

Integrated Assessment of Physiological and Biochemical Responses of Vegetable Crops under Natural Farming Practices

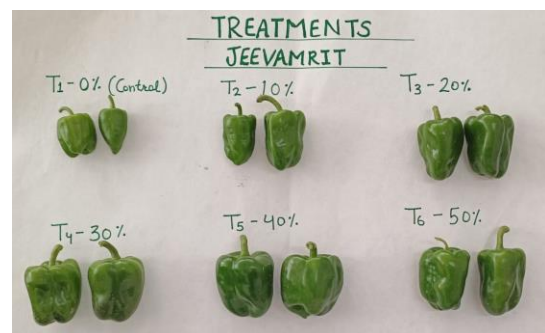
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INTRODUCTION

Vegetable crops are essential for human nutrition, supplying vitamins, minerals, dietary fibre and bioactive compounds. However, intensive production often depends heavily on mineral fertilizers and plant-protection chemicals. Natural Farming (NF) reduces dependence on external inputs by using locally available resources such as cow dung, cow urine, jaggery and pulse flour to improve soil fertility, microbial activity and crop productivity. Natural farming improves crop performance through four pillars: Jeevamrit, Beejamrit, Acchadhana and Whapasa. Its effect on vegetable crop extends beyond yield, influencing physiological processes such as photosynthetic rate, stomatal behaviour, transpiration and nutrient uptake, as well as biochemical traits including phenols, flavonoids and antioxidants, helping plants grow better and tolerate environmental stress. Recent studies, including cabbage grown under mid-hill conditions of Himachal Pradesh, indicate that different concentration of jeevamrit can improve these attributes, with moderate or optimum doses can be more effective than the highest dose (Verma et al. 2026). Similar improvements in crop growth and stress tolerance have been reported in spinach treated with jeevamrit and Beejamrit (Patel et al. 2024). These findings indicate that the influence of natural farming extends beyond crop yield and involves interconnected changes in the soil health, plant physiological processes and biochemical metabolism (Figure 1 & 2).



Figures 1 & 2: Layout of the natural farming experimental field (Fig. 1) and impact of Jeevamrit concentrations on *Capsicum annum* L. fruit growth at 60 DAT (Fig. 2)

2. Influence of Natural Farming on Physiological Attributes of Vegetable Crop

Physiological traits indicate how effectively vegetable crop respond under Natural Farming practices. Changes in soil biological activity, nutrient availability and moisture conditions may influence photosynthesis, canopy development and plant water relations, ultimately affecting crop growth and reproduction.

2.1 Photosynthesis, chlorophyll and carbon assimilation

Photosynthesis is the primary process through which plants convert light energy into chemical energy, producing the carbon assimilates required for growth and development. Chlorophyll content, photosynthetic rate and gas-exchange characteristics

are therefore important indicators of plant physiological performance. Under NF improved soil biological activity, nutrient availability and soil moisture conditions may support these processes, helping plants maintain efficient photosynthesis and growth under varying environmental conditions. For example, in ornamental kale, weekly application of 20% jeevamrit improve plant growth and chlorophyll content, along with greater accumulation of carotenoids and anthocyanins (Pangtu et al. 2026). Similarly, jeevamrit-based nutrient management in okra improved chlorophyll content and nutrient uptake, including better plant nutritional and physiological status (Jadhav et al. 2024).

2.2 Leaf development and canopy function

Leaf development determines the photosynthetic surface available for light interception, while the canopy determine how effectively plant capture sunlight and convert it into biomass. Natural Farming can promote leaf development and canopy growth by improving nutrient availability, soil moisture and biological activity around the roots. Jeevamrit application improved vegetative growth and plant spread in marigold under mid-hill conditions of Himachal Pradesh (Kaushal et al. 2024). Similarly in case of broccoli, integrated use of jeevamrit with other organic and inorganic inputs improved plant nutrient uptake, reflecting better crop growth and canopy development (Shukla et al. 2023).

2.3 Stomatal regulation, transpiration and water relations

Stomata serve to maintain equilibrium between intake of carbon dioxide and loss of water. The functioning of stomata has a direct impact on transpiration and photosynthesis, which means they have an important relation to the strategies of the plants concerning water economy. In case of tomato and okra, salinity altered stomatal conductance and transpiration, highlighting the role in stomatal regulation in maintaining water use efficiency (Yunusa et al. 2022). Similarly, in spinach, Jeevamrit and Beejamrit improved relative water content and reduce electrolyte leakage under drought and salinity (Patel et al. 2024).

3. Impact of Natural Farming on the Biochemical Attributes

3.1 Biochemical responses and antioxidant defence

Vegetables contain natural compounds such as phenol, flavonoids and antioxidant activity that contribute to nutritional quality and help to protect the plants from environmental stress. Natural farming can influence these compounds as well as the plant's antioxidant defence system. In case of a field experiment of cabbage, at different concentration of jeevamrit showed increased phenolic and flavonoid content along with antioxidant activity (Verma et al. 2026). Similarly, Jeevamrit and Beejamrit enhanced antioxidant enzymes such as SOR, CAT, APX and GR in spinach under drought and salinity, while improving plant water status (Patel et al. 2024).

3.2 Pigments, nutrient uptake and produce quality

Plant pigments such as chlorophyll and carotenoids serve roles other than those of photosynthesis. They provide protection against excess light and serve the purpose of harvesting light for photosynthesis and carotenoids in certain cases have nutritional significance. In case of fenugreek, Jeevamrit application increased chlorophyll and protein content, with 5% Jeevamrit spray showing a favourable response (Sugumaran et al. 2025).

4. Natural Farming and Tolerance to Environmental Stresses

Plants are sensitive to environmental stresses. Because of its relatively high need for water and nutrients, vegetable crops are particularly vulnerable. Environmental factors like drought, salinity and temperature changes affect the process of photosynthesis, water relations and oxidative stress in plants. The use of Jeevamrit and Beejamrit in spinach provides convincing proof of this. The treated spinach plants displayed improved growth, relative water content and activity of antioxidant enzymes as well as decreased electrolyte leakage during drought and salt stress (Patel et al., 2024).

5. Soil–Microbe–Plant Interactions: The Biological Basis of Crop Response

The response of crops under natural farming is closely associated with soil biological activity and rhizosphere processes. The rhizosphere serves as an important interface where microorganisms interact with plant roots and influence nutrient cycling and resource availability. Jeevamrit-based practices have been reported to improve soil fertility and microbial diversity observed increases in soil organic carbon, available phosphorus and potassium, along with diverse bacterial communities including *Bacillus*, *Pseudomonas* and *Rhizobium* indicating enhanced microbial functions related to nutrient and carbon metabolism.

6. Challenges and Research Gaps

Despite increasing evidence on natural farming, several scientific questions remain unresolved. The composition of preparations such as Jeevamrit can vary with the source and quality of ingredients, preparation method, fermentation period

and environmental conditions, making standard recommendation difficult. Its optimal levels may also vary among crops, with intermediate doses sometime performing better than higher levels (Verma et al. 2026). More long-term, replicated field studies across different soils, climates and vegetable crops are needed, as improved soil biological activity may not immediately increase yield.

7. Future Perspectives

Future research should move towards quantitative, crop and site-specific recommendations for natural farming. Standardizing jeevamrit preparation, concentration and application frequency is essential. A combined assessment of physiological, biochemical, soil microbial and nutrient use responses can better explain crop performance. Long-term, multi-season comparison with organic and conventional systems are also needed to identify where Natural Farming offers clear advantages in productivity, quality, resource use efficiency and soil health.

8. Conclusion

Natural farming influences vegetable crops through a combination of soil, microbial, physiological and biochemical processes. Practices such as Jeevamrit application, Beejamrit treatment and mulching can improve the biological condition of the rhizosphere, support nutrient cycling and moisture conservation and influence plant physiological processes such as photosynthesis, stomatal behaviour and water relations. These changes can subsequently affect biochemical characteristics. An integrated assessment combining soil health, plant physiology, biochemical composition, stress tolerance, yield and nutritional quality provide a more meaningful understanding of its potential.

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