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Evaluation of various nutrient sources on productivity, economics and soil health in maize (*Zea mays* L.)

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Abstract

An experiment was carried out to know the influence of different nutrient sources on yield, economics and nutrient uptake and soil nutrient status in Maize (*Zea mays* L.) at Agricultural College Farm, Agricultural College, Mahanandi, Acharya N. G. Ranga Agricultural University during *rabi* Season, 2022-2023. The experiment was designed in randomized block design with three replications and comprised of ten treatments viz., T₁: Control, T₂: Neem cake @ 750 kg ha⁻¹, T₃: *Pongamia* cake @ 750 kg ha⁻¹, T₄: Cotton seed cake @ 750 kg ha⁻¹, T₅: Vermicompost @ 2.5 t ha⁻¹, T₆: Farm yard manure @ 10 t ha⁻¹, T₇: Neem oil @ 75 l ha⁻¹, T₈: *Pongamia* oil @ 75 l ha⁻¹, T₉: Cotton seed oil @ 75 l ha⁻¹ and T₁₀: Recommended dose of N, P, K kg ha⁻¹ (250:60:60). Among different treatments, application of recommended dose of NPK @ 250:60:60 kg ha⁻¹(T₁₀) significantly increased the grain yield of maize, net returns, benefit cost ratio, nutrient uptake and soil nutrient status over conventional and non-conventional manures like compost, vermicompost, oil cakes and non-edible oils.

Keywords: Maize, yield, economics, soil nutrient status, soil parameters, conventional and non - conventional nutrient sources

Introduction

Maize (*Zea mays* L.), is an important cereal crop globally, with a production of 1210 million tonnes and a productivity of 6000 kg/ha. Maize comprises 60-68% starch and 7-15% protein, and is notably rich in phosphorus and potash. In India, maize is grown on an area of 12.09 million hectares, with a production output of 43.40 million tonnes and a productivity rate of 3590 kg ha⁻¹ (www.indiastat.com, 2023-2024) [4]. In Andhra Pradesh, maize cultivation is in an area of 3.30 lakh hectares with a production of 21.48 lakh tonnes and productivity of 6510 kg ha⁻¹ in 2023-2024 (www.indiastat.com).

Since maize is an exhaustive crop that heavily depletes soil nutrients, effective nutrient management is essential for achieving higher yields (Adhikari *et al.*, 2016) [1]. Proper nutrient management is key to ensuring optimal growth and productivity. However, in ancient times, farmers depended on organic manures for crop cultivation, which were beneficial for soil health but slow in impacting crop yields. In present scenario, rapid economic progress has prompted farmers to turn to mineral fertilizers, as they are more cost-effective, accessible, easy to apply, and provide quick results. The excessive use of these fertilizers is causing land degradation, declining soil health, and nutrient leaching into groundwater, posing environmental threats to human and animal health. Additionally, the unbalanced use of chemical fertilizers presents a significant challenge, especially for small and resource-poor farmers. In contrast to chemical fertilizers, traditional and alternative sources like compost, vermicompost, farmyard manure, oil cakes, and oils provide necessary nutrients while enhancing soil properties, boosting crop yields, protecting crops from pests and diseases, and ultimately reducing the financial burden on farmers for purchasing chemical fertilizers.

Alternative sources of nutrients through non-conventional and conventional manures such as oilcakes derived from neem, cottonseed, and *Pongamia*, have been utilized extensively to enhance nutrient content and manage pest populations. These organic amendments provide secondary and micronutrients in addition to organic matter, thereby improving nitrogen utilization, soil structure, water retention, beneficial microbial activity and pathogen suppression.

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Neem cake comprises 5.2% nitrogen, 1.0% phosphorus, and 1.4% potash, and possesses fungicidal and nematicidal properties. Cottonseed cake contains 3.1-3.3% oil, 9-10% moisture, and 14-15% crude proteins, which contribute to the acidification of alkaline soils and function as a natural slow-release biofertilizer rich in minerals. *Pongamia* (*Pongamia pinnata*) serves as an effective organic fertilizer, providing 4.89% nitrogen, 1.52% phosphorus, 1.49% potassium, minerals, and amino acids, while also enhancing microbial activity. Consequently, it is imperative to assess the efficacy of various non-conventional and conventional organic nutrient sources to sustain crop yields without compromising soil fertility and productivity. In consideration of these factors, a field study was conducted at Agricultural College, Mahanadi, to evaluate the impact of conventional and non-conventional manures on maize productivity, economic viability and soil health.

Materials and Methods

A field study was conducted at College Farm, Agricultural College, Mahanandi, ANGRAU during rabi 2022-23 to study the performance of conventional and non-conventional sources of manures on maize (*Zea mays* L.). The experimental soil was sandy loam (pH 7.33), low in organic carbon (0.48%) and available N (248 kg ha⁻¹), medium in available P (49 kg ha⁻¹), and high in available K (586 kg ha⁻¹). The study comprised ten treatments viz., T₁: Control, T₂: Neem cake @ 750 kg ha⁻¹, T₃: *Pongamia* cake @ 750 kg ha⁻¹, T₄: Cotton seed cake @ 750 kg ha⁻¹, T₅: Vermicompost @ 2.5 t ha⁻¹, T₆: Farm yard manure @ 10 t ha⁻¹, T₇: Neem oil @ 75 l ha⁻¹, T₈: *Pongamia* oil @ 75 l ha⁻¹, T₉: Cotton seed oil @ 75 l ha⁻¹ and T₁₀: Recommended dose of N, P, K kg ha⁻¹ (250:60:60). The experiment was designed in randomized block design (RBD) with three replications. In case of treatment T₁₀, the fertilizers like P and K were applied basally; N in three equal splits at different stages of crop growth i.e., basal, knee-high and tasseling. Oil cakes (750 kg ha⁻¹) were ground and applied at 10 DAS. Non-conventional Oils (75 L ha⁻¹) were diluted 1:100 with detergent and drenched at the base 1 week after sowing. FYM and vermicompost were applied pre-sowing. Maize hybrid NMH 8352 was sown at 60 × 20 cm spacing. Data from five tagged plants were analysed statistically (Panse and Sukhatme, 1978) [3].

Results and Discussion

Impact on Yield

A significant and higher grain yield (8731 kg ha⁻¹) and stover yield (9290 kg ha⁻¹) were noted with application of recommended dose of N, P, K @ 250:60:60 kg ha⁻¹ (T₁₀) over all other treatments (Table.1), and the lower grain yield (3491 kg ha⁻¹) and stover yield (6480 kg ha⁻¹) were obtained with T₁ (control). The application of recommended dose of N: P: K @ 250:60:60 kg ha⁻¹ (T₁₀) resulted in the higher grain yield, demonstrating a 250% increase compared to the control (T₁). This yield was 58% greater than that achieved with Neem cake at 750 kg ha⁻¹ (T₂), 102% higher than with *Pongamia* cake at 750 kg ha⁻¹ (T₃), 120% more than with cotton seed cake at 750 kg ha⁻¹ (T₄), 70% above vermicompost at 2.5 t ha⁻¹ (T₅), 89% over farm yard manure at 10 t ha⁻¹ (T₆), 53% more than Neem oil at 75 l ha⁻¹ (T₇), 104% higher than *Pongamia* oil at 75 l ha⁻¹ (T₈), and 73% greater than cotton seed oil at 75 l ha⁻¹ (T₉). In case of organic manures, vermicompost at 2.5 t ha⁻¹ (T₅) proved more effective than farm yard manure at 10 t ha⁻¹ (T₆). Among the various oilcakes, Neem oil cake at 750 kg ha⁻¹ (T₂) yielded better results than both *Pongamia* cake at 750 kg ha⁻¹ (T₃) and cotton seed cake at 750 kg ha⁻¹ (T₄). As for non-conventional oils, Neem oil at 75 l ha⁻¹ (T₇) led to higher yields, followed by cotton seed oil at 75 l ha⁻¹ (T₉) and *Pongamia* oil at 75 l ha⁻¹

(T₈). The increased in grain and stover yields of maize might be due to an abundant supply of essential nutrients from inorganic fertilizers. The grain and stover yields were influenced by various factors such as the synthesis and accumulation of photosynthates from the higher leaf area, chlorophyll content and extent of distribution into sink (grain) and enhanced growth of plant during the early stages of plant. These results are in conformity with the findings of Madhukar *et al.* (2021) [12] and Gurjar *et al.* (2022) [5].

Impact on Economics

Regarding economics (Table.1), significantly higher gross returns (₹ 174865 ha⁻¹), net returns (₹ 139417.17 ha⁻¹) and B:C ratio (3.93) were obtained with the treatment T₁₀ i.e., application of recommended dose of N, P, K @ 250:60:60 kg ha⁻¹, while the control (T₁) had the lower gross returns (₹ 70237 ha⁻¹) and net returns (₹ 44447.23 ha⁻¹). However, the lower B:C ratio (0.96) was observed with T₄ (cotton seed cake @ 750 kg ha⁻¹). The higher economics like gross returns, net returns and B:C ratio were observed with recommended dose of N: P: K @ 250:60:60 kg ha⁻¹ through chemical fertilizers might be due to supply of sufficient nutrients at reduced cost resulted in the higher grain and stover yield which in turn led to higher gross returns, net returns and B:C ratio of maize. Similar findings were reported by Viswanath *et al.* (2019) [8] and Mahato *et al.* (2020) [7].

Impact on nutrient uptake

Different sources of manures and chemical fertilizer significantly influenced the nutrient uptake by maize crop (Table.2). Higher nitrogen uptake by grain (81.20 kg ha⁻¹) and stover (69.37 kg ha⁻¹) were observed with the treatment T₁₀ (recommended dose of N, P, K @ 250:60:60 kg ha⁻¹). On the other hand, T₁ (control) exhibited the lowest grain and stover nitrogen uptake by maize. However, the nitrogen uptake by stover was comparable with T₉ i.e., application of cotton seed oil @ 75 l ha⁻¹ (54.46 kg ha⁻¹) and T₂ i.e., application of neem cake @ 750 kg ha⁻¹ (60.40 kg ha⁻¹). Phosphorus uptake and potassium uptake, showed a similar trend as nitrogen uptake by maize. However, higher phosphorus uptake by grain and stover (25.90 and 16.10 kg ha⁻¹, respectively) and potassium up take by grain and stover (29.54 and 114.58 kg ha⁻¹, respectively). The lower phosphorus and potassium uptake were obtained by control (T₁). Though the higher phosphorus uptake by stover was comparable to the phosphorus uptake with the treatments received vermicompost @ 2.5 t ha⁻¹ (T₅: 14.65 kg ha⁻¹), neem cake @ 750 kg ha⁻¹ (T₂: 14.27 kg ha⁻¹) and neem oil @ 75 l ha⁻¹ (T₇: 13.95 kg ha⁻¹). The increased nutrient uptake in maize might be attributed to the presence of sufficient nutrients in the plant's rhizosphere, facilitating enhanced absorption by the crop. Consequently, this led to the attainment of optimal yield parameters. These results were also supported by the studies of Masood *et al.* (2014) [9], Viswanath *et al.* (2019) [8].

Impact on physio-chemical properties after harvest

Soil pH: Soil pH (Table.3) was not significantly influenced by various sources of manures and fertilizers; however, variation was observed in individual treatment levels. Among different treatments, T₁₀ i.e., application of recommended dose of N: P: K @ 250:60:60 kg ha⁻¹ recorded maximum pH (7.48) and T₃ (*Pongamia* cake @ 750 kg ha⁻¹) recorded lowest pH (7.29). The pH was increased with recommended dose of N: P: K @ 250:60:60 kg ha⁻¹ from initial soil P^H 7.33 to 7.48 and this might be due to temporary and localised effect of nitrogenous fertilizers as phosphorus and potassium did not have any significant influence on P^H. The decrease in pH observed with the use of organic manures can be ascribed to the discharge of

organic acids generated by the enhanced microbial population within the soil. Similar findings were also reported by Santhosh Kumar *et al.* (2017) ^[11].

Organic Carbon: The soil organic carbon content (Table.3) after crop harvesting did not show any significant difference between the various treatments in the study. Application of different organic sources of nutrients could not change organic carbon content in soil in one season. Similar report was documented by Garba and Oyinlola (2014) ^[10].

Nutrient Status: The soil's nitrogen, phosphorus and potassium levels (Table.3) under different treatments in maize had a notable impact on the nutrient status of the soil. Maximum available nitrogen (241.50 kg ha⁻¹) was observed in T₁₀ (recommended dose of N, P, K @ 250:60:60 kg ha⁻¹) which was comparable to T₂ (neem cake @ 750 kg ha⁻¹). In contrast, T₁ (control) exhibited the lowest nitrogen content (147.00 kg ha⁻¹) when compared to the other treatments. Regarding available phosphorus in soil, the treatment T₈ (*Pongamia* oil @ 75 l ha⁻¹) exhibited the highest available phosphorus (56.00 kg ha⁻¹) which

was comparable to the levels observed in T₂ (neem cake @ 750 kg ha⁻¹), T₅ (vermicompost @ 2.5 t ha⁻¹), T₆ (farm yard manure @10 t ha⁻¹) and T₉ (cotton seed oil @ 75 l ha⁻¹). In contrast, the control (T₁) displayed the lowest phosphorus content. The higher potassium content (574.34 kg ha⁻¹) in soil after harvest was observed when T₁₀ (recommended dose of N, P, K @ 250:60:60 kg ha⁻¹) was applied which was comparable to T₁ (control), T₂ (neem cake @ 750 kg ha⁻¹), T₄ (cotton seed cake @ 750 kg ha⁻¹), T₅ (vermicompost @ 2.5 t ha⁻¹), T₆ (farm yard manure @10 t ha⁻¹) and T₈ (*Pongamia* oil @ 75 l ha⁻¹). Conversely, the use of T₃ (*Pongamia* cake @ 750 kg ha⁻¹) resulted in the lowest potassium content in the soil. The soil fertility dynamics after crop harvest are mainly governed by the amount of nutrients supplied by the soil at different stages of crop over initial soil fertility status and the amount of nutrients absorbed by the crop that resulted in crop production (grain and stover). In the current study, the higher levels of residual soil nutrients were observed in T₁₀ (recommended dose of N, P, K @ 250:60:60 kg ha⁻¹) in which adequate amount of nutrients were supplied to the soil. Garba and Oyinlola (2014) ^[10], Masood *et al.* (2014) ^[9] and Madhukar *et al.* (2021) ^[6] also recorded comparable outcomes.

Table 1: Impact of different conventional and non-conventional manures on yield and economics of Maize (*Zea mays* L.)

Treatments	Yield (kg ha ⁻¹)		Economics (₹ ha ⁻¹)		
	Grain yield	Stover yield	Gross returns	Net returns	B:C ratio
T ₁ : Control	3491	4249	70237.23	44447.23	1.72
T ₂ : Neem cake @ 750 kg ha ⁻¹	5508	6483	110610.06	69820.06	1.71
T ₃ : <i>Pongamia</i> cake @ 750 kg ha ⁻¹	4315	5561	86926.58	46135.58	1.13
T ₄ : Cotton seed cake @ 750 kg ha ⁻¹	3961	5447	79927.81	39136.81	0.96
T ₅ : Vermicompost @ 2.5 t ha ⁻¹	5129	7324	103714.37	62924.37	1.54
T ₆ : Farm yard manure @10 t ha ⁻¹	4602	6480	92989.62	61698.62	1.97
T ₇ : Neem oil @ 75 lt ha ⁻¹	5699	6863	114535.20	73745.20	1.81
T ₈ : <i>Pongamia</i> oil @ 75 lt ha ⁻¹	4272	6413	86480.50	46023.50	1.12
T ₉ : Cotton seed oil @ 75 lt ha ⁻¹	5043	6920	101831.42	64791.42	1.75
T ₁₀ : Recommended dose of N, P, K @ 250:60:60 kg ha ⁻¹	8731	9290	174865.17	139417.17	3.93
S.Em. ±	598.8	271.0	11633.99	11662.72	0.32
CD (p = 0.05)	1779.2	805.1	34566.37	34651.73	0.94

Table 2: Impact of different conventional and non-conventional manures on Nutrient uptake (kg ha⁻¹)

Treatments	Nitrogen uptake (kg ha ⁻¹)		Phosphorus uptake (kg ha ⁻¹)		Potassium uptake (kg ha ⁻¹)	
	Stover	Grain	Stover	Grain	Stover	Grain
T ₁ : Control	34.77	35.03	11.49	11.40	72.19	13.21
T ₂ : Neem cake @ 750 kg ha ⁻¹	55.97	60.40	14.27	18.44	96.86	20.20
T ₃ : <i>Pongamia</i> cake @ 750 kg ha ⁻¹	45.42	49.34	12.23	13.95	75.26	14.83
T ₄ : Cotton seed cake @ 750 kg ha ⁻¹	35.59	36.97	12.17	13.07	70.41	11.50
T ₅ : Vermicompost @ 2.5 t ha ⁻¹	41.01	55.06	14.65	16.41	92.82	14.41
T ₆ : Farm yard manure @10 t ha ⁻¹	32.74	38.51	12.96	14.12	77.49	10.52
T ₇ : Neem oil @ 75 lt ha ⁻¹	41.63	59.84	13.95	17.67	83.61	15.22
T ₈ : <i>Pongamia</i> oil @ 75 lt ha ⁻¹	35.92	44.29	12.92	13.67	76.22	13.90
T ₉ : Cotton seed oil @ 75 lt ha ⁻¹	58.13	54.46	12.23	15.80	85.86	14.82
T ₁₀ : Recommended dose of N, P, K @ 250:60:60 kg ha ⁻¹	69.37	81.20	16.10	25.90	114.58	29.54
S.Em. ±	7.98	3.70	0.84	0.54	3.58	1.03
CD (p = 0.05)	23.70	10.98	2.51	1.61	10.64	3.05

Table 3: Impact of different conventional and non-conventional manures on Soil physio chemical parameters

Treatments	pH	OC (%)	N (kg ha ⁻¹)	P2O5 (kg ha ⁻¹)	K2O (kg ha ⁻¹)
T ₁ : Control	7.36	0.54	147.00	42.56	527.37
T ₂ : Neem cake @ 750 kg ha ⁻¹	7.31	0.54	226.80	52.27	555.33
T ₃ : <i>Pongamia</i> cake @ 750 kg ha ⁻¹	7.29	0.46	191.10	50.03	507.36
T ₄ : Cotton seed cake @ 750 kg ha ⁻¹	7.38	0.49	195.30	50.03	543.20
T ₅ : Vermicompost @ 2.5 t ha ⁻¹	7.33	0.50	197.40	52.27	537.45
T ₆ : Farm yard manure @10 t ha ⁻¹	7.32	0.48	201.60	54.51	529.35
T ₇ : Neem oil @ 75 lt ha ⁻¹	7.35	0.48	186.90	49.28	509.99
T ₈ : <i>Pongamia</i> oil @ 75 lt ha ⁻¹	7.31	0.46	189.00	56.00	524.31
T ₉ : Cotton seed oil @ 75 lt ha ⁻¹	7.35	0.58	195.30	51.52	523.15
T ₁₀ : Recommended dose of N, P, K @ 250:60:60 kg ha ⁻¹	7.48	0.50	241.50	49.28	574.34
S.Em. ±	0.03	0.06	7.29	1.81	17.05
CD (p = 0.05)	NS	NS	21.66	5.36	50.67

Conclusion

Based on the above data, applying nitrogen, phosphorus and potassium @ 250:60:60 kg ha⁻¹ (T₁₀) is the most effective treatment among all tried in the study for maximizing maize grain and stover yields, higher economic returns and ensuring efficient nutrient uptake by maize. While organic amendments alone did not match the results of balanced inorganic fertilization in this study, they significantly enhance soil nutrient availability. Thus, they can be integrated into sustainable nutrient management strategies to complement inorganic fertilizers and promote long-term soil health.

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