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SHORT COMMUNICATION

Sustainable cauliflower production using inorganic fertilizers and natural farming formulations

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Cauliflower (*Brassica oleracea* var. *botrytis* L.) is a significant vegetable crop in the Brassicaceae family, widely cultivated worldwide due to its adaptability, nutritional benefits and high yield potential. It is rich in essential vitamins, protein and minerals such as potassium, sodium, calcium, iron, phosphorus and magnesium. Cauliflower is known for its versatile use in various cuisines, including vegetable dishes, soups, pickles and more, thanks to its tender white curds with a delightful taste and aroma. Despite its nutritional value and culinary versatility, cauliflower is a heavy feeder, requiring substantial nutrients from the soil. High-yielding cauliflower varieties have significantly increased production, but they demand large quantities of chemical fertilizers to meet their nutrient requirements, which has adverse effects on the environment and human health. The excessive use of chemical fertilizers since the Green Revolution has led to environmental pollution, soil degradation and depletion of non-renewable energy sources. Moreover, chemical fertilizers are costly and diminish the quality of produce, resulting in higher production costs and lower profits for farmers. To address these challenges, there is a growing need for integrated nutrient management (INM) practices that combine organic and inorganic nutrient sources. This approach aims to enhance nutrient availability, synchronize nutrient supply with crop demand, minimize nutrient imbalances and improve soil physical, chemical and biological properties. INM systems have shown promise in improving soil quality, increasing microbial populations and enhancing nutrient uptake in crops like cauliflower (Kumar and Srivastava, 2016).

Natural farming (NF) offers a sustainable alternative to chemical fertilizers by using homemade products like *Jeevamrit*, *Ghanjeevamrit* and *Beejamrit* (Palekar, 2009). These natural farming formulations, particularly those derived from cow products, contain beneficial microorganisms, nutrients, vitamins, amino acids and growth-promoting substances. They improve soil microflora, increase soil enzyme activity and enhance crop growth, yield and quality (Gore and

Sreenivasa, 2011). *Jeevamrit* is an organic preparation made from cow dung, cow urine, pulse flour, jaggery or molasses and farm soil, which stimulates microbial activity in the soil. It contains nitrogen-fixing bacteria (*Azotobacter*), phosphorus-solubilizing bacteria (*Pseudomonas*) and potash-solubilizing bacteria (*Bacillus sp.*), which help in nutrient availability and soil mineralization (Sreenivasa et al., 2010). Research by Palekar (2009) has shown that *Jeevamrit* application significantly increases nutrient uptake by crops. *Ghanjeevamrit* is a solid form of *Jeevamrit* suitable for areas with limited water availability and can be stored for longer periods compared to *Jeevamrit*. Integrated nutrient management, through the synergistic use of organic fertilizers alongside inorganic fertilizers, has the potential to sustain yield and quality while also enhancing soil health and productivity, thereby fostering sustainable crop production. This study aimed to explore how the combined use of various levels of inorganic fertilizers and natural farming formulations impacts nutrient absorption, soil attributes, soil microbial count and the economic viability of different treatments in cauliflower cultivation.

An exploration spanning the *Rabi*, 2021-22 and 2022-23 took place at the Experimental Research Farm of the Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. Positioned at an altitude of 1276 meters above mean sea level, the farm is situated between 30.51° North latitude and 77.10° East longitude. The research centered on cauliflower cv. PSBK-1 and encompassed thirteen treatments (Table 1), each with differing levels of inorganic fertilizers and natural farming formulations (Table 1). The cauliflower seeds were procured from ICAR-IARI, Regional Research Station, Katrain, Kullu, Himachal Pradesh. Prior to sowing, the seeds were subjected to treatment with *Beejamrit* at a rate of 1 liter per kilogram of seed. Seedlings were then transplanted at a spacing of 60 × 45 cm, following a Randomized Block Design with three replications. *Ghanjeevamrit* and *Jeevamrit* were applied at different quantities according to treatments at transplanting and as soil drench at 21-day intervals, prepared following Devvrat's methodology (2017). Soil samples were collected before and after the experiment at a depth of 0 to 15 cm and analyzed for various chemical and biological properties. Soil available nitrogen, phosphorus and potassium were also determined using standard procedures. The nutrient uptake in kilograms per hectare (kg ha^{-1}) was calculated by multiplying the nutrient content by biomass on a dry weight basis. Economic analysis, including cultivation costs, gross income, total cultivation costs, net income and benefit-cost ratio, was conducted using the Panse and Sukhatme (2000) model with MS-Excel and the OPSTAT package.

The uptake of nutrients in cauliflower plants was significantly affected by different combinations of inorganic fertilizers and natural farming formulations (Table 2). Maximum nitrogen (N) uptake (120.47 kg ha^{-1}) was recorded in 80% RDN + *Jeevamrit* 15% (soil drenching at 21 days intervals), significantly higher than all other treatments, while the minimum uptake was in 60% RDN + *Ghanjeevamrit* 90% (soil application @ 0.9 t ha^{-1}) (91.07 kg ha^{-1}). Integrated nutrient supply through various sources enhances nutrient uptake by increasing microbial activity and root growth, improving the growing medium (Kachot et al., 2001). Organic formulations like *Jeevamrit* and *Ghanjeevamrit* increase soil microorganism activity, improving soil properties and enhancing nitrogen uptake, leading to increased cauliflower yield compared to sole application of inorganic fertilizers

Table 1: Details of the treatments used in study

Treatment code	*Treatment details*
T1	Recommended Dose of Nutrients (RDN*)
T2	80% RDN + *Ghanjeevamrit* 110% (soil application @ 1.1 t ha^{-1})
T3	80% RDN + *Ghanjeevamrit* 100% (soil application @ 1 t ha^{-1})
T4	80% RDN + *Ghanjeevamrit* 90% (soil application @ 0.9 t ha^{-1})
T5	80% RDN + *Jeevamrit* 15% (soil drenching at 21 days interval)
T6	80% RDN + *Jeevamrit* 10% (soil drenching at 21 days interval)
T7	80% RDN + *Jeevamrit* 5% (soil drenching at 21 days interval)
T8	60% RDN + *Ghanjeevamrit* 110% (soil application @ 1.1 t ha^{-1})
T9	60% RDN + *Ghanjeevamrit* 100% (soil application @ 1 t ha^{-1})
T10	60% RDN + *Ghanjeevamrit* 90% (soil application @ 0.9 t ha^{-1})
T11	60% RDN + *Jeevamrit* 15% (soil drenching at 21 days interval)
T12	60% RDN + *Jeevamrit* 10% (soil drenching at 21 days interval)
T13	60% RDN + *Jeevamrit* 5% (soil drenching at 21 days interval)

RDN*: 125 kg ha^{-1} N, 76 kg ha^{-1} P_2O_5, 72 kg ha^{-1} K_2O

(Sharma et al., 2008). Optimum doses of NPK promote root development, nutrient deposition and water transportation, as seen in cole crops (Kumar and Devi, 2016). The uptake of phosphorus also differed significantly among treatments (Table 2). Maximum uptake (25.43 kg ha^{-1}) was in 80% RDN + *Jeevamrit* 15% (soil drenching at 21 days intervals) significantly higher than the minimum uptake (12.83 kg ha^{-1}) in 60% RDN + *Ghanjeevamrit* 90% (soil application @ 0.9 t ha^{-1}). The higher phosphorus uptake in 80% RDN + *Jeevamrit* 15% (soil drenching at 21-day intervals) was attributed to the combined application of inorganic fertilizers and *Jeevamrit*, which ensured phosphorus availability throughout the season. *Jeevamrit* contains essential micronutrients which are likely known to increase root activity and micronutrient chelates, enhancing nutrient uptake (Sharma et al., 2009). Potassium uptake also varied significantly among treatments, with maximum uptake (110.90 kg ha^{-1}) in 80% RDN + *Jeevamrit* 15% (soil drenching at 21 days intervals) and minimum (80.20 kg ha^{-1}) in treatment 60% RDN + *Ghanjeevamrit* 90% (soil application @ 0.9 t ha^{-1}). Organic formulations like *Ghanjeevamrit* and *Jeevamrit*, with beneficial microorganisms, might have improved nutrient availability and potassium uptake (Devakumar et al., 2014). Several studies reveal that *Jeevamrit* increases microbial load and growth hormones, enhancing nutrient absorption and crop production (Boraiah et al., 2017). The amalgamation of the recommended dose of fertilizers (RDF) with *Beejamrit*, *Jeevamrit* and P*anchagavya* demonstrated a notable increase in the concentration of nitrogen, phosphorus and potassium (NPK) in plants, as highlighted by Gore and Sreenivasa in 2011. The minimum NPK uptake in 60% RDN + *Ghanjeevamrit* 90% (soil application @ 0.9 t ha^{-1}) may be due to low levels of *Ghanjeevamrit* and inorganic fertilizers, insufficient for optimal plant growth.

Table 2: Pooled effects of inorganic fertilizers and natural farming formulations on N, P and K uptake (kg ha^{-1})

Treatment code	*N (kg ha^{-1})*	*P (kg ha^{-1})*	*K (kg ha^{-1})*
T1	113.37	20.93	102.20
T2	110.07	19.13	99.40
T3	107.37	18.53	96.60
T4	104.17	16.43	93.40
T5	120.47	25.43	110.90
T6	117.17	23.13	107.70
T7	115.77	22.43	104.50
T8	94.37	13.93	83.60
T9	93.17	13.43	82.10
T10	91.07	12.83	80.20
T11	100.57	15.83	89.90
T12	98.17	15.03	87.10
T13	96.37	14.63	85.70
CD (0.05)	0.81	0.86	0.15

The available NPK content of the soil after the experiment showed significant differences among treatments, as presented in Table 3. Recommended Dose of Nutrients (RDN) had the maximum available N (395.80 kg ha^{-1}), P (27.77 kg ha^{-1}) and K (439.70 kg ha^{-1}) in the soil, while 80% RDN + *Jeevamrit* 15% (soil drenching at 21 days interval) had the minimum values for available N (375.17 kg ha^{-1}), P (22.60 kg ha^{-1}) and K (410.93 kg ha^{-1}). The increase in available N, P and K content of soil after harvest in RDN could be attributed to the addition of 100% inorganic fertilizers, which directly increased the available NPK pool in the soil. Conversely, the minimum available NPK in the soil in 80% RDN + *Jeevamrit* 15% (soil drenching at 21-day intervals) could be due to increased uptake of available NPK by plants, leading to a reduction in soil NPK content. Similar findings were reported by Murmu *et al.* (2013) observed that plots receiving higher doses of nitrogen through inorganic fertilizers had maximum available N, attributed to the faster mineralization process in inorganic fertilizers, leading to immediate release and availability of nitrogen in the soil. They also suggested that the comparatively lower utilization of nitrogen by plants in RDN, due to low microbial activity, could be another reason for the increase in residual nitrogen content of the soil. Similar findings were reported by Tekasangla et al. (2015), who found maximum soil NPK values after harvest in plots receiving a sole application of 100% NPK fertilizers.

Analysis of the data presented in Table 3 reveals a significant impact of different levels of inorganic fertilizers and natural farming formulations on the viable microbial count in the soil. Notably, 80% RDN + *Jeevamrit* 15% (soil drenching at 21-day intervals) exhibited the highest bacterial (128.4×10^6 cfu g^{-1} of soil), fungal (16.5×10^4 cfu g^{-1} of soil) and actinomycetes count (67.80×10^4 cfu g^{-1} of soil). In contrast, RDN displayed the lowest bacterial (102.2×10^6 cfu g^{-1} of soil), fungal (6.2×10^4 cfu g^{-1} of soil) and actinomycetes count (40.03×10^4 cfu g^{-1} of soil). The heightened microbial count observed in 80% RDN + *Jeevamrit* 15% (soil drenching at 21-day intervals) is attributed to the substantial application of *Jeevamrit*, ensuring a consistent influx of microorganisms into the soil. The comparatively low microbial count in *Ghanjeevamrit* treatments compared to *Jeevamrit* treatments could be due to the low quantity and single application of *Ghanjeevamrit* at the time of transplanting, resulting in a relatively lower microbial population. Manjunatha et al. (2009) also found that the application of *Jeevamrit* provides a congenial environment for the growth of microorganisms, leading to increased nutrient availability for crop growth. Devakumar et al. (2014) reported the highest bacterial cfu of various species in *Jeevamrit*. The minimum viable microbial

Table 3: Pooled effects of inorganic fertilizers and natural farming formulations on available N, P and K content of soil (kg ha^{-1}) and viable microbial count (cfu g^{-1} of soil) after termination of the experiment

Treatment code	*Available N, P and K content of soil (kg ha^{-1})*			*Viable microbial count (cfu g^{-1} of soil)*		
	Soil N	*Soil P*	*Soil K*	*Bacteria (10^6 cfu g^{-1} of soil)*	*Fungi (10^4 cfu g^{-1} of soil)*	*Actinomycetes (10^4 cfu g^{-1} of soil)*
T1	395.80	27.77	439.70	102.20	6.20	40.03
T2	378.07	23.87	424.80	121.20	13.50	56.40
T3	380.77	24.07	426.10	120.00	12.10	56.07
T4	383.41	24.27	427.57	118.40	11.60	55.43
T5	375.17	22.60	410.93	128.40	16.50	67.80
T6	376.87	23.07	413.83	126.50	16.00	64.87
T7	378.00	23.20	419.50	123.40	15.20	62.90
T8	386.23	24.73	435.13	113.00	9.80	52.70
T9	389.41	24.90	437.03	112.00	9.20	52.47
T10	393.45	25.03	438.20	109.90	8.90	51.77
T11	383.70	24.33	428.37	115.80	10.80	60.07
T12	384.50	24.47	430.73	114.20	10.50	58.77
T13	388.30	24.63	433.10	113.70	10.20	57.17
$CD_{(0.05)}$	1.46	0.43	1.47	0.80	0.60	1.26

Table 4: Economics of cauliflower as affected by different treatments

Treatment Code	*Yield (q ha^{-1})*	*Gross Income (₹)*	*Cost of cultivation (₹)*	*Net Returns (₹)*	*B:C Ratio*
T1	221.45	221450	98056	123394	1.26
T2	218.96	218960	109510	109450	1.00
T3	218.20	218200	108310	109890	1.01
T4	216.96	216960	107110	109850	1.03
T5	268.39	268390	110710	157680	1.42
T6	260.09	260090	105910	154180	1.45
T7	228.89	228890	101110	127780	1.26
T8	194.37	194370	107771	86599	0.80
T9	190.60	190600	106571	84029	0.79
T10	169.85	169850	105371	64479	0.61
T11	207.90	207900	108971	98929	0.91
T12	205.92	205920	104171	101749	0.98
T13	199.00	199000	99371	99629	1.00
$CD_{(0.05)}$	5.59				

Sale Rate: ₹ 1000/quintal

count in RDN may be due to the lack of additional application of the organic formulation, which could have enhanced the microbial population.

The economic evaluation of cauliflower cultivation, impacted by various treatments, is condensed in Table 4. Over 80% RDN + *Jeevamrit* 15% (soil drenching at 21-day intervals) yielded the highest gross income per hectare, totaling ₹268,390, closely trailed by ₹260,090 in 80% RDN + *Jeevamrit* 10% (soil drenching at 21 days interval). Conversely, the lowest gross income per hectare, amounting to ₹169,850, was recorded at 60% RDN + *Ghanjeevamrit* 90% (soil application @ 0.9 t ha^{-1}). 80% RDN + *Jeevamrit* 10% (soil drenching at 21 days interval) also had the maximum benefit-cost (B:C) ratio of 1.45, followed by 1.42 in 80% RDN

+ *Jeevamrit* 15% (soil drenching at 21 days interval). Similar results were recorded by Amareswari and Sujathamma (2014). In the present study, 80% RDN + *Jeevamrit* 15% (soil drenching at 21 days interval) yielded the maximum income and net returns but with a comparatively lower B:C ratio compared to 80% RDN + *Jeevamrit* 10% (soil drenching at 21 days interval), which produced the maximum B:C ratio. This difference could be attributed to the lower amount of *Jeevamrit* used in 80% RDN + *Jeevamrit* 10% (soil drenching at 21-day intervals) (4800 liters) compared to 80% RDN + *Jeevamrit* 15% (soil drenching at 21 days interval) (7200 liters), resulting in lower expenditure for *Jeevamrit* ingredients. The economic analysis highlights the importance of integrated nutrient management practices, such as the application of *Jeevamrit* in maximizing gross income and B:C ratio in cauliflower cultivation.

In conclusion, the application of 80% RDN in conjunction with soil drenching of *Jeevamrit* @ 15% at 21-day intervals recorded the highest uptake of NPK, which had a significant effect on yield attributing traits. Best treatment recorded a 21% increase in yield over control and gave the highest net returns of Rs.157680/-.Thus, application of 80% RDN (100 kg N: 60.8 kg P_2O_5: 57.6 kg K_2O ha^{-1}) + *Jeevamrit* @ 15% (soil drenching at 21 days interval) can be recommended for cultivation of late group cauliflower for maximizing benefits.

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