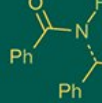


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Sustainable chickpea production through integrated nutrient management under Doon Valley Agro-ecosystem: A review

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Abstract

Chickpea (*Cicer arietinum* L.) a nutritionally significant gram legume and plays a crucial role for sustaining agriculture, improving soil fertility and ensuring nutritional security and security in world. India is the leading nation in both cultivation and consumption of chickpea but also, nutrient depletion, soil health and imbalance in fertilizer use limit chickpea productivity. Integrated Nutrient Management (INM) revolves around the sensible combination of chemical fertilizers, organic manures and biofertilizers together and it has been revolving around the functional combination for improving soil fertility and crop productivity. This review examines the effect of INM practices on soil, physical, chemical and biological properties as well as growth, yield and nutrient uptake of chickpea. The integrated use of farmyard manure, vermicompost, Rhizobium and recommended fertilizer doses resulted in a significant improvement in soil organic carbon, microbial activity, nutrient availability and grain yield in various studies. The review also highlights the instruments leading to yield enhancement in INM system and identify critical research under Doon Valley conditions. The nutrient management ensure that the sustainability of chickpea production in the shifting the climatic pattern, long-term soil fertility maintenance and precision nutrient management approaches.

Keywords: Chickpea, Integrated Nutrient Management, Soil Health, Biofertilizers, Productivity, Vermicompost, Doon Valley

Introduction

Chickpea (*Cicer arietinum* L.) ranks among the major pulses of the Fabaceae family which thrives across semi-arid and sub-tropical agro-climatic zones across the world. It plays an important role in food and nutritional security, especially in developing countries. Chickpea seeds are rich in protein (18-24%), carbohydrates, dietary fiber, minerals and vitamins, which are indispensable to human diets. In addition to its nutritional value, chickpea is also valuable for its biological nitrogen fixation and crop rotation capabilities in improving soil fertility (Sande *et al.*, 2024)^[1].

Chickpea is one of the important pulse crops globally as it is very adaptable to various agro-climatic zones and is comparatively low water demanding crop. India produces the largest quantity of chickpea plant and contributes approximately two-thirds of the total global chickpea output. Major chickpea-growing states within the country include Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh and Karnataka. Despite its significance, the productivity of chickpea is comparatively low attributed to nutrient imbalance, low soil fertility, poor nutrient use efficiency, and variability in rainfall (Kumar *et al.*, 2025)^[7].

The excessive dependence on synthetic fertilizers has caused imbalance in nutrient levels, decreased soil microbial activity, soil degradation and pollution of the environment. Relying exclusively on inorganic fertilizers in the long term can lead to reduced fertilizer use efficiency and overall agricultural production. Thus, sustainable nutrient management strategies are essential for preserving long term soil productive and ensuring stable crop production under the growing pressure of environmental and climatic worries (Dwivedi *et al.*, 2024)^[5].

Integrated Nutrient Management (INM) represents one of the sustainable practices that has been developed to promote soil health and productivity. INM is the sensible balanced integration of mineral fertilizers, organic amendments and microbial inoculants for providing

best crop nutritional requirements while maintaining ecological balance. Biofertilizers like Rhizobium, phosphate-solubilizing bacteria (PSB) can also be used to improve the nutrient solubilization and biological nitrogen fixation (Meravi *et al.*, 2024) ^[3], while carbon rich organic inputs such as farmyard manure (FYM) play a significant role in naturalizing soil biological health.

The Doon Valley region of Uttarakhand has distinct agro-ecological conditions with respect to moderate climatic conditions and varying amount of rainfall and soil conditions. The soil has become depleted and soil fertility has been reduced through continuous cultivation and over use of fertilizer. So, adaptation of an integrated approach to nutrient management becomes imperative to restore soil vitality and achieve sustainable chickpea productivity.

2. Global and Indian Scenario of Chickpea

Globally, chickpea occupies the third position among pulse crops in terms of importance, following dry chickpea, and its cultivation extends across more than 50 nations spanning Asia, Africa, Australia and the Mediterranean belt. Global status of the agricultural production indicate that the production of chickpeas has increased in the recent years as a result of increased awareness of the importance of protein-rich diets and sustainable farming practices. The value of chickpeas is associated with their capacity in nitrogen fixation and soil fertility improvement in agricultural production (FAO, 2024).

India has its favorable climate conditions which contribute to its dominance in global chickpea production and cultivation area. The crop is mostly grown in the rabi season in rainfed condition. Growing of chickpea not only helps in enhancing the farm income, but also helps in enhancing the fertility of the soil by virtue of its symbiotic nitrogen fixation. Chickpea has a deep root system which helps in enhancing soil physical style and utilization of residual soil moisture.

The use of conjunctive nutrient management strategies resulted towards better productivity of chickpea cultivation as well as soil fertility. The use of combined FYM + biofertilizers + recommended fertilizer dose has also resulted in higher grain yield and nutrient uptake than provided by the fertilizer alone Sharma *et al.* (2023) ^[8]

The chickpea yield performance in India is still low as compared to its potential productivity due to nutrient deficiency, low organic matter content and poor soil management practices. In several chickpea growing areas, micronutrient deficiencies (Zinc, Sulfur and Boron) are now prevalent. Hence, there is a need for balanced nutrient management strategies for better crop performance and soil sustainability.

Current research has shown that using organic manures in combination with inorganic fertilizers not only increases the efficiency of use of nutrients but also increases the biological activity and moisture holding capacity of the soil. These practices are particularly beneficial in agriculture with rainfed and limited resource farming systems where soil degradation is a great challenge (Abisankar *et al.*, 2024) ^[4].

3. Concept and Importance of the Integrated Nutrient Management Approach

Integrated Nutrient Management can be described as efficient and balanced utilization of synthetic fertilizers,

carbon rich organic inputs and biofertilizers for long term productivity while maintaining the soil fertility. Its primary goal of INM is to optimize nutrient availability, minimize nutrient depletion and maintain ecological balance without compromising soil health.

Chemical fertilizers are sources of rapidly available nutrients to the crops and are also used to gain higher yield in a short period. However, over-fertilization can lead to imbalance and pollution of the environment. Organic manures elevate soil organic matter content and stimulate microbial populations which increase water holding capacity. Biofertilizers have a major role in nutrient mobilization and N fixation.

The nutrient integration had a significant positive bearing on soil productive capacity and overall crop output, mainly due to the improvement of nutrient cycling the interaction between soil microbes and rhizosphere, under the rhizosphere. The benefits of using organic and inorganic nutrients together, both in terms of their availability and nutrient losses from soil Sande *et al.*, (2024) ^[1].

Leguminous crops like chickpea can be enhanced by biofertilizers like Rhizobium which enhances nitrogen fixation. The phosphate-solubilizing bacteria convert and fixed, unavailable forms of phosphorous into plant-accessible soluble forms, thereby facilitating phosphorous acquisition by roots and promoting root proliferation. Likewise, under nutrient deficiency situations, potassium-solubilizing bacteria enhances the availability of potassium and consequently crop growth.

The integrated use of vermicompost, Rhizobium and recommended dose of fertilizer increased soil organic fractions, mineral nitrogen availability and microbial population density in chickpea field. The grain yield and economic returns were also higher for the combined treatment than the single chemical fertilizers Dwivedi *et al.*, (2024) ^[5].

Integrated nutrient management further contributes significantly in environmental sustainability, since less resilience on chemical fertilizers and the leaching of nutrients. Regular addition of organic matter enhances soil aggregation, soil aeration and soil water infiltration. Such enhancements foster a more conducive environment for root expansion and microbial activity and, in the end, improve nutrient use efficiency and productivity.

4. Influence of Integrated Nutrient Management on Soil characteristics

4.1 Impact on Physical Attributes of soil

Soil physical characteristics occupy a central position in regulating crop development and degerming agricultural output. Key Parameters include Soil structure, porosity, bulk density and water retention capacity is significantly improved by the use of integrated nutrient management practices (INMPs) which involve the addition of organic matter. Farmyard manure and vermicompost application enhances the soil aggregation and decreases soil compaction that improves root penetration and water movement. Better soil structure will improve aeration and provide good conditions for microorganisms.

The application of integrated use of Rhizobium, seaweed extract and 75% RDF significantly affected soil moisture holding capacity, porosity in the cultivation of chickpea. The soil combination was improved and bulk density was decreased by the use of carbon rich organic amendments

instead of sole dependence on synthetic fertilizers. Also, incorporation of organic materials considerably improves moisture retention ability of the soil, a particularly valuable advantage under moisture stress conditions. Increased water holding capacity will improve plant water status and increase the drought tolerance of crops in rainfed agriculture Rani *et al.*, (2023)^[6]

vermicompost in combination with inorganic fertilizer substantially affected the soil texture and decreased hardness of the soil in chickpea fields. The better physical conditions encouraged better root growth and uptake Meravi *et al.*, (2024)^[3].

4.2 Effect on Soil Chemical Properties

Incorporation of Integrated nutrient management practices has a beneficial effect on soil chemical properties which includes enhancement of soil nutrient availability and soil fertility balance. Organic manures are slowly released and improve nutrient holding capacity of soil.

The use of FYM and compost improves the soil organic carbon content which is a major factor in soil nutrient cycling and cation exchange capacity. An increase in organic carbon will result in a greater nutrient retention and reduce nutrient losses from leaching. After harvesting of chickpea, Sharma *et al.* (2023)^[8] reported that macro-nutrients availability including nitrogen, potassium and potassium recoded a marked increase when FYM was conjunctively applied alongside the recommended fertilizer schedule. The authors also observed that micronutrient availability, especially sulfur and zinc was improved.

Biofertilizers promote efficient uptake of nutrients and nutrient solubilization. The phosphate-solubilizing bacteria convert insoluble phosphorus (IP) compounds into available phosphorus (AP) which facilitates uptake by the plants. It shows the INM system have large effect on soil fertility parameters and nutrient uptake in chickpea. Available phosphorus and zinc content in soil was higher in treatments that received PSB and the zinc-solubilizing bacteria. Also, using organic manures continuously reduces the toxicity of nutrients in soil pH. The nutrient balance in the soil improved with INM practices, which directed to sustainable nutrient management and accordingly long-term productivity Kumar *et al.* (2025)^[7].

4.3 Biological property of soil under INM for Chickpea Production

Soil biological characteristics are connected with the processes related to nutrient cycling, organic matter decomposition, microbial activity and overall soil fertility; these properties are important indicators of soil health. Integrated Nutrient Management (INM) practices improve being adopted enhances biological condition of soil with the use of fertilizers together with organic manure and biofertilizer. Farmyard manure (FYM), vermicompost, poultry manure application along with Rhizobium and phosphate solubilizing bacteria (PSB) has shown to enhance microbial biomass, enzyme activities and soil respiration in chickpea alone soils Mukati *et al.*, (2021)^[12]. These biological improvements help in enhancing nutrient mineralization improved availability to plants and promotion of soil development and sustainable productivity to support better crop growth Prakash *et al.*, (2022)^[13].

5. Future Scope

Significant research advances have been achieved in the field of integrated nutrient management of chickpea, but there are areas of research that require further and detailed study particularly under Doon Valley conditions. Further studies are needed with the aim of developing nutrient management practices to be applied to the specific geographic location depending on soil type, climatic conditions, cropping systems in the area. Nutrient availability and crop response differ according to sites, so site-specific recommendations for INM will be beneficial for efficient nutrient utilization and higher crop yield. Extended field investigations are necessary to evaluate the lasting effects of INM practices on soil health, microbial population and the sustainable of chickpea cropping systems. Long term monitoring of soil organic carbon, nutrient dynamics and biological activity under integrated nutrient application will help in understanding long term impact on soil health.

Focus should also be placed on the micronutrient management, especially zinc, sulfur, boron and iron, as deficiencies of these micronutrients are emerging in the regions of growing pulses. Future research is required on micronutrient interaction with organic manures and biofertilizers to enhance uptake of micronutrients and yield of chickpea. Another critical research interest is the study of approaches to nutrient management that can help mitigate climate impacts. Higher temperatures, and unpredictable or moisture stress rainfall conditions, may have an impact on nutrient availability and crop growth. Therefore, integrated nutrient practices that can be adopted in drought and climate stress conditions for sustainable pulse production should be developed.

Besides this, the use of innovative technologies like use of nano-fertilizers, microbial groups, precision nutrient management and remote sensing also provide opportunities to optimize nutrient use efficiency in the cultivation of chickpea. Research related to the combination of nano-nutrients and organic manure along with the biofertilizers can be helpful to find new solutions for sustainable agriculture. The next step is to consider how integrated nutrient management practices economically applied and accepted by farmers in the Doon Valley region. Allowing farmers through training and awareness-building enterprises on sustainable nutrient management can contribute to the uptake of such practices and enhance the sustainability of agriculture. So, the future research on integrated nutrient management should focus on sustainable options, climate-resilient strategies, soil biological health and precision agriculture techniques to increase chickpea productivity to ensure long-term soil fertility under the conditions of Doon Valley.

Conclusion

Integrated Nutrient Management (INM) has emerged as a reliable and eco- friendly strategy for improving soil health, nutrient availability and productivity of chickpea (*Cicer arietinum* L.). Inorganic fertilizers, organic manures and biofertilizers together can improve crop growth performance and yield characteristics along with soil fertility and environmental sustainability. Several researchers reported that the application of farmyard manure, vermicompost, Rhizobium, phosphate-solubilizing bacteria (PSB) and recommended doses of fertilizer has important impact on the

physical, chemical and biological characteristics of soil. Soil improvements led to better soil structure, water holding capacity, microbial population, nutrient absorption and soil organic carbon levels, which result in higher grain production and improved crop productivity.

Integrated nutrient management practices contributed to higher plant height, nodulation, dry matter accumulation and improved nutrient use efficiency in chickpea than the one chemical fertilizer application. The integrated use of organic and inorganic nutrient sources provided in acceptable nutrient supply at all growth phases of the crop and reduced nutrient losses from the soil system. Integrated nutrient management is also an important aspect of sustainable agriculture, as it can help to minimize the use of chemical fertilizers and promote ecological balance. Organic modifications promote biological activity and boost soil biological health, while biofertilizers increase biological nitrogen fixation and nutrient solubilization Sharma *et al.*, (2023).

Therefore, INM also helps in maintaining soil fertility for future generations as well as boosts productivity of chickpea. Hence, site-specific nutrient management practices are crucial for sustainable production of chickpea in the region. In conclusion, integrated nutrient management is a favored and environmentally friendly option for improving the soil fertility, soil productivity and sustainability of chickpea cultivation.

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