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Evaluation of organic inputs against major foliar diseases of turmeric

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A two-year field experiment was conducted during 2020–21 and 2021–22 to evaluate selected organic inputs for the management of leaf spot caused by *Colletotrichum capsici* and leaf blotch caused by *Taphrina maculans* in turmeric. The experiment was laid out in a randomized block design with ten treatments and three replications. Turmeric rhizomes were treated with Beejamrit at 50 L per 100 kg rhizomes for 2 h, followed by five foliar sprays of cow urine, Panchgavya, liquid Jivamrit or fermented buttermilk at 5 or 10%, with the first spray applied at disease initiation and the remaining four sprays at 10-day intervals. Significant differences were observed among the treatments for disease intensity and rhizome yield. Rhizome treatment with Beejamrit followed by cow urine at 10% recorded the lowest pooled leaf spot intensity of 19.92%, compared with 29.76% in the untreated control. Beejamrit followed by liquid Jivamrit at 10% recorded the lowest pooled leaf blotch intensity of 33.61%, compared with 54.53% in the control. The same treatment also produced the highest rhizome yield of 25,216 kg ha{ ^{1}, whereas the untreated control yielded 15,771 kg ha{ ^{1}. It also recorded the highest reported incremental cost–benefit ratio of 1:20.41. The findings indicate that Beejamrit-based rhizome treatment combined with foliar application of liquid Jivamrit or cow urine may provide an effective and economical eco-safe approach for managing major foliar diseases of turmeric.

Keywords : *Colletotrichum capsica*, leaf blotch, leaf spot, management, organic inputs, *Taphrina maculans,* turmeric

INTRODUCTION

Turmeric (*Curcuma longa* L.), a rhizomatous herbaceous crop belonging to the family Zingiberaceae, is cultivated extensively in tropical and subtropical regions. Its rhizomes are widely used as a spice, natural colourant, food preservative and traditional medicine and also serve as an important raw material for the pharmaceutical, nutraceutical, cosmetic and textile industries. The growing demand for natural food additives and plant-derived bioactive compounds has further increased the agricultural and commercial importance of turmeric. Curcuminoids, particularly curcumin, together with volatile oils and other phenolic constituents, are primarily responsible for the antioxidant, anti-inflammatory, antimicrobial and other biological properties associated with turmeric (Iweala *et al.*, 2023; El-Saadony *et al.* 2023).

Despite its economic importance, turmeric production and rhizome quality are affected by several fungal and oomycetous diseases. The major diseases reported in turmeric include leaf spot or anthracnose caused by *Colletotrichum capsici* (Syd.) Butler and Bisby, leaf blotch caused by *Taphrina maculans* Butler, leaf rust caused by *Puccinia curcumae*, rhizome rot caused mainly by *Pythium* spp. and storage rots associated with pathogens such as *Sclerotium rolfsii*. Among these, leaf spot and leaf blotch are the most important foliar diseases because they damage the photosynthetically active leaf area and adversely affect rhizome development, yield and

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quality. Recent field investigations have reaffirmed that both diseases are widely prevalent and constitute serious constraints to profitable turmeric cultivation (Gohel *et al.* 2022; Kumar and Mishra, 2022).

Leaf spot generally appears as oblong, elliptic or irregular brown lesions, which may develop greyish-white centres and dark-brown margins. Under favourable conditions, the lesions enlarge and coalesce, resulting in extensive leaf blighting and premature drying. Leaf blotch initially develops as numerous small, oval to irregular, yellowish-brown or reddish-brown spots on both leaf surfaces. These spots subsequently enlarge and merge to form irregular necrotic patches, giving severely infected leaves a scorched appearance. Warm and humid weather, frequent rainfall, prolonged leaf wetness, dense crop canopy and cultivation of susceptible varieties favour the initiation and rapid development of these foliar diseases (Gohel *et al.* 2022; Kumar and Mishra, 2022).

Leaf spot and leaf blotch are important not only because of their widespread occurrence but also because of their adverse effects on rhizome yield and quality. Infection by *C. capsici* has been reported to reduce curcumin content to 2.08% in diseased rhizomes compared with 4.17% in healthy rhizomes, indicating that leaf spot affects the commercial quality as well as productivity of turmeric (Hudge and Ghugul, 2010). Severe leaf spot infection may cause substantial reductions in the fresh and dry weights of mother and finger rhizomes (Nair and Ramakrishnan, 1973). Similarly, leaf blotch caused by *T. maculans* may cause yield losses ranging from 37.6 to 52.9%, depending on cultivar susceptibility, crop stage, environmental conditions and disease severity (Panja *et al.* 2002). More recent studies have also recognized leaf spot and leaf blotch as destructive foliar diseases requiring timely and effective management under field conditions (Mishra and Singh, 2019; Gohel *et al.* 2022; Kumar and Mishra, 2022).

Management of these diseases has conventionally relied on rhizome treatment and repeated foliar applications of synthetic fungicides. Ready-mix and systemic fungicides can substantially reduce leaf spot and leaf blotch severity and improve rhizome yield when applied at appropriate concentrations and crop stages (Gohel *et al.* 2022). However, indiscriminate and repeated use of fungicides may increase production costs, leave undesirable residues in the harvested produce, disturb beneficial microorganisms and increase selection pressure for the development of fungicide-resistant pathogen populations. These concerns, together with the increasing demand for organically produced turmeric, have encouraged the development of environmentally compatible disease-management strategies.

Recent eco-safe plant-disease management emphasizes the combined use of healthy planting material, sanitation, cultural practices, organic inputs, botanical preparations, microbial antagonists and need-based application of safer plant-protection products. The use of disease-free rhizomes, rhizome treatment, removal of infected crop residues, adequate spacing, improved drainage and reduction of prolonged leaf wetness can lower the initial pathogen inoculum and make the crop environment less favourable for disease development. Botanicals and cow-urine-based formulations have also shown inhibitory activity against *T. maculans*, indicating their potential as components of eco-friendly leaf-blotch management programmes (Mishra and Singh, 2019; Kumar and Mishra, 2022).

Microbial antagonists such as species of *Trichoderma*, *Bacillus* and *Pseudomonas* are increasingly used in sustainable crop protection because they can suppress plant pathogens through competition for nutrients and infection sites, antibiosis, mycoparasitism, production of hydrolytic enzymes and induction of plant defence responses. Recent studies have highlighted the potential of *Trichoderma*- and *Bacillus*-based formulations as alternatives or supplements to conventional pesticides in integrated plant-disease management (Guzmán-Guzmán *et al.* 2023; Santoyo *et al.* 2024). Nevertheless, their performance under field conditions can be influenced by the antagonist strain, formulation, application method, pathogen population and prevailing environmental conditions.

Traditional organic preparations such as Beejamrit, Jivamrit, Panchgavya, fermented buttermilk and cow urine are locally available, comparatively inexpensive and compatible with organic farming systems. These preparations may contain nutrients, organic acids, indigenous microorganisms and biologically active metabolites capable of directly inhibiting pathogens, modifying the phyllosphere microbial community or improving the defensive capacity and vigour of plants. Beejamrit is commonly used for treating seeds or other planting materials, whereas Jivamrit and Panchgavya are applied to the soil or foliage to enhance microbial activity, nutrient availability and plant growth. Field evidence from other crops has demonstrated that the combined use of Beejamrit and Jivamrit can provide economical suppression of foliar diseases, although their effectiveness depends on preparation quality, concentration, application schedule, crop species and target pathogen (Patel and Gohel, 2023).

Although botanicals, microbial antagonists and organic formulations are receiving increasing attention, comparatively limited field information is available on the efficacy and economics of Beejamrit, Jivamrit, Panchgavya, fermented buttermilk and cow urine against both leaf spot and leaf blotch of turmeric. A systematic comparison of these locally available inputs is therefore necessary to identify treatments that provide consistent disease suppression, improve rhizome yield and remain economically feasible for growers. Considering the economic importance of turmeric, the destructive nature of leaf spot and leaf blotch and the need to reduce dependence on synthetic fungicides, the present investigation was undertaken to evaluate the efficacy and economics of selected organic inputs for the management of major foliar diseases of turmeric under field conditions.

MATERIALS AND METHODS

The field experiment was conducted during two consecutive kharif seasons, 2020–21 and 2021–22, at the Horticulture Farm, College of Horticulture, Anand Agricultural University, Anand, Gujarat, India. The susceptible turmeric variety Gujarat Navsari Turmeric-2 was used for the study. Healthy rhizomes were planted at a spacing of 45 × 15 cm following the recommended agronomic practices for turmeric, except for disease-management practices. All treatments from T_1 to T_9 received rhizome treatment with Beejamrit at 50 L per 100 kg rhizomes for 2 h. This treatment was followed by foliar application of different organic inputs at 5 or 10% concentrations. The untreated control did not receive any disease-management treatment. T_1- Rhizome dips treatment with *Beejamrit*, 50 liter/ 100 kg rhizomes for 2 hrs., T_2- T_1+ foliar spray of cow urine @ 5%, T_3- T_1 + foliar spray of cow urine @ 10%, T_4- T_1 + foliar spray of *panchgavya* @ 5%, T_5- T_1 + foliar spray of *panchgavya* @10%, T_6- T_1 + foliar spray of liquid *jivamrit* @ 5%, T_7-T_1 + foliar spray of liquid *jivamrit* @10%, T_8-T_1 + foliar spray of fermented buttermilk @5%, T_9- T_1 + foliar spray of fermented buttermilk @ 10% and T_{10}- Control. The Panchagavya (table 1) was prepared as per the method devised by the National Centre for Organic Farming (NCOF), Ghaziabad (Anonymous, 2017). Jeevamrutha (table 1) and Beejamrutha (table 1) were prepared as per the method given by Devvrat (2020) and the bioassay test was performed as mentioned above in cow urine. Three days' old cow-based buttermilk and fresh cow dung were used to test in-vitro efficacy against the pathogen. Additionally, microbial count, EC and pH of various organic inputs presented in Table 2.

The first foliar spray was applied at the initiation of disease, approximately 90 days after planting. The remaining four sprays were applied at 10-day intervals. A sticker was added to each spray solution at 1 ml L{ ^{1} of water. The total spray volume used per hectare and the actual quantity of each formulation applied per spray should be stated, because these values are required to verify the treatment dose and economic analysis. The experiment was conducted during two consecutive cropping seasons, i.e., *Kharif* 2020–2021 and *Kharif* 2021–2022 at Horticulture farm, College of Horticulture, Anand Agricultural University, Anand, Gujarat. Rhizomes of susceptible turmeric variety (Gujarat Navsari Turmeric- 2) [spacing: 45×15 cm] were planted into the experimental plot under recommended agronomical practices except disease management practices. Each replicate plot size was [gross: 3.60 × 1.8 m, net: 2.70 × 0.9 m]. All experiments were conducted during the *kharif* seasons in a randomized block design with three replications and ten treatments. The first spray of the organic inputs was given at the initiation of the disease and subsequently remaining four sprays were given at 10 days' interval. Buttermilk was placed for 3 days for fermentation. Sticker was added during spray at 10ml/10lit solution. The observation on disease intensity was recorded and to know the disease intensity, five plants were selected randomly from each plot. Three leaves each from top, middle and bottom portion of the plants were observed critically. The yield of rhizome per plot was recorded and converted in to hector for each treatment. The data on disease intensity was subjected to ANOVA. The disease rating was recorded by adopting the methodology suggested by Palarpawar and Ghurde (1989). Scale 0 = no infection, 1 = 0.1 to 10.0% necrotic leaf area, 2= 10.1 to 20% necrotic leaf area, 3= 20.1 to 30 % necrotic leaf area, 4=30.1 to 40% necrotic leaf area, 5= 40.1 to 50% necrotic leaf area and 6 = > 50% necrotic leaf area. Treatment used in the study are as follows: T_1- Rhizome dips treatment with *Beejamrit*, 50 liter/ 100 kg rhizomes for 2 hrs., T_2- T_1+ foliar spray of cow urine @ 5%, T_3- T_1 + foliar spray of cow urine @ 10%, T_4- T_1 + foliar spray of *panchgavya* @ 5% , T_5- T_1 + foliar spray of *panchgavya* @10%, T_6- T_1 + foliar spray of liquid *jivamrit* @ 5%, T_7-T_1 + foliar spray of liquid *jivamrit* @10%, T_8- T_1 + foliar spray of fermented buttermilk @5%, T_9- T_1 + foliar spray of fermented buttermilk @ 10% and T_{10}- Control. The Percent Disease Intensity (PDI) was calculated according to the formula suggested by Wheeler, 1969): PDI= [Sum of individual disease rating/ Number of leaves observed × Maximum disease scale] ×100. Fresh rhizome yield (kg /plot) was recorded treatment-wise at harvest of the crop. A significant difference ($p < 0.05$) between the treatments was determined by Duncan's multiple range test. Economic parameters such as cost of production and Incremental Cost–Benefit Ratio (ICBR) were calculated by considering all outputs and inputs. ICBR was calculated by the usage of the following formula; ICBR = [Net realization/ total cost of plant protection]. For the treatment effects which were found to be significant, the critical difference (CD) at 5% level of probability was worked out to compare two treatment means. Here we have used *panchgavya* with microbial count: 2.1×10^9 CFU/ml, EC: 11.5 (ds/m), pH: 6.18, *Jivamrit* with microbial count: 3.7×10^9 CFU/ml, EC: 4.5 (ds/m), pH: 8.41, Fermented butter milk with microbial count: 3.2×10^9CFU/ml, EC: 10.5 (ds/m), pH: 6.10 and cow urine with microbial count: 4.3×10^4 CFU/ ml, EC: 28 (ds/m), pH: 9.32.

RESULTS AND DISCUSSION

Effect of organic inputs on foliar disease intensity

All the organic-input treatments reduced the intensity of leaf spot and leaf blotch compared with the untreated control, although their effectiveness varied significantly. In the pooled analysis (Table 3), the lowest leaf spot intensity was recorded with rhizome dipping in Beejamrit followed by foliar application of cow urine at 10% (T3; 19.92%). This treatment was followed by cow urine at 5% (T2; 21.74%) and liquid Jivamrit at 10% (T7; 22.30%). In contrast, the untreated control recorded the highest leaf spot intensity of 29.76%.

The reduction in leaf spot following cow-urine application may be associated with its alkaline reaction and the presence of volatile compounds, salts and biologically active constituents that create conditions unfavourable for pathogen germination and infection. The cow urine used in the present study had a pH of 9.32 and an electrical conductivity of 28.0 dS m{ ^{1}, which may have contributed to direct inhibition of the pathogen on the leaf surface. In addition, the microbial population associated with the formulation may have modified the phyllosphere environment and restricted pathogen establishment. However, these mechanisms were not measured directly in the present investigation and should therefore be considered plausible explanations rather than experimentally confirmed modes of action.

The present findings agree with Mishra and Singh (2019), who reported effective suppression of *Taphrina* leaf blotch of turmeric by a cow-urine-based botanical formulation under field conditions. Kumar and Mishra (2022) also demonstrated the inhibitory activity of several botanicals against *T. maculans* and emphasized the potential of plant-

Table 1: Ingredients used for the preparation of *Panchagavya*

Ingredients	Quantity required
Fresh cow dung	7 kg
Fresh cow urine	10 litre
Cow milk	3 litre
Cow curd	2 litre
Cow ghee	1 kg
Jaggery	3 kg
Ripened banana	12 no.
Coconut water	3 litre
Water	10 litre
Fresh cow dung	10 kg
Fresh cow urine	10 litre
Jaggery	2 kg
Soil under banyan tree	500 g
Pulse flour	1 kg
Water	180 litre
Fresh cow dung	500 g
Fresh cow urine	500 ml
Rhizosphere soil of banyan tree	100 g
Lime	10 g
Water	2 litre

derived and locally available products for eco-friendly disease management. Their observations support the present finding that non-synthetic formulations can restrict the development of turmeric foliar diseases. Recent field research has nevertheless shown that the level of disease suppression depends on the formulation, concentration, application timing and prevailing environmental conditions (Gohel *et al.* 2022).

In the case of leaf blotch, rhizome treatment with Beejamrit followed by liquid Jivamrit at 10% (T_7) recorded the lowest disease intensity of 33.61%. This treatment was statistically at par with Beejamrit followed by cow urine at 10% (T_3; 36.23%). The untreated control recorded considerably higher leaf blotch intensity of 54.53%. These results indicate that a preventive rhizome treatment followed by repeated foliar application was more effective than rhizome treatment alone. The superior performance of liquid Jivamrit may be related to its high viable microbial population, which was 3.7 × 10y CFU ml{ ^{1} in the formulation used in this study. Jivamrit is a fermented organic preparation containing cow dung, cow urine, jaggery, pulse flour and soil. Such formulations may act as microbial inoculants and nutrient sources and may increase populations of beneficial microorganisms. Recent metagenomic evidence indicates that natural-farming inputs can alter microbial community structure and support organisms involved in nutrient cycling, plant growth and disease resilience (Gajjar *et al.* 2025). Natural-farming literature also describes Beejamrit as a treatment for protecting planting material against seed- and soil-borne pathogens, whereas Jivamrit is primarily used to enhance beneficial microbial activity and plant nutrition.

Table 2. Microbial analysis of organic inputs

Organic inputs	Microbial population (cfu/ml)	pH	EC (ds/m)
Cow urine (fresh)	8.3×10^{5}	8.88	43.0
Buttermilk	2.5×10^{7}	3.80	7.4
Panchgavya	9.9×10^{10}	4.38	13.8
Jivamrit	6.8×10^{8}	7.12	3.8
Beejamrit	7.6×10^{8}	7.54	13.0

Table 3 : Effect of organic inputs on foliar diseases and rhizome yield of turmeric (Pooled: 2020-21 & 2021-22)

	Disease intensity (%)		
Treatment	Leaf spot	Leaf blotch	Rhizome yield
T_1	31.93^{ab} (27.97)	42.64^{b} (45.89)	16913^{de}
T_2	27.79^{f} (21.74)	38.34^{cd} (38.48)	20308^{bc}
T_3	26.51^{g} (19.92)	37.01^{de} (36.23)	21957^{b}
T_4	31.86^{ab} (27.86)	41.48^{bc} (43.87)	18518^{cd}
T_5	30.29^{cd} (25.44)	39.62^{bcd} (40.67)	19151^{bcd}
T_6	29.27^{de} (23.90)	39.37^{bcd} (40.24)	17376^{de}
T_7	28.18^{ef} (22.30)	35.43^{e} (33.61)	25216^{a}
T_8	31.54^{bc} (27.36)	41.01^{bc} (43.06)	17253^{de}
T_9	29.50^{de} (24.25)	39.56^{bcd} (40.56)	19259^{bcd}
T_{10}	33.06^{a} (29.76)	47.60^{a} (54.53)	15771^{e}
S. Em.± T	0.45	0.11	848
Spray (S)	0.20	0.76	-
Y	0.20	0.24	416
SxT	0.94	1.43	-
YxS	0.28	0.34	1315
YxT	0.64	0.76	-
YxSxT	0.91	1.07	-
C.D. at 5% T	Sig.	Sig.	Sig.
C. V. %	5.26	4.64	12.77

Figures in the parentheses are retransformed values; those outside arc sin transformed values Treatments means with letter(s) in common are not significant by DNMRT at 5% level of significance Significant parameters and interactions: S,Y, YxSxT

Table 4 : Economics of organic inputs evaluated against the foliar disease of turmeric

Sr. No.	Organic input	Quantity of organic input required for 5 sprays (ml/ha)	Price of organic input (Rs./litre)	Cost of organic input (Rs./ha)	Labour cost (Rs./h)	Total Cost of plant protection (Rs./ha)	Yield (kg/ha)	Net gain over control (kg/ha)	Realization (Rs./ha)	ICBR
1	2	3	4	5	6	7	8	9	10	11
1	Rhizome dips treatment with *Beejamrit* @ 50 liter/ 100 kg rhizomes for 2 hrs.	1500	0.50	750	1234	1984	16913	1142	22840	1:12.51
2	T_1 + foliar spray of cow urine @ 5%	1500 +1250	0.50 + 1.00	2000	7404	9404	20308	7165	143300	1:16.24
3	T_1 + foliar spray of cow urine @ 10%	1500 +2500	0.50 + 1.00	3250	7404	10654	21957	8814	176280	1:17.55
4	T_1 + foliar spray of *panchgavya* @ 5%	1500 +1250	0.50 + 2.20	3510	7940	11450	18518	5375	107500	1:10.39
5	T_1 + foliar spray of *panchgavya* @ 10%	1500 +2500	0.50 + 2.20	6270	7940	14210	19151	6008	120160	1:9.46
6	T_1 + foliar spray of liquid *jivamrit* @ 5%	1500 +1250	0.50 +1.50	2625	7940	10565	17376	4233	84660	1:9.01
7	T_1 + foliar spray of liquid *jivamrit* @ 10%	1500 +2500	0.50 +1.50	4500	7940	12440	25216	12073	241460	1:20.41
8	T_1 + foliar spray of fermented buttermilk @ 5%	1500 +1250	0.50+ 20	25750	7404	33154	17253	4110	82200	1:3.48
9	T_1 + foliar spray of fermented buttermilk @ 10%	1500 +2500	0.48+ 20	50750	7404	58154	19259	6116	122320	1:3.10
10	Untreated check						15771	2628		

Note: 1. Labour charges: @ Rs. 349 per day x 2 Labour=698 Rs./ha and Rs. 268 per day x 2 labour = 536 Rs/ha. 698+536=1234. 1234 x 5 spray= 6170 2. Treatment no 4,5,6 and 7 required two unskilled labour (268 Rs.) for preparation of *Panchgavya* and *Jivamrit*. 3. Price of Turmeric rhizome yield: Rs.20/kg

The effectiveness of the Beejamrit–Jivamrit treatment may therefore have resulted from complementary effects. Beejamrit treatment of rhizomes might have reduced the initial load of rhizome-associated inoculum and protected emerging roots and shoots, while subsequent Jivamrit sprays might have modified the leaf-surface microbial environment and enhanced crop vigour. A recent review of natural-farming disease-management practices similarly reported that Beejamrit is used for treatment of planting material, whereas microbial formulations such as Jivamrit are employed to promote beneficial microbial diversity and disease resilience. Fermented buttermilk and other farm-made formulations have also been described as sources of metabolites capable of suppressing plant pathogens.

The relatively better disease reduction obtained with the 10% concentrations of cow urine and Jivamrit compared with their 5% concentrations suggests a concentration-dependent response. A higher concentration may have supplied a greater quantity of inhibitory metabolites, soluble nutrients and beneficial microorganisms to the treated leaf surface. Nevertheless, concentrations above 10% were not evaluated; consequently, the optimum concentration and the possibility of phytotoxicity at higher levels require further investigation.

Panchgavya and fermented buttermilk also reduced both foliar diseases compared with the untreated control, but they were less effective than cow urine and liquid Jivamrit. Panchgavya contains fermented dairy and cow-derived constituents and had a microbial population of 2.1 × 10y CFU ml{ ¹ in the present study. Fermented buttermilk contained 3.2 × 10y CFU ml{ ¹ and had an acidic pH of 6.10. Their moderate disease-suppressive effects may be associated with microbial competition, organic acids and fermentation-derived metabolites. However, microbial count alone did not determine treatment efficacy, because formulations with similar microbial populations produced different levels of disease control. The composition and activity of the microbial community, formulation pH, electrical conductivity, metabolite profile and survival of microorganisms on the leaf surface may all influence field performance.

Effect on rhizome yield

The pooled rhizome yield differed significantly among the treatments. The highest yield was obtained with Beejamrit rhizome treatment followed by liquid Jivamrit at 10% (T_7; 25,216 kg ha{ ¹). This represented an increase of 9,445 kg ha{ ¹ over the untreated control, which produced 15,771 kg ha{ ¹. The next highest yield was recorded with Beejamrit followed by cow urine at 10% (T_3; 21,957 kg ha{ ¹).

The higher yield obtained with liquid Jivamrit at 10% may be attributed partly to the lower intensity of leaf blotch and the consequent retention of greater photosynthetically active leaf area. Leaf blotch and leaf spot reduce functional leaf area and interfere with the production and translocation of photosynthates required for rhizome development. Recent studies continue to identify these diseases as important causes of turmeric yield reduction and emphasize that effective suppression of foliar infection is associated with improved rhizome productivity (Gohel *et al.*, 2022; Kumar and Mishra, 2022).

In addition to disease suppression, Jivamrit may have improved crop growth through enhanced nutrient availability and beneficial plant–microbe interactions. Studies of natural-farming systems have reported that Jivamrit and related fermented formulations can support microbial activity, nutrient cycling and nutrient uptake. Recent work has also shown that organic formulations including Beejamrit, Panchgavya and Jivamrit can improve soil biological properties and plant productivity, although the magnitude of response varies with crop, soil and management system.

The combined disease-suppressive and growth-promoting effects provide a reasonable explanation for the higher yield under T7. However, soil nutrient availability, leaf nutrient status, microbial-community composition and plant defence enzymes were not measured in the present study. Thus, the yield increase cannot be assigned to any single mechanism and is most appropriately interpreted as the combined outcome of reduced foliar disease and improved crop performance. Patel and Gohel (2023) similarly reported that treatment of potato tubers with Beejamrit followed by foliar sprays of Jivamrit provided effective and economical management of early blight. Although that investigation involved a different crop and pathogen, it supports the present observation that combining planting-material treatment with subsequent foliar application of fermented organic inputs may provide greater benefits than either intervention alone.

Economics of organic-input treatments

The economic analysis showed that Beejamrit followed by liquid Jivamrit at 10% recorded the highest incremental cost–benefit ratio of 1:20.41. It was followed by Beejamrit plus cow urine at 10% with an ICBR of 1:17.55 and Beejamrit plus cow urine at 5% with an ICBR of 1:16.24 (Table 4). The high economic return from liquid Jivamrit at 10% resulted from its comparatively low preparation cost and the substantial increase in rhizome yield over the untreated control.

The results demonstrate that biological effectiveness alone does not determine the suitability of an organic input. The cost of ingredients, labour required for preparation and application, quantity of formulation used and increase in marketable yield collectively determine economic feasibility. Fermented buttermilk treatments reduced disease intensity but recorded lower ICBR values because of their comparatively high input cost. In contrast, cow urine and Jivamrit were locally available at lower cost and produced greater yield advantages.

The favourable economics of Beejamrit and Jivamrit are consistent with the principle of natural farming, which emphasizes the use of locally available farm resources to reduce dependence on purchased external inputs. Recent studies have reported that such formulations can improve biological activity and crop performance at relatively low input cost, although their economic advantage varies across production systems.

Overall, rhizome treatment with Beejamrit followed by foliar application of liquid Jivamrit at 10% provided the best combined performance against leaf blotch, rhizome yield and economic return. Cow urine at 10% was the most effective treatment against leaf spot and also produced a favourable ICBR. These treatments may therefore be considered promising components of an eco-safe management programme for turmeric foliar diseases. Nevertheless, their performance should be validated across additional locations, varieties and seasons, and future studies should characterize the microbial communities and antimicrobial metabolites responsible for disease suppression.

CONCLUSION

The two-year field investigation demonstrated that the organic inputs evaluated in the present study significantly reduced leaf spot and leaf blotch intensity and improved turmeric rhizome yield compared with the untreated control. Rhizome treatment with Beejamrit followed by five foliar sprays of cow urine at 10% was the most effective treatment against leaf spot, recording the lowest pooled disease intensity of 19.92%. In contrast, rhizome treatment with Beejamrit followed by five foliar sprays of liquid Jivamrit at 10% was the most effective treatment against leaf blotch, with the lowest pooled disease intensity of 33.61%. The Beejamrit plus liquid Jivamrit treatment also produced the highest rhizome yield of 25,216 kg ha^{-1} and the highest incremental cost–benefit ratio of 1:20.41. Beejamrit followed by cow urine at 10% was the next most promising treatment, producing 21,957 kg ha^{-1} rhizome yield and an ICBR of 1:17.55. These findings indicate that Beejamrit-based rhizome treatment combined with foliar application of liquid Jivamrit or cow urine can serve as an economical and eco-safe component of integrated management programmes for the major foliar diseases of turmeric.

However, the efficacy of these preparations may vary with formulation quality, microbial composition, crop variety, location and prevailing environmental conditions. Therefore, further studies should validate the treatments across additional seasons, locations and turmeric cultivars. Future research should also standardize the preparation and storage procedures of these organic inputs and characterize their beneficial microorganisms, antimicrobial metabolites and possible mechanisms of disease suppression. Integration of these formulations with resistant cultivars, cultural practices and other biological control agents may further improve the consistency and sustainability of turmeric foliar-disease management.

DECLARATION

Conflict of Interest. Authors declare no conflict of interest.

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