton from 2006-07 to 2021-22 respectively. Similarly, other major cumin growing district in Rajasthan also measured increasing trend due to impressive growth in area and yield consequently production. The cumin production in Jodhpur found highest volatile (instability index 0.99) among major districts because one-fourth of cumin acreage fall under this district and productivity ranged wider from 113 kg ha^{-1} in 2006-07 to 813 kg ha^{-1} in 2018-19 amplifies variations in production in Jodhpur. Cumin productivity in Jodhpur is increasing at highest pace resulting increasing production during study period. Bairwa *et al.* (2020) has decomposed the production of cumin in Jodhpur and identified yield effect as major contributor in its production during 2004-05 to 2018-19. Climatic, edaphic, hydrological, physiological and management factors primarily determine productivity of a crop. Other factors, such as cultivar, its physiology and crop management, interacts with weather and soils to influence yield level (Agrawal, 2009). Cumin productivity is determined by innumerable controlled and uncontrolled factors e.g. varying weather and climate in growing district, its soil type, in time application and right dose of inputs like seed, fertilizers, plant protection measures, occurrence of diseases and pests and their management, availability and quality of irrigation water, cultural practices etc. In highest yielding district in the state *i.e.* Nagaur here, yield harvested utilizing the best available technologies is considered as the "attainable yield".The average yield harvested in other respective districts at prevailing climate, soils, technology and skill of farmers is taken as actual yield of particular district. Cumin yield in Rajasthan has increased more than 3-folds,at CGR of 5.32% annually from 158 to 523 kg $ha^{-1}$from 2006-07 to 2020-21,with a maximum of 560 kg ha^{-1} in 2018-19. At state level, there exists a yield gap of 23% (115 kg ha^{-1}). In Barmer (43% area share), Jaisalmer (31% area share), Pali (21% area share) and Jalore (21% area share) are having YG of 214, 153,107 and 106 kg ha^{-1}respectively, over Nagaur during TE 2020-21(Table 3). Barmer and Jaisalmer, jointly contributing three-fourth of state cumin acreage are harvesting below state average yield (544 kg ha^{-1}) by 100 and 38 kg ha^{-1}. Singh and Sharma (2017) analyzed the YG in cumin in Jodhpur during 2010-11 to 14-15, measured a YG of 25.87% over farmers practices. They concluded that the yield of cumin was increased by 15.17 to 47.07 per cent by different technological interventions. The results clearly established the facts that the adoption of advance production technologies improves the cumin productivity and profitability. Lal *et al.* (2013) harvested 39.82% higher yield over farmers' traditional practice under the FLD of improved variety with technological interventions in Pali district of Rajasthan. Different studies found a wide YG and points scope for productivity enhancement in cumin. If state could adopt appropriated strategies and tools to bridge 25% of YG over Nagaur reaching to 573 kg $ha^{-1}$by 2025-26 over base TE 20-21, it would be able to harvest an extra 20,000 tons of cumin seed from existing acreage of 6.88 lakh ha.

Table 2. Area (ha), production (ton) and yield (kg ha^{-1}) of cumin in major growing districts in Rajasthan during 2006-07 to 2021-22

District	Particulars	Average	TE 2010 -11	TE 2021-22	CGR	Instability
	Area	123762.56	77124.33	177502.33	8.38	0.21
Barmer	Prod uction	36788.25	17184.33	64031.33	13.31	0.48
	Yield	287.20	210.33	412.06	5.32	0.32
	Area	109255.69	41890.00	164277.67	14.54	0.18
Jodhpur	Production	53398.38	19279.00	63767.67	17.53	1.00
	Yield	493.87	463.33	640.32	6.79	0.57
	Area	90459.13	64804.33	111906.00	5.75	0.27
Jalore	Production	36265.00	23416.00	45241.67	8.44	0.48
	Yield	388.99	361.33	392.62	2.54	0.37
	Area	44829.31	20003.00	62591.67	12.21	0.31
Nagaur	Production	25335.25	9055.00	42176.33	19.47	0.55
	Yield	510.53	451.33	668.16	6.47	0.47
	Area	41122.13	11339.33	87213.67	20.95	0.24
Jaisalmer	Production	16873.00	4310.67	35064.00	28.78	0.52
	Yield	352.44	335.35	391.37	6.47	0.39
	Area	12565.00	5913.00	13573.33	5.78	0.47
Pali	Production	5438.56	2039.67	9608.67	13.35	0.66
	Yield	412.41	316.00	675.20	6.94	0.45

Source: Data compiled from DACNET, Agri. statistics at a glance various issue.

Table 3. YG in cumin in Rajasthan during 2006-07 to 20-21

District	Yield Kg ha^{-1}			YG over state	YG over Nagaur
	Average	TE 10-11	TE 20-21		
Barmer	287.00	210.33	410.67	99.60	214.40
Jodhpur	488.87	463.33	721.67	-102.27	12.53
Jalore	394.80	361.33	468.33	-8.20	106.60
Nagaur	501.40	451.33	689.67	-114.80	0.00
Jaisalmer	348.33	335.35	423.67	38.27	153.07
Pali	393.60	316.00	647.67	-7.00	107.80
State	386.60	332.00	544.00	0.00	114.80

Source: Authors calculation based on data compiled from DACNET, Gujarat and Rajasthan agriculture statistics at a glance various issue

Cumin cultivation and YG in Gujarat

In Gujarat, during 2006-07 to 2021-22, Surendranagar, Banaskantha, Patan, Jamnagar, Rajkot and Kutch are top cumin growing districts, jointly contributing 79 and 66% of state area and production respectively (Table 4). In above period cumin cultivation expanded at highest speed in Kutch district at CGR of 18.35% coupled with yield enhanced from 600 kg ha^{-1} in 2006-07 to 889 kg ha^{-1}in 2021-22, resulting highest production growth in the state. In turn, share of Kutch in state total area increased from 2 to 14% and production share increased from 3 to 12%. In Banaskantha, cumin production increased consistently as expressed by least instability, due to consistent area expansion coupled with highest steady yield growth. The share of Banaskantha in state area increased from 12 to 16 and in production from 12 to 15% from TE 2010 to TE 2021. Surendranagar, the largest cumin growing district (27% area share) of Gujarat recorded comparatively lower growth in area and production compared to other major districts. Decreasing trend in cumin yield in Surendranagar measured negative growth rate in yield results in its lowering area share from 21 to 15%and production from 35 to 10% during TE 2010 to TE 2021 needs detail investigation.

Table5 illustrate the yield gap measured for major cumin growing districts in Gujarat during 2006-07 to 2021-22, over state average as well as highest yielding district *i.e.* Kutch. The average state yield during above period was 808 kg ha^{-1},with highest in Kutch (970 kg ha^{-1}) and lowest in Patan 553 kg ha^{-1}. Over Kutch, highest YG of 43% (417 kg ha^{-1}) was measured in Patan district, followed by Jamnagar (35%). Surendranagar, the largest cumin growing district harvested 27% (264 kg ha^{-1}) lower yield than in Kutch. More than this, cumin productivity in Surendranagar decreased from 855 kg ha^{-1} in TE 2011 to 541 kg ha^{-1} in TE 2021, alarms investigation for reasons behind decreasing productivity and appropriate check for arresting further and reverting above trend. Bhoraniya *et al.* (2017) studied YG in cumin in Surendranagar during 2013-14 to 15-16,measuredYG of 79 kg ha^{-1} between demonstration and farmer's field pointing technology gap in the district. Banaskantha with 17% of Gujarat cumin acreage, measured YG of 308 kg ha^{-1}. Desai *et al.* (2020) in their study in Banaskantha district during 2016-17 to 2018-19 measured YG up to 36% in cumin. At state level during 2006-07 to 21-22, a YG of 17% (162 kg ha^{-1}) is found. Based on the yield level of TE 2021, if major growing district increased the yield level by 25% by 2025-26, Gujarat will be able to harvest 15000 tons additional cumin seed from exiting acreage in state (~4.39 lakh ha). The vision document or policy paper at state and national level is required with means to bridge above existing YG in cumin. Both state can produce additional 35000 tons of cumin seed from existing acreage in the country if 25% of YG could be bridged in next five years.

Factors responsible for YG

Crop yields changes from one region to another amid varying multiple factors that regulate it. Worldwide yield differentiating factors can be grouped into three basic categories as technological, biological and environmental (Liliane and Charles, 2020). Climate, soil health, crop management, input use, farm mechanization, agriculture extension services, post-harvest management, etc. are key yield determining factors. These variables differ from district to district causing yield gap in one over other district. Cumin is very fragile crop, its production is highly susceptible to the weather prevails during the growing season especially during reproductive stage i.e. flowering. Its yield is negatively impacted by unseasonal rain, high relative humidity, temperature instability, drought, and cloudy weather during the reproductive stage causing pest and disease infestation (Meena *et al.*, 2010; Kumar *et al.*, 2023). Currently, cumin cultivation in India is mainly taken in undulating field with sandy to sandy loam soil with low organic matter, less water holding capacity and quick moisture loos from upper layer accounts for low final plant stand results in low seed yield (Mali *et al.*, 2022). Farmers follow mono culture develops invasion of fungal inoculums in the soil causing severe fungal infestation throughout cumin growing season. (Sharma *et al.,* 2013). The output is further decreased by a lack of macro nutrients (NPK), improper fertilizer application techniques, and excessive fertilizer use in the main areas where cumin is grown.

Cumin productivity in both the states vary from district

Table 4. Area (ha), production (ton) and yield (kg ha^{-1}) of cumin in major growing districts in Gujarat during 2006-07 to 2021-22

District	Particulars	Average	TE 2011	TE 2021	CGR	Instability
	Area	69064	57767	64010	5.30	0.29
Surendra Nagar	Production	49699	51600	42668	4.72	0.60
	Yield	706.16	855.40	669.34	-0.55	0.43
	Area	55166	33900	71063	6.44	0.26
Banaskantha	Production	38388	17967	62567	10.68	0.36
	Yield	661.186	528.93	865.98	3.99	0.26
	Area	39145	19767	34382	3.48	0.39
Patan	Production	22570	7800	21255	6.56	0.53
	Yield	552.67	389.82	623.78	2.98	0.27
	Area	34024	25967	98936	2.60	1.44
Jamnagar	Production	23595	16533	75805	4.49	1.55
	Yield	62591	635.29	747.64	1.84	0.22
	Area	25704	5933	58391	18.35	1.26
Kutch	Production	200.97	4600	51146	18.79	0.87
	Yield	969.73	551 .94	835.97	3 .24	0.81
	Area	29794	24000	47178	2.96	0.60
Rajkot	Production	216.89	14167	37351	5.29	0.68
	Yield	716.33	592.40	791.71	2.27	0.22

Source: Data compiled from DACNET, Agri. statistics at a glance various issue.

Table 5. Yield gap analysis in cumin in Gujarat during 2005-06 to 2021-22

District name	Yield (kg ha^{-1})			Yield Gap (kg ha^{-1})	
	Average	TE 2011	TE 2021	over state	over Kutch
Surendranagar	706.16	855.40	541.15	393.52	294.82
Banaskantha	661.19	528.93	849.44	85.23	- 13.47
Patan	552.67	389.82	601.44	333.23	234.53
Jamnagar	625.91	635.29	759.43	175.24	76.54
Rajkot	716.33	592.40	724.24	210.43	111.73
Kutch	969.73	551.94	835.97	98.70	0.00
Gujarat	807.53	516.33	934.67	0.00	- 98.70

Source: Authors calculation based on data compiled from DACNET, Gujarat and Rajasthan statistics at a glance various issue to district, due to use of non-descript seed, inadequate supply of nutrients and improper disease management practices (Desai, 2020).Soil health of cumin field, agronomic management by farmer, right time and quantity of inputs directly affects its productivity. Deficiency of macro nutrient (NPK), inappropriate dose and method of fertilizer application reduces the productivity (Harisha *et al*., 2017). Limited varietal options like GC-4, RZ-19, lack of resistant cultivars, lower adoption of Good Agricultural Practices (GAP) like line sowing, seed replacement, seed treatment, recommended seed rate, weed management, plant protection measures etc. are very common among cumin grower (Mehriya *et al*., 2007; Pagaria and Sharma, 2019).Increasing weed infestation especially *Zeeri*, (looks alike cumin plant)no-label claim, limited availability and use of pre-emergence herbicide, and non-availability of post-emergence herbicide are major hurdles in weed management. The biggest challenge is high infestation of wilt and blight, results up to 60% yield loos due to wilt (Lodha and Mawar, 2014) and complete loos in blight otherwise quality of produce deteriorates (Didwania, 2019).Low farm mechanization and availability of suitable machineries for land preparation, sowing, intercultural and harvesting, etc. make it a labor-intensive crop with high cost of cultivation. Agriculture extension services (AES) play a crucial role in farm productivity, output, and farm earnings (Birthal, 2015). The scarcity of extension staff in the country in general and in cumin growing belt in particular is one of the major constraints. Sixty-six percent of the seed spice growers pursue information from input dealer who provides manipulated information (Meena *et al.,* 2022; NSSO 2005). Extension constraints creates discrepancy between recommended and farmers practices (Jain and Pagaria, 2016; Padmaiah *et al.,* 2012). ICAR-NRCSS surveyed more than 2700 farmers cumin and coriander growers and observed a wide gap between technological recommendation and actual adoption of GAP in cumin. Other than this marketing constraints namely high price fluctuations, lack of MSP, absence of quality testing labs, lack of harmonized standard are major reasons for existing YG in cumin.

Remedial measure to bridge YG in cumin

The existing gap between attainable and actual yields can be bridged over the period employing appropriator medial measures to mitigate existing problems. Proper management of existing constraints with available advanced production technologies could raise current productivity levels by 30 to 40 percent in around 5-6 years (Jain *et al*., 2017; Meena *et al*., 2012).A study by ICAR-NRCSS during 2022-23 surveyed 150 cumin growers from Gujarat and Rajasthan and identified major constraints in cumin cultivation (ICAR-NRCSS, 2022). Cumin is mostly grown in sandy soil with low carbon content. The application of FYM and organic amendments can improve soil health. Farmers in western Rajasthan mostly follows mono-cropping with moth, bajra in kharif followed by cumin in *rabi*, increases the incidences of wilt, needs crop rotation. Currently single variety of cumin *i.e*. GC-4 is mostly grown by farmers with low seed replacement rate calls for alternate variety. The farmers participatory seed production module in cumin of ICAR-NRCSS may be adopted by other agencies with more inclusion of farmers. It will cater the increasing seed demand and replacement in cumin. Increasing weed infestation especially *Zeeri* (mimicry plant of cumin) contaminate cumin seed and deteriorate its quality fetching lower market prices received by farmers. Therefore, it must be removed or controlled before flowering stage with manual of chemical control. Weed control throughout growing season with especial emphasis during early stage is essential. A study by Yadav and Dahama, 2023 highlighted 80–90% yield loss in cumin due to weed infestation, was highest compared to other loss-causing factors like disease, pest and insects. Cloudy weather coupled with higher relative humidity during flowering invites blight, a mass destruction for cumin, resulting complete loss or very poor seed yield. Blight in cumin needs top priority research in the country today. Recommended doses of fertilizer and manure should be applied because over and under dose attracts pests & diseases and nutrient deficiency. Level of mechanization in cumin cultivation is poor need special attention for developing suitable machineries like seed drill, land preparation equipment, harvester combine

Table 6. Major constraints and appropriate remedial measure in cumin

Constraints		Remedial measure
Technological	Agronomic practices	I. Soil solarization, Appropriate field preparation like deep ploughing followed by 2 -3 harrowing, collection of stubbles of previous crop, bed preparation and leveling etc. II. Adoption of GAP throughout cropping season III. Crop rotation
	HYV seed	I. Increasing seed replacement rate. II. Selection of HYV seed III. Research efforts to develop new wilt and blight resistant varieties.
	Poor germination	I. Seed priming for fast germination II. Seed treatment with PGPR III. Timely sowing with recommended seed rate IV. Line sowing at proper spacing and suitable depth V. Light pre-emergence irrigation for enhanced germination
	Low farm mechanization	I. Development o f suitable farm machineries suitable for cumin sowing harvesting and intercultural operations. II. Establishment of custom hiring centers in cumin belts III. Suitable govt. support as farm equipment subsidy
Biotic stress	Diseases	I. Integrated disease management especially Wilt& Blight II. Seed treatment before sowing III. Recommended plant protection chemicals in right dose at right time with experts' advice IV. Disease forewarning system in cumin V. Studies on new label claims for cumin
	Insects, pests	I. Adoption of IPM module for insects and pest e.g. Aphid, Jassid, thrips, etc. II. Bio-chemical measures e.g. Biocontrol agent, plant extracts, neem cake & oil, sticky traps, etc. III. Development of disease and pest forewarning system in cumin
	Weeds infestation	I. Integrated weed management with deep ploughing, soil solarization, pre - emergence weedicide, till use of post emergence use of herbicide if required, 2-3 manual hand weeding with intercultural operation. II. Development of new molecule and reco mmendation on post -emergence herbicide
Abiotic stress	Climatic stress	I. Use of weather forecasting information II. Establishment of new weather station in major areas III. Cloud and frost management with measures like irrigation, smoke in field, and recommended spr ay
	Drought	I. Water harvesting system at field II. Use of micro irrigation system like drip, sprinkler etc., for highest water productivity III. Adjusting sowing dates according to weather forecast
	Soil fertility	I. Soil health management with FYM, organic manure, recommended NPK doses, use of micronutrient based on soil health report from certified labs, II. Site specific micro-nutrient management III. Establishing new and mobile soil testing labs. IV. Mixed and intercropping, V. Adoption of organic cultivation practices
	Salinity	I. Developing proper drainage system, II. Use of soil amendments like gypsum/lime, mulching, green manuring, etc.
Marketing and value addition		I. MSP and insurance coverage to cumin growers II. Guideline on price forecasting or future trading for minimizing price fluctuations in cumin III. Rewards system for organic and pesticide free cumin IV. Clean and safe export quality cumin promotion V. Strict compliance with international standards VI. Traceability adopting barcoding/geotagging system

Source: Authors survey to cumin farmers during 2022-23 etc. so that cost of cultivation and drudgery of farmers can brought down with mechanization.

Based on existing constraints suggested remedial measures are given below in table 6. There is need to educate all the stakeholders in cumin supply chain through capacity building and outreach programmes like front line demonstrations on GAP in cumin, farmers training, seminars, workshops and brain storming sessions on dissemination and adoption of improved cultivation technologies. It will be helpful in mitigating existing yield gap (Davis and Franzel, 2018). There is need to strengthen exiting Agricultural Extension System in cumin growing belts of Gujarat and Rajasthan (Meena *et al.,* 2022). Deployments of more extension services to distant farmers in arid and semi-arid areas of Rajasthan and Gujarat will be helpful in reaching unreached cumin growers. In service capacity building of extension personnel on advances cultivation technologies in cumin with more emphasis of integrated nutrients, disease and pest management in cumin.

Conclusion

Yield Gap analysis of major cumin growing district during 2006-07 to 2020-21 found a wide yield gap in Gujarat (17%) and Rajasthan (23%) varying from district to district. There is need to bridge the above yield gap in major cumin growing districts employing integrated cumin cultivation approach, right from field preparation and selection of variety till final harvest and sale to the market yards. Farmers must follow available advance package of practices and researcher should resolve the R&D issues in cumin like new blight resistance varieties. Joint efforts of all stakeholders will enhance cumin production for domestic as well as export demand in the country from its existing acreage.

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