International Journal of Plant & Soil Science

Volume 36, Issue 5, Page 143-151, 2024; Article no.IJPSS.114409
ISSN: 2320-7035

Influence of Integrated Nutrient Management Practices on Soil Fertility and Yield of Fodder Maize in Chennai

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2024/v36i54511

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/114409

Original Research Article

Received: 08/01/2024
Accepted: 11/03/2024
Published: 20/03/2024

ABSTRACT

Field experiments were conducted to study the influence of fodder maize (*Zea mays* L.) by adopting different bulky organic manures and fertilizer levels on the soil fertility status and fodder yield of maize. The study was conducted during *rabi* season of 2019 and 2020 at the Department of Agronomy, Madras Veterinary College, Chennai. An experiment was laid out in split plot design. Main plots consisted of different organic manure treatments *viz*., No manure, farm yard manure (25 t ha^{-1}), vermicompost (12 t ha^{-1}) and poultry manure (12 t ha^{-1}). Sub plots consisted of varying level of fertilizer treatments viz., No fertilizer, 125% RDF, 100% RDF, 75% RDF. The blanket recommendation of fertilizer to fodder maize is 60 kg N ha^{-1}: 40 kg P_2O_5 ha^{-1}: 20 kg K_2O ha^{-1}. The organic manures were applied as per the N equivalent basis to inorganic nutrient recommendation. The results revealed that all the soil parameters, green and dry fodder yield were significantly affected with the application of organic manures and fertilizer levels. Organic sources of nutrients tended to improve soil physico-chemical properties *viz.,* bulk density, water holding capacity, porosity and organic carbon. The highest organic carbon content was noticed with the application

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of poultry manure (0.50 %) followed by poultry manure. The post harvest available soil nutrients was high in fodder maize grown with poultry manure along with 125% recommended dose of inorganic fertilizer to fodder maize recorded higher soil available nitrogen (109.48 kg ha^{-1}), phosphorus (15.46 kg ha^{-1}) and potassium (118.65 kg ha^{-1}). Significantly higher green and dry fodder yield of maize was recorded with application of poultry manure along with 75 % recommended dose of fertilizer. Hence, application of organic manures specifically poultry manure along with low level of fertilizer improved the soil fertility and thus increased the green fodder yield of maize.

Keywords: Fodder maize; soil pH; organic carbon; soil available nutrients; fodder yield; fertilizer; organic manures.

1. INTRODUCTION

"Nowadays, crop production in the world is mainly affected by over use of land and poor soil fertility. It is a major threat to food security due to ever increasing growth rate of human population every year" [1]. Land available for agricultural purposes is shrinking and demands for food to feed the growing population is increasing every year. Hence, the available cultivable lands should be used effectively with proper soil fertility management.

"In order to increasing crop yields and to meet out public needs, the inputs in the form of fertilizers, pesticides and weedicides along with intensive irrigation practices helped to achieve the target to a certain stage. However, decrease in crop yield, low availability of soil microorganisms and poor soil fertility took place despite the application of fertilizer. Moreover, ground water, air, human and animal health will also be affected by these chemicals directly and indirectly" [2].

"To minimize this adverse effect of chemical fertilizers, organic manures are being promoted now, giving rise to the concept of organic agriculture. Organic manures include Farm Yard Manure, Vermicompost, Poultry Manure, Sheep Manure and Goat Manure etc., Organic fertilizers have long since been known to improve physical and chemical properties, increases the humus content and biological properties of soil that help in flourishing of beneficial macro- and microorganisms" [3]. Organic amendments increase soil humus, soil carbon and nitrogen content, which results in enhanced soil fertility and crop productivity and it is also eco-friendly and cost-effective.

"In India, maize is cultivated as important food crop next to rice and wheat. It can be cultivated throughout the year due its wide adaptability and acceptability. Maize is used as food grain; feed and fodder, preparation of starch etc. Maize green forage, particularly when it contains the stalks, leaves and ears, is an energy-rich feed for ruminant livestock (Maize is quick growing, yields high biomass, and is highly palatable" [4]. "It contains sufficient quantities of protein and minerals and possesses high digestibility as compared to other non-legume fodders" [5].

To meet the needs of ever increasing livestock population, the production and productivity of fodder crops to be increased. The area under fodder cultivation has been decreasing. Hence, the available land will be effectively used for increasing fodder production throughout the year. Though maize is a year round crop it will not produce more yield without proper nutrient management. Maize is an exhaustive crop and requires more amount nutrients for its growth and productivity. Only scanty information is available on integrated nutrient management of fodder maize. Hence, the present study was under taken to increase maize fodder productivity and sustain the soil fertility by integrated application of organic manures and inorganic fertilizers to fodder maize.

2. MATERIALS AND METHODS

Field experiment was carried out at the Department of Agronomy, Madras Veterinary College, Chennai during the *Rabi season* of 2019 and 2020. The soil of the field was red sandy loam in texture classified under the order *Alfisols* belonging to Typic Ustropept. pH was slightly alkaline (7.43) having an electrical conductivity of 0.28 dSm^{-1}. The organic carbon content was 0.26 per cent. The nutrient status of the soil was low in available Nitrogen (128.5 kg ha^{-1}), medium in available Phosphorus (25.3 kg ha^{-1}), and medium in available potassium (226.3 kg ha^{-1}). African tall is the maize variety used for this experiment.

The experiment was laid out in RCBD with four replications. The treatments comprised of different organic sources of nutrients such as No manure (M_1), Farm Yard Manure (M_2), Vermicompost (M_3) and Poultry Manure (M_4). Different level of fertilizers are used such as, No fertilizer (F_1), 125% RDF (F_2), 100% RDF (F_3) and 75% RDF (F_4). The blanket recommendation of fertilizer for fodder maize is 60: 40: 20 Kg NPK ha^{-1}, respectively. Organic manures were applied equivalent to recommended dose of nitrogen fertilizer basis. The fertilizers used for this study are urea, single super phosphate and muriate of potash for supplying nitrogen, phosphorus and potassium nutrients, respectively.

2.1 Soil Physical Properties

For measuring the bulk density, the soil sample was collected by core sampler method and recorded by Keen's cup method developed by Piper [6] for the soil samples collected after the harvest of the crop and expressed in g cm^{-3}. Maximum water holding capacity of the soil was recorded by Keen's cup method developed by Piper [6]. It was recorded after harvest of crops from each plot and expressed in percentage. Per cent of pore space of soil was recorded by Keen's cup method developed by Piper [6]. It was also recorded after harvest of crops from each plot and expressed in percentage.

2.2 Soil Chemical Properties

Mechanical composition of the experimental field soil was analyzed as per the procedure suggested by Piper [6] for the soil samples collected after the harvest crop. "Soil pH and EC were estimated by using pH meter and Conductivity Bridge, respectively, in a soil: water suspension of 1: 2.5 ratio" [7]. The soil was also analyzed for soil organic carbon [8].

The soil samples collected from 0-15 cm depth after the harvest of the crop were air dried, sieved through 2 mm mesh and used for available N, P, and K estimation.The available soil nitrogen was estimated by the method proposed by Subbiah and Asija [9] and expressed in kg ha^{-1}. Available soil phosphorus was estimated by the procedure outlined by Olsen et al. [10] and expressed in kg ha^{-1}. Available soil potassium was estimated by the method proposed by Stanford and English [11] and expressed in kg ha^{-1}.

2.3 Fodder Yield

The maize plants were cut or harvested above the ground level and taken fresh weight by using weighing balance and recorded the yield in all plots having different treatments and expressed to t ha^{-1} which gave green fodder yield of maize. For computing the dry fodder yield, the plant samples were dried using hot air oven at 65°C for 48 hours. The dried plant samples were weighed by using weighing balance and recorded dry fodder yield of maize (t ha^{-1}). All the parameters were analyzed using ANOVA mentioned by Panse and Sukhatme [12] F-value was tested at 5 % significance level.

3. RESULTS AND DISCUSSION

3.1 Soil Physical Properties

Application of organic manures tended to improve soil physical properties viz, bulk density, water holding capacity and porosity of soil compared to initial status. Application of poultry manures resulted in lower bulk density (1.38 g cm^{-3}) and higher water holding capacity (41.82 %) and porosity (43.90 %) after the harvest of fodder maize as compared to other organic manures (Table 1). This might be due to adding of poultry manure may also reduce compactness of soils or increased the looseness of soil resulting in increased soil volume as compared to that of other organic manures.

"The reduced bulk density with the organic manures application was due to the improvement of soil aggregation, soil structural improvement and increased porosity" [13]. "Application of organic manures increased moisture content of the soil better than the chemical fertilizers due to its high organic carbon content and addition of organic matter of the soil. Organic matter has the ability to retain appreciable amounts of soil moisture as suggested by" Agyenim et al. [14]. Similar results were also reported by Jagadeesha et al. [15].

"With regard to fertilizers, application of 125% RDF recorded higher bulk density (1.39 g $cm^{-3)}$, low water holding capacity (41.65 %) and porosity (43.94 %) than 75 % RDF. This might be attributed to deterioration of soil structure by higher dose of inorganic fertilizer application" [16].

Table 1. Influence of bulky organic nutrients and fertilizers on physical parameters of soil after harvest of fodder maize (Pooled data)

Treatments	Bulk density (g cm^{-3})					Maximum water holding capacity (%)					Porosity (%)				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
M_1	1.54	1.53	1.52	1.41	1.50	33.43	35.15	34.87	36.06	34.88	36.28	37.25	36.97	38.16	37.17
M_2	1.54	1.49	1.45	1.48	1.49	33.32	36.04	35.93	36.89	35.54	35.45	37.37	38.06	39.02	37.48
M_3	1.52	1.49	1.42	1.35	1.44	38.18	37.94	38.43	39.16	38.43	39.32	40.17	38.41	42.05	39.99
M_4	1.41	1.39	1.38	1.35	1.38	40.23	41.65	42.15	43.24	41.82	42.52	43.94	44.44	44.70	43.90
Mean	1.50	1.47	1.44	1.40		36.29	37.69	37.85	38.84		38.39	39.68	39.47	40.98	
	M	F	M at F			M	F	M at F			M	F	M at F		
SE	0.035	0.035	0.069			1.039	0.743	1.486			1.164	0.837	1.674		
CD (p=0.05)	0.085	0.071	NS			2.54	1.53	NS			2.85	1.73	NS		

3.2 Soil Chemical Properties

3.2.1 Soil PH and EC

The INM practice, organic manures and recommended NPK fertilizers application did not showed any significant difference on soil pH at post harvest stage of the soil (Table 2). However, slight decrease in pH was observed due to use of poultry manure which could have been due to their acidic nature.With regard to EC, 75% RDF recorded significantly lower EC followed by 100%RDF. These results are in agreement with the findings of Rukmangada et al. [17]. Treatments without any fertilizer recorded higher EC when compared to all other treatments.

3.2.2 Soil organic carbon

At post harvest stage, higher organic carbon content was recorded with application of poultry manure (0.50%) followed by vermicompost application (0.45%). This might be due to slow mineralization could lead to high organic carbon accumulation in soil. Invariably, all the organic treatments registered with the organic carbon content ranged from 0.44 to 0.50%.The findings are in agreement with Dinesh [18].

The 125% RDF recorded lower organic carbon (0.49%) when compared to 100 % RDF and 75% RDF, respectively. “The control (No manure - M1) and (No fertilizer- F_1) registered with lower organic carbon content in this study. This might be due to application of inorganic NPK fertilizer fails to sequestrate SOC, only the application of organic manure alone has showed effective for sequestrating soil organic carbon” [19].

3.2.3 Post harvest soil available nutrients

The post harvest available soil nutrients was significantly influenced by organic manures and inorganic fertilizers during both the years of study. The treatments differed for the available nutrient status of the soil (Table 3).

Among the organic manures, application of poultry manure registered higher soil available N (99.28 kg ha^{-1}), soil available P (13.35 kg ha^{-1}) and soil available potassium (107.53 kg ha^{-1}) followed by application of vermicompost to the fodder maize crop (Table 2). Higher nutrient availability in the organic manures such as poultry manure might be due to continuous and slow release of nutrients from organic manure and increased biomass and accumulated soil organic matter. Similar findings were also reported by Alagappan and Venkitaswamy [20]. Application of farm yard manure for the fodder maize resulted in lower quantity of soil available nutrients followed by no application of organic manures to the fodder maize.

The soil available nutrients were lesser under the 75% recommended dose of fertilizer followed by no application of inorganic fertilizer. This might be due to lower amount of residual nutrient in low dose of inorganic fertilizer applied field. Inorganic fertilizers cause immediate release of nutrients, which will be utilized by the crop or might have lost the environment through leaching or identification process. Similar results were also noted by Singh et al. [21]. The soil available nutrients were higher with the application of 125% recommended dose of fertilizer followed by the application of 100% recommended dose of inorganic fertilizer.

The interaction between organic manures and inorganic fertilizers was found significant. The treatment combination of poultry manure along with 125% recommended dose of inorganic fertilizer to fodder maize recorded higher soil available nitrogen (109.48 kg ha^{-1}), phosphorus (15.46 kg ha^{-1}) and potassium (118.65 kg ha^{-1}) followed by application of poultry manure along with 100 % recommended dose of inorganic fertilizer to fodder maize crop. This could be due to slow release of nutrients from organic manures and excess quantity of inorganic fertilizers was not fully utilized by the maize crop and leads to accumulation of nutrients in the soil after harvest of the crop. The least soil available nutrients were recorded under the control plots.

3.3 Green and Dry Fodder Yield of Maize

“Among organic manures, application of poultry manure (equivalent to 50 kg N or 12 t ha^{-1}) produced higher green fodder yield (21.17 t ha^{-1} at 45 DAS and 28. 22 t ha^{-1}at 60 DAS). Maize dry fodder yield (3.54 t ha^{-1} at 45 DAS and 4.66 t ha^{-1}) (Table 4) also recorded higher under the treatment of poultry manure application which is followed by application of Farm Yard Manure at 45 and 60 DAS. This could be ascribed to the higher nutrient composition in poultry manure coupled with slow and steady rate of nutrient release in to soil solution was responsible for better absorption of nutrients by fodder maize in different crop growth stages starting from vegetative to grain formation stage” [22].

Table 2. Influence of bulky organic nutrients and fertilizers on chemical parameters of soil after harvest of fodder maize (Pooled data)

Treatments	pH					EC (ds m^{-1})					Organic carbon (%)				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
M_1	7.52	7.47	7.45	7.42	7.46	0.293	0.280	0.280	0.270	0.281	0.32	0.33	0.34	0.38	0.34
M_2	7.43	7.45	7.44	7.35	7.42	0.280	0.280	0.270	0.270	0.275	0.42	0.43	0.44	0.46	0.44
M_3	7.57	7.40	7.38	7.37	7.43	0.275	0.270	0.260	0.268	0.268	0.45	0.43	0.45	0.46	0.45
M_4	7.32	7.38	7.35	7.29	7.34	0.280	0.270	0.260	0.253	0.266	0.46	0.49	0.52	0.54	0.50
Mean	7.46	7.43	7.41	7.36		0.282	0.275	0.268	0.265		0.41	0.42	0.44	0.46	
	M	F	M at F			M	F	M at F			M	F	M at F		
SE	0.140	0.15	0.308			0.008	0.006	0.011			0.01	0.001	0.017		
CD (p=0.05)	NS	NS	NS			NS	0.012	NS			0.029	0.018	NS		

Table 3. Influence of bulky organic nutrients and fertilizers on post-harvest available soil nutrients (Pooled data)

Treatments	N (Nitrogen Kg ha^{-1})					P (Phosphorus Kg ha^{-1})					K (Potassium Kg ha^{-1})				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
M_1	70.6	80.7	78.7	72.4	75.6	7.7	9.0	8.9	8.2	8.5	74.7	85.5	83.7	79.9	80.9
M_2	84.1	91.3	89.7	85.5	87.6	9.6	10.9	10.1	9.9	10.1	91.5	98.7	95.6	92.5	94.6
M_3	83.6	100.5	97.6	94.6	94.1	9.3	12.5	12.0	11.0	11.2	90.6	107.9	104.7	100.8	101.0
M_4	80.7	109.5	104.3	102.7	99.3	9.0	15.5	13.5	15.5	13.4	85.5	118.6	115.5	110.7	107.5
Mean	79.8	95.5	92.5	88.8		8.9	12.0	11.1	11.1		85.6	102.6	99.9	95.9	
	M	F	M at F			M	F	M at F			M	F	M at F		
SE	2.38	1.85	3.69			0.30	0.21	0.43			2.58	1.98	3.97		
CD (p=0.05)	5.82	3.81	7.62			0.73	0.44	0.88			6.31	4.09	8.19		

Table 4. Influence of bulky organic nutrients and fertilizers on green and dry fodder yield (t ha [1]) of fodder maize (Pooled data)

Treatments	Green fodder yield (t ha^{-1})										Dry fodder yield (t ha^{-1})									
	45 DAS					60 DAS					45 DAS					60 DAS				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
M_1	16.1	17.3	17.3	16.3	16.8	23.3	24.4	24.3	23.6	23.9	1.9	2.6	2.5	2.2	2.3	3.1	3.7	3.6	3.4	3.4
M_2	16.8	19.4	19.6	19.8	18.9	23.9	26.5	26.9	27.1	26.1	2.4	3.2	3.4	3.4	3.1	3.5	4.4	4.5	4.5	4.2
M_3	18.5	17.8	18.2	18.7	18.3	25.2	24.9	25.2	25.8	25.3	2.5	2.8	3.0	3.0	2.8	3.6	3.9	4.1	4.2	4.0
M_4	17.4	20.5	22.2	24.5	21.2	24.5	27.4	29.2	31.8	28.2	2.6	3.6	3.8	4.1	3.5	3.7	4.7	5.0	5.2	4.7
Mean	17.2	18.8	19.3	19.8		24.2	25.8	26.4	27.1		2.36	3.07	3.16	3.2		3.5	4.2	4.3	4.3	
	M	F	M at F			M	F	M at F			M	F	M at F			M	F	M at F		
SE	0.51	0.39	0.78			0.70	0.55	1.09			0.08	0.06	0.12			0.11	0.08	0.17		
CD (p=0.05)	1.25	0.81	1.61			1.70	1.13	2.25			0.20	0.12	0.25			0.27	0.17	0.35		

With regard to fertilizer levels, higher green fodder yield was recorded under the 75% RDF (19.84, 27.07 t ha^{-1} at 45 and 60 DAS, respectively). Higher yield of maize dry fodder was registered (3.20 and 4.30 at 45 and 60 DAS, respectively) in 75% RDF followed by 100% RDF. The increase levels of fertilizer (125% RDF) have not increased the green fodder and dry fodder yield. Primary nutrients are the important nutrients, which enhanced the plant growth parameters such as plant height, number of leaves, dry matter accumulation etc. and other yield parameters of fodder maize. Hence, lower dose of fertilizer will be enough to increase the plant growth and thus increase the green fodder yield. The findings were similar to the previous findings of Rama et al. [23].

The treatment combination of bulky organic nutrients and different fertilizers were significant. Green and dry fodder yield were recorded higher under the poultry manure + 75% RDF (31.8 t ha^{-1} and 5.20 t ha^{-1} at 60 DAS, respectively), when compared to this, the treatment of poultry manure + 100% RDF recorded low green and dry fodder yield. The reason for increased green and dry fodder yield might be due to slow and steady release of nutrients from poultry manure and effective utilization of applied nutrients by fodder maize. These combined nutrients enhanced the maize plant height and dry matter accumulation at different stages and thus increased green and dry fodder yield.

In this study, the applied poultry manure had higher amount of all nutrients and it improved the physical, chemical and biological properties of the soil. So, applied nutrients of 75% RDF were effectively utilized by the maize crop. These results were similar to the findings of Mahmooda et al. [24] in maize crop.

Nitrogen nutrient can be supplied by many commercial fertilizers like urea and ammonium nitrate, which are commonly used by the farmers. In case of bulky organic nutrients, which also supply all essential nutrients to the crop growth and thus improves soil fertility which will finally increase the crop growth and yield in a sustainable way [25,26].

4. CONCLUSION

The imbalanced use of inorganic fertilizers and organic manures has led to the deterioration of soil health and productivity. Organic manure contains essential plant nutrients that can be used for crop production efficiently. In the present study, use of organic manures, specifically poultry manure resulted in improve of soil physical and chemical properties *viz.,* bulk density, water holding capacity, porosity and organic carbon. Similarly, integrated nutrient combination of poultry manure along with 125% RDF to fodder maize recorded higher soil available nutrients than 75% RDF. Significantly higher green and dry fodder yield of fodder maize was recorded with application of poultry manure along with 75% recommended dose of fertilizer. Therefore, it is concluded that integrated nutrient management is crucial for sustainable crop production. It can be recommended for fodder maize production under irrigated conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/114409