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Enhancing coriander productivity, profitability, and energy efficiency through cluster frontline demonstrations on integrated crop management

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Abstract

Coriander cultivation in Rajasthan faces challenges like stem gall disease and climate variability. This study evaluates the impact of integrated crop management (ICM) practices in Baran district through Cluster Frontline Demonstrations (CFLDs), ICM practices were implemented, leading to significantly higher coriander yields (19.1 to 21.6 q ha^{-1}) compared to traditional farmer practices (16.4 to 18.9 q ha^{-1}). Adoption rates of ICM practices increased, reaching up to 100% post-demonstration. Energy analysis revealed that ICM plots consumed 33.52% less input energy than FP plots, resulting in higher energy productivity and profitability. These findings underscore the importance of scaling up ICM practices for sustainable coriander farming.

Keywords: Coriander, energy, Integrated Crop Management, stem gall, yield.

Introduction

Coriander cultivation serves dual purposes, catering to both seed spice production during the *rabi* season and leafy vegetable production in the summer and rainy seasons across states such as Rajasthan, Madhya Pradesh, Uttar Pradesh, Gujarat, Andhra Pradesh, and several others. A major growing region for coriander is Kota, Baran, Bundi and Jalawar of Rajasthan and Nimach and Mandsore of Madhya Pradesh (Lal *et al.*, 2017). In Rajasthan, coriander marketed under various regional names such as '*Kota Dhania*,' '*Jhalawar Dhania*,' and '*Haroti Dhania*,'. Rajasthan alone accounts for 45% of the country's total coriander production, cultivated across 2.49 lakh hectares, primarily concentrated in three districts: Kota, Baran, and Jhalawar (DASD, 2020-21).

Despite its significance, coriander production faces challenges, notably a decline in productivity attributed to factors such as stem gall disease and climate variability. Stem gall disease, caused by the *Protomyces macrospores* fungus, has been increasingly severe in popular varieties like CS-6, RKD 18, and local varieties, leading to a reduction in both yield and quality. The disease manifests through hypertrophy in stems, leaves, inflorescence, and fruits, significantly impacting crop health and yield potential (Chaudhary *et al.*, 2020). Furthermore, climate change exacerbates disease prevalence, with prolonged foggy weather and reduced sunshine during winter favouring disease spread.

Efforts to mitigate disease impact and enhance productivity have included the development of new varieties such as Ajmer Coriander-2 (ACr 2) by the National Research Centre on Seed Spices, Ajmer. Additionally, integrated crop management (ICM) practices, developed by Agriculture University Kota and disseminated by Krishi Vigyan Kendra (KVK), Baran, have shown promise in enhancing yields and disease resistance compared to traditional farmer practices. Stem gall disease remains a pressing concern, with its ability to cause significant yield losses, reaching up to 100% under severe incidence.

In light of these challenges, the introduction of disease-resistant varieties stands as a crucial strategy for maintaining coriander production sustainability. By addressing disease vulnerabilities and implementing effective management practices, stakeholders aim to safeguard coriander cultivation and secure livelihoods dependent on its production. The integrated crop management practices may be milestone strategies to increase production, productivity and profitability of coriander.

Materials and methods

The study was conducted in the fields of Baran district, Rajasthan, during the *rabi* seasons spanning from 2021-22 to 2023-24. Positioned at the South-Eastern corner of the state, the study area's geographical coordinates are 26.0982° N latitude and 87.9450° E longitude. Characterized by predominantly black soil of alluvial origin with a clay loam texture, the region boasts a diverse cropping pattern, including *kharif* crops such as soybean, black gram, paddy, and maize, and *rabi* crops such as wheat, mustard, gram, garlic, and coriander.

Before initiating Cluster Frontline Demonstrations (CFLDs), a team of scientists conducted a comprehensive survey to collect baseline information and assess the soil fertility status of the area in 2021. Subsequently, farmers were trained to adopt Integrated Crop Management (ICM) practices for coriander as recommended by the Agriculture University, Kota (Rajasthan). These ICM practices were validated against local farmer practices, serving as a control group within the cluster. In the CFLD plots, ICM practices were meticulously implemented, involving the use of treated seeds of the improved variety Ajmer Coriander 2 (ACr 2), an optimum seed rate of 20.0 kg ha^{-1}, seed treatment with fungicide (Carbendazim 50% WP @ 0.75 g + Thiram @ 1.5 g kg^{-1} seed) and culture (*Azotobacter* + PSB @ 5 g kg^{-1} seed each), and sowing at optimal spacing (30 cm × 10 cm). Additionally, a full dose of P: K (30:20 kg ha^{-1}) and half dose (25 kgha^{-1}) of N and 10 t ha^{-1} FYM was applied as a basal dose, with the remaining half dose (25 kg ha^{-1}) of N top-dressed at the first irrigation through urea. Infestation of Aphid (*Hyadaphis coriandri*) was effectively managed through the establishment of yellow sticky traps and application of Azadirachtin 10000 ppm @ 2.0 ml $liter^{-1}$ at the Economic Threshold Level (ETL).

A total of 100 farmers were selected to participate in the CFLDs focusing on ICM practices for coriander. Correspondingly, an equal number of farmers were purposively selected as samples for the present investigation. Yield data from demonstration plots and control plots were meticulously collected immediately after harvesting to assess the impact of CFLD interventions on different parameters of coriander. Furthermore, input and output prices of commodities prevailing in the district during the demonstration years were utilized to calculate net returns and benefit-cost ratios. Structured and pre-tested interview schedules were employed to gather information from beneficiary farmers regarding adoption, horizontal spread of production technologies, economics, and energy budgeting in the study area. Personal interviews were conducted with beneficiary farmers upon the completion of each year.

To evaluate the impact of CFLDs on different parameters of the coriander crop, established formulas referenced from Wadkar*et al.* (2018) and Kumar *et al.* (2024) were utilized.

Impact on yield (% change)

[{Yield of ICM plot (q ha^{-1}) – Yield of FP plot (q ha^{-1})}/ {Yield of FP plot (q ha^{-1})}] × 100

Impact on adoption (% change):

{(No. of adopters after CFLD – No. of adopters before CFLD)/ No. of adopters before CFLD} × 100

The cost of cultivation and energy analysis were meticulously conducted through personal interviews with beneficiary farmers during 2023-24. Input amounts and energy requirements from sowing to transportation for each input item were quantified. The total dry weight of the coriander crop, encompassing both grain and stover yield, was considered as output. Energy input and output were expressed in MJ ha^{-1} using equivalents from published literature (Table 1). Various energy-related indicators such as energy balance, energy productivity, net energy returns, energy use efficiency, energy intensity, and specific energy were calculated based on established formulas from previous research studies conducted by Malhi *et al*. (2021), Choudhary *et al*. (2017), Ali and Behera (2014), and Alipour *et al*. (2012).

Net energy (MJ ha^{-1}): Energy output - Energy input

Energy use efficiency: Energy output (MJ ha^{-1})/ Energy input (MJ ha^{-1})

Energy productivity (kg MJ^{-1}): Economic yield/ Energy input

Energy intensiveness (MJ INR^{-1}): Energy input/ Cost of cultivation

Energy profitability: Net energy/ Energy input

Specific energy (MJ kg^{-1}): Energy input/ Seed yield

Energy intensity in physical terms (MJ kg^{-1}): Total energy input/ Total biological yield

Energy intensity in economic terms (MJ INR^{-1}): Total energy output/ Cost of cultivation

Table 1. Energy equivalent of inputs and output in coriander

Particulars	Unit	Energy Equivalent (MJ unit $^{-1}$)	References
A. Input			
1. Human labour	MJ h^{-1}	01.96	Choudhary *et al.,* 2017
2. Machinery	MJ h^{-1}	62.70	Choudhary *et al*., 2017
3. Diesel	MJ l^{-1}	56.31	Choudhary *et al*., 2017
4. Nitrogen (N)	MJ kg^{-1}	60.60	Kumar *et al*., 2021
5. Phosphorus (P)	MJ kg^{-1}	11.10	Kumar *et al*., 2021
6. Potash (K)	MJ kg^{-1}	6.70	Nandan *et al*., 2021
7. Water for irrigation	MJ m^{-3}	01.02	Pandiaraj *et al*., 2017
8. Seed (Coriander)	MJ kg^{-1}	14.70	Hetta *et al*., 2023
9. Bio -inoculant	MJ kg^{-1}	14.50	Mihov and Tringovska, 2010
10. Insecticide	MJ kg^{-1}	184.63	Paramesh *et al*., 2019
11. Fungicide	MJ kg^{-1}	97.00	Paramesh *et al*., 2019
B. Output			
1. Seed (Coriander)	MJ kg^{-1}	14.70	Hetta *et al*., 2023
2. By product (Stover)	MJ kg^{-1}	12.50	Koocheki *et al*., 2011

Results and discussion

Yield and economics

The comparison of productivity levels between ICM practices and FP is detailed in Table 2. It reveals that the average yield of coriander in ICM practice plots over three years remained consistently higher, ranging from 19.1 to 21.6 q ha^{-1}, compared to FP yields ranging from 16.4 to 18.9 q ha^{-1} throughout the study period. ICM practices exhibited a significant increase in coriander yield over FP by 15.9%, 11.9%, and 14.3% during 2021-22, 2022-23, and 2023-24, respectively.

Economic evaluation showed that the adoption of ICM practices in CFLDs resulted in a higher cost of cultivation (6.87-7.13%), gross return (Rs. 124,344-197,876), net return (Rs. 92,751-166,916), and benefit-cost ratio (2.94-5.39) compared to FP during all years of the study, as illustrated in Table 3.

The higher yield of coriander in ICM plots can be attributed to several factors, including the utilization of the improved variety ACr-2, optimal seed rate, appropriate plant geometry, seed and soil treatment, effective nutrient management, efficient water management, and integrated pest management practices. These combined efforts in ICM plots contribute to maximizing yield potential.

Conversely, the lower yield observed in FP can be attributed to several practices that may hinder optimal growth and development. These include a higher seed rate, dense planting, and excessive use of nitrogenous fertilizers. The excessive application of nitrogenous fertilizers in FP plots often leads to overly vigorous crop growth, which can negatively impact yield attributes and overall productivity.

In ICM practices, the utilization of variety ACr-2 offers notable benefits, as it exhibits resistance to stem gall, a prevalent disease that significantly reduces yield and quality in coriander. Unlike the varieties commonly used by farmers, which are susceptible to this disease, ACr-2 contributes to improved crop health and productivity. Stem gall infection is often exacerbated by the excessive use of nitrogenous fertilizers, as noted by Verma *et al*. (2019) and Hossain *et al*. (2018), underlining the importance of balanced nutrient management practices.

Furthermore, weed management poses a significant challenge in coriander cultivation, with various weed species observed in the study area. Weeds such as *Anagalli sarvensis, Asphodelu stenuifolius, Chenopodium album, Convolvulus arvensis, Melilotus indicus, Parthenium hysterophorus,* and *Rumex dentatus* were identified, which were not effectively managed in FP plots. In contrast, ICM plots implemented hoeing and weeding techniques, effectively controlling weeds. The smothering effect of coriander also contributed to weed suppression. This aligns with findings by Rathod *et al.* (2021), who observed that hand weeding resulted in higher yields and net returns compared to weedy conditions and other treatments.

Overall, the integrated approach of ICM not only addresses specific challenges such as disease resistance and weed management but also contributes to enhanced crop health, yield, and economic returns in coriander cultivation. Furthermore, need-based nutrient supply and IPM also contributed to higher yields in ICM plots. There were excellent results in managing insects and diseases using integrated pest management and integrated disease management techniques. Soil treatment with *Trichoderma viride* prevented many fungal diseases like powdery mildew, root rot, and used variety having stem gall resistance stem gall. This not only prevented disease but also strengthened farmers' ability to cultivate coriander. Khan and Praveen (2018) reported that the application of biocontrol agents, such as *Trichoderma* in soil, is beneficial for enhancing plant growth and yield attributes, while also reducing stem gall intensity by 52.54% to 84.82%. The benefit cost ratio is more in 2021-22 as compared to 2022-23 and 2023-24. It was due to higher market price in 2021-22 as compared to other years.

ICM plots consistently yielded higher benefit-cost ratios due to increased yields. Research conducted worldwide has conclusively demonstrated that Integrated Crop Management (ICM) practices lead to higher returns on investment. Studies by Lal (2020), Meena *et al*. (2016), Tetarwal and Ramniwas (2022), Kumar *et al*. (2021), Dhaka *et al*. (2015), and Poonia *et al*. (2017) have consistently reported the superiority of improved production techniques over traditional farmer practices in cultivating coriander.

Table 2. Impact of integrated crop management practices on yield performance of coriander

Year	ICM demo. area (ha)	No. of ICM demo.	Average yield of ICM (q ha^{-1})		Average yield of FP (q ha^{-1})		Impact over FP (% change in grain yield)
			Grain yield	Stover yield	Grain yield	Stover yield	
2021-22	10	25	19.1	35.9	16.4	33.9	15.9
2022-23	20	50	19.8	37.8	17.7	36.9	11.9
2023-24	10	25	21.6	41.6	18.9	40.2	14.3

Table 3. Impact of integrated crop management practices on economics of coriander

Year	Economics of ICM				Economics of FP			
	Cost (Rs. ha^{-1})	Gross Return (Rs. ha^{-1})	Net Return (Rs. ha^{-1})	B:C	Cost (Rs. ha^{-1})	Gross Return (Rs. ha^{-1})	Net Return (Rs. ha^{-1})	B:C ratio
2021-22	30960	197876	166916	5.39	28970	169904	140934	4.86
2022-23	31593	124344	92751	2.94	29495	111156	81661	2.77
2023-24	32304	150552	118248	3.66	30193	131733	101540	3.36

Adoption of technology

The adoption data for coriander ICM practices is summarized in Table 4. Prior to the demonstrations, there were no adopters of the improved variety ACr-2 of coriander; however, post-demonstration, the adoption rate reached 100%. ACr-2 is noted to be a stem gall resistant variety (Lal *et al.*, 2021). Significant adoption was also observed across various aspects such as seed rate, spacing, nutrient management, and insect management, with adoption rates increasing from 24% to 94%, 12% to 59%, 47% to 86%, 63% to 92%, 44% to 94%, and 63% to 96%, respectively. Notably, the 30 cm x 10 cm spacing yielded the highest seed yield of coriander, closely followed by 25 cm x 15 cm spacing with the same variety (Kaium *et al.* 2015).

Furthermore, substantial increases in the number of adopters were observed for seed treatment, soil treatment, and stem gall management during both pre- and post-demonstration periods, with adoption rates rising from 26% to 94%, 12% to 59%, and 38% to 96%, respectively. Tetarwal and Ramniwas (2022) reported similar findings, indicating adoption rates of 60%, 90%, and 100% for improved variety, proper seed rate, and seed treatment, respectively. Comparable results were also documented in coriander crop by Dhaka *et al.* (2015) and Poonia *et al.* (2017).

Energy budgeting

The input energy requirement of ICM demonstrations was measured at 6610 MJ ha^{-1}, which marked a 33.52% reduction compared to FP plots at 8826 MJ ha^{-1}. Within ICM plots, the majority of input energy was allocated to nitrogen (45.8%), followed by diesel (26.4%), machinery use (7.7%), and phosphorus (5.0%). Seed, potash, and insecticides accounted for 5.0%, 2.0%, and 1.19% of the input energy in ICM plots, respectively. Conversely, irrigation, fungicides, human labor, and bio inoculants consumed the least input energy, constituting 1.9%, 1.5%, 1.2%, and 1.2%, respectively, in ICM plots.

Table 4: Impact of integrated crop management practices of coriander on adoption of production technologies

Technology	Number of adopters (N=100)		Change in no. of adopters	Impact (% change)
	Before ICM	After ICM		
Improved variety: Ajmer Coriander 2	0	100	+100	-
Seed treatment: Fungicide: Carbendazim 50% WP@ 0.75 g + Thiram @1.5 g kg^{-1} seed & Culture: *Azotobacter* + PSB	26	94	+68	262
Soil treatment with *Trichodermaviride* @ 5 kg ha^{-1}	12	59	+47	392
Seed rate @ 20.0 kg ha^{-1}	47	86	+39	83
Spacing: 30 cm × 10 cm	47	86	+39	83
Nutrient management: N:P:K @ 50:30:20 kg ha^{-1}	63	92	+29	46
Hoeing and weeding	91	95	+4	4
Irrigation at 35-45 DAS	100	100	0	0
Insect management: Yellow sticky traps and use of Azadirachtin 10000ppm @ 2.0 ml litre^{-1} at ETL	44	94	+50	114
Stem gall management: Seed treatment + Soil treatment with *Trichodermaviride* @ 5 kg ha^{-1} + Spray of Tebuconazole 25.9 EC @ 650 ml ha^{-1}	38	96	+58	153

Source: Field survey of 2023-24

In FP plots, 52.0% of the total input energy was utilized for nitrogen and diesel alone (21.6%). The excessive use of nitrogenous fertilizers and additional tillage operations in FP plots led to increased total input energy consumption, despite no energy consumption for potassic fertilizer and bio inoculants. Table 5 illustrates that the total output energy from ICM plots was 92072 MJ ha^{-1}, inclusive of grain and stover yield, whereas in FP plots, it was only 86073 MJ ha^{-1}. ICM plots recorded 9.51%, 29.31%, 33.83%, and 31.57% higher net energy, energy use efficiency, energy productivity, and energy profitability, respectively. Conversely, energy intensiveness, specific energy, and energy intensity in physical terms were lower in ICM plots. Energy intensity in economic terms was similar in both farmers' practices and ICM practices. Similar findings were reported by Parihar *et al.* (2013), potentially attributed to lower input energy and higher yield and returns in ICM plots compared to FP. The higher input energy consumption in FP plots may be attributed to increased energy consumption from additional tillage operations, higher seed rates, and indiscriminate use of insecticides and fertilizers. Kumar *et al.* (2021) reported that the total input energy of integrated crop management practices for chickpeas was 5872.88 MJ ha^{-1}, which was 7.03% lower than traditional farmer practices (6316.79 MJ ha^{-1}) in irrigated clay loam soils. Energy inputs in the production of *rabi* annual crops typically involve fuel energy, chemical fertilizer energy, seed energy, machinery energy, farmyard manure energy, human labor energy, and chemical energy inputs (Dekamin *et al.*, 2022, Abshar and Sami 2016, Yadav *et al.*, 2018).

Conclusion

The study highlights the efficacy of integrated crop management (ICM) practices in enhancing coriander cultivation. Compared to traditional farmer practices (FP), ICM resulted in consistently higher yields, improved profitability, and increased adoption rates among farmers. Factors contributing to higher yields in ICM plots include disease-resistant varieties, optimal seed rates, and effective pest and disease management. Despite higher initial costs, ICM demonstrated superior economic returns and energy

Table 5. Impact of integrated crop management practices on energy budgeting of coriander

Particulars	ICM	FP
	Total energy equivalents ($MJ\ ha^{-1}$)	**Total energy equivalents ($MJ\ ha^{-1}$)**
A. Inputs		
Human labour	80.4 (1.2)	84.3 (1.0)
Machinery	511.0 (7.7)	592.5 (6.8)
Diesel	1745.6 (26.4)	1886.4 (21.6)
Nitrogen (N)	3030.0 (45.8)	4545.0 (52.0)
Phosphorus (P)	333.0 (5.0)	510.6 (5.8)
Potash (K)	134.0 (2.0)	00.0 (0.0)
Water for irrigation	122.4 (1.9)	122.4 (1.4)
Seed	294.0 (4.4)	529.2 (6.1)
Bio-inoculant	78.3 (1.2)	00.0 (0.0)
Insecticide	184.6 (2.8)	276.9 (3.2)
Fungicide	97.0 (1.5)	194.0 (2.2)
Total	6610.3 (100)	8741.3 (100)
B. Output		
Seed (kg)	31752	27783
By product (kg)	60320	58290
Total	92072	86073
C. Net energy ($MJha^{-1}$)	85462	77332
D. Energy use efficiency	13.93	9.85
E. Energy productivity ($kgMJ^{-1}$)	0.33	0.22
F. Energy intensiveness ($MJINR^{-1}$)	0.20	0.29
G. Energy profitability	12.93	8.85
H. Specific energy ($MJkg^{-1}$)	3.06	4.63
I. Energy intensity in physical terms ($MJkg^{-1}$)	1.05	1.48
J. Energy intensity in economic terms ($MJINR^{-1}$)	2.85	2.85

Figures in parentheses indicate percentage efficiency. The findings emphasize the importance of scaling up ICM practices to ensure the sustainability and resilience of coriander farming. By promoting innovation and knowledge transfer, stakeholders can drive positive outcomes for farmers and the environment alike.

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