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Chaithra GM
Ph.D. Scholar, Department of Agronomy, UAS, Raichur, Karnataka, India

Basavanneppa MA
Professor and Head, Department of Agronomy, OFRI, UAS, Raichur, Karnataka, India

Satyanarayana Rao
Professor, Department of Agronomy and Dean (Agri.), CoA, UAS, Raichur, Karnataka, India

Koppalkar BG
Professor and Head, Department of Agronomy, CoA, UAS, Raichur, Karnataka, India

Pralhad
Associate Professor and Head, Department of Microbiology, Veterinary College, Hassan, India

Ashok Kumar Gaddi
Senior Soil Scientist, ARS, Siruguppa, Karnataka, India

Corresponding Author:
Chaithra GM
Ph.D. Scholar, Department of Agronomy, UAS, Raichur, Karnataka, India

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

Chaithra GM, Basavanneppa MA, Satyanarayana Rao, Koppalkar BG, Pralhad and Ashok Kumar Gaddi

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Abstract
A field experiment was carried out during *Rabi* season of 2021-22 and 2022-23 in foxtail millet-chickpea cropping system to study the effect of 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 on crop growth, yield attributes and yield of chickpea. The pooled mean data of two years study revealed that among the treatments, the highest seed yield (6367 kg ha^{-1}) and stover yield (2084 kg ha^{-1}) of chickpea 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 (seed 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 attributes *viz*., number of pods per plant, number of seeds per pod, seed weight per plant, test weight and growth attributes *viz*., plant height and total dry matter production during the both the years of pooled data. The findings of the present study emphasizes the importance of integrated nutrient management techniques in chickpea production, particularly in the Tungabhadra project area of Karnataka, to boost production, improve agricultural performance and promote sustainable agriculture.

Keywords: Chickpea, inorganic fertilizers, integrated farming system, organic manures, seed yield

Introduction
Based on agroclimatic regions, the nation practices a number of cereal based cropping sequences. Finger millet-chickpea cultivation is mostly used in rainfed conditions. The state is now seeing a continuous or slight decrease in the yield of finger millet-chickpea farming system. According to Srivastava (1998) [11], factors that have led to the depletion of nutrients and soil organic carbon as well as the degradation of soil physical conditions include the burning of crop residues, intense cropping cultivation of high yielding varieties and careless use of chemical fertilizers. Thus, it is necessary to regulate soil productivity over the long term by utilizing both organic and inorganic sources of nutrients in an integrated manner. Manure from farms, goats, vermicompost, and compost are examples of organic nutrient sources that have the ability to enhance soil organic matter while lowering the need for artificial fertilizers. India is the world's largest producer and consumer of pulses, and pulse crops are an essential part of Indian agriculture. According to Umamadevi and Ganesan (2007) [13], pulses have about three times the amount of high-quality protein as cereals. As a result, they provide an affordable source of protein that helps combat human starvation. Due to their high organic matter content and ability to fix nitrogen biologically, pulses provide an affordable source of protein for diets. They are also excellent for animal feed and have a major impact on maintaining and enhancing soil fertility. Due to their excellent fit in crop rotation and crop sequence, as well as their greatest suitability for crop diversification, pulses are an essential component of cropping systems. Among the grain legumes, chickpea (*Cicer arietinum* L.), often referred to as Bengal gram and locally as Chana, is a significant and distinctive food legume due to its usage in a broad range of

food products such as snacks, candies, *etc*., as well as the preparation of vegetables and sauces worldwide. It is also eaten as dal flour (Besan) or as processed whole seeds that have been cooked, rosted, parched, fried, steamed, or sprouted. A excellent source of protein (18 to 22%), carbohydrates (52 to 70%), fat (4 to 10%), minerals, and vitamins is chickpeas. Additionally, it makes a great animal feed because of the high forage value of its stover. A significant pulse crop that is cultivated everywhere in the globe is chickpea. After beans and peas, it is the third-most significant pulse crop in the world. India is the world's biggest producer of chickpeas, accounting for the greatest percentage of both output (67.2%) and area (65.3%) worldwide (FAO, 2022). Generally, rain-fed marginal and sub-marginal areas with poor fertility and a variety of biotic and abiotic stressors are used to grow chickpeas. As a result, India's total chickpea productivity is rather low when compared to other nations. By fixing atmospheric nitrogen into the soil, chickpeas significantly increase soil fertility. Chickpeas can fix up to 80% of the nitrogen in the air and fulfill their nitrogen fixing needs. Being a legume, chickpeas require more nitrogen from biological nitrogen fixation, which may be facilitated by maintaining the physical and chemical conditions of the soil. Under an organic production system, the edaphic environment will be more favorable for healthy crop development and frequent application of organics keeps it at its ideal level. Research has demonstrated that an organic farming method may both increase and maintain the yield of legume crops. In addition to producing environmental contamination, the continual and indiscriminate use of chemical fertilizers has been demonstrated to have a negative impact on the physical, chemical, and biological aspects of soil, which in turn affects the sustainability of crop production (Virmani, 1994) [14]. Consequently, a research was planned to determine how various nutrition management techniques affected the development and productivity of chickpeas.

2. Materials and Methods

Field experiment was carried out at Agricultural Research Station, Siruguppa, University of Agricultural Sciences, Raichur, Karnataka, India for two consecutive years during *rabi* 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% 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 chickpea was 25:50:0 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. Chickpea cv. BGD-103 was sown @ 50 kg ha^{-1} by keeping planting geometry of 30 × 10 cm in second fortnight of October and harvested in the second fortnight of January during both the years. All the recommended agronomic practices except treatment were adopted. Periodic data on plant height and total dry matter accumulation were recorded at different growth stages, where as data related to yield attributes were recorded at the physiological maturity stage. Grain yields were recorded on a plot basis and converted into kilograms per hectare.

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) [8]
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) [4]
2.	Electrical conductivity (dS m^{-1})	0.40	Conductivity bridge	Jackson (1973) [4]
3.	Organic carbon (%)	0.83	Wet oxidation method	Jackson (1973) [4]
4.	Available nitrogen (kg ha^{-1})	232.10	Alkaline potassium permanganate method	Subbaiah and Asija (1956) [12]
5.	Available phosphorus (kg ha^{-1})	44.2	Olsen's method	Jackson (1973) [4]
6.	Available potassium (kg ha^{-1})	450.0	Flame-photometry method	Jackson (1973) [4]
7.	Available sulphur (kg ha^{-1})	26.4	Turbidometric method	Jackson (1973) [4]
8.	Exchangeable calcium (cmol (p+) kg^{-1})	43.38	Versenate (EDTA) titration method	Jackson (1973) [4]
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) [6]
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 chickpea (*Rabi)* 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 @ 14 kg ha^{-1} + SSP @ 240 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 @ 27 kg ha^{-1} + SSP @ 264 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 @ 41 kg ha^{-1} + SSP @ 288 kg ha^{-1}
N_4: 100% RDF through inorganic fertilizers	Urea @ 54 kg ha^{-1} + SSP @ 313 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
	2022-23	0.71	0.58	0.83

3. Results and Discussion

3.1 Growth parameters

Data related to chickpea plant height at various intervals are presented in Table 5. In pooled mean data, at all the growth stages, the treatment N_4: 100% RDF through inorganic fertilizers recorded significantly higher plant height (27.47, 41.21 and 49.86 cm at 30, 60 DAS and at harvest, respectively) and it was found on par with the treatment N_3: 75% N through inorganic fertilizer + 25% N through organic manures (23.46, 35.38 and 42.81 cm at 30, 60 DAS and at harvest, respectively), followed by N_2: 50% N through inorganic fertilizer + 50% N through organic manures recorded higher plant height (22.21, 33.32 and 40.31 cm at 30, 60 DAS and at harvest, respectively), which was significantly different from N_3: 75% N through inorganic fertilizer + 25% N through organic manures. Whereas, significantly lower plant height was recorded with the treatment N_1: 25% N through inorganic fertilizer + 75% N through organic manures (16.37, 24.56 and 29.71 cm at 30, 60 DAS and at harvest, respectively). The pooled mean data shows that the chickpea plant height increased with increasing nitrogen (N) fertilizer application, regardless of whether inorganic or organic fertilizers were used. The data also shows that the general mean plant height increased with increasing age of the crop and was highest at harvest. This is because chickpea plants continue to grow and develop throughout the growing season. The treatment N_4: 100% RDF through inorganic fertilizers recorded significantly higher plant height in chickpea might be due to the reasons that the inorganic fertilizers were fast-acting and provided nutrients to plants immediately. This was because inorganic fertilizers were in a soluble form, which meant that they could be easily absorbed by plant roots and inorganic fertilizers provided high levels of nutrients. This was important for chickpea plants, which needed a lot of nitrogen, phosphorus and potassium to grow and produce seeds. In contrast, organic manures were slow-acting and released nutrients to plants gradually. This was because organic manures needed to be broken down by soil microbes before they could be absorbed by plant roots. Organic manures also typically contained lower levels of nutrients than inorganic fertilizers. As a result, chickpea plants that were fertilized with inorganic fertilizers were able to grow taller and faster than chickpea plants that were fertilized with organic manures. The treatment N_3: 75% N through inorganic fertilizer + 25% N through organic manures also recorded higher plant height than the treatment N_1: 25% N through inorganic fertilizer + 75% N through organic manures. This was because the treatment N_3 received more nitrogen from inorganic fertilizers, which were fast-acting and provided nutrients to plants immediately. Organic manures were still important for chickpea production. Organic manures improved soil health and fertility, which could lead to increased yields in the long term. However, for optimal plant growth and yield, it was best to combine organic manures with inorganic fertilizers. These results are in corroborate the findings of Jakhar *et al.* (2020) [5] and Sodavadiya *et al.* (2021) [10].

The data pertaining to total dry matter production are presented in Table 6. Perusal of the pooled mean data presented in the table revealed that at all growth stages, the application of 100% RDF through inorganic fertilizers (N_4) in chickpea crop recorded significantly higher total dry matter production (1.49, 11.49 and 24.08 g $plant^{-1}$ at 30, 60 DAS and at harvest, respectively) than rest of the treatments under investigation. However, it was on par with the treatment N_3: 75% N through inorganic fertilizer + 25% N through organic manures (1.38, 10.59 and 23.14 g $plant^{-1}$ at 30, 60 DAS and at harvest, respectively), followed by N_2: 50% N through inorganic fertilizer + 50% N through organic manures recorded higher total dry matter production (1.12, 9.52 and 20.38 g $plant^{-1}$ at 30, 60 DAS and at harvest, respectively), which was significantly different from N_3: 75% N through inorganic fertilizer + 25% N through organic manures. Whereas, significantly lower total dry matter production was recorded with the treatment N_1: 25% N through inorganic fertilizer + 75% N through organic manures (0.95, 7.52 and 19.17 g plant^{-1} at 30, 60 DAS and at harvest, respectively). Further, data showed that the general mean total dry matter production was gone on increase with increasing age of the crop and seen maximum at harvest.

The application of 100% RDF through inorganic fertilizers (N_4) in chickpea crop recorded significantly higher total dry matter production than other treatments because inorganic fertilizers were a readily available source of nitrogen, so plants treated with inorganic fertilizers had more nitrogen available to produce dry matter and increased plant growth: inorganic fertilizers could increase plant growth, which led to higher dry matter production. This was because inorganic fertilizers provided plants with the nutrients they needed to grow taller, produce more leaves, and develop more extensive root systems. The treatment N_3 (75% N through inorganic fertilizer + 25% N through organic manures) also resulted in high total dry matter production, which was comparable to N_4. This was likely because N_3 also provided a significant amount of nitrogen to the plants. However, the organic manures in N_3 may have taken some time to decompose and release their nitrogen, which could explain why the total dry matter production in N_3 was slightly lower than N_4 at the early stages of crop growth. The treatment N_2 (50% N through inorganic fertilizer + 50% N through organic manures) resulted in lower total dry matter production than N_3, but it was still significantly higher than N_1 (25% N through inorganic fertilizer + 75% N through organic manures). This was likely because N_2 provided less nitrogen to the plants than N_3, but it was still more than N_1. The general mean total dry matter production of a crop increased with increasing age and reached a maximum at harvest because as the crop matured, it diverted more resources to reproductive growth and development. This meant that more photosynthates and nutrients were transported to the reproductive parts, which led to an increase in total dry matter production and older plants had more developed root systems, which allowed them to absorb more nutrients from the soil. This was important for dry matter production, as nitrogen, phosphorus, and potassium are essential nutrients for plant growth. Chickpea plants developed nodules on their roots that contained nitrogen-fixing bacteria. These bacteria converted atmospheric nitrogen into a form that could have been used by the plant. As the plant matured, the nodules may have become more developed and efficient at nitrogen fixation, which could have led to an increase in dry matter production. These results lend further credence to the findings of Sindhi *et al.* (2016) [9], Mahapatra *et al.* (2018) [17] and Sodavadiya *et al.* (2021) [10].

3.2 Yield and yield attributes

The data pertaining to yield and yield attributes are presented in Table 7. The results indicated the chickpea crop grown under the treatment N_4: 100% RDF through inorganic fertilizers produced significantly higher seed yield and stover yield (1981 and 3285 kg ha^{-1}, respectively) than rest of treatments under study and it was found on par with the treatment N_3: 75% N through inorganic fertilizer + 25% N through organic manures (1760 and 2961 kg ha^{-1}, respectively), followed by N_2: 50% N through inorganic fertilizer + 50% N through organic manures (1493 and 2788 kg ha^{-1}, respectively), which was significantly different from N_3: 75% N through inorganic fertilizer + 25% N through organic manures. Whereas, significantly lower seed yield was recorded with the treatment N_1: 25% N through inorganic fertilizer + 75% N through organic manures (1124 and 1980 kg ha^{-1}, respectively). Crop yield is the complex function of physiological processes and biochemical activities, which modify the plant anatomy and morphology of the growing plants. Significantly higher grain yield recorded with the application of 100% RDF through inorganic fertilizers was due to better yield attributing characteristics like higher number of pods per plant (18.55), number of seeds per pod (1.81), seed weight per plant (7.82 g) and test weight (24.77 g) (Table 7).

The chickpea crop grown under the treatment N_4: 100% RDF through inorganic fertilizers had produced significantly higher seed yield than the other treatments because it had received the highest amount of nitrogen. Nitrogen had been an essential nutrient for plant growth and development and it had played a particularly important role in seed production. When plants had access to sufficient nitrogen, they had been able to produce more biomass, which had been able to lead to higher seed yields. The other treatments had received less nitrogen and as a result, the plants in those treatments had not been able to produce as much biomass or as many seeds. The treatment N_3: 75% N through inorganic fertilizer + 25% N through organic manures had produced a similar seed yield to the N_4 treatment, likely because the organic manures had provided the plants with additional nitrogen and other nutrients. The treatment N_2: 50% N through inorganic fertilizer + 50% N through organic manures had produced a significantly lower seed yield than the N_3 treatment, likely because the plants in that treatment had not had access to as much nitrogen. The treatment N_1: 25% N through inorganic fertilizer + 75% N through organic manures had produced the lowest seed yield, likely because the plants in that treatment had the least access to nitrogen. In addition to the amount of nitrogen applied, the timing of fertilizer application had also been able to affect seed yield. Nitrogen should have been applied to chickpea crops at specific times during the growing season to ensure that the plants had access to the nutrient when they had needed it most. If nitrogen had been applied too early or too late in the growing season, it may not have been available to the plants when they had needed it, and this had been able to lead to lower seed yields. These results are in agreement with the research findings of Jakhar *et al.* (2020) [5] and Sodavadiya *et al.* (2021) [10].

Table 5: Plant height of chickpea as influenced by different nutrient management practices periodically during *Rabi* under foxtail millet - chickpea system (pooled mean data of two years)

Treatment	Plant height (cm)		
	30 DAS	60 DAS	Harvest
N_1: 25% N through inorganic fertilizer + 75% N through organic manures	16.37	24.56	29.71
N_2: 50% N through inorganic fertilizer + 50% N through organic manures	22.21	33.32	40.31
N_3: 75% N through inorganic fertilizer + 25% N through organic manures	23.46	35.38	42.81
N_4: 100% RDF through inorganic fertilizers	27.47	41.21	49.86
Grand mean	22.38	33.62	40.68
S. Em. ±	1.10	1.67	2.02
C. D. (P=0.05)	3.38	5.14	6.22

Table 6: Total dry matter accumulation of chickpea as influenced by different nutrient management practices periodically during *Rabi* under foxtail millet - chickpea system (pooled mean data of two years)

Treatment	Total dry matter production (g plant^{-1})		
	30 DAS	60 DAS	Harvest
N_1: 25% N through inorganic fertilizer + 75% N through organic manures	0.95	7.52	19.17
N_2: 50% N through inorganic fertilizer + 50% N through organic manures	1.12	9.52	20.38
N_3: 75% N through inorganic fertilizer + 25% N through organic manures	1.38	10.59	23.14
N_4: 100% RDF through inorganic fertilizers	1.49	11.49	24.08
Grand mean	1.23	9.78	21.69
S. Em. ±	0.06	0.48	1.04
C. D. (P=0.05)	0.19	1.47	3.19

Table 7: Yield attributes and yield of chickpea as influenced by different nutrient management practices periodically during *Rabi* under foxtail millet - chickpea system (pooled mean data of two years)

Treatment	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Number of pods per plant	Number of seeds per pod	Seed weight per plant (g)	Test weight (g)
N_1	1124	1980	14.76	1.36	6.31	21.31
N_2	1493	2788	15.49	1.51	6.58	21.57
N_3	1760	2961	17.17	1.63	7.72	22.66
N_4	1981	3285	18.55	1.81	7.82	24.77
Grand mean	1589	2753	16.49	1.58	7.11	22.58
S. Em. ±	79	136	0.78	0.08	0.34	0.99
C. D. (P=0.05)	243	418	2.41	0.24	1.04	3.04

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. Conclusion
The experimental data revealed 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 growth and productivity of chickpea in Tungabhadra project area of Karnataka.

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6. Competing interests
Authors have declared that no competing interests exist.

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