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Research Article

Impact of soil fertility characteristics on artificial fertility gradient approach developed using sorghum (*Sorghum bicolor*) in *Alfisols*

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Abstract

In the advent of precision agriculture, applying fertilizer based on soil testing is a crucial tool to prescribe nutrient levels for crops, to increase nutrient use efficiency and production. A field experiment was conducted in a farmer's field in the Dindigul district, Southern agro-climatic zone of Tamil Nadu to ascertain the effect of artificial soil fertility gradient method on soil fertility, green fodder production of sorghum (*Sorghum bicolor* (L.) Moench) (var. CO 30) and nutrient absorption. A fertility gradient technique has been investigated to produce fertilizer recommendations for location-specific in red soils (Alfisols, Typic Rhodustalf). The experimental field was separated into three equal strips: strip I, II, and III, which received applications of the three graded levels of ertilizer $N_0P_0K_0$, $N_1P_1K_1$, and $N_2P_2K_2$, respectively. Urea, single super phosphate, and muriate of potash fertilizers, respectively, were used to apply NPK. As a gradient crop, *S. bicolor* was raised. The N_1 level was set based on the general fertilizer recommendation of feed sorghum, while the P_1 and K_1 values were set based on the soil's ability to fix 100 kg ha^{-1} of phosphorus and 100 kg ha^{-1} of potassium, respectively. Plant samples were taken at harvest time, and their NPK content and nutrient uptake were determined. With addition of graded doses of nitrogen, phosphorus and potassium fertilizer in Strip I, II & III increased the soil's available N, P & K status substantially in the order of Strip I<II<III and minimize the heterogeneity in the soil population , management strategies employed, and prevailing climate conditions to induce fertility variations in the same field. The outcomes showed that sorghum crop yields for fodder (Strip III – 25.01 t ha^{-1}) and NPK uptake were significantly impacted by the application of graded amounts of NPK fertilizers.

Keywords: Gradient, Sorghum, Soil fertility, NPK uptake

INTRODUCTION

Nutrient management strategies and cropping practises considerably impact the soil fertility level and the nutrients available to plants. The loss of soil fertility brought on by crops that continuously utilize nutrients without getting enough replacement puts our food supply and the ecosystem at immediate risk. Farmyard manure (FYM) application is an ancient practise that must be revitalized to maintain soil fertility and provide a variety of vital plant nutrients for crop productivity. Crop yields were decreased and soil quality was impacted by declining soil fertility brought on by unbalanced fertilization during crop cultivation. Because of this, essential crop responses to fertilizer application are frequently far lower than possible and realistic yields. Fertilization imbalance during crop cultivation depletes soil nutrients, reduces crop yields, and deterioration of soil nutrients (Rawal *et al.,* 2018). Therefore, to maintain agricultural production, it is crucial to keep the nutrients in the soil by applying the optimum amount of fertilizers in a balanced manner.

Colwell (1968) of Australia established the deductive technique, which entails conducting multilocational experiments and pooling the data produced to construct the calibration based on soil tests. Velayutham et al. (1978) utilized this model for wheat farmed on black soils to generate location-specific fertilizer recommendations. For crops including rice, millets, groundnuts, and cotton, the All India Co-ordinated Research Project used the Colwell's optimization approach to conduct multilocational soil test crop response trials in farmers' farms. However, the experimental results from these tests have not been very successful in India in selecting proper test-based fertilizer calibrations (Velayutham *et al.,* 1985).

In order to reduce heterogeneity in the soil fertility population studied, management practices used, and seasonal variations, the "Inductive Approach" of STCR field experimental work unfairly creates all the needed variations in soil fertility level rather than choosing the most appropriate at distinct destinations as in preceding agronomic trials. This Inductive technique and the STCR field design were pioneered by Ramamoorthy and Velayutham (1971, 1972, and 1974), who were also cited by Black (1993). The experimental data may be utilized to provide fertilizer recommendations for optimal production and profit as well as for targeted crop yield objectives.

Sorghum (*Sorghum bicolor* L.) is a crop with several uses, among other exhaustive crops like cotton, wheat, sugarcane, etc. (Yousaf *et al*., 2023) can also be used for fodder and feed purposes. Sorghum is a nutrient-exhaustive crop that requires correct fertilizer treatment to increase production and improve its feed quality (Prajapati *et al*., 2023). Sorghum may be cultivated in various soil types and is resistant to drought and water-logging. It can be grown in semi-arid regions with little precipitation since it is a crop that can withstand water stress. It is important to understand the impact of soil fertility features and creating an artificial fertility gradient using sorghum were the purposes of this experiment. The goal of the present study was, to the greatest degree feasible, to vary the soil fertility of the experimental field and to provide data that covered the acceptable range of values for each controlled variable (fertilizer dose) at various levels was of the uncontrollable variable (soil fertility), which not anticipated to occur at one location regularly.

MATERIALS AND METHODS

Site description

Field experiments were conducted at Thoppupatti village, in the Vedasandur block of the Dindigul District of Tamil Nadu, the experimental site. It was at 261 meters above mean sea level, latitude 10°34’ 49” N, longitude 78°04’ 35” E. The soil at the site of the experiment is an Alfisol order classified under the *Typic Rhodustalf* belonging to Palaviduthi soil series. The site location was mapped using QGIS - 3.16 software, shown in Fig. 1.

Gradient experiment

Prior to testing with the gradient crop, sorghum (*Sorghum bicolor* (L.) Moench) (*var*. CO 30) was grown (from December 2021 – March 2022) in a fertility gradient observational study to induce alterations in soil fertility. An exhaustive crop of fodder-purpose, sorghum was grown successfully to enhance soil fertility. It was harvested at the pre-flowering stage as roughage using the inductive method developed by Ramamoorthy *et al.* (1967). At first, the fertility gradient was artificial means created by applying 3 levels of fertilizers, namely level 1 ($N_0P_0K_0$), level 2 ($N_1P_1K_1$), and level 3 ($N_2P_2K_2$) doses. The standard dose of P_2O_5 and K_2O fertilizer was formulated based on the soil's capacity to fix phosphorus and potassium. The standard dose of N is established per the general recommendations for the gradient crop of sorghum.

90 kg ha^{-1} of nitrogen fertilizer is the standard recommended dose for feedstock sorghum. In contrast, to strip I, which received no fertilizer application, strips II and III received basal applications of 50% N, 100% P_2O_5 and K_2O, and subsequent application of 50% N 30 days after planting. The fertilizers utilized were urea, single super phosphate, and muriate of potash. A graphical representation of the artificial fertility gradient experiment is shown in Fig. 2. To measure the progression of the fertility gradient, soil samples were gathered after the sorghum crop was harvested and the major

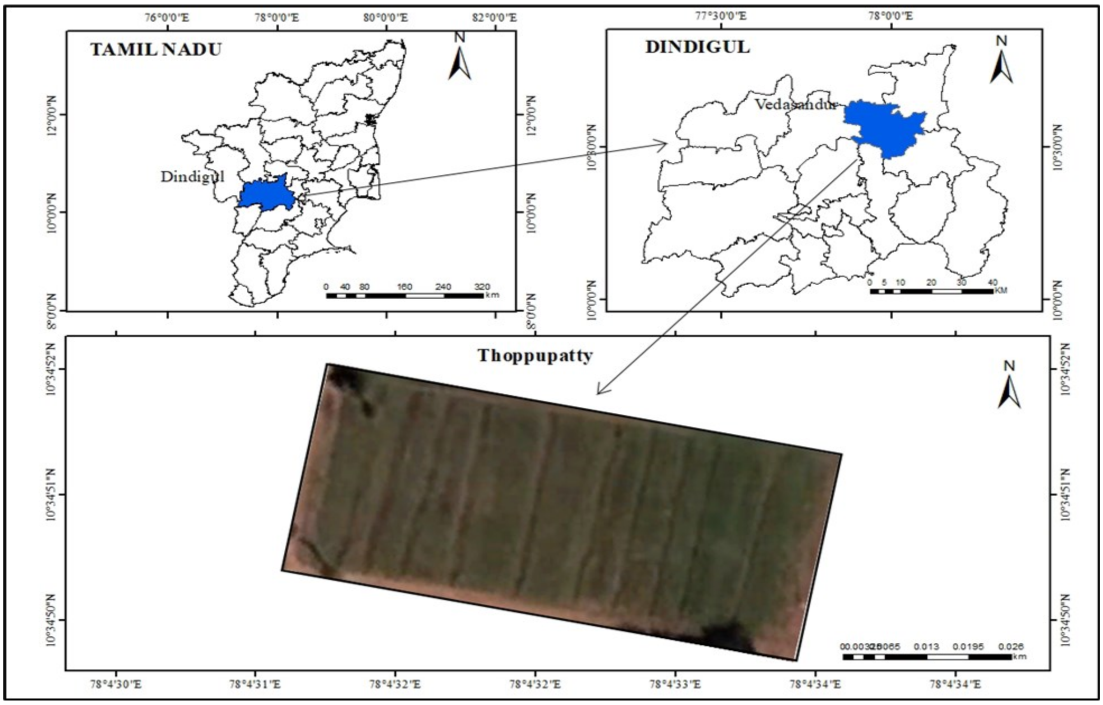

Fig. 1. *Location of the Gradient experimental field*

nutrients N, P and K were analyzed.

Soil physical, physico-chemical and chemical properties

From each plot, eight undisturbed samples were randomly obtained at a depth of 0.0 to 0.15 m. The samples were dried in an oven at 100 °C for 24 hours before being used to estimate bulk density. Each experimental plot's soil was sampled after the experiment for chemical analysis. After being collected, the soil samples were crushed, dried by air, and passed through a 2 mm screen. Then the sieved soil samples were transported to the lab for a chemical evaluation. Using the dichromate wet oxidation method, Walkley and Black's process was used to calculate the amount of soil organic carbon. Organic carbon was multiplied by 1.724 to get the amount of organic matter. Micro-Kjeldahl digestion and distillation methods were used to calculate the total N (Humphries, 1956), and available P was extracted using Olsen solution and measured using Colorimetry (Olsen *et al.,* 1954). K that could be exchanged was removed using 1 N ammonium acetate (Hanway and Heidal, 1952). Then, total P and K were calculated using Piper's (1966) approach. Using 1:2.5 soil-to-water media, a digital electronic pH meter and an electrical conductivity meter were used to measure the pH and electrical conductivity of the soil.

Growth and yield parameters determination

SPAD chlorophyll meter reading(SCMR): SPAD-502 portable chlorophyll meter was used to determine the sorghum's Soil and Plant analysis development value by collecting leaves on different days after planting.

Plant height: From the plant's base to its top, the height of the plants was measured at various growth phases. The mean plant height in cm was used to indicate the average values of randomly chosen plants.

Biological yield: The weight of the mature above-ground biomass of the plants in a plot was calculated and translated to kg per hectare. It was simplified by drying a sample of plants at 105°C until a consistent weight was achieved.

Nutrient uptake: Nutrient content and the respective stalk yield in ha^{-1} were multiplied to determine the amount of nutrients taken up by the stalk. The total nutrient intake by biomass was calculated and represented in kg ha^{-1} (Weldegebriel *et al.,* 2018). The nutrient uptake was calculated empirically using the method below:

Nutrient uptake by Stalk (Kg ha^{-1}) = Stalk Yield(Kg ha^{-1}) x Nutrient concentration (Kg ha^{-1}) / 100 Eq.1

Enzymatic and microbial diversity assessment

To estimate urease activity, the soil was exposed to an aqueous urea solution for two hours at 378 ^{0}C. Ammonium was extracted using 1M KCl and 10 mM HCl, and colorimetric NH_4^+ determination using a modified indophenol reaction was performed (Kandeler and Gerber, 1988). Dehydrogenase (ADh) was detected using the colorimetric method described by Casida *et al*. (1964) using 1% solution of TTC (2,3,5-tri-phenyl tetrazolium chloride) as a substrate after 24 hours at 30 °C and a wavelength of 485 nm (TTC test). Phosphatase activity was determined colorimetrically using p- nitrophenol as substrate and measured at 420 nm (Tabatabai and Bremner, 1969).The serial dilution method was used for the microbiological analysis, which required counting the colony-forming units (CFU g^{-1} of soil) of all the bacteria, actinomycetes, and fungi present (Martin, 1950).

Statistical analysis

Agress softwarewas used for statistical analysis of the data collected during investigations (Snedecor and Cochran, 1967). At P=0.05, the critical difference was generated to compare the treatment means.

RESULTS AND DISCUSSION

Initial soil characteristics

The research area's sandy loam soil texture was taxonomically identified as Typic Rhodutalf belonging to the Palaviduthi soil series. The findings of initial soil characteristics showed that the pH, electrical conductivity, WBC (Walkley and Black organic C), available N, available P, and available K values were 7.49, 0.13 dS m^{-1}, 6.5 g kg^{-1}, 215, 21.3, and 219 kg ha^{-1}. The DTPA extractable zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu) were in the sufficient range (0.92, 3.81, 7.78 and 1.11 mg kg^{-1}, respectively). The soil's total N, P and K contents were 0.08, 0.06 and 0.24 %, respectively (Table 1). The soil's P and K fixing capacities were 100 and 100 kg ha^{-1}, respectively (Table 2).

Soil available nutrient status

Available nutrient status of initial soil samples

Before planting the gradient crop of fodder sorghum, twenty-four soil samples were taken and tested for $KMnO_4$-N, Olsen-P, and NH_4OAc-K. The range of $KMnO_4$-N values was 211 to 219 kg ha^{-1}, with the mean value for strips I, II, and III being 216, 214, and 216 kg ha^{-1}, respectively. With a mean value of 22.8, 21.0, and 21.6 kg ha^{-1} for strips I, II, and III, respectively, the status of Olsen-P varied from 20.1 to 24.7 kg ha^{-1}. Regarding NH_4OAc-K, the values ranged from 214 to 225 kg ha^{-1}, with the average values for strips I, II, and III being 221, 216 and 217, respectively.

Available nutrient status of post-harvest soil samples

The post-harvest soil samples from the gradient experiment for the status of $KMnO_4$-N, Olsen-P, and NH_4OAc-K showed the impact of graded fertilizer application amounts on establishing fertility gradients. Table 2 displays the mean values of the nutrients readily available in the soil. Following the harvest of the fodder sorghum, soil samples were collected. Analysis of those samples revealed that $KMnO_4$-N values ranged from 198 kg ha^{-1} in strip I to 249 kg ha^{-1} in strip III, with the mean values in strips I, II, and III, respectively, being 201, 224, and 244 kg ha^{-1}. The range of soil test results for Olsen-P status was 19.8 to 39.1 kg ha^{-1}, with the mean value being 20.9, 29.6, and 34.9 kg ha^{-1}, respectively. The soil's NH_4OAc-K status ranged from 195 to 250 kg ha^{-1}, with mean values in strips I, II, and III of 198, 227, and 248 kg ha^{-1}, respectively. The statistical analysis revealed that each strip differs statistically from the others, and the addition of graded doses of nitrogen, phosphorus and potassium fertilizer increased the soil's available N, P & K status substantially.

Table 1. Characteristics of the initial surface soil sample of the experimental field

Physical and physico-chemical properties										
Sand (%)	**Silt (%)**	**Clay (%)**	**Texture**	**pH**	**EC (dS m^{-1})**	**Free calcium carbonate (%)**	**P fixing (kg ha^{-1})**	**K fixing (kg ha^{-1})**		
64.2	17.16	18.40	SL	7.49	0.13	2.5	100	100		
Chemical properties										
Total N	**Total P**	**Total K**	**Organic carbon (g kg^{-1})**	**$KMnO_4$ –N (kg ha^{-1})**	**Olsen-P (kg ha^{-1})**	**NH_4OAc -K (kg ha^{-1})**	**DTPA-Zn (mg kg^{-1})**	**DTPA - Fe (mg kg^{-1})**	**DTPA-Mn (mg kg^{-1})**	**DTPA- Cu (mg kg^{-1})**
0.08	0.06	0.24	5.5	215	21.3	219	0.92	3.81	7.78	1.11

Table 2. Effect of application of graded levels of N, P_2O5 and K_2O on soil fertility status of gradient experiment

Strip	Levels of Nutrients			Fertiliser doses (kg ha^{-1})			Pre-sowing soil test values			Post-harvest soil test values		
	N	P_2O_5	K_2O	FN	FP_2O_5	FK_2O	$KMnO_4$– N	Olsen - P	NH_4OAc- K	$KMnO_4$– N	Olsen - P	NH_4OAc- K
								(kg ha^{-1})			(kg ha^{-1})	
I	N_0	P_0	K_0	0	0	0	216	22.8	221	201	20.9	198
II	N_1*	P_1**	K_1**	90	229	121	214	21.0	216	224	29.6	227
III	N_2	P_2	K_2	180	458	242	216	21.6	217	244	34.9	248
SEd										2.3	0.95	3.3
CD (P= 0.05)										7	2.6	9

* N_1: as per blanket recommendation; ** P_1 and K_1: as per P and K fixing capacities of the experimental field (P-100 kg ha^{-1} and K-100 kg ha^{-1})

SCMR (SPAD Chlorophyll Meter Reading)

Readings from the Soil and Plant Analysis Development (SPAD) meters are directly related to the amount of nitrogen in the leaves (Joshi, 2015). Compared to the extraction approach, the chlorophyll meter (SPAD 502) is a more suitable, simple, speedy, rapid, and non-destructive method for determining leaf chlorophyll concentration (Yamamoto *et al*., 2002).The administration of increasing fertilizer dosages had a substantial ($P < 0.05$) impact on SPAD, quantifying chlorophyll content. Strip III plots had the greatest SPAD measurement (51.31), whereas the unfertilized control had the lowest chlorophyll reading (43.73) (Fig. 3). Compared to single -dose fertilized plots, the N skipped control plots' SPAD value was considerably lower (Strip I). The increased nitrogen accumulation of sorghum leaves, which ultimately helped to synthesize more chlorophyll, would be related to an increase in the SPAD value with the administration of N fertilizer. Ajeigbe *et al.* (2018) indicated that the maximum SPAD value was found at higher dosages of nitrogen fertilizers in Bayero University Kano and Minjibir Nigeria, which is consistent with this finding.

Plant height

Fertilization significantly impacted the plant height of fodder sorghum, with Strip III having the greatest mean plant height (183 cm). At strips II and I, the average plant height was 159 and 124 cm, respectively. Stronger nutrient absorption by feed sorghum and a comparatively higher fertility condition in strip II may be the causes of the 28.2 per cent increase in plant height in strip II over strip I (Fig. 3). Nitrogen availability and uptake by the crop led to increased vegetative growth and a faster rate of cell division, differentiation and expansion, resulting in luxuriant growth. The height of fodder sorghum increased as a result of nitrogen fertilisation, as nitrogen enhance protein synthesis and consequently vegetative growth which resulted in increasing of photosynthetic rate and stimulated of further growth as stated by Mopagar *et al*. (2023), confirming the results mentioned previously. Due to the enhanced availability of these nutrients in the soil and improved root development, P and K treatments also raised plant height and sorghum's capacity to absorb N, P, and K. In the end, this led to a greater yield (Qamar et al., 2022). These treatments also increased soil fertility, which can result in higher crop yields and higher crop quality.

Biological yield

The findings demonstrated that N, P, and K levels considerably impacted green feed production (Table 3). By raising the fertiliser's N, P_2O_5, and K_2O levels compared Sorghum in Strip I, where fertilizers were not used ($N_0P_0K_0$), produced 13.53 t ha^{-1} of green fodder. The fodder production produced in strip II where nitrogen was treated at 90 kg ha^{-1} (the blanket guideline) and phosphorus and potassium fertilizers at a rate corresponding to the soil's P and K fixing capacities—was 20.87 t ha^{-1}, or 54.3% more than in strip I. The yield in strip III, which had twice as much N, P_2O_5, and K_2O applied as in strip II, was 25.01 t ha^{-1}, an increase of 84.85 and 19.84 % over strips I and II, respectively. It could be because applying fertilizer at graduated levels improved nutrient absorption and growth factors like plant height, eventually leading to higher overall green yields. Verma et al. (2014) also reported that applying graded fertilizers to a rice crop gradient increased grain and straw output. The significant influence of N on enhancing plant growth properties may explain the rise in sorghum's green and dry fodder yields (Meena *et al*., 2012).

Additionally, Marsalis *et al*. (2010) reported that nitrogen fertilization had a favorable impact on the sorghum crop's ability to produce fodder. The findings of the present study and those in sorghum from Singh (2014) are quite similar. This might result from increased soil nutrient availability brought on by higher levels of N, P, and K fertilizers as well as the beneficial effects of these nutrients on the growth of fodder crops. Rashid and Iqbal (2012) on feed sorghum and Alias *et al*. (2012) on fodder maize both came to similar conclusions. Meena *et al*. (2012) also stated that hybrid sorghum's green fodder output significantly increased when N levels

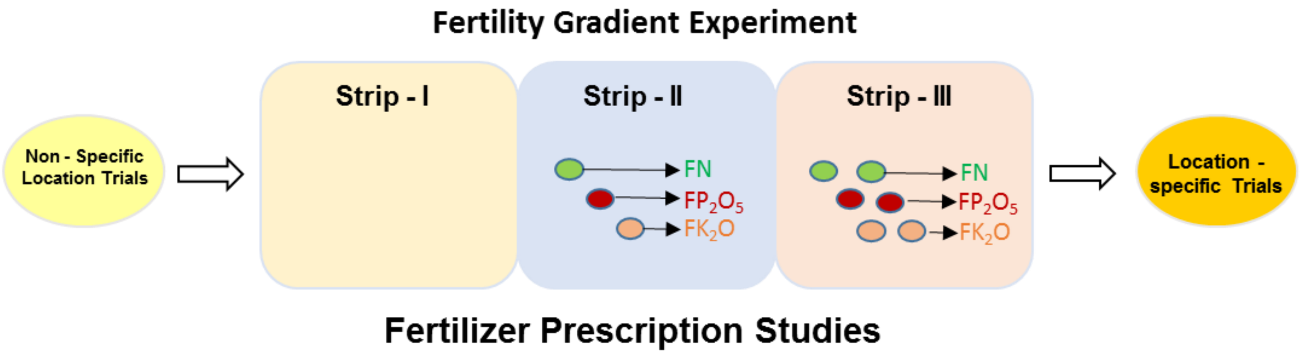

Fig. 2. *Graphical representation of Fertility gradient Experiment*

were raised.

Nutrient uptake

Due to fertilizer treatment, strip III treated with a twofold dosage of fertilizer (Table 3) recorded the best yield and had the highest N uptake in stalk (73.7 kg ha^{-1}). While the strip I used as a control had the lowest N uptake by the stalk (33.8 kg ha^{-1}). Thus, the presence of K (Sharma and Ramna, 1993) revealed that applying K freed the fixed NH^{4+} from the soil and assisted the crop in greater nitrogen absorption. As a result, the difference in N uptake within the treatment is related to the presence of K. This outcome was consistent with that of Wang *et al*. (2017), who found that adequate nutrition administration greatly improved stalk N-uptake. Bhoya *et al*. (2013) also found that sorghum uptake was more for nitrogen when 120 kg N per hectare was applied.

Strip III had the maximum stalk uptake, whereas the control strip had the least P uptake. The greatest absorption by the stalk owing to the interaction with the graded dosage of fertilizers is 20.3 kg ha^{-1} in the double dose-treated strip. In contrast, the minimum was 9.8 Kg ha^{-1} reported in control. The highest growth was produced by a method that collects the most P nutrients (Weldegebriel *et al*., 2018). Higher amounts of phosphorus treatments, which result in more root multiplication of the crop, are responsible for the considerable increase in P absorption (Verma *et al*., 2015).

In present study, similar outcomes were also shown in potassium uptake, with the strip treated with a twofold dose of potassium recording the maximum potassium uptake (70.4 kg ha^{-1}) and the untreated strip recording the lowest (25.7 kg ha^{-1}) values. The use of graded levels of N, P_2O_5, and K_2O fertilizers boosted the N, P, and K absorption and the rice crop's grain and straw yield, according to Singh *et al*. (2015). This most active absorption stage was relatively slow for Fe and Mn, beginning at 32 days after emergence and stabilizing at 38 and 37 days after emergence, while it was much faster for Cu and Zn, beginning at 30 days after emergence and lasting until 55 and 56 days after emergence, respectively (Cavalcante *et al.,* 2018). Applying a twofold NPK fertilisation dosage, the maximum Zn uptake (1.35 kg ha^{-1}) and Fe uptake (1.71 kg ha^{-1}) at harvest were measured. Strip III recorded the highest absorption of Zn and Fe, whereas no fertilized strip produced the lowest uptake of Zn and Fe (control). The fact that biomass sorghum accumulates a lot of Fe may mean that Fe is the most limited micronutrient. With 0.29 and 0.48 Kg ha^{-1}, Mn and Cu were the least absorbed micronutrients (Figure 4). According to Suganya *et al.* (2020) for observations on maize, the decreased Cu absorption may be connected to the antagonistic bivalent cation absorption interactions. According to Kumar *et al.* (2006), the impact of micronutrient delivery with a soil test-based response on starch content was extremely significant.

The order of the overall macro- and micronutrient demands in sorghum was N > K > P > Fe > Zn > Cu > Mn. The largest nutrient accumulation among the plant's component fractions was brought on by the increased dry matter accumulation carried on by the graded dose of NPK fertilizer used.

Assessment of microbial population in soil

The population of bacteria (79 cfu /g soil), fungi (19 cfu /g soil), and actinomycetes (22 cfu /g soil) was the highest in the treatment, where double the dose of nutrients was administered (Table 4). This could be attributed to the fact that the NPK provided a large quantity of readily available nutrients, resulting in a microbial system that was more diverse and dynamic. Further, most soil microorganisms are chemo-heterotrophs,

Table 3. Effect of application of graded levels of N, P_2O_5 and K_2O on yield and nutrient uptake by fodder sorghum (CO - 30)

Strip	Fertiliser doses (kg ha^{-1})			Green fodder yield (t ha^{-1})	Nutrient uptake (kg ha^{-1})		
	N	P_2O_5	K_2O		N	P	K
I	0	0	0	13.53	33.8	9.8	25.7
II	90	229	121	20.87	56.4	15.7	51.2
III	180	458	242	25.01	73.7	20.3	70.4
SEd				0.91	2.6	1.0	2.1
CD (P= 0.05)				2.53	7.2	2.8	5.7

Table 4. Enzymatic and microbial diversity on graded levels of N, P_2O5 and K_2O on soil fertility gradient

Parameters		Urease (µg NH_4 g^{-1} hr^{-1})	Phosphatase (µg P-NP g^{-1} hr^{-1})	Dehydrogenase (µg TPF g^{-1} day^{-1})	Bacteria @ 10^{-6} (cfu g^{-1} soil)	Fungi @ 10^{-3} (cfu g^{-1} soil)	Actinomycetes @ 10^{-3} (cfu g^{-1} soil)
Strip	I	16.2	23.6	17.2	44.7	11.8	8.5
	II	23.5	27.7	28.3	72.8	15.8	18.1
	III	24.3	28.4	33.4	79.2	19.1	22.3
SEd		0.7	0.6	0.7	0.9	1.3	1.5
CD (P= 0.05)		2.0	1.8	1.9	2.4	3.7	4.0

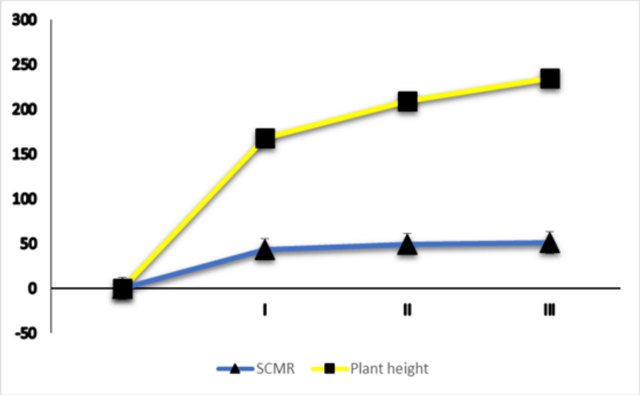

Fig. 3. *Response of SCMR and Plant height to the graded dose of NPK fertilizers*

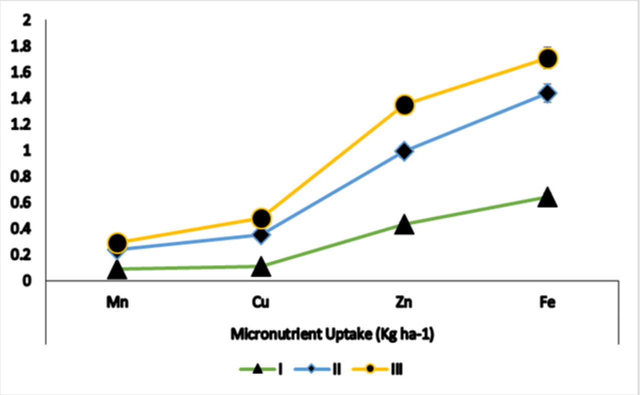

Fig. 4. *Uptake of Micronutrients (Mn, Cu, Zn & Fe) to the graded dose of NPK fertilizers*

which require a natural wellspring of carbon as food and oxidation of natural substances gives energy. This may explain working on microbial populace in Integrated Nutrient Management. Similarly, when compared to balanced fertilization or concurrent fertilization, no fertilization of sorghum resulted in a decrease in the microbial population. This was attributed to the possibility of a decrease in the number of microorganisms due to continued cropping exhausting the native pool of nutrients. So, the findings suggest that applying organics and inorganics to soil based on a soil test helps to increase the population of beneficial microbial organisms and their activities in organic matter decomposition, biological nitrogen fixation, phosphorus solubilization, and the availability of plant nutrients. The increase in microbial population associated with fertilizer application indicating improved biological soil health, has also been reported earlier (Haney *et al*., 2018).

Assessment of enzymatic activity in soil

The study of soil enzymes provides indicators of ecological change and information about the release of nutrients from organic matter degradation and microbial activity in soil. According to Kumar *et al*. (2013) soil enzyme analysis aids in determining the succession stage of an ecosystem by establishing correlations with soil fertilization, microbial activity, biochemical cycling of various elements in soil, and pollution level. Prasanthi *et al*. (2017) mentioned that the enzymatic activity of urease, dehydrogenase and phosphatase was increased throughout the growth of crops by the application of organic and inorganic and also, the enzymatic activity was in positive correlation with the availability of soil nutrients such as nitrogen, phosphorus, potassium and organic carbon.

Microorganisms produce urease, an enzyme that hydrolyzes urea into carbon dioxide and ammonia (Mekonnen *et al*., 2021). Urease is an important extracellular enzyme that can help plants absorb NH_4^+ by promoting the hydrolysis of urea into NH4+ (Sun *et al*., 2013).The increased application of nitrogen in the form of urea lead to an increase in urease activity among the inorganic fertilization treatments. The present results showed that double dose fertilizer applied strip (strip III) showed significantly higher urease activity (24.3 µg NH_4^+ g^{-1} hr^{-1}) which was higher than strip II (single dose of fertilizer) (23.5 µg P-NP NH_4^+ g^{-1} hr^{-1}) and the lowest was recorded (Table 4) in absolute control strip (strip I) (16.2 µg P-NP NH_4^+ g^{-1} hr^{-1}). Due to the absence of organic inputs and lower root biomass production, the absolute control plot, Strip I, had the lowest urease activity (Mohammadi *et al*., 2014).

Phosphatase enzyme production by microbes and root hairs are important factors in improving the availability of orthophosphate needed for the plant and microbial growth (Cabugao et al., 2017). The basic idea of using soil enzyme activity as a measure of microbial indicators for soil fertility was introduced and established by Waksman (1992). In present study, The soil phosphatase activity ranged from 23.6 mg P-NP g^{-1} hr^{-1} in absolute control to 28.4 mg P-NP g^{-1} hr^{-1} in strip III. The soil dehydrogenase activity in soils provides correlative information on the soil's biological activity and microbial populations. Post-harvest rhizosphere soil dehydrogenase activity ranged from 17.2 µg TPF g^{-1} day^{-1} in Strip I (absolute control) to 33.4 µg TPF g^{-1} day^{-1} in Strip III (Double dose of fertilizer).

Conclusion

The present findings showed that using graded amounts of N, P, and K fertilizers produced an artificial soil fertility gradient in the test field and substantially impacted the sorghum crop's post-harvest soil test values, nutrient absorption, and green fodder output. The inductive approach must be considered for additional STCR field experimentation-based fertilizer prescriptions for the prevailing climatic circumstances and management approach used to apply.

Conflict of interest

The authors declare that they have no conflict of interest.

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