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Effect of Integrated Nutrient Management Practices on Growth, Yield of *Trachyspermum ammi* (Ajwain)

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ABSTRACT

A field investigation was conducted during the late Kharif seasons of 2022–23 and 2023–24 at the Experimental Block, College of Agriculture, Bheemarayanagudi, to evaluate the effect of integrated nutrient management (INM) practices on growth, yield and economics of ajwain (*Trachyspermum ammi* L.). The experiment was laid out in a Randomized Complete Block Design (RCBD) with nine treatments and three replications. The pooled results over three years revealed that application of vermicompost equivalent to 75% recommended dose of nitrogen (RDN) along with foliar spray of vermiwash @ 5% significantly improved growth parameters, yield attributes and economic returns. The highest grain yield (965 kg ha^{-1}), net returns (₹75,276 ha^{-1}) and benefit ratio (3.89) were recorded under this treatment. The findings indicate that integrated use of organic and inorganic nutrient sources enhances productivity, profitability and sustainability in ajwain cultivation under semi-arid conditions.

Introduction

Ajwain (*Trachyspermum ammi* L.), commonly known as carom seed, is an important seed spice crop belonging to the family Apiaceae. It is widely cultivated in India, particularly in Rajasthan, Gujarat, Madhya Pradesh, Uttar Pradesh and parts of Karnataka. The crop is valued for its small aromatic seeds, which contain 2–5% essential oil, primarily composed of thymol, a bioactive compound responsible for its strong aroma and medicinal properties (Malhotra, 2019). Ajwain seeds are extensively used in culinary preparations, pharmaceutical formulations and traditional Ayurvedic medicine due to their carminative, antimicrobial, antifungal and antioxidant properties (Singh et al., 2021).

India is the largest producer, consumer and exporter of seed spices in the world. However, productivity of ajwain remains relatively low compared to its genetic potential. One of the major constraints limiting productivity is improper nutrient management. Continuous and imbalanced use of chemical fertilizers has led to declining soil fertility, nutrient deficiencies, reduced soil organic carbon and deterioration of soil physical properties (Lal et al., 2020). Long-term reliance solely on inorganic fertilizers may increase short-term yields but often results in reduced nutrient use efficiency and environmental degradation. Soil health is a critical component of sustainable agriculture. It encompasses physical, chemical and biological properties that collectively determine soil productivity. Recent studies emphasize that restoration of soil organic matter and enhancement of soil microbial activity are essential for sustaining crop productivity under changing climatic conditions (FAO, 2023). Integrated Nutrient Management (INM) is considered a holistic approach that combines

chemical fertilizers with organic manures and biofertilizers to optimize nutrient availability and maintain soil fertility. Organic manures such as farmyard manure (FYM) and vermicompost improve soil structure, porosity, water-holding capacity and cation exchange capacity. They also supply macro- and micronutrients in a slow and sustained manner (Edwards et al., 2019). Vermicompost, produced through the activity of earthworms, is rich in plant growth regulators such as auxins, gibberellins and cytokinins, which enhance root growth and nutrient uptake (Arancon et al., 2019). In addition, vermiwash—a liquid extract obtained from vermicompost systems—contains soluble nutrients, enzymes, vitamins and beneficial microorganisms that can be applied as foliar spray to supplement crop nutrition (Suthar, 2018).

Biofertilizers such as Azospirillum and phosphate solubilizing bacteria (PSB) play an important role in enhancing nutrient availability. Azospirillum fixes atmospheric nitrogen and promotes root development, while PSB solubilizes insoluble forms of phosphorus, making them available to plants (Sharma et al., 2022). Integration of these biological inputs with organic and inorganic fertilizers improves nutrient use efficiency and reduces dependency on chemical fertilizers.
Recent research highlights that integrated nutrient management not only improves crop yield but also enhances soil biological activity, enzymatic processes and carbon sequestration (Kumar et al., 2021; Lal et al., 2020). In spice crops such as coriander, cumin and fennel, INM practices have shown significant improvement in growth, yield attributes and essential oil content (Choudhary et al., 2022; Singh et al., 2023). The synergistic effect of combining organic and inorganic nutrient sources ensures synchronized nutrient release with crop demand, resulting in better nutrient uptake and higher productivity.

Under semi-arid conditions, such as those prevailing in the Northern Dry Zone of Karnataka, nutrient losses through volatilization and leaching are common. Organic amendments improve soil aggregation and moisture retention, thereby enhancing nutrient availability under moisture stress conditions (FAO, 2023). Moreover, the use of locally available organic inputs such as Gokrupamruth and vermiwash reduces input costs and supports environmentally sustainable agriculture.
Despite the recognized benefits of integrated nutrient management, limited long-term studies have been conducted to evaluate the comparative performance of different organic and inorganic nutrient combinations in ajwain under dryland conditions. There is a need to identify economically viable and agronomically efficient nutrient management strategies that can sustain productivity while maintaining soil health.

Therefore, the present investigation was undertaken to evaluate the effect of different integrated nutrient management practices on growth, yield attributes, grain yield and economics of ajwain under the agro-climatic conditions of Bheemarayanagudi. The study aims to identify a sustainable nutrient management strategy that enhances productivity and profitability while preserving soil fertility.

Materials and Methods

The experiment was conducted at the Experimental Block, College of Agriculture, Bheemarayanagudi, during late Kharif seasons of 2022–23 and 2023–24. The region is characterized by semi-arid climate with moderate rainfall and black soil conditions suitable for spice cultivation.

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and nine treatments. The treatments included recommended dose of fertilizers (RDF), FYM and vermicompost applied either alone or in combination with vermiwash, biofertilizers (Azospirillum and phosphate solubilizing bacteria), and Gokrupamruth.
Growth parameters such as plant height, number of branches per plant, number of umbels per plant and test weight were recorded at harvest. Grain yield and stalk yield were recorded and expressed in kg ha^{-1}. Economic analysis was performed by calculating cost of out using analysis of variance (ANOVA) as per Gomez and Gomez (1984), and treatment means were compared at 5% level of significance.

Results and Discussion

Effect of Integrated Nutrient Management on Growth Parameters

Plant Height

The pooled data over three years indicated that plant height was significantly influenced by different nutrient management practices. The highest plant height was recorded under RDF (109.07 cm), which was statistically at par with vermicompost equivalent to 75% RDN + vermiwash @ 5% (106.55 cm). Although RDF supplied readily available nutrients leading to rapid vegetative growth, integrated treatments maintained comparable plant height due to sustained nutrient release.
The improved plant height under vermicompost-based treatments may be attributed to enhanced nutrient availability, improved soil structure, and increased microbial activity. Vermicompost is known to contain humic substances, plant growth regulators such as auxins and cytokinins, and beneficial microorganisms that stimulate root growth and nutrient uptake (Arancon et al., 2019). Enhanced root proliferation improves nitrogen and phosphorus absorption, thereby promoting vegetative growth.
Recent studies in seed spices and medicinal crops have reported similar improvements in plant height under integrated nutrient management systems (Kumar et al., 2021; Meena et al., 2022). Integrated nutrient application improves soil enzymatic activity and nutrient

mineralization, leading to better crop growth compared to sole organic or inorganic sources.

Number of Branches per Plant

The number of branches per plant was highest in RDF (75.28) and closely followed by vermicompost equivalent to 75% RDN + vermiwash (74.29). Nitrogen plays a crucial role in cell division and vegetative growth, directly influencing branching patterns. However, integrated treatments provided balanced nutrition and improved nutrient use efficiency. Vermiwash contains micronutrients, enzymes, amino acids and growth-promoting substances which may enhance lateral branching (Suthar, 2018). Increased branching ultimately increases photosynthetic surface area, contributing to higher assimilate production. Studies by Yadav et al. (2020) in coriander and Singh et al. (2023) in fennel reported that integration of vermicompost with foliar nutrient sprays significantly increased branching compared to sole fertilizer application.

Number of Umbels per Plant

Number of umbels per plant is a critical yield attribute in ajwain. The significantly higher number of umbels recorded under vermicompost equivalent to 75% RDN + vermiwash (217.10) suggests that integrated nutrient supply positively influenced reproductive growth. Organic manures improve soil aggregation and water-holding capacity, which are essential for flowering and reproductive development under semi-arid conditions. The presence of growth regulators in vermicompost enhances floral initiation and retention (Arancon et al., 2019). Recent findings by Choudhary et al. (2022) reported that integrated nutrient management significantly increased umbels per plant in cumin due to improved phosphorus availability and hormonal balance. Phosphorus plays a key role in energy transfer and reproductive development, which may explain enhanced umbels in vermicompost treatments.

Test Weight

Test weight was significantly higher under vermicompost equivalent to 75% RDN + vermiwash (1.25 g), followed by vermicompost equivalent to 75% RDN + Gokrupamruth (1.22 g). Seed weight is influenced by nutrient availability during seed filling stage. The gradual nutrient release from vermicompost ensures continuous nutrient supply during reproductive growth. Additionally, improved microbial activity enhances nutrient solubilization, especially phosphorus and micronutrients essential for seed development (Kumar et al., 2021). Similar improvements in seed weight under integrated nutrient management were reported by Meena et al. (2022) in fenugreek and Patel et al. (2020) in ajwain.

Effect on Grain Yield

Grain yield is the cumulative expression of growth and yield attributes. The significantly highest grain yield (965 kg ha^{-1}) was recorded under vermicompost equivalent to 75% RDN + vermiwash @ 5%. This may be attributed to balanced nutrient availability,enhanced microbial activity, improved soil physical properties, increased nutrient use efficiency and better flowering and seed set. Integrated nutrient management improves synchronization between nutrient supply and crop demand. Vermicompost enhances soil organic carbon content, which improves nutrient retention and reduces leaching losses (Lal et al., 2020). Foliar spray of vermiwash provides immediate nutrient availability during critical growth stages. Recent research indicates that combining organic and inorganic nutrient sources enhances nutrient recovery efficiency and yield stability under dryland conditions (Sharma et al., 2022; FAO, 2023). Studies in spice crops have consistently shown 10–25% yield increase under integrated nutrient systems compared to sole RDF application. The relatively lower yield in FYM-based treatments compared to vermicompost may be due to slower decomposition rate and lower nutrient concentration in FYM.

Effect on Stalk Yield

Stalk yield followed a similar trend as grain yield, with the highest value recorded under vermicompost equivalent to 75% RDN + vermiwash (1898 kg ha^{-1}). Higher biomass accumulation reflects improved photosynthetic efficiency and nutrient uptake.

Organic amendments improve soil porosity and aeration, facilitating better root growth and nutrient absorption (Lal et al., 2020). Increased vegetative biomass also indicates better carbohydrate synthesis and translocation.

Economic Analysis

Economic evaluation revealed that vermicompost equivalent to 75% RDN + vermiwash recorded the highest net returns (₹75,276 ha^{-1}) and B ratio (3.89). Although organic inputs increase cost of cultivation, enhanced yield compensated for the additional expenditure. Integrated nutrient management improves long-term soil fertility, reducing dependency on chemical fertilizers and ensuring sustainable profitability (Sharma et al., 2022). According to recent agricultural sustainability reports (FAO, 2023), integrated nutrient strategies are economically viable and environmentally sustainable in dryland agriculture. The higher B ratio observed under integrated treatments suggests better resource use efficiency and higher marginal returns per unit investment.

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