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Impact Assessment of PGPR in Cumin through on Farm Trials in Arid Zone of Gujarat

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Abstract

The increasing demand for crop production with a significant reduction of synthetic chemical fertilizers and pesticides use is a big challenge nowadays. The use of PGPR has been proven to be an environmentally sound way of increasing crop yields by facilitating plant growth through either a direct or indirect mechanism. The present study was carried out by ICAR-CAZRI, Krishi Vigyan Kendra, Kukma, Bhuj for the assessment of PGPR in Cumin in different villages during rabi season for consecutive two years (2017-18 and 2018-19) as an On-Farm Trial at 10 farmers fields of Bhuj Talukas of Kachchh, Gujarat. The strains used in the bioformulations were *Pseudomonas pituda* and *Microbacterium taraoxidens*, respectively. The bioformulations were applied as seed coating as well as soil application. It was revealed that, the use of PGPR increased the seed yield as well as netincome of the cumin growers. The average seed yield under improved practice was 1008 kg ha^{-1} compared to the farmers practice (849.5 kg ha^{-1}) and increased significantly by 18.66% an average over farmers practice output. The average extension gap, technology gap and technology index were 158.5 kg ha^{-1}, 92 kg ha^{-1} and 8.36%, respectively. Through adoption of improved practice, farmers get additional average returns of Rs.21920 ha^{-1} and B: C ratio 3.69.

Key words : *Arid zone, cumin, gross return, On Farm Trial (OFT), PGPR, technology gap, technology index*

Introduction

Towards a sustainable agricultural vision, crops produced need to be equipped with disease resistance, salt tolerance, drought tolerance, heavy metal stress tolerance, and better nutritional value. To fulfil the above desired crop properties, one possibility is to use soil microorganisms (bacteria, fungi, algae, etc.) that increase the nutrient uptake capacity and water use efficiency (Armado, *et al.,* 2014). Among these potential soil microorganisms, bacteria known as plant growth promoting rhizobacteria (PGPR) are the most promising. In this sense, PGPR may be used to enhance plant health and promote plant growth rate without environmental contamination (Calvo, *et al.,* (2014). Plant growth promoting rhizobacteria (PGPR) is a group of bacteria that can be found in the rhizosphere (Ahmad, *et al.,* 2008). The term "plant growth promoting bacteria" refers to bacteria that colonize the roots of plants (rhizosphere) that enhance plant growth. Rhizosphere is the soil environment where the plant root is available and is a zone of maximum microbial activity resulting in a confined nutrient pool in which essential macro- and micronutrients are extracted.

Cumin is a small hairy, brownish in color, boat shaped seed plant that have a spicy sweet aroma property and powerful slightly bitter and pungent flavor (Rebey, *et al.,* 2012). The cumin commonly known as Jeera, (*Cuminum cyminum* L.) belongs to family Apiaceae. Cumin is believed to be the native of upper Egypt, Turkey and East Mediterranean region. Cumin as condiment is an essential ingredient in all mixed spices, curry powders and for flavouring soups, sausages, pickles etc. Seed are also used for seasoning bakery products such as bread and cakes. It is widely used in Indian, Iranian, Egyptian and Turkish dishes. Cumin is commonly used in confectionary, meat, sausages and bread manufacturing and as a preservative in food processing. The essential oil is used in perfume, cosmetics and flavouring beverages. The characteristic odour of Cumin oil is due to the presence of cumin aldehyde in cumin oil. The oil is extensively used in perfumery and for flavouring liquors and cordials. Cumin possesses carminative, stimulant, stomachic, antimicrobial and astringent properties. It is widely used as traditional medicine to treat flatulence, digestive disorders, diarrhea, insomnia, colds, and fevers and in the treatment of wounds. In India, it is popularly used as a carminative in veterinary practice. Consumption of cumin seeds increase secretion of mother milk after birth of child. Cumin powdered seed mixed with honey, salt and butter is applied externally for scorpion bite. The by product Ark Jeera after extraction of essential oil possess good medicinal properties for curing indigestion problems at home level. The essential oil of cumin has a number of documented medicinal uses like it has effects on the gastrointestinal system, reproductive system, nervous system and immune system and hypoglycaemic, hypolipidaemic, antimicrobial, antioxidant and chemoprotective activity but defined uses and validation of its active secondary metabolites are still awaited (Srivastava, 1989). Alcohol and water extract of cumin are reported to possess many nutraceutical properties like anti-allergic, antioxidant, anti-platelet aggregation, and hypoglycemic. Cumin and value added products from cumin can be a good source of nutraceuticals with many biological activities. The cumin is mainly cultivated in India, Turkey, Syria, United Arab Emirates (UAE), Iran, Egypt, Pakistan, and Italy. In India Cumin is mostly cultivated in Rajasthan and Gujarat and in some part of M.P. and U.P. as a rabi crop. Rajasthan and Gujarat have important position in terms of area and production and contribute 99% of the total production of cumin in India. In India, cumin occupies an area of 12.41 lakh hectares and the total production is 8.56 lakh tonnes (2019-20) with the productivity of 690 kg/ha (Anonymous 2021a). The seeds were exported to the tune of 299000 MT values worth Rs. 425310 lakh from India during 2020-21 (Anonymous, 2021b). Gujarat is the largest producer of cumin in the country produced 399389 tonnes from 473800 hectare area with a productivity of 842.95 kg/ha (Anonymous, 2020-21c). In Gujarat state, it is mainly cultivated in Devbhoomi Dwarka, Banaskantha, Kachchh, Surendranagar and Patan districts.

The productivity level of cumin in our country is low. The main reasons of low productivity are low fertility of soils, low germination of seed, slow initial growth, lack of adoption of improved variety, package of practices including weed management and control of insect pests as well as inadequate extension services and laggard attitude of farmers for adoption of new innovation due to fear of poor performance on their fields. In light of these considerations, we conducted OFTs on farmers' fields to encourage the adoption of the PGPR as well as an improved package of practices in the arid Kutch, with the goal of increasing productivity and increasing net profit from this spice crop. The plant growth promoting rhizobacteria (PGPR) are reported to alleviate both biotic and abitic stress in several crops. With this in mind, the current study seeks to investigate the Yield Gap, Technological Gap, Extension Gap, Technology Index, and Yield Gap between OFT plots and farmers' practices, as well as the level of technology adoption and economics of the technology. The following objectives were undertaken in present study :

To compare the yield level of improved practice (OFT plot) with conventional or farmers' practice

To exhibit the performance of high yielding varieties with improved package of practices by comparative economic analysis

To generate feedback information for further strengthening of research and extension system.

Research Methodology

The current study was conducted by the ICAR-CAZRI, Krishi Vigyan Kendra, Bhuj-Kachchh (Gujarat) during the rabi season from 2017-18 to 2018-19 at farmer's fields. The average area under each demonstration was 0.4 ha with 10 (5 per year) beneficiaries through surveys, field & diagnostic visits and farmer meetings. The factors that contribute to low productivity like improper nutrition management, varietal issues, unavailability of quality seed, gaps in cultivation practices and plant protection measures were identified. Site and farmer selection, layout of demonstration, farmers' participation etc. were followed as suggested by Choudhary (1999). In case of local check (control plots), no change was made in the existing cultural practices of improper use of organic and inorganic fertilizers and limited or no application of fungicides and pesticides. The critical inputs of PGPR (*Pseudomonas pituda* and *Microbacterium paraoxidens*) were distributed to the selected farmers in talc formulation for seed treatment as well as soil application along with the entire recommended package of practices. The PGPRs were procured from Indian Institute of Spice Research, Calicut, Kerala, India. The isolate *P. Putida* (FK-14) is from rhizosphere of fenugreek and *M. Paraoxidens* (FL-18) is an endophyte from fennel roots. Data regarding yield, cost of cultivation, net income and benefit/cost ratio were collected from demonstration plots and control (Existing farmers practice). Table-1 lists the practices adopted for the current study with improved package of practices, where existing farming techniques were viewed as a local check or farmers practice (FP). The soils in the study area were primarily saline to alkaline with pH value 8.0 to 8.5 and EC ranging from 0.9 to 2.5 dSm^{-1}, a sandy to sandy loam texture having low levels of important micronutrients and organic carbon.

To know the overall impact over two years assessment (2017-18 and 2018-19), data were analyzed for cumulative mean and variance using F-test. Statistical tools such as frequency and percentage were used to collect, tabulate, and analyse the data. The extension gap, technology gap, and technology index were calculated using the *Samui et al*. (2000) and Sagar and Chandra (2004) equations equations.

Technology gap = Potential yield - Demonstration yield

Extension gap = Demonstration yield - yield under existing practice

Technology index = [(Potential yield - Demonstration yield)/Potential yield] x 100

Benefit cost ratio (BCR)

$$= \frac{\text{Gross return (Rs. ha}^{-1}\text{)}}{\text{Total cost of cultivation (Rs. ha}^{-1}\text{)}}$$

Table-1 : Comparision of technology gap between On Farm Trials (OFTs) and existing farmers practice (FP).

S. No.	Operation	Farmer's practice	OFTs	Technology Gap
1.	Variety	Unknown local variety	GC-4 (Improved variety from SDAU, Dantiwada) and Ajmer Coriander-1 (From NRCSS, Ajmer)	Full
2.	Seed rate	18 kg/ha	12 kg/ha	Partial gap
3.	Seed treatment	None	Trichoderma 10g/kg seed followed seed coating with PGPR	Full gap
4.	Sowing time	20-30th November	10-15th November	Partial gap
5.	Sowing method	Broadcasting	Line sowing : 30 x 10 cm (R x P)	Full gap
6.	Manure & Fertilizer application	Without recommendation	FYM: 8-10 t/ha 30:15:00 (Kg N: P: K/ha) 1.5 kg Fe and 0.75 kg Zn ha^{-1} enriched with FYM	Partial gap
7.	Weeding	Generally, one hand weeding at 25-30 DAS	Oxadiargyl 6% EC @50 gm a.i. per ha. at 20 DAS followed by one hand weeding at 45 DAS	Partial gap
8.	Integrated pest and disease management	Broadly used chemicals fungicide mancozeb (Dithane M45)	● Use of bio-pesticide Trichoderma viridae as seed treatment @10g/kg seed and soil application @ 2.5 kg Trichoderma mixed with 25 kg FYM before sowing for the management of Fusarium wilt. ● Application of Neem oil 2% as precautionary measure followed by two foliar sprays of flonicamid 50WG @ 5g/15 litre water at 15 days interval to manage the aphid population. ● Foliar spray of wettable sulphur/ Kerathane @ 0.2% at 60 DAS (50 % of flowering stage) to manage the powdery mildew incidence. ● For control of blight disease two sprays with Mancozeb 75WP @ 2 gm/litter water	Partial gap

Table-2 : Year wise yield performance of cumin under OFT.

Year	No. of OFTs	Area (ha)	Yield (kg ha^{-1})		Additional yield over local check (kg ha^{-1})	Increased yield over local check (%)
			Demo Yield (IP)*	Check Yield (FP)		
2017-18	5	2.0	1020	851	169	19.86
2018-19	5	2.0	996	848	148	17.45
Average		2.0	1008	849.5	158.5	18.66

*IP=Improved Practice; FP= Farmers Practice

Table-3 : Extension gap, technology gap and technology index of cumin under OFTs.

Year	No. of OFTs	Technology Gap (kg ha^{-1})	Extension Gap (kg ha^{-1})	Technology Index (%)
2017-18	05	80	169	7.27
2018-19	05	104	148	9.45
Average		92	158.5	8.36

Results and Discussion

Seed Yield Performance : The yield data of cumin obtained during two year (2017-18 and 2018-19) of OFT presented in Table 2. There was a quantum leap in demonstration yield of cumin (1020 kg ha^{-1} and 996 kg ha^{-1}) against the local check control (851 ha^{-1} and 848 kg ha^{-1}) by a margin of 169 kg ha^{-1} and 148 kg ha^{-1} with a percentage increment of 19.86% and 17.45% over the local check (farmer's practice) during 2017-18 and 2018-19, respectively. The result indicates mean yield (mean of 2 years) of 1008 kg ha^{-1} and 849.5 kg ha^{-1} for demonstration and local check, respectively. It was also found that the demonstrated technologies under OFT resulted in an increase in yield by 18.66% over Local Check. The results clearly demonstrated that the positive influence of PGPR on higher average seed yields in demonstration plots over the compared to farmer's practice were achieved may be due to the improved ability of the crop to absorb nutrients, photosynthesis and better sink-source relationship as these play vital role in various biochemical processes. The direct mechanism of plant growth promoting rhizobacteria include the increase in bioavailable phosphorus for plant uptake, biological

Table-4 : Economic analysis of OFT in cumin crop.

Year	Cost of cultivation (Rs/ha)		Gross Return (Rs/ha)		Net Return (Rs/ha)		Additional Return (Rs/ha)	B:C Ratio	
	IP*	FP	IP	FP	IP	FP		IP	FP
2017-18	38250	38000	142800	119140	104550	81140	23410	3.73	3.14
2018-19	38250	38000	139400	118720	101150	80720	20430	3.64	3.12
Average	38250	38000	141100	118930	102850	80930	21920	3.69	3.13

*IP=Improved Practice; FP= Farmers Practice

nitrogen fixation, production of plant hormones like auxins, cytokinins and gibberellins and decrease of ethylene level. The indirect mechanism used by plant growth promoting rhizobacteria include the biotic protection against pathogenic bacteria, reduction of iron available to phytopathogens in the rhizosphere, synthesis of fungal cell wall lysing enzymes and competition with detrimental microorganisms. The increase in yield may be attributed to increased plant height, maximum number of umbels and umbellets, which were positively affected by the application of PGPRs. Similar results are also found by Shivran *et al*., (2012), Shivran *et al*., (2013) and Anandraj and Bini (2011) in various seed spices crops.

Yield Gap Analysis of cumin cultivation : The yield in OFTs and potential yield of the crop was compared for estimating yield gaps. These gaps were further categorized as technology and extension gaps. Technology gap indicates a gap in demonstration yield over the potential yield and this was 80 and 104 kg ha^{-1} during 2017-18 and 2018-19, respectively (Table 3). The technology gap observed may be attributed to dissimilarities in soil fertility, salinity, quality of irrigation water, surrounding microclimate, insect-pests and disease risk, level of crop management by farmer, and others are responsible for the changes in this gap.

The data presented in the Table-3 showed the wide extension gap between demo and check varied between 148 and 169 kg ha^{-1}, with an average of 158.5 kg ha^{-1}, during the period under study. This large extension gap indicated that there was a need to raise awareness about a better package of techniques in order to increase productivity. Greater use of the latest improved technologies can subsequently bridge this extension gap between demonstration yield and farmers yield. The extension gap was recorded at its lowest (148 kg ha^{-1}) in the concluding year 2018-19, indicating the greater adoption of superior technologies of the KVK. The findings of *Bhoraniya et al.* (2017), *Lal et al.* (2013) and *Singh et al.* (2011) corroborate the conclusions of this study. The acceptability and practicality of a technology are always inversely proportional to the technology index; the higher the acceptability of the demonstrated technology, the lower the technology index value (Sagar and Chandra, 2004). Over the years, the average technology index was 8.36 per cent. During the study period, the technology index showed that the intervened technology was widely accepted and viable by the farmers. The findings of *Choudhary et al.* (2018), *Mishra et al.* (2009), *Dayanand et al.* (2012), *Jain* (2014), *Jain* (2018), *Pagaria and Kantwa* (2014) and *Chauhan et al.* (2020) on the impact of FLDs in different crops are in agreement with the current studies.

Economic Analysis : To assess their profit above existing technology, it is essential to comprehend the economic viability of any technique exhibited on farmers' fields. The cost of inputs and output statistics for coriander production under OFT were gathered and analysed to determine gross return, net return, additional income, and the benefit cost (B:C) ratio. Evaluation of economic analysis (Table-4) clearly revealed that besides higher yield, participating farmers in OFTs realized a higher mean gross return of (Rs. 141100) and mean net returns (Rs. 102850) with an average benefit: cost ratio (3.69) compared to the local check. These benefits can be attributed to the technological intervention provided in on farm trials. Thus, favorable cost-benefit ratio and higher net returns proved the economic viability of the assessed technology and convinced the farmers on the utility of technology provided at real farming situation. *Poonia et al.* (2017), *Meena et al.* (2016) and *Singh et al.* (2013), *Choudhary et al.* (2018), and *Singh et al.* (2011) in various seed spices were also found similar results.

Conclusions

Outcome of the 'on farm trials' organized clearly brings out that the dissemination of assessed technology is feasible, economically viable and environmentally safe for improving yield and economics.The PGPRs assessed during the study proved as an effective tool in changing attitude, skill and knowledge of farmers in eco-friendly cumin production which gives better yield due to proper utilization of plant nutrients, enhance plant health, minimizing disease incidences and promote plant growth rate without environmental contamination. Based on farmer's feedback, it was highly acceptable, easily compatible in existing production and cropping system. The productivity gain under OFT over conventional practice of cumin cultivation created a greater awareness and motivated to others farmers to adopt appropriate scientific production and protection technologies of cumin. The selection of critical inputs and participatory approach in planning and conducting the demonstration definitely help in the transfer of technology to the farmers.

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