E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(3): 599-603
Received: 24-01-2024
Accepted: 28-02-2024

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Impact of nutrient management practices on yield and economics of foxtail millet under foxtail millet-chickpea cropping system in integrated farming system under Tungabhadra project area of Karnataka, India

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i3h.488

Abstract
A field experiment was conducted on clay soils at Agricultural Research station, Siruguppa, University of Agricultural Sciences, Raichur during 2021-22 and 2022-23 to find out the impact of nutrient management practices on foxtail millet yield and economics under foxtail millet-chickpea cropping system. A week before foxtail millet seeding, required quantity of organic manures and inorganic fertilizers were added to the soil as per the treatment. A two-year study's worth of combined data showed that different approaches to nutrient management improved foxtail millet production and profitability significantly. Among the treatments, the highest biological yield (6367 kg ha^{-1}), grain yield (2084 kg ha^{-1}) and stover yield (4269 kg ha^{-1}) were recorded with the application of 100% RDF through inorganic fertilizers followed by the application of 75% N through inorganic fertilizers + 25% N through organic manures (biological yield: 5697 kg ha^{-1}; grain yield: 1832 kg ha^{-1} and stover yield: 3875 kg ha^{-1}), both were statistically on par with each other while superior over rest of the treatments. Similar trend was also recorded for gross return, net returns and benefit cost ratio during the both the years of pooled data. However, harvest index of foxtail millet crop recorded non-significant values among the different nutrient management practices. In order to maximize the foxtail millet productivity and economics under foxtail millet-chickpea cropping system, it is therefore feasible to grow the crop under combined application of organic manures (75% N) and inorganic fertilizers (25% N).

Keywords: Foxtail millet, inorganic fertilizers, integrated farming system, organic manures, and yield

Introduction
In various regions of India, foxtail millet (*Setaria italica* L.) is referred to as Italian millet, German millet, Korralu, Kangu, Kangani, Koni and Kaon. It is among the first crops that have been grown for hay, grazing, grain and sustenance. It comes in second position globally in terms of millet production and it still plays a significant role in global agriculture by feeding millions of people in arid and semiarid regions (Ipsitha *et al*., 2022) [5]. The world's leading producer of foxtail millet is India. It is mostly cultivated in Andhra Pradesh, Tamil Nadu, Telangana, Karnataka, Uttar Pradesh and Southern Rajasthan in India. The three states that produce the most foxtail millet in India are Andhra Pradesh, Karnataka and Tamil Nadu, accounting for around 79% of the total area (Munirathnam *et al*., 2006) [9]. In India, it is often farmed as a crop that is rainfed. Its upright, green stem reaches a height of 60 to 75 cm and when it reaches maturity, the weight of the ear head causes it to bow somewhat. One hundred grams of foxtail millet grain provides a high-quality source of fiber 8 g, 12.3 g of protein, 60.9 g of carbohydrates, 4.3 g of fat, 31 mg of calcium, 2.8 mg of iron, 290 mg of phosphorus, 3.3 g of vitamins, 3.3 g of amino acids, minerals and 323–350 K Cal of dietary energy (Vanithasri *et al*., 2012) [17]. Owing to its low glycemic index, it is utilized in the creation of low-GI biscuits and burfi, a confection that is perfect for those with diabetes. Since higher soil temperatures cause organic material to turnover more quickly, the soils in dry and semiarid climates are naturally poor in organic carbon and mostly deficient in nitrogen.

Efficient nutrient management is crucial in these regions due to their severe weather and low soil fertility, which makes it difficult to overcome the limited yield scenarios. By implementing enhanced production methods such as integrated nutrient management, farmers might potentially boost the poor productivity of their foxtail millet fields. Chemical fertilizer use is rising these days in an effort to increase agricultural yields. The use of inorganic fertilizer is the only one that harms soil health and production, aside from the fact that the expense of chemical fertilizers is always rising.

For farmers, this holds enormous potential as the integration of inorganic and organic fertilizers is essential to maintaining soil fertility and increasing crop output. Large and small plant nutrients are abundant in organic manure, such as vermicompost. Moreover, it boosts microbial activity in soil and makes nitrogen and phosphorus more available (Choudhary *et al.*, 2014) [2]. Therefore, in addition to enhancing the physicochemical qualities of soil, an integrated nutrient delivery system incorporating organic manures like farm yard manure, goat manure, vermicompost, compost and chemical fertilizer is required to satisfy the nutrient need. The current study was conducted to examine the impact of nutrient management on the productivity and economics of foxtail millet foxtail millet-chickpea cropping system due to the paucity of information available on the aforementioned factors.

2. Material and Methods

Field experiment was carried out at Agricultural Research Station, Siruguppa, University of Agricultural Sciences, Raichur, Karnataka, India for two consecutive years during *kharif* season of 2021-22 and 2022-23. The station is situated at 76º 54" East longitude and 15º 38" North latitude, with an altitude of 380 meters above mean sea level (MSL). It comes under Agro-Climatic Region-II and Northern Dry Zone (Zone-3). The climate in Siruguppa is hot and humid, with a distinct wet season from July to September. During the year 2021-22 higher rainfall of 630.10 mm was received as against normal rainfall of 623.20 mm with uneven distribution. During the year 2022-23 higher rainfall of 716.60 mm was received as against normal rainfall of 623.20 mm with uneven distribution (Table 1). The soil of the experimental site is Vertisol with slightly alkaline pH (8.16) and low in soluble salts content (0.40), high in soil organic carbon content (0.83%). The soil is low in available nitrogen (232.10 kg ha^{-1}) and sulphur (26.4 kg ha^{-1}), medium in phosphorous (44.20 kg ha^{-1}) and high in available potassium (450.00 kg ha^{-1}). However, the all available micronutrients are in sufficient range except zinc, which is deficient in soil (Table 2). The experiment consisted of four nutrient management practices, *viz.* N_1: 25% N through inorganic fertilizer + 75% N through organic manures, N_2: 50% N through inorganic fertilizer + 50% N through organic manures, N_3: 75% N through inorganic fertilizer + 25% N through organic manures and $N_{4:}$ 100% RDF through inorganic fertilizers. Organic manures: 37.5 each of vermicompost, goat manure and 25 per cent farm yard manure (FYM), compost were applied to supplement the nutrient requirement of component crops as per the treatments. Recommended phosphorous and potassium was common for all the treatments for the respective crop. These treatments were tested in a randomized block design with five replications. The plot size of 12.8 m × 4.2 m was used. The state recommendation of nutrient management for foxtail millet was 30:15:15 kg ha^{-1} N:P:K. In different treatments the recommended quantity of nutrients were supplied through vermicompost, goat manure, farm yard manure and compost as organic source of nutrients (obtained from integrated farming system unit) and urea, SSP and MOP were used as a inorganic sources of NPK. The organic manures and inorganic fertilizers in all the treatments were applied based on recommended N equivalent (Table 3). The equivalent quantity of the manures was calculated based on the nutrient content in different manures. Before incorporation of organic manures, NPK contents were analysed and nutrient content of organic manures used in the experiment are given in Table 4. All the necessary agronomic procedures were used to raise the crop. Data on biological yield, grain yield, stover yield and harvest index were collected at the harvest stage of the foxtail millet crop, along with their economic implications. The data pertaining to yield and economics were subjected to statistical analysis and was done as per methodology suggested by Gomez and Gomez (1984) [3]. Wherever the treatment differences were significant, the results have been discussed based on the critical differences at P=0.05.

Table 1: Normal and actual rainfall distribution at Agricultural Research Station, Siruguppa

Month	Normal rainfall (mm)	Actual Rainfall (mm)	
	2007 to 2021	2021-22	2022-23
Jul	79.60	157.80	70.30
Aug	131.80	62.30	187.50
Sep	166.50	43.50	151.40
Oct	70.40	67.90	196.80
Nov	21.70	137.00	3.20
Dec	2.00	0.00	11.60
Jan	2.10	0.00	0.00
Feb	1.40	0.00	0.00
Mar	9.80	0.00	4.60
Apr	11.60	0.00	6.30
May	39.80	57.00	57.00
Jun	86.50	104.60	27.90
Total	623.20	630.10	716.60

Table 2: Initial physico-chemical properties of experimental site at ARS, Siruguppa during 2021

Sl. No.	Particulars	Initial values	Method adopted	Reference
I. Physical properties				
1	Particle size distribution			
a.	Sand (%)	23.65	International pipette method	Piper (1966) [10]
b.	Silt (%)	21.39		
c.	Clay (%)	54.96		
d.	Soil texture	Clay		
2	Bulk density (g cc^{-1})	1.22	keen cup method	Black (1965) [1]
II. Chemical properties				
1	Soil pH	8.16	pH meter	Jackson (1973) [6]
2	Electrical conductivity (dS m^{-1})	0.40	Conductivity bridge	Jackson (1973) [6]
3	Organic carbon (%)	0.83	Wet oxidation method	Jackson (1973) [6]
4	Available nitrogen (kg ha^{-1})	232.10	Alkaline potassium permanganate method	Subbaiah and Asija (1956) [14]
5	Available phosphorus (kg ha^{-1})	44.2	Olsen's method	Jackson (1973) [6]
6	Available potassium (kg ha^{-1})	450.0	Flame-photometry method	Jackson (1973) [6]
7	Available sulphur (kg ha^{-1})	26.4	Turbidometric method	Jackson (1973) [6]
8	Exchangeable calcium (cmol (p+) kg^{-1})	43.38	Versenate (EDTA) titration method	Jackson (1973) [6]
9	Exchangeable magnesium (cmol (p+) kg^{-1})	19.40		
10	Available iron (ppm)	15.62	DTPA extraction method (Atomic absorption spectrophotometer)	Lindsey and Norvell (1978) [7]
11	Available zinc (ppm)	10.93		
12	Available manganese (ppm)	0.54		
13	Available copper (ppm)	2.20		

Table 3: Application of nutrient source in foxtail millet (*kharif)* as per treatment

Treatment	Quantity of manures and fertilizers applied
N_1: 25% N through inorganic fertilizer + 75% N through organic manures	VC @ 0.55 t ha^{-1} + GM @ 0.26 t ha^{-1} + FYM @ 0.50 t ha^{-1} + compost @ 0.34 t ha^{-1} + Urea @ 27 kg ha^{-1} + SSP @ 21 kg ha^{-1} + MOP @ 3 kg ha^{-1}
N_2: 50% N through inorganic fertilizer + 50% N through organic manures	VC @ 0.37 t ha^{-1} + GM @ 0.17 t ha^{-1} + FYM @ 0.33 t ha^{-1} + compost @ 0.22 t ha^{-1} + Urea @ 54 kg ha^{-1} + SSP @ 45 kg ha^{-1} + MOP @ 10 kg ha^{-1}
N_3: 75% N through inorganic fertilizer + 25% N through organic manures	VC @ 0.18 t ha^{-1} + GM @ 0.09 t ha^{-1} + FYM @ 0.16 t ha^{-1} + compost @ 0.11 t ha^{-1} + Urea @ 82 kg ha^{-1} + SSP @ 70 kg ha^{-1} + MOP @ 18 kg ha^{-1}
N_4: 100% RDF through inorganic fertilizers	Urea @ 130 kg ha^{-1} + SSP @ 94 kg ha^{-1} + MOP @ 25 kg ha^{-1}

Note: VC-Vermicompost; GM-Goat manure; FYM-Farm yard manure; SSP-Single super phosphate; MOP-Muriate of potash

Table 4: Nutrient content of organic manures used in the experiment

Source of manure	Year	Nutrient content (%)		
		N	P	K
Farm yard manure	2021-22	0.47	0.23	0.49
	2022-23	0.48	0.24	0.50
Goat manure	2021-22	2.81	1.33	1.87
	2022-23	2.78	1.21	0.86
Vermicompost	2021-22	1.29	1.01	1.06
	2022-23	1.31	1.02	1.07
Compost	2021-22	0.72	0.59	0.84

3. Results and Discussions

3.1 Effect on yield

The pooled mean data of two years study (Table 5) clearly indicate that various treatments of nutrient management practices showed significant improvement in yields *viz.*, biological yield, grain yield, stover yield as well as harvest index. The biological yield (6367 kg ha^{-1}), grain yield (2084 kg ha^{-1}) and stover yield (4269 kg ha^{-1}) were recorded highest in the treatment N_4: application of 100% RDF through inorganic fertilizers which was statistically on par with the treatment N_3: application of 75% N through inorganic fertilizer + 25% N through organic manures followed by the treatment N_2: application of 50% N through inorganic fertilizer + 50% N through organic manures, which was significantly different from the treatment N_3. However, significantly lower biological yield (4743 kg ha^{-1}), grain yield (1404 kg ha^{-1}) and stover yield (3330 kg ha^{-1}) were observed with the treatment N_1: 25% N through inorganic fertilizer + 75% N through organic manures. However, harvest index of foxtail millet crop recorded non-significant values among different nutrient management practices. The treatment N_4: 100% RDF through inorganic fertilizers produced significantly higher grain yield than the other treatments because it provided the foxtail millet plants with the optimal amount of nitrogen they needed to produce more grains. Nitrogen was an essential nutrient for plant growth and development and it was particularly important for grain production. Nitrogen helped to promote cell division and elongation, which was necessary for the production of large and well-filled grains. Inorganic fertilizers provided a readily available source of nitrogen that plants could have taken up and used immediately. This was important for grain production, which occurred early in the plant's reproductive stage. The treatment N_3, which provided 75% N through inorganic fertilizer and 25% N through organic manures, may not have provided the plants with as much nitrogen as the treatment N_4 during the early stages of grain development. This was because organic manures released nitrogen into the soil more slowly than inorganic fertilizers. The treatment N_2, which provided 50% N through inorganic fertilizer and 50% N through organic manures, provided an intermediate amount of nitrogen. This was why the treatment N_2 produced higher grain yield than the treatment N_1, but less grain yield than the treatment N_4. The treatment N_1, which provided 25% N through inorganic fertilizer and 75% N through organic manures, provided the least amount of nitrogen. This was why the treatment N_1 produced the lowest grain yield. These observations corroborate the findings of Ipsita *et al.* (2020) [4], Raviraja *et al.* (2020) [11] and Tejaswi *et al.* (2022) [15].

3.2 Effect on economics

The total cost of cultivation of foxtail millet varied due to the different nutrient management practices. The pooled mean data of two years study (Table 5) clearly indicate that various treatments of different nutrient management practices showed significant enhancement in gross returns, net returns as well as benefit cost ratio. Among the various treatments, the maximum gross returns (Rs. 68807 ha^{-1}), net returns (Rs. 48140 ha^{-1}) as well as benefit cost ratio (3.33) were recorded with the treatment N_4: application of 100% RDF through inorganic fertilizers which was statistically on par with the treatment N_3: application of 75% N through inorganic fertilizer + 25% N through organic manures followed by the treatment N_2: application of 50% N through inorganic fertilizer + 50% N through organic manures, which was significantly different from the treatment N_3. However, significantly lower gross returns (Rs. 46603 ha^{-1}), net returns (Rs. 21578 ha^{-1}) as well as benefit cost ratio (1.87) as well as harvest index were observed with the treatment N_1: 25% N through inorganic fertilizer + 75% N through organic manures.The significantly highest gross returns, net returns and benefit cost ratio under the treatment N_4: 100% RDF through inorganic fertilizers were attributed to the higher crop yields obtained under this treatment. Inorganic fertilizers are a quick-release source of nutrients that helped plants grow quickly and produce high yields. The treatment N_3: 75% N through inorganic fertilizer + 25% N through organic manures also resulted in high gross returns, net returns and benefit cost ratio. Organic manures are a slow-release source of nutrients that improved soil health and fertility. However, organic manures could not provide all the nutrients that plants needed for high yields. The treatment N_2: 50% N through inorganic fertilizer + 50% N through organic manures resulted in lower gross returns, net returns and benefit cost ratio than N_3 and N_4. This was because the lower proportion of inorganic fertilizers in this treatment limited crop yields. The treatment N_1: 25% N through inorganic fertilizer + 75% N through organic manures resulted in the lowest gross returns, net returns and benefit cost ratio. This was because the lower proportion of inorganic fertilizers in this treatment limited crop yields and the organic manures could not provide all the nutrients that plants needed for high yields. These results are in coincidence with the findings of Mohanty *et al.* (2013) [8], Roy and Singh (2014) [12], Tiryak (2015) [16], Sandya *et al.* (2017) [13] and Raviraja *et al.* (2020) [11].

Table 5: Yields of foxtail millet as influenced by different nutrient management practices under foxtail millet-chickpea system (pooled mean data of two years)

Treatment	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Benefit cost ratio
N_1	4743	1404	3330	0.297	46603	21578	1.87
N_2	5109	1589	3510	0.312	52603	29139	2.24
N_3	5697	1832	3875	0.321	60560	38497	2.75
N_4	6367	2084	4269	0.328	68807	48140	3.33
Grand mean	5479	1727	3746	0.315	57143	34339	2.55
S. Em. ±	244	84	180	0.015	2793	1769	0.12
C. D. (P=0.05)	751	260	556	NS	8606	5450	0.38

Note:
N_1: 25% N through inorganic fertilizer + 75% N through organic manures
N_2: 50% N through inorganic fertilizer + 50% N through organic manures
N_3: 75% N through inorganic fertilizer + 25% N through organic manures
N_4: 100% RDF through inorganic fertilizers

4. Conclusions

Based on the findings presented in this study, it can be said that the integrated nutrient management (75% N through inorganic fertilizers + 25% N through organic manures) under foxtail millet–chickpea cropping systems found to be optimum for realizing maximum productivity and profitability of foxtail millet in Tungabhadra project area of Karnataka.

5. Acknowledgement

Authors wish to acknowledge the immense help received from the scholars whose articles are cited and included in the references of this manuscript. The authors are also grateful to the authors/editors/publishers of all those articles, journals and books from where the literature for this article has been reviewed and discussed. Authors are thankful and would like to express our special thanks gratitude to University of Agricultural Sciences, Raichur and Agricultural Research Station, Siruguppa for providing land, inputs and facilities for conducting research work, their able guidance and support in completion of research.

6. Conflict of interests: The authors have declared no conflicts of interests exist.

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