Effect on integrated nutrient management on finger millet (*Eleusine coracana* (L.) Gaertn.): A review

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Abstract

Millets, one of the ancient foods known to mankind, are often referred to as the crops of the future due to its adaptability to harsh soil and climatic conditions and ability to support sustainable diets. Among millets, finger millet, recognised as Ragi ranks fourth in importance. In spite of multi-various benefits, millets are cultivated as rainfed crops in marginal lands with few or no external inputs. Therefore, nutrient management assumes paramount importance in boosting the productivity of the crop. Integrated Nutrient Management (INM) and organic nutrition are two means for achieving these goals of sustainability. It was found that INM had significant effect on finger millet in terms of growth and growth attributes, yield attributes and yield, nutritional quality of the grains, nutrient uptake, nitrogen use efficiency indices, soil nutrient status and economics. Several studies have also brought out the positive effects of adopting organic nutrition in finger millet.

Keywords: integrated nutrient management (INM), finger millet, yield, growth, nutritional quality, economics

Introduction

Millets have been recognized as super cereals by virtue of their climate resilience and superior nutritional profile. Finger millet (*Eleusine coracana* (L.) Gaertn.), the domesticated coarse cereal of African origin, forms staple food for the people in the drier parts of India, Africa and some of the other Asian countries. Being a minor millet, finger millet cultivation is traditionally rainfed and confined to marginal soils, resulting large yield gaps. Optimization of nutrient management with emphasis on organics will help in attaining and sustaining higher yields. The present study was undertaken to assess the effect of integrated nutrient management on the growth, yield, nutritional quality and profitability of finger millet. The research work done in this area is reviewed in this chapter. The work done on related cereals and millets were also considered to get a comprehensive view on the topic.

Finger millet as a super cereal

Adaptation and Resilience of Finger Millet

Finger millet (*Eleusine coracana* (L.) Gaertn.) is the staple food for people in the dry areas and is cultivated by farmers on marginal lands with limited resources. Since the crop is primarily cultivated and consumed by the small to marginal households, it is often referred to as ‘poor man’s crop’ or as ‘famine food’. Of the total millet area in the world, 12 per cent is finger millet, spread over more than 25 countries in Africa and Asia, accounting for 10 per cent of the total millet production (Dida et al., 2008; Kumar et al., 2016a) [18], [30]. It is estimated that, in India, the crop covered an area of 1.27 million hectares with a total production and productivity of 1.93 million tonnes and 1.60 tonnes per hectare respectively (DES, 2017) [14]. The crop has extraordinary potential to adapt itself to multiple stresses encountered in rainfed to dry areas. Finger millet is a principal tropical millet with adaptations to support the dry and semi-dry regions of India (Mandal and Swamy, 2005) [41]. Mgonja et al. (2007) [43] highlighted the status of finger millet as a famine crop by virtue of its capability to assure year-round food supply due to its long shelf life and storage-pest resistance of grains, which extended to more than 10 years. Gupta et al. (2014) [38] reported reduced leaf area, high water use efficiency and high CO2 fixation rate in finger millet, making it a crop suitable for semi-arid climates. Finger millet was also observed to utilize nitrogen efficiently.
The drought tolerating capacity of finger millet was accredited to its proficient antioxidant properties and augmented signal discernment (Chandra et al., 2016) [10]. Finger millet is conferred with adaptation to different agro-climatic conditions, ability to thrive on marginal soils, tolerance to major pests, diseases and drought and weed suppression capacity (Prakash et al., 2018) [53]. Finger millet, being a C₄ crop, helped in sequestering carbon, resulting in CO₂ abatement (Brahmachari et al., 2018) [8].

Nutritional and Nutraceutical Importance of Finger Millet

The endosperm of finger millet acts as sinks of carbon and nitrogen compounds and this in turn increases the protein content (Balconi et al., 1997) [6]. The occurrence of essential amino acids such a tryptophan and methionine marked the superiority of finger millet over the soft cereals like rice and wheat (Fernandez et al., 2003) [21]. That the slow digestibility property of finger millet in diets was able to provide energy throughout the day. They also noted the diaphoretic, diuretic and vermifuge properties of finger millet (Dida and Devos, 2006) [17]. Finger millet is free of gluten and this makes it valuable to people ailing from celiac diseases (Pagano, 2006) [47]. Further, the risk of gastrointestinal tract infestions and diabetes could be efficiently curbed by including finger millet in routine diets. Chethan and Malleshi (2007) [11] observed that the level of antioxidant in whole meal of finger millet was around 2.0 to 2.6 gallic acid equivalents (gae). The high polyphenol content in the seed coat of finger millet confers it with anti-cancer, anti-diabetic and anti-oxidant activities. Devi et al. (2011) [16] reported that among different millets, finger millet had the highest calcium content (0.38%), dietary fibre (18%) and phenolic components (0.3-3%). Finger millet is a rich protein source and the nutraceutical property of protein in finger millet is that it maintains homeostasis (Mathangi and Sudha, 2012) [42]. Finger millet has been reported to contain certain anti-nutritional factors, viz., tannins, non-starch polysaccharides (betaglucans), protease inhibitors, oxalates and phytates, which could affect the nutrient digestibility (Kumar et al., 2016b) [16]. However, the anti-nutrients have been identified to possess commendable therapeutic value. The anti-nutrients like polyphenols, tannins, flavonoids, etc. have therapeutic role in managing diabetes, cardiovascular conditions, cataract, inflammation, gastrointestinal disorders and cancer (Sarita and Singh, 2016) [61].

Unlike many other crop-borne proteins, the finger millet protein has not registered any allergic reactions (Pandian et al., 2017) [50]. Finger millet contains five to eight per cent protein (Devi and Sinthiya, 2018) [15]. Giridhar (2019) [23] reported that finger millet contained proteins (5-8%), ether (1-2%), carbohydrates (65-75%), 2.5 to 3.5 per cent minerals and 15 to 20 per cent dietary fibres. Phytochemicals present in finger millet act as antioxidants and helps to maintain physiological balance and protect against oxidative damage (Prajapati et al., 2019) [52]. The comparison made between the nutritional profile of rice and finger millet revealed the pre-eminence of the latter in terms of the contents of total, soluble and insoluble dietary fibre, flavonoids and phenolics (Lansankara et al., 2020) [37]. Ramesh et al. (2020a) [57] observed that compared to other crops, the fat content in finger millet was relatively low and it was a rich source of essential amino acids. On the whole, finger millet is a crop which has the capacity to address the global concerns about rising temperature, poor soils, reduction in agricultural productivity, food insecurity and malnutrition.

Effect of integrated nutrient management on finger millet

Integrated nutrient management (INM) is a system approach in which all the possible nutrient resources, both on-site and off-site are mobilized, integrated and managed, giving due importance to all. The poor availability, imbalanced and inconsistent nutrient content and high cost of transport pose problems in promoting organic nutrition. Thus, the conjunctive use of chemical fertilizers and organics in soil fertility management is considered as the alternative to come out of the ‘vicious spiral’ of agrochemical menace (Palaniappan and Annadurai, 1999) [48].

Growth and Growth Attributes

Studies conducted in the sandy soils of Bapatla by Babu (2006) revealed that finger millet responded significantly to application of recommended dose of NPK as fertilizers in conjunction with farm yard manure (FYM) at the rate of 3 t ha⁻¹ with respect to plant height, number of tillers and dry matter production. Finger millet supplied with 100 per cent recommended dose of fertilizers (RDF) at the rate of 50: 40: 25 kg NPK ha⁻¹ combined with FYM (7.5 t ha⁻¹) resulted in higher total dry matter production, in the red sandy loam soils of Bengaluru (Govindappa et al., 2009) [25]. Saunshi (2012) [63] reported that FYM at the rate of 10 t ha⁻¹ supplemented with bio-digested liquid manure augmenting with rock phosphate and poultry manure equivalent to 60 kg N ha⁻¹ resulted in taller plants (141.1 cm), higher leaf area (1886.3 cm² per plant), leaf area index (6.29) and total dry matter accumulation (43.08 g per plant). Dass et al. (2013) [13] observed that growth attributes of finger millet was significantly better when 50 per cent RDF was substituted with FYM, during two out of three study years in eastern India. A field experiment carried out at Dapoli showed that addition of 150 per cent FYM and RDF resulted in taller plants with more number of tillers, functional leaves and dry matter accumulation per hill in finger millet (Neve et al., 2013) [46]. In a study undertaken by Thimmaiah et al. (2016) [68] at Shivamogga in rainfed finger millet, it was observed that among the nutrient management practices tested, application of recommended dose of NPK in conjunction with FYM (7.5 t ha⁻¹) and plant growth promoting rhizobacteria (PGPR) at the rate of 2 kg ha⁻¹ followed by top dressing with vermicompost and composted coconut fronds each at 3.75 t ha⁻¹ at 25 days after transplanting resulted in superior plant height (145.27 cm), greater leaf area (1177.30 cm² per plant), tiller count (4.07 per plant) and total dry matter production (59.13g per plant). Raman and Krishnamoorthy (2016) [55] reported that finger millet responded positively to the substitution of 50 per cent of recommended dose of N with vermicompost + recommended doses of P and K in conjunction with biofertilizer (Azospirillum + Phosphobacteria), with respect to plant height, leaf area index and dry matter production. Gani et al. (2016) [52] reported significantly superior plant height, leaf area index and relative growth rate with RDF and poultry manure at 5 t ha⁻¹. Application of FYM in adequate quantity (7.5 to 10 t ha⁻¹) was observed to enhance the root growth and development of finger millet (Prabhakar et al., 2017) [51]. Mahapatra (2017) [39] compared the effect of different organic sources and chemical fertilizers in finger millet. He concluded that 100 per cent recommended dose of nutrients as inorganic fertilizers resulted in maximum plant height, tiller production, leaf area and dry matter and at all stages of observation. Hundred per cent recommended dose of nutrients supplemented with organic manures resulted in significantly taller plants (81.11 cm), leaf area index (2.61), tillers per hill.
(4.96) and SPAD (27.93) in finger millet (Goudar et al., 2017) [24]. They attributed this to the better nutrient availability and improvement in the soil properties. Hebbal et al. (2018) [29] highlighted the importance of INM through their observation on significantly superior plant height (68.7 cm), tiller count (10.8), leaf area (1934 cm²) and dry matter production (39.74 g per hill) with FYM (7.5 t ha⁻¹) + recommended dose of fertilizers (50:40:37.5 kg NPK ha⁻¹) as compared to lower values with application of FYM alone on N equivalent basis. Ullasa et al. (2020) [71] recorded significantly taller plants (83.4 cm) with more number of leaves (52.8) and leaf area index (5.16) at 90 days after transplanting and dry matter production at harvest (35.8 g per hill) with recommended dose of FYM in conjunction with vermicompost (4 t ha⁻¹) on nitrogen equivalent basis. Finger millet recorded taller plants at grand growth stage and maturity, with application of 25 per cent nitrogen as vermicompost + Azospirillum + 50 per cent nitrogen as inorganic fertilizer, at Anand (Gujarat) during the kharif season (Himanshi and Shroff, 2020) [31].

**Yield Attributes and Yield**

Integrating organic nutrient sources with inorganics was observed to enhance the productive tiller count and finger length of finger millet in the clay loam soils of Coimbatore (Jagathjothi et al., 2008) [32]. Adesemoye et al. (2008) [1] reported that plant growth promoting rhizobacteria (PGPR) promoted plant growth, yield and nitrogen content in grain. The field experiment undertaken by Govindappa et al. (2009) [25] red sand loamy soils of Bengaluru, registered superior grain and straw yields for rainfed finger millet when nutrients were applied totally as inorganic in conjunction with recommended dose of FYM (7.5 t ha⁻¹). Yield parameters of finger millet were observed to improve significantly in response to application of 75 per cent RDF along with FYM (5 t ha⁻¹) and biofertilizers (Ahiwale et al., 2011) [2]. Sankar et al. (2011) [66] observed that FYM at (10 t ha⁻¹) in conjunction with 50 per cent recommended dose of NPK as chemical fertilizers resulted in significantly higher yield than that with 100 per cent recommended NPK in finger millet. Substitution of 50 per cent RDF with vermicompost increased the yield of finger millet in contrast to application of nutrients as inorganic alone (Chander et al., 2013) [9]. Integrated application of 100 per cent recommended dose of NPK integrated with FYM increased the grain yield (3125 kg ha⁻¹) and straw yield (5123 kg ha⁻¹) of finger millet and this was attributed to enhanced sink capacity and efficient utilization of nutrients (ArulmozhiSelvan et al., 2015) [4]. Tsado et al. (2016) [69] did not observe significant effect for INM on finger millet. Their study recorded longest fingers (15.3 cm), higher number of fingers (12), seeds per ear (4855) and grain yield (4530.7 kg ha⁻¹) application of 100 per cent recommended dose of nutrients as inorganic fertilizers. Application of recommended dose of NPK and FYM (7.5 t ha⁻¹) + PGPR (2 kg ha⁻¹) followed by top dressing with vermicompost (3.75 t ha⁻¹) + coconut frond compost (3.75 t ha⁻¹) at 25 DAT recorded higher yield in terms of grain and straw, the grain yield being 118.9 per cent and 87 per cent greater than the local farmers’ practice and recommended dose of NPK alone, respectively (Thimmaiah et al., 2016) [68].

Integration of organic and inorganic nutrient sources enhanced plant metabolism and growth, and consequently recorded higher grain yield. Mineralisation of organic sources of nutrients favoured better nutrient absorption through improved shoot and root (Pallavi et al., 2016) [49]. Ullasa et al. (2017) [70] investigated the influence of organic nutrition in finger millet. They observed that the effect of application of 100 per cent recommended dose of NPK as vermicompost based on nitrogen equivalence + FYM (7.5 t ha⁻¹) and FYM alone at the rate of 7.5 t ha⁻¹ was significantly high and comparable with respect to the number of productive tillers and fingers per head, finger length and grain yield per plant. In a field experiment conducted during the kharif season at Shivamogga, Naik et al. (2017) [44] reported the benefit of applying FYM (10 t ha⁻¹) along with biodigester liquid manure equivalent in two splits at 70 kg N ha⁻¹ in significantly increasing the panicle weight (12.22g), thousand grain weight (13.87g), grain yield (1.84 t ha⁻¹), straw yield (3.49 t ha⁻¹) and harvest index (0.46). The study conducted by Hatti et al. (2018) [28] recorded significantly higher grain yield (3.03 t ha⁻¹) and straw yield (4.69 t ha⁻¹) with 100 per cent recommended dose of NPK integrated with FYM at the rate of 7.5 t ha⁻¹. Roy et al. (2018a) [59] reported significant increase in grain and straw yield of finger millet with different doses of inorganic fertilizers along with FYM and biofertilizers. Grain yield (3.77 t ha⁻¹) and straw yield (6.98 t ha⁻¹) were significantly greater with FYM (10 t ha⁻¹) + 75 per cent recommended dose of fertilizers + biofertilizers (Azospirillum brasilense + Bacillus spp. + Pseudomonas fluorescens @ 20 g kg⁻¹ seed each) + ZnSO₄ (12.5 kg ha⁻¹) + borax (5 kg ha⁻¹). Maitra et al. (2020) [40] also observed increased growth and productivity of finger millet in response to application of 100 per cent of RDF as organic or application of organics in combination with inorganic nutrient sources. Application of FYM (7.5 t ha⁻¹) and substituting the recommended dose of nutrients with vermicompost on N equivalent basis resulted in significantly higher number of productive tillers, finger per ear head, finger length and higher yield (Ullasa et al., 2020) [71], Aravind et al. (2020) [3] studied the impact of organic supplements on the productivity of finger millet. They opined that the substantial yield increase in response to organics was due to better availability of nutrients to crops through mineralization and solubilisation effects of organic manures.

**Nutritional Quality**

In an experiment conducted at New Delhi, Bana et al. (2016) noted that application of leaf compost (10 t ha⁻¹) resulted in higher iron, zinc and protein content in grains of pearl millet, followed by FYM (10 t ha⁻¹), leaf compost mixed cow dung compost (10 t ha⁻¹) and 100 per cent recommended dose of fertilizers, respectively. Seventy-five per cent recommended dose of nitrogen in combination with 25 per cent N as poultry manure resulted in higher content of nitrogen (1.31%), phosphorus (0.264%) and potassium (0.47%) in finger millet (Pallavi et al., 2016) [49]. Rani et al. (2017) [58] carried out a field study on the influence of nutrient management on the production and nutritional quality of finger millet in the sandy loam soils of Vizianagaram. Integration of inorganic nutrients and organics recorded higher contents of protein, zinc and iron in the grains of finger millet. Krishnaprabu (2019) [33] assessed the response of pearl millet to INM. He observed that the nutrient content, protein content and protein yield of pearl millet were significantly superior with 75 per cent of recommended dose of fertilizers in association with biofertilizers (5 kg ha⁻¹) incubated with vermicompost (500 kg ha⁻¹).

**Effect of INM on nutrient uptake**

Pallavi et al. (2016) [49] undertook an experiment on the response of rainfed finger millet to INM and reported...
significantly higher nitrogen uptake with 100 per cent RDF, followed by 75 per cent recommended dose of nitrogen as inorganics + 25 per cent nitrogen as poultry manure and 75 per cent recommended dose of nitrogen + 25 per cent nitrogen as vermicompost. Uptake of phosphorus and potassium was highest with by 75 per cent recommended dose of nitrogen as inorganics + 25 per cent N as poultry manure followed by 100 per cent RDF. While total uptake of N and P were observed to be significantly higher in finger millet supplied with 75 per cent recommended dose of fertilizers + FYM (10 t ha\(^{-1}\)) + biofertilizer + ZnSO\(_4\) (12.5 kg ha\(^{-1}\)) + borax (5 kg ha\(^{-1}\)), K uptake was higher with 100 per cent recommended dose of fertilizers + FYM (10 t ha\(^{-1}\)) + biofertilizer + ZnSO\(_4\) (12.5 kg ha\(^{-1}\)) + borax (5 kg ha\(^{-1}\)) (Roy et al., 2018)\(^{[59]}\) The field study conducted by Harika et al. (2019)\(^{[27]}\) on the effect of INM on nutrient uptake of finger millet, revealed highest values for uptake of major nutrients with 100 per cent recommended dose of fertilizers. Total NPK uptake of finger millet was reported to respond significantly to the application of 125 kg neem cake + vermicompost (1.25 tons ha\(^{-1}\)) + NPK (50: 50 kg NPK ha\(^{-1}\)) + borax (2%) spray at flowering (Kumar, 2020)\(^{[30]}\). Results of the study undertaken by Prashanth et al. (2020)\(^{[54]}\) in the eastern dry cracks of Karnataka, showed that continuous application of 100 per cent recommended dose of NPK as FYM enhanced the nutrient content and uptake by the grains, straw, roots and stubbles of finger millet. Nutrient uptake of pearl millet was reported to increase significantly with integrated nutrient management. The treatment comprising 100 per cent recommended dose of fertilizers in combination with pressmud (2.5 t ha\(^{-1}\)) resulted in higher NPK uptake (Nalini et al., 2020)\(^{[45]}\). Shilpa et al. (2021)\(^{[64]}\) assessed the effect of INM on long-term basis in finger millet and reported that the crop recorded significantly higher uptake of nitrogen (63.43 kg ha\(^{-1}\)), phosphorus (11.35 kg ha\(^{-1}\)) and potassium (78.85 kg ha\(^{-1}\)) in response to application of 100 per cent recommended dose of fertilizers + FYM (10 t ha\(^{-1}\)). They concluded that INM, not only supported crops with essential nutrients in accordance with their nutrient requirement, but, it also created congenial soil physico-chemical properties required for a healthy soil.

**Effect of INM on nitrogen use efficiency**

Nitrogen use efficiency is a complex trait which measures how efficiently a crop can utilize and retain applied N. World over, all conventional agricultural systems have low nitrogen use efficiency, indicative of a non-synchrony between the crop demand and supply of N. Liang et al. (2013)\(^{[38]}\) unravels the manner in which organic manures helped to synchronise N supply according to the crop demand. Application of chemical N in conjunction with organic manures resulted in N immobilization during early crop growth stages followed by release of mineral N from the microbial N pool during the grand growth stage of the crop. Integrated nutrient management has been identified as a potential approach for improving fertilizer use efficiency, especially with respect to nitrogen sources (Das et al., 2015)\(^{[12]}\). Nitrogen use efficiency could be enhanced by the application of N fertilizers in combination with organic manures. The slow-release behavior of organic manures also led to considerable residual effect on the succeeding crops (Sarkar, 2015)\(^{[62]}\). Biofertilizers, like PGPR comprising efficient microbial strains have been reported to supplement fertilizer N requirement of crops and enhance nitrogen use efficiency (Singh, 2015)\(^{[65]}\). Enhancing the nitrogen use efficiency of crops, usually less than 40 per cent, is a major challenge in soil fertility and nutrient management. One of the promising options feasible for increasing nitrogen use efficiency is INM. Integrated use of N fertilizers and organic manures helped in maintaining continuous supply of N, reduced losses and thus resulted in more effective utilization of the applied N. Organic nutrient sources operate like slow-release fertilizers, synchronizing temporal and spatial nutrient requirement of the crops, both from the labile soil pool and applied sources (Dwivedi et al., 2016)\(^{[10]}\). Zhang et al. (2016)\(^{[72]}\) reported the importance of combining organic manures and fertilizers in a rational manner for enhancing nitrogen use efficiency. They observed that nitrogen use efficiency decreased with accumulation of soil residual nitrate, when excessive N was combined with organics. Ramesh et al. (2020b)\(^{[56]}\) could not observe enhancement in nitrogen use efficiency in foxtail millet with INM. On the contrary they recorded higher agronomic nitrogen use efficiency with 125 per cent recommended dose of N.

**Effect of INM on soil nutrient status**

Govindappa et al. (2009)\(^{[25]}\) reported increase in soil N balance with increase in application of organics and inorganics. Residual P and K were significantly higher with 100 per cent recommended dose of fertilizers + FYM (7.5 t ha\(^{-1}\)). Sankar et al. (2011)\(^{[60]}\) observed higher NPK status in soil following finger millet cultivation which received 100 per cent recommended dose of NPK in conjunction with FYM (10 t ha\(^{-1}\)) when compared to chemical fertilizers alone. Long term application of FYM as component of INM for finger millet was observed to increase the carbon stock of the soil after the crop (Srinivasarao et al., 2012)\(^{[67]}\). Application of 100 per cent NPK along with FYM enhanced the cation exchange capacity, soil organic carbon, and availability of N, P and K status of the soil compared to chemical fertilizers alone in finger millet – maize sequence (Hemalatha and Chellamuthu, 2013)\(^{[30]}\). As part of the study was conducted by Roy et al. (2018)\(^{[59]}\) to assess the performance of finger millet under INM, it was observed that the available N and P status of the soil increased significantly with the application of FYM (10 t ha\(^{-1}\)) + biofertilizer + ZnSO\(_4\) (12.5 kg ha\(^{-1}\)) + borax (5 kg ha\(^{-1}\)) + 100 per cent recommended dose of fertilizers, while available K remained non-significant. Prashanth et al. (2020)\(^{[54]}\) reported that continuous adoption of INM involving 100 per cent recommended dose of NPK as chemical fertilizers in association with FYM increased the availability of macronutrients in soil. Significantly higher soil organic carbon content was registered with recommended dose of FYM (7.5 t ha\(^{-1}\)) + 100 per cent recommended dose of N as FYM on N equivalent basis compared to that with FYM in combination with 75 per cent recommended N as vermicompost, in finger millet (Ullasa et al., 2020)\(^{[71]}\).

**Effect of INM and organic nutrition on economics of cultivation**

Substituting 50 per cent of the recommended dose of fertilizers with organic sources on N equivalent basis resulted in the highest net returns and BCR (2.39) in finger millet (Dass et al., 2013)\(^{[13]}\). The study carried out by Thimmaiah et al. (2016)\(^{[68]}\) on the effect of INM on finger millet revealed that gross returns, net returns and benefit cost ratio (BCR) varied significantly with diverse sources of nutrients like inorganic fertilizers, organic manures and biofertilizers. Hundred per cent recommended NPK + FYM (7.5 t ha\(^{-1}\)) + PGPR (2 kg ha\(^{-1}\)) + top dressing with vermicompost (3.75 t ha\(^{-1}\)) and frond compost (3.75 t ha\(^{-1}\)) at 25 DAT recorded

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higher gross returns. While, the same treatment avoiding vermicompost recorded the highest net returns, BCR was observed to be higher when top dressing with organics was avoided. The unit cost of production increased progressively with integration of organics and it ranged from ₹4.60 to ₹10.29 per kg grains. Naik et al. (2017) [44] probed into the possibilities of organic cultivation of finger millet and observed that among the organic nutrition options tested, application of FYM (10 t ha⁻¹) + biodigested liquid manure in two splits at 75 kg N ha⁻¹ registered better economics in terms of gross returns, net returns and benefit cost ratio. This study highlighted the importance of effective utilization of on-farm resources for realizing higher returns from organic nutrition. Harika et al. (2019) [127] recorded highest gross returns from finger millet with the application of 75 per cent RDF along with FYM (2 t ha⁻¹) and Azospirillum. Net returns and BCR were highest when 100 per cent recommended dose of nutrients was supplied as chemical fertilizers. Integrated application of chemical fertilizers and organic manures along with biofertilizer (Azospirillum). Highest net returns was realized with 50 recommended dose of N as fertilizers + 25 per cent N as vermicompost + Azospirillum. However, BCR was highest when the entire dose of N was applied as chemical fertilizers (Himanshi and Shroff, 2020) [31]. Singh (2020) [166] observed that the yield of crops raised as organic was on an average 6.79 per cent lower than conventional farming. He also suggested the need for premium price for organic produce for profitability. Organic produce is generally more costly than conventional produce mainly because of its limited supply and higher production cost on account of higher cost of organic inputs and labour per unit of output (FAO, 2021) [120].

The review made on the impact of INM on growth, yield, nutritional quality and economics of finger millet and other minor millets revealed the advantage accrued as a result of integrating chemical fertilizers, organic sources and biofertilizers. A judicious and rational blending of nutrient sources is imperative to harvest the benefits of INM. Several studies have brought out the positive effects of adopting organic nutrition in finger millet. However, organic nutrition was observed to become cost effective only with proper utilization of on-farm nutrient sources and premium price for the produce.

References

1. Adsemoye AO, Torbert HA, Kloeppelew JW. Enhanced plant nutrient use efficiency with PGPR and AMF in an integrated nutrient management system. Can. J Microbiol. 2008;54:876-886.

2. Ahiwale PH, Chavan LS, Jagtap DN. Effect of establishment methods and nutrient management on yield attributes and yield of finger millet (Elesine coracana G.). Adv. Res. J Crop Improv. 2011;2(2):247-250.

3. Aravind SA, Kumar NS, Hemalatha M, Paramasivan M. Influence of organic supplements on growth and yield of finger millet (Elesine coracana L.). J Pharmacognosy Phytochem. 2020;9(3):1564-1567.

4. Arulmozhiselvan K, Sathyaa S, Elayarajan M, Malarikodi M. Soil fertility changes and crop productivity of finger millet under continuous fertilization and manuring in finger millet-maize cropping sequence. Res. Environ. Life Sci. 2015;8(4):751-756.

5. Babu BG. Productivity and quality of finger millet [(Elesine coracana (L.) Gaertn.] cultivars as affected by nutrient management system. M.Sc. (Ag) thesis, Acharya N. G. Ranga Agricultural University, Hyderabard, 2006, 125p.

6. Balconi C, Bosio D, Rizzi E, Nembrini L, Mott M. Effects of organic and inorganic N supplies on protein and carbohydrates accumulation in high and low protein maize endosperms grown in vitro. Maydica 1997;42(3):257-264.

7. Bana RS, Pooniya V, Choudhary AK, Rana KS, Tyagi VK. Influence of organic nutrient sources and moisture management on productivity, biofortification and soil health in pearl millet (Pennisetum glaucum) + cluster bean (Cyamopsis tetragonoloba) intercropping system of semi-arid India. Indian J Agric. Sci 2016;86(11):1418-1425.

8. Brahmachari K, Sarkar S, Santra DK, Maitra S. Millet for food and nutritional security in drought prone and red laterite region of eastern India. Int. J Plant Soil Sci 2018;26(6):1-7.

9. Chander G, Wani SP, Sahrawat KL, Kamdi PJ, Pal CK, Pal DK, et al. Balanced and integrated nutrient management for enhancing and economic food production: case study from rainfed semi-arid tropics in India. Arch. Agron. Soil Sci 2013;59(12):1643-1658.

10. Chandra D, Chandra S, Pallavi N, Sharma AK. Review of finger millet (Elesine coracana (L.) Gaertn.): a powerhouse of health benefitting nutrients. Food Sci. Hum. Wellness 2016;5(3):149-155.

11. Chethan S, Malleshi NG. Finger millet polyphenols: optimization of extraction and the effect of pH on their stability. Food Chem 2007;105:862-870.

12. Das D, Dwivedi BS, Meena MC, Singh VK, Tiwari KN. Integrated nutrient management for improving soil health and crop productivity. Indian J Fertil 2015;11(4):64-83.

13. Dass A, Sudhishri S, Lenka NK. Integrated nutrient management to improve finger millet productivity and soil conditions in hilly region of eastern India. J Crop. Impro. 2013;27(5):528-546.

14. DES [Directorate of Economics and Statistics], Pocket Book of Agricultural Statistics 2017. Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, New Delhi, 2017, 115p.

15. Devi NV, Sinthiya R. Development of value added product from finger millet (Elesine coracana). Int. J Res. – Granthaalaya 2018;6:109-119.

16. Devi PB, Vijayabharathi R, Sathyahama S, Malleshi NG, Priyadarshini VB. Health benefits of finger millet (Elesine coracana L.), polyphenols and dietary fibre : a review. J Food Sci. Technol 2011;51:1021-1040.

17. Dida MM, Devos KM. Finger millet. In: Kole, C. (ed.), Cereals and Millets. Springer, New York, 2006. 333-343.

18. Dida MM, Wanyera N, Dunn MLH, Bennetzen JL, Devos KM. Population structure and diversity in finger millet (Elesine coracana) germplasm Trop. Plant Biol 2008;1(2):131-141.

19. Dwivedi BS, Singh VK, Meena MC, Dey A, Datta SP. Integrated nutrient management for enhancing nitrogen use efficiency. Indian J Fertil 2016;12(4):62-71.

20. FAO [Food and Agriculture Organization of the United Nations]. Organic Agriculture. FAO Inter-departmental Working Group on Organic Agriculture 2021. Available: http://www.fao.org/organicag/oa-faq/oa-faq5/en/ [24 July, 2021].
21. Fernandez DR, Vanderjagt DJ, Millson M, Huang YS, Chuan LT, Pastuszyn A. Fatty acid, amino acid and trace mineral composition of *Eleusine coracana* (Pwanua) seeds from northern Nigeria. Plant Foods Hum. Nutr. 2003;58:1-10.

22. Gani M, Mahadi MA, Dadari SA, Babaji BA, Shinggu CP. Effect of seed rate, sowing method and poultry manure on the performance of finger millet (*Eleusine coracana* L. Gaertn.) in Samaru northern Guinea Savanna, Nigeria. Equity J Sci. Technol. 2016;4(1):51-56.

23. Giridhar P. Preparation and sensory evaluation of finger millet khakhra. J Food Sci. Nutr. 2019;2:61-64.

24. Goudar PK, Ramachandrappa BK, Thimmegowda MN, Sahoo S. Influence of rotation, use of organic and inorganic sources of nutrients on growth, yield and quality of *Eleusine coracana* (L.) Gaertn. Environ. Ecol. 2017;35(3):2306-2311.

25. Govindappa M, Vishwanath AP, Harsha KN, Thimmegowda P, Jnanesh AC. Response of finger millet (*Eleusine coracana* L.) to organic and inorganic sources of nutrients under rainfed condition. J Crop Weed 2009;5(1):291-293.

26. Gupta S, Gupta SM, Gupta AK, Gaur VS, Kumar A. Fluctuation of Dof1/Dof2 expression ratio under the influence of varying nitrogen and light conditions: Involvement in differential regulation of nitrogen metabolism in two genotypes of finger millet (*Eleusine coracana* L.). Gene 2014;546:327-335.

27. Harika JV, Maitra S, Shankar T, Bera M, Manasa P. Effect of integrated nutrient management on productivity, nutrient uptake and economics of finger millet. Int. J Agric. Environ. Biotechnol 2019;12(3):273-279.

28. Hatti V, Ramachandrappa BK, Muralagiriappaya S, Sathish A, Thimmegowda MN. Soil properties and productivity of rainfed finger millet under conservation tillage and nutrient management in eastern dry zone of Karnataka. J Environ. Biol. 2018;39(5):612-624.

29. Hebbar N, Ramachandrappa BK, Muralagiriappaya S, Thimmegowda MN. Yield and economics of finger millet with establishment methods under different planting geometry and nutrient source. Indian J Dryland Agric. Res. Dev. 2018;33(1):54-58.

30. Hemalatha S, Chellamuthu S. Impacts of long-term fertilization on soil nutritional quality under finger millet – maize cropping sequence. J Environ. Res. Dev. 2013;7:1571-1576.

31. Himanshi HP, Shroff JC. Growth, yield and economics of finger millet (*Eleusine coracana* (L.) Gaertn.) as influenced by integrated nutrient management. Int. J Curr. Microbiol. Appl. Sci 2020;11:724-729.

32. Jagathjothi N, Ramamoorthy K, Kokilavani S. Effect of FYM with and without enrichment on soil microbial population, soil fertility, yield and economics. Res. J Agric. Biol. Sci 2008;4(6):647-650.

33. Krishnaprabhu S. Nutrient content, quality and water productivity of pearl millet in response to integrated nutrient management. Plant Arch 2019;19(2):1588-1591.

34. Kumar A, Metwal M, Kaur S, Gupta AK, Puranik S, Singh S et al. Nutraceutical value of finger millet [*Eleusine coracana* (L.) Gaertn.] and their improvement using omics approaches. Front. Plant Sci 2016a;7:934-942.

35. Kumar R. Effect of integrated nutrient management and seed priming on nutrient uptake and yield of finger millet (*Eleusine coracana*). M.Sc. (Ag) thesis, Indira Gandhi Krishi Viswavidyalaya, Raipur 2020, 136p.

36. Kumar SI, Babu CG, Reddy VC, Swathi B. Anti-nutritional factors in finger millet. J Nutr. Food Sci 2016b;6(3):162-164.

37. Lansankara P, Liyanage R, Jayawardana B, Vidanarachchi J. A comparative study on nutritional and nutraceutical properties of finger millet (*Eleusine coracana*) and rice (*Oryza sativa*). Wild J Biol. Pharm. Health Sci 2020;1(1):17-24.

38. Liang B, Zhao W, Yang XY, Zhou JB. Fate of nitrogen-15 as influenced by soil and nutrient management history in a 19-year wheat–maize experiment. Field Crops Res 2013;144:126-34.

39. Mahapatra SS. Nutrient management through organics for sustained productivity of finger millet. M. Sc. (Ag) thesis, Acharya N. G. Ranga Agricultural University, Hyderabad 2017, 112p.

40. Maitra S, Reddy MD, Nanda SP. Nutrient management in finger millet (*Eleusine coracana* L. Gaertn) in India. Int. J Agric. Environ. Biotechnol 2020;13(1):3-21.

41. Mandal S, Swamy SN. Productivity potential and economics of finger millet (*Eleusine coracana*) based intercropping patterns with legumes in rainfed alfisols of Hyderabad. Agric. Sci. Digest 2005;25(2):115-117.

42. Mathangi SK, Sudha K. Functional and phytochemical properties of finger millet for health. Int. J Pharm. Chem. Biol. Sci 2012;2:431-438.

43. Mgonja MA, Lenne JM, Manyasa E, Sreenivasaprasad S. (eds). Finger Millet Blast Management in East Africa : Creating Opportunities for Improving Production and Utilization of Finger Millet. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh 2007, 196p.

44. Naik TB, Naik AHK, Naik KPS. Nutrient management practices for organic cultivation of finger millet (*Eleusine coracana L.*) under southern transitional zone of Karnataka, India. Int. J Curr. Microbiol. Appl. Sci. 2017;6(11):3371-3376.

45. Nalini N, Vani KP, Devi KB, Suneetha S, Surendra BP. Effect of integrated nutrient management and dates of sowing on nutrient uptake and yield of pearl millet (*Pennisetum glaucum*). Indian J Agro. 2020;65(3):331-336.

46. Nevse GP, Chavan LS, Jagtap DN. Performance of finger millet (*Eleusine coracana* [L.] Gaertn) to age of seedlings, FYM and fertilizer levels. J Indian Soc. Coastal Agric. Res. 2013;31(2):64-70.

47. Pagano AE. Whole grains and the gluten-free diet. In: Parrish, C.R. (ed.), The Celiac Diet Series: Creating Opportunities for Improving Production and Utilization of Finger Millet. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh 2007, 196p.

48. Palaniappan SP, Annadurai K. Organic Farming- Theory and Practices. Scientific Publishers, Jodhpur, India, 1999, 243p.

49. Pallavi C, Joseph B, Khan MAA, Hemalatha S. Effect of integrated nutrient management on nutrient uptake, soil available nutrients and productivity of rainfed finger millet. Int. J Sci. Environ. 2016;5(5):2798-2813.

50. Pandian S, Sivasankar C, Muthuramalingam P, Ramesh M. An amazing nutritional value in wonderful finger millet makes this “the most lovable food crop to the world. Sci. J Food Sci. Nutr. 2017;3:34-36.

51. Prabhakar PC, Boraiah GB, Bhat S, Nandini C, Tippeswamy VK, Manjunath HA. Improved Production Technologies for Finger Millet. Project Co-ordinating
52. Prajapati MR, Dave PH, Sable PA. Nutritional and functional benefits of finger millet (Eleusine coracana). Int. J Pure Appl. Biosci 2019;7(1):342-345.

53. Prakash G, Murthy KNK, Prathima AS, Meti RN. Effect of spacing and nutrient levels on growth attributes and yield of finger millet (Eleusine coracana L. Gaertn.) cultivated under gunplant method in red sandy loam soil of Karnataka, India. Int. J Curr. Microbiol. Appl. Sci 2018;7(5):1337-1343.

54. Prashanth DV, Krishnamurthy R, Naveen DV. Long-term effect of integrated nutrient management on soil nutrient status, content and uptake by finger millet crop in a Typic Kandiustalf of eastern dry zone of Karnataka. Commun. Soil Sci. Plant Anal 2020;51:161-174.

55. Raman R, Krishnamoorthy R. Response of INM on finger millet (Eleusine coracana (L.) Gaertn.). Int. J Agron. Crop Sci 2016;1(2):9-12.

56. Ramesh G, Rao CP, Prasad PVN, Prasad PRK. Influence of INM on yield attributes, yield, economics and nitrogen use efficiency of foxtail millet. Int. J Chem. Stud 2020b;8(2):2485-2487.

57. Ramesh V, Mathur M, Kiran S, Rajeswari N, Tidke SA. Nutraceutical potential of finger millet : review. J Path. Res. Rev. Rep 2020a;2(2):1-5.

58. Rani YS, Triveni U, Patro TSSK, Anuradha N. Effect of nutrient management on yield and quality of finger millet (Eleusine coracana (L.) Gaertn.). Int. J Chem. Stud 2017;5(6):1211-1216.

59. Roy AK, Ali N, Lakra RK, Alam P, Mahapatra P, Narayan R. Effect of integrated nutrient management practices on nutrient uptake, yield of finger millet (Eleusine coracana) and post-harvest nutrient availability under rainfed condition of Jharkhand. Int. J Curr. Microbiol. Appl. Sci 2018;7(8):339-347.

60. Sankar GRM, Sharma KL, Dhanapal GN, Shankar MA, Mishra PK, Venkateswarlu B, et al. Influence of soil and fertilizer nutrients on sustainability of rainfed finger millet yield and soil fertility in semi-arid alfisols. Commun. Soil Sci. Plant Anal 2011;42:1462-1483.

61. Sarita, Singh E. Millet’s anti-nutrients and their therapeutic effects. Pharma Innovation J 2016;5(8):42-46.

62. Sarkar S. Management practices for enhancing fertilizer use efficiency under rice – wheat cropping system in the Indo-Gangetic plains. Indian J Agric. Sci 2015;3:5-10.

63. Saumshi S. Effect of enriched bio-digester liquid manure on growth and yield of organic finger millet [Eleusine coracana (L.) Gaertn.] M.Sc. (Ag) thesis, University of Agricultural Sciences, Bangalore, 2012, 133p.

64. Shilpa Vasanthy BG, Meena HM. Long-term effect of integrated nutrient management practices on growth, yield and nutrient uptake of finger millet (Eleusine coracana G.) in alfisols under different cropping systems. Int. J Plant Soil Sci 2021;33(6):46-53.

65. Singh JS. Plant growth promoting rhizobacteria – potential microbes for sustainable agriculture. Resonance 2015;18(3):275-281.

66. Singh S. Comparative Profit-Cost Analysis of Organic and Conventional Farming (In Reference of Haridwar District). Project Report. Department of Economics, B. S. M. (P.G.) College, Roorkee, Uttarakhand, 2020, 112p.

67. Srinivasarao C, Venkateswarlu B, Singh AK, Vittal KPR, Kundi S, Chary GR et al. Critical carbon inputs to maintain soil organic carbon stocks under long-term finger-millet (Eleusine coracana [L.] Gaertn.) cropping on alfisols in semi-arid tropical India. J Plant Nutr. Soil Sci. 2012;175:681-688.

68. Thimmaiah M, Kumar MD, Nandish MS, Veeranna HK. Effect of integrated nutrient management on growth, yield and economics of rainfed finger millet (Eleusine coracana (L.) G.). Green Farming 2016;7(4):875-879.

69. Tsado EK, Jatau DB, Dania E. Performance of finger millet (Eleusine coracana (L.) Gaertn.) as influenced by nutrient sources in the Southern and Northern Guinea Savanna, Nigeria. Direct Res. J Agric. Food Sci 2016;4(7):182-192.

70. Ulla, Pradeep S, Shrikanta CD, Sridhar S, Ganapathi K. Effect of different organic nutrient management practices, on growth, yield and economics of finger millet, Eleusine coracana (L) Gaertn. Int J Farm Sci 2017;7(2):10-14.

71. Ulla, Pradeep S, Sridhar S, Sunil C, Ganapathi K, Divya M. Long term effect of different organic nutrient management practices growth, yield of finger millet (Eleusine coracana L) and soil properties. J Farm Sci 2020;3(3):342-347.

72. Zhang HQ, Yu XY, Zhai BN, Jin ZY, Wang ZH. Effect of manure under different nitrogen application rates on winter wheat production and soil fertility in dryland. IOP Conf. Ser. Earth Environ. Sci. 2016;39:1-10.