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Evaluating organic and bio fertilizers as an integrated nutrient management practice in Tomato (*Solanum lycopersicum* L.)

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Abstract

In India, organic inputs are primarily used in agriculture. The process of increasing farmer production through the effective use of organic inputs such as vermicompost, neem cake and biofertilizers is known as integrated nutrient management. These organic fertilizers enhance the soil quality and growth parameters, as well as its properties, which makes it healthier over the long run. Due to previous decays, the majority of farmers use chemical fertilizers, which reduce soil fertility. In order to produce high-quality food and maintain healthy soil, the majority of farmers now use integrated nutrition management in conjunction with organic, inorganic, and biofertilizers. In addition to increasing agricultural output, integrated nutrient management also helps to prevent the emergence of micronutrient shortages.

Keywords: Biofertilizers, INM, organic, tomato, vermicompost

Introduction

Tomato (*Solanum lycopersicum* L.) is native to Peru Ecuador region (Jenkins, 1948) [8]. This crop is indigenous to Central and South America (Vavilov, 1951) [60]. The Indian subcontinent is capable of producing tomato in large quantity. Being diploid, its chromosomal number is $2n=24$. It belongs to the Solanaceae family. It is a significant crop which is grown extensively over the world due to its high nutritional value, therefore also goes by the name "poor man's orange." Tomato is one of the important vegetable crops grown around the world due to its diverse adaptability, high yielding potential, and suitability for a number of usages as fresh and processed food industries. It is the most abundantly planted for multipurpose as garden vegetable (Kumar *et al.* 2013) [9]. It is a tropical day neutral crop that is primarily self-pollinated, though sometimes cross-pollination also occurs. The optimal environmental conditions for growth and flowering observed to be 25 to 30 °C day temperature and 16 to 20 °C night temperature along with about six hours of sunlight, whereas for fruit set temperature between 18 to 24 °C is reported best. Tomato can be grown successfully on a wide range of soil types, from sandy to fine textured, but best suitable soil is with the high organic content and pH range of 5.5-7.0 is required for best cultivation. The tomato production is 47.5 Million MT in world and placed in second position, similarly in India its position is after potato amongst vegetable production. The improved cultural practices and scientific technologies adopted by farmers have enhanced the production and productivity of vegetable crops year after year. This is because Indian farmers choose cash crops over vegetable crops because they yield higher profits (Rani and Tripura, 2021) [20]. In India Punjab, Haryana, Maharashtra, Uttar Pradesh, Karnataka and Bihar are major producers of tomato. In India, 20,818 (000 MT) of Tomato are produced on 841 (000 ha) of land. The area of tomato cultivation in Himachal is 13.72 (000 ha) and annual crop production is 474.34 MT (Anonymous, 2023–2024) [4]. Himachal Pradesh is the off season producer of tomato crop due to the huge diversity of terrain, climatic conditions, soil etc. These environmental conditions are suitable for producing high quality tomato crop. The production obtained under open field conditions is comparatively lower due to fluctuation of environmental conditions, whereas under polyhouse conditions, better

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The production obtained under open field conditions is comparatively lower due to fluctuation of environmental conditions, whereas under polyhouse conditions, better production is obtained due to controlled environment conditions which increase number of harvestings. It is a good source of income for small and marginal farmers because fresh tomatoes are in high demand all year round across the country. Due to its great nutritional value and high production under various climatic conditions, it plays a significant role to uplift the socio economic status of the farmers. Tomato has high nutritional value, therefore, used as raw as well as in processed form (Rani and Tripura, 2021) [20]. It helps to reduce many ailments due to rich source of various vitamins like A, B, and C. The lycopene, which is found in tomatoes, lowers the risk of prostate cancer. Additionally, it has antioxidants and minerals that are beneficial to human health. It can be used in processed forms like ketchup, puree, powder, paste, etc., and can be consumed raw or cooked (Rani and Tripura, 2021) [20]. India today stands first in the area of milk production at the world level, with an annual growth rate of about 4%. The country's milk production in 2010 was estimated to be 110

million tons. A large quantity of milk produced in the country, amounting to over 46%, is being consumed as liquid milk. The production and use of animal products in the use of human diet is receiving tremendous attention. (Singh *et al.*, 2012) [21]. The productive improvements among dairy animals can be made through proper management, feeding, handling, etc., which may influence the expression of productive characters as per their heritability nature. Before identifying the animals for breeding and production purposes, screening of animals shall be performed on the basis of physical traits (Singh *et al.*, 2013) [22]. The goat population of our country increased from 47.14 million in the year 1951 to 124.5 million during 2005 (Singh and Sharma, 2013a) [23] and (Singh and Sharma, 2014) [25]. The Gir breed, which is rated as a relatively better milk producer of indigenous breeds, needs exploration of its production potentiality with a view to knowing its further prospect. Improvement can be made through proper management, feeding, handling, and other environmental conditions that will influence the expression of characters, but a limit of which is set by the heredity of the individual (Singh *et al.*, 2013b) [24].

Goats are an integral part of livestock production and play a vital role in the socio-economic structure of the rural poor. The aim of this study was to project the importance and significance of goat milk with special reference to Indian field and farm rearing conditions. There are adverse ecological and physiological constraints in the Indian system of goat farming. Poultry farming is an ancient business in India, but scientific upkeep of poultry is very new. It has got economic, nutritional, industrial, recreational, and research importance. It also plays an important role in improving the economy of the poultry owner. Various government and non-government organizations have also recognized the importance of poultry farming as an employment-generating enterprise and are engaged in motivating more and more entrepreneurs to take up this enterprise (Singh *et al.*, 2014a) [26]. Goats play a vital socio-economic role in Asian agriculture, particularly for resource-poor people living in harsh environments (Singh *et al.*, 2014b) [27]. The global goat population currently stands at 921 million, of which over 90% are found in developing countries. Asia is home to about 60% of the total world goat population and has the largest goat breed share of 26%. Goats play a vital socioeconomic role in Asian agriculture, particularly for resource-poor people living in harsh environments. Non-cattle milk accounts for approximately 15% of the total milk consumption by humans worldwide (Singh *et al.*, 2014c) [28]. Goats are more often poorly managed, and this is attributed to their ability to survive under harsh conditions and also because most people in rural areas rear goats for their subsistence purposes to support their families. This benefit is often not shown in national statistics because of informal trading and slaughtering (Singh *et al.*, 2014d) [29]. The milk is naturally homogenized since it lacks the protein agglutinin. The milk also has a more similar makeup (percentage of fats, etc.) to human milk than cow's milk. For these reasons, goat milk may be recommended for infants and people who have difficulty digesting cow's milk (Singh *et al.*, 2014e) [30]. Goat meat, being a high-quality protein source, is the choicest meat in the domestic market. It is leaner than other red meats, and its fat has desirable fatty acids. The goat was domesticated as early as 6-7 BC, as evidenced by

archaeological remains collected in western Asia (Singh *et al.*, 2014f) ^[31]. The major population of India is primarily dependent on an agricultural-based system for their daily life, including goat keeping, that constitutes an important rural business of small marginal farmers and landless laborers (Singh *et al.*, 2014g) ^[32]. Reproductive management of an animal is governed through a number of parameters, *viz.* age at first conception, age at first calving, first gestation length, etc. However, this study is limited to studying the reproductive management in terms of the age of the animal at first calving (Singh *et al.*, 2014h) ^[33]. Goats, which were known as “wet nurses of infants” in the United Kingdom and “poor man's cow” in India, were the first animals to be domesticated. Goat milk contains less lactose than cow's milk, so it is less likely to trigger lactose intolerance (Singh and Sharma, 2015) ^[24]. Goat meat, being a high-quality protein source, is the choicest meat in the domestic market. It is leaner than other red meats, and its fat has desirable fatty acids. The goat was domesticated as early as 6-7 BC, as evidenced by archaeological remains collected in western Asia. It has since played a significant socioeconomic role in the evolution of human civilization around the world (Singh and Sharma, 2015a) ^[35]. Pearl millet was recognized as a main source of energy for livestock and is fed at critical times, such as during lactation, illness, and for weight gain. Farmers felt that grass is more useful to fill the animals' stomachs and would therefore come before crop stover as a feed. Farmers preferred Deda over Kona because it has more biomass (Singh and Sharma, 2015b) ^[36]. This explains why goat farmers seldom consider the possibilities of increasing production through either crossbreeding or artificial insemination. A very important aspect in this regard is the awareness of risk by resource-poor farmers and their emphasis on minimizing it (Singh and Sharma, 2016) ^[37]. Goats, being a multipurpose animal, produce meat, milk, skin, fiber, and manure. The country is endowed with a large and biologically diverse population of goats. (Singh and Sharma, 2016a) ^[38]. The nutritional value of milk is closely related to its composition, which is affected by factors such as breed, diet, stage of lactation, season, etc. Goat milk has more calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg), and chloride (Cl) and less sodium (Na) and sulfur (S) content than cow milk (Singh and Sharma, 2016b) ^[39]. Livestock production is the backbone of Indian agriculture, contributing 7% to national GDP and being a source of employment and livelihood for 70% of the population in rural areas. India ranks first in terms of milk production (129.7 million tonnes); however, the productivity is quite low, mainly because of the scarcity of feeds and fodders (Singh *et al.* 2017) ^[40]. Animals reared in intensive production systems consume a considerable amount of protein and other nitrogen-containing substances in their diets (Singh *et al.* 2017a) ^[41]. Small ruminants have a large impact on the economy and food supply of people in subtropical and tropical countries. This benefit is often not shown in national statistics because of informal trading and slaughtering (Singh and Sharma, 2017b) ^[42]. Jamnapari (or Jamunapari) is a breed of goat originating from the Indian subcontinent. Since 1953 they have been imported to Indonesia (popular as Etawa goats, and their mixture with a local goat called "PE," *peranakan Etawa*, or Etawa mix), where they have been a great success. It is bred for both milk and meat. The name is derived from the rivers

Yamuna, Jamuna (West Bengal), and Jamuna (Bangladesh) of India and Bangladesh. There is a great variation in coat color, but the typical coat is white with small tan patches on the head and neck. The typical character of the breed is a highly convex nose line with a tuft of hair, yielding a parrot mouth appearance (Singh *et al.* 2017c) ^[43]. The consequence of domestication was a change in the phenotypic characteristics of wild goats, which resulted in the development of a multiplicity of goat breeds or types. These breeds or types were distributed across the world as a result of the migration and translocation of humans, usually due to changing climatic conditions and natural resources (Singh and Sharma, 2017d) ^[44]. Goats play a vital socio-economic role in Asian agriculture, particularly for resource-poor people living in harsh environments. Non-cattle milk accounts for approximately 15% of the total milk consumption by humans worldwide. Asia contributes approximately 59% to world goat milk production (Singh *et al.* 2018) ^[45]. There is a large commercial chicken industry that provides us with eggs and meat. A major constraint to poultry production is the high value placed upon crop production rather than livestock production. Over recent decades the poultry industry has made tremendous adjustments to meet the increasing demand for an inexpensive and safe supply of meat and eggs (Singh, G. 2019) ^[46]. India is endowed with a significant share of the world's livestock population, growing steadily and continuously. Buffalo are predominantly animals of poor countries with a very high density of livestock and human population and with poor feed resources. In tropical and subtropical regions, dairy cattle usually depend exclusively on native or introduced pastures as their only source of nutrients, and in particular, during critical periods of the year, such as the winter or dry season, the animals cannot fulfill their nutrient requirements because forage is either scarce or of low quality (Singh, G., 2019a and Singh *et al.* 2025c) ^[47, 59]. Milk-secreting tissues and various ducts throughout the udder can be damaged by bacterial toxins, and sometimes permanent damage to the udder occurs. Severe acute cases can be fatal, but even in cows that recover, there may be consequences for the rest of the lactation and subsequent lactations (Singh and Singh, 2020) ^[48]. Livestock has become an integral part of all interventions aimed at reducing rural poverty and enhancing food and nutrition security. The dairy livestock owners who raise cattle and buffaloes are yet ignorant of scientific management practices (Singh and Somvanshi, 2020a) ^[49]. The goat is thought to have been the earliest domesticated ruminant and, of all the species of domesticated animals except the dog, has the widest ecological range. Originating in Asia, goats have spread over all the continents and inhabit almost all climatic zones from the Arctic Circle to the equator (Singh, G., 2024) ^[50]. Man, animal, and nature are in a symbiotic relationship for their survival and sustenance. The balance maintained among the three for several millennia has been disturbed by the overexploitation of natural resources to meet the demands of the increasing population of men and animals (Singh *et al.*, 2024a) ^[51]. The nutritional value of milk is closely related to its composition, which is affected by factors such as breed, diet, stage of lactation, and season. Goat milk has more calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg), and chloride (Cl), and less sodium (Na) and sulfur (S) compared to cow milk (Singh *et al.* 2024b) ^[52] and (Singh *et*

al. 2025a)^[57]. Minerals are required by dairy animals for their metabolic functions, growth, milk production, reproduction, and health. Animals cannot synthesize minerals inside their bodies, and usually, feeds and fodders fed to the dairy animals do not provide all the minerals in the required quantity (Singh *et al.* 2024c)^[53]. The goat is thought to have been the earliest domesticated ruminant and, of all the species of domesticated animals except the dog, has the widest ecological range (Singh *et al.* 2024d)^[54]. The productive improvements among dairy animals can be made through proper management, feeding, handling, etc., which may influence the expression of productive characters as per their heritability nature. (Singh *et al.* 2024e)^[55]. The production and use of animal products in the use of human diet is receiving tremendous attention. (Singh *et al.* 2025 and Singh *et al.* 2025b, Singh *et al.* 2025d)^[56, 58]. Rising living standards in rural regions, where the bulk of the poor live and get their food, are one of the primary problems confronted by agricultural planners and decision makers in the goal of a world without hunger and poverty (Wheller and Braun, 2018)^[61]. To reach the objective of ending hunger, crop production and productivity should be raised in light of the worrying global population growth and land scarcity. Management of soil fertility is crucial for boosting crop output. (Panta and Parajulee, 2021)^[18]. A variety of chemical free, eco-friendly organic manures may improve vegetable production, which include FYM, compost, biofertilizers, vermicompost, and others manures. They help in maintaining the environment and enhance the health of soil, plants, and end users (Radhika and Savita, 2021)^[19]. Fertilizers play an important role in production and productivity of tomato crop but the excessive use of chemical fertilizers led to major issues such as low production quality, environment pollution, soil degradation, and residual effect which cause health risks to end users. Various nations are struggling to supply food free of chemicals because of their expanding populations. The continuous use of synthetic fertilizers results in depletion of soil fertility due to destruction of important microbes and reduction in organic matter in the soil (Diacono and Montemurro, 2010)^[5]. The farmers traditionally practice the conventional farming, which include use of synthetic fertilizers, weedicides and pesticides along with the high yielding varieties to obtain maximum revenue from small land holding. On the other hand the crop grown by traditional practices is not good for consumers' health as it magnifies the residual content in the body as it is consumed as raw as well as in processed form.

Integrated Nutrient Management

Anonymous (1995)^[3] emphasized on integrated nutrition management (INM) to maximize the utilization of synthetic and organic soil nutrients to maintain soil fertility for future generations and boost agricultural yield. Use of INM increases crop yields by 8–15%, in comparison to traditional methods and produce the crops with neutral nutrients and improve soil fertility for long-term to provide high production (Meena and Reddy, 2021)^[14]. The use of INM methods enhance nutrient by reducing losses through leaching, volatilization, immobilization, runoff and emissions (Zhang *et al.* 2012)^[62]. The organic fertilizer used in INM enhances the availability of soil's nutrition by maintaining soil fauna, organic matter and texture. Therefore, the integrated nutrient management method may

safeguard production sustainability while being practically feasible, technically sound and affordable.

However, the combined use of chemical fertilizers, organic manures, and biofertilizers shows significant potential for maintaining high crop productivity, excellent quality along with shielding soil health from pollution risks and deterioration. The solanaceous vegetable crops require a considerable amount of primary (N.P.K.) as well as secondary nutrients (calcium, magnesium and sulfur) for optimal plant growth, fruit production, and seed yield. Tomato crop being a heavy macronutrient feeder (N.P.K.), require balanced application of fertilizers at the appropriate time, to attain improved growth, development and fruit production. The adequate supply of nutrients to tomato crop improves fruit quality (color, taste, and acidity), fruit size and shelf life (Maji and Ghosh, 2006, 2007a and b)^[11, 12-13]. The traditionally used manure, farmyard manure (FYM) contains 0.5% nitrogen, 0.2% phosphorus, 0.5% potassium, therefore, improves biomass of soil with beneficial microorganisms which enhance soil fertility to provide better plant growth and yield.

Organic fertilizers

Neem cake, a byproduct of the extraction of neem seed oil, contains mineral compounds and is one of the important organic fertilizer which provides Nitrogen (2.0% to 5.0%), Phosphorous (0.5% to 1.0%) and Potassium (1.0% to 2.0%) as well as help in management of nematodes and other soil-born organisms. It helps directly or indirectly to increase crop productivity (Agbenin *et al.* 1999)^[1]. It serves as a pesticide as well as soil conditioner which improves soil health and boosts plant yields (Oyinlola *et al.* 2017)^[16]. It improves the population of organic nitrogen fixing microbes and also increases soil electrical conductivity (Elnasikh *et al.* 2011)^[7]. It's combination with N:P:K fertilizers favors vegetative growth of tomato (Eifediyl *et al.* 2017)^[6].

Vermicompost contains macronutrients as well as micronutrients, such as nitrogen (1.6%), potassium (0.7-0.8%), zinc, manganese and phosphorous (0.7%) (Kumari and Srivastava, 2007)^[10], which help to increase the soil structure, permeability, aeration, drainage, retention of water capacity as well as inhibition of soil deterioration (Pal *et al.* 2015)^[17]. Vermicompost improves soil fertility, resulting in higher yields and higher quality, as well as increased nutritive value in tomato. Organic manures such as cow dung, chicken manure and crop waste were used as substitutes to the inorganic fertilizers, but results obtained were significant to establish benchmark for organic sources of nutrition to attain high tomato yield (Ali *et al.* 2014)^[2].

Biofertilizers

Nowadays there is a trend to use Bio-fertilizers which are included in organic fertilizers. It contains living microbial inoculants that improves nutrient uptake of plant. Bio-fertilization plays an important role in sustainable agriculture practices to prevent environmental deterioration and preserve natural resources. Traditional biomass (organic matter and soil fauna) were maintained in the cropping areas for nutrient management, which has grabbed the attention of agriculture scientists to approach them for the improvement of soil health to enhance nutrient uptake by plants and reducing environmental contamination.

The bio-intensive management of crops by using biofertilizers shows promising results in terms of increase in

crop yield, improvement of soil fertility, enhanced plant development, reduction in production costs along with negligible impact on environment. Various microorganisms, including nitrogen-fixing soil bacteria (*Azotobacter* and *Rhizobium*), nitrogen fixing cyanobacteria (*Anabaena*), phosphate-solubilizing bacteria (*Pseudomonas*) and arbuscular mycorrhizal fungi, which help to retain moisture in soil and facilitate the nutrient flow in plants are commonly used as biofertilizers. Nitrogen fixing bacteria, *Azotobacter* secretes substances like pantathonic acid and gibberellins that aid in root growth. In addition, it secretes ammonia into the rhizosphere, which aids plant nutrient uptake (Narula and Gupta, 1986) ^[15]. Due to the low levels solubility of phosphorus, which hinders its mobility, phosphate solubilizing bacteria (PSB) are useful to access phosphorus to the vegetable crops. Bio-fertilizers also help to keep the pH balanced of soil and significantly increase C, N, P, and K content (Ali *et al.* 2014) ^[12]. Biofertilizers constituted of living microorganisms therefore observed eco-friendly, effective for long term and cost effective. The use of biofertilizers in combination with the manures and inorganic fertilizer may result in a higher yield and better quality of crop, which increases profit margins of the farmers. These are used in fertigation as well as with the manures. They survive for long time in the soil which has rich organic matter and boost the plant growth and development, production and productivity. Although the use of different types of fertilizers provide good results in terms of production of the crop but show one or the other constraints in terms of availability of organic manures survival of bio-fertilizers for long term in the soil due to lack of organic matter and use of excessive inorganic fertilizers.

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