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Characterization of fortified organic manures and its effect on yield and economics of pigeonpea + sunflower intercropping system

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Abstract

A field experiment was conducted to evaluate the effect of fortified organic manures on soil properties, yield and economics of pigeonpea + sunflower intercropping system (1:1) under rainfed conditions at Biofarm of OFRI, UAS, Raichur, during 2022–23 and 2023–24. The experiment was laid out in a Randomized Complete Block Design (RCBD) with 12 treatments and three replications. The experiment includes FYM, vermicompost, fortified FYM, fortified vermicompost equivalent to 100% and 75% of RDN and their combinations with or without foliar spray of liquid organic manures such as cow urine, panchagavya and vermiwash. Characterization of organic manures indicated that fortification improved the qualities of FYM and vermicompost. Pooled yield data of two years revealed that both pigeonpea and sunflower recorded the higher seed yields (983 kg ha⁻¹ and 474 kg ha⁻¹, respectively) under treatment T₁₁ (Fortified FYM + Fortified vermicompost equivalent to 75% RDN + Panchagavya 3% fb Vermiwash 5%), followed by treatment T₁₀ (959 and 470 kg ha⁻¹, respectively) and T₉ (935 and 448 kg ha⁻¹, respectively). The treatment receiving fortified FYM and fortified vermicompost also recorded higher uptake of nutrients by both pigeonpea and sunflower. Besides, it also improved the available nutrient status in soil. Among the different treatments, available N (192.3 kg ha⁻¹), P₂O₅ (59.0 kg ha⁻¹) and K₂O (553.3 kg ha⁻¹), were found to be higher in treatment T₁₁ followed by T₁₀ (Fortified vermicompost equivalent to 75% RDN + Panchagavya 3% fb Vermiwash 5% foliar spray) and T₉ (Fortified FYM equivalent to 75% RDN + Panchagavya 3% fb Vermiwash 5% foliar spray). The application of fortified organic manures such as FYM and vermicompost enhanced nutrient availability and contributed to sustained soil fertility. Economic analysis showed that treatment T₁₁ recorded the highest gross return (₹ 1,03,779 ha⁻¹) and net return (₹ 56,069 ha⁻¹) with a benefit-cost ratio of 2.18, followed by treatment T₉ (₹ 50,101 ha⁻¹, B:C ratio 2.14) and T₁₀ (₹ 45,514 ha⁻¹, B:C ratio 2.05). Overall, treatment T₁₁ (Fortified FYM + Fortified VC equivalent to 75% RDN + Panchagavya 3% fb Vermiwash 5% foliar spray) emerged as the best treatment in terms of yield, economics making it the most suitable option for sustainable and profitable pigeonpea + sunflower intercropping system.

Keywords: Fortified vermicompost, intercropping system, cow urine, panchagavya, vermiwash

1. Introduction

Pigeonpea is the leading pulse crop in Karnataka, grown on 1.48 million ha with a production of 0.94 million tonnes and a productivity of 647 kg ha⁻¹. Its cultivation is mainly concentrated in the northern districts of Kalaburgi, Vijayapur, Bidar and Raichur, where low and erratic rainfall makes soil moisture a major limiting factor. Karnataka also ranks first in sunflower cultivation, contributing 52% of the total area (0.14 million ha) and 40% of the total production (0.11 million tonnes). However, intensive farming and indiscriminate use of chemical fertilizers and pesticides have resulted in declining productivity, reduced fertilizer use efficiency, environmental degradation and poor soil health. This threatens the sustainability of agriculture, ecological balance and human health. To address these issues and restore soil fertility, organic manures such as farmyard manure, compost, animal wastes and vermicompost have traditionally been used. However, the use of traditional organic manures is limited due to their low nutrient content, bulkiness, handling problems and labour-intensive application. Enriching manures helps

to overcome these drawbacks by improving nutrient content, microbial activity, enzyme activity and overall soil fertility. Enrichment is usually done by adding mineral additives (like rock phosphate and zinc salts), biofertilizers (nitrogen-fixing and nutrient-solubilising bacteria) and bio-inoculants (such as *Trichoderma* and *Pseudomonas*). This process offers many benefits, including higher crop yield, better quality and improved resistance to pests and diseases. Pigeonpea and sunflower are a legume and non-legume crop combination. These crops differ in their maturity period, growth habits, and growth rates, but both are highly adaptable to changes in plant population. Since, a careful selection of crops having different growth habit can reduce the mutual competition to a considerable extent (Marer *et al.* 2007) [4]. With these things in view, the field experiment was undertaken with pigeonpea + sunflower inter cropping system (1:1) using fortified organic manures at different doses along with foliar spray of bio-enhancers, viz, panchagavya, cow urine and vermiwash.

2. Methodology

Fortification of organic manures was made by mixing of FYM and vermicompost with $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 15 kg ha⁻¹, moistened with 20% cow urine at weekly intervals for 30 days, maintaining 60% of maximum water-holding capacity. After 21 days, a PGPR consortium (*Azospirillum*, *Pseudomonas fluorescens*, PSB, *Trichoderma harzianum*) each @ 2 kg and 1% cattle dung slurry were inoculated to stimulate microbial activity and the mixture was allowed to decompose for another two weeks. The field experiment was conducted at the Bio-farm, OFRI, UAS Raichur during Kharif of 2023 and 2024 in a Randomized Complete Block Design (RCBD) with 12 treatments and 3 replications, using pigeonpea (TS-3R) and sunflower (RSFH-1887) in a 1:1 intercropping system with a spacing of 90 × 30 cm. The treatments consisted of various combinations of FYM, vermicompost, their fortified forms and foliar spray of bio-enhancers (cow urine, vermiwash, Panchagavya), compared to absolute control. Manures were characterized for chemical properties and total microbial count as per standard procedure outlined in piper (1966) [2] and Pramer and Schmidt (1964) [3], respectively.

3. Results and Discussion

3.1 Characterization of fortified and non-fortified organic manures for different parameters

Marked variations were observed between fortified and non-fortified organic manures. The fortified manures were prepared by mixing calculated quantity of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ with organic manure, moistened the manures at weekly interval with 20 per cent cow urine, followed by the addition of microbial cultures such as *Azospirillum*, *Pseudomonas fluorescens*, phosphate-solubilizing bacteria (PSB) and *Trichoderma harzianum*, along with one per cent cattle dung slurry as a starter inoculum. Moisture content of organic manures was maintained throughout incubation period to facilitate proper decomposition. The fortified and non-fortified manures were then analysed using standard methods.

The maximum water holding capacity of organic manures ranged from 89.02 per cent in non-fortified FYM to 113.15 per cent in fortified vermicompost. Vermicompost either fortified or non-fortified exhibited superior moisture retention (110.2 - 113.15%) compared to fortified FYM or non-fortified FYM, owing to their finer texture, higher organic matter content and enhanced humification. Similar findings were also reported by Tripathi and Kumar (2009) [5], who observed higher moisture

retention in vermicompost due to finer texture and greater humus content.

The marked increase in maximum water holding capacity (MWHC) due to fortification of organic manures may be attributed to a higher degree of decomposition, polysaccharides, mycelia growth and improved aggregate stability, resulting in increased pore space and moisture retention. Similar results were also reported by Reddy *et al.* (2004) [7].

The pH of non-fortified FYM (6.56) and fortified FYM (6.32) remained slightly acidic, whereas that of non-fortified vermicompost (7.19) and fortified vermicompost (7.08) were near-neutral, which appears to be favourable for nutrient availability and microbial activity. The electrical conductivity values were low in non-fortified FYM (1.12 dS m⁻¹) and non-fortified vermicompost (1.01 dS m⁻¹) which were increased by almost three times due to fortification (3.17 dS m⁻¹ in fortified FYM and 3.98 dS m⁻¹ in fortified vermicompost), indicating enhanced release of soluble salts due to fortification (Table 1). Relatively a higher total organic carbon (TOC) content was recorded in fortified vermicompost (16.45%) followed closely by non-fortified vermicompost (16.25%), while non-fortified FYM and fortified FYM showed comparatively lower TOC content (13.87% & 14.71%, respectively). The nutrient concentration also increased substantially upon fortification. Fortified vermicompost registered the higher total N (1.12%), total P (0.90%) and total K (1.09%), followed by fortified FYM (0.77, 0.32 & 0.69%, respectively) whereas non-fortified FYM recorded the lowest value of these major nutrients (0.51, 0.16 & 0.61%, respectively). The higher nutrient concentration observed in fortified manures can be ascribed to contribution of nutrients and microbes from cow urine and microbial consortia added during fortification might have accelerated decomposition and nutrient mineralization in organic manures. Similarly, total sulphur content was also improved in fortified FYM and vermicompost (0.55 to 0.63%) compared to non-fortified FYM (0.29%).

Fortification led to a remarkable enhancement in total Zn. Zinc content increased drastically from 1.65 mg kg⁻¹ in non-fortified FYM to 270.6 mg kg⁻¹ in fortified FYM and 288.2 mg kg⁻¹ in fortified vermicompost, reflecting the effect of addition of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ during fortification. Content of total iron, copper and manganese in the organic manures increased slightly following fortification. The content of these micronutrients in fortified vermicompost are as follows; Fe: 41.25 mg kg⁻¹, Cu: 18.87 mg kg⁻¹, Mn: 73.09 mg kg⁻¹.

A substantial increase in microbial populations was observed due to fortification of organic manures. Among the manures, fortified vermicompost recorded the highest bacterial population of 156.53×10^5 CFU g⁻¹, followed by fortified FYM with 139.79×10^5 CFU g⁻¹, non-fortified vermicompost 41.11×10^5 CFU g⁻¹ and non-fortified FYM with 37.53×10^5 CFU g⁻¹. Similarly, fungal populations were highest in fortified vermicompost (36.52×10^3 CFU g⁻¹) and fortified FYM (31.22×10^3 CFU g⁻¹) compared to non-fortified vermicompost (17.05×10^3 CFU g⁻¹) and non-fortified FYM (12.18×10^3 CFU g⁻¹). Actinomycetes populations were higher in fortified vermicompost (41.64×10^4 CFU g⁻¹) and fortified FYM (35.06×10^4 CFU g⁻¹) than that of non-fortified vermicompost 32.44×10^4 CFU g⁻¹ and non-fortified FYM 27.85×10^4 CFU g⁻¹.

Results clearly demonstrated that fortification significantly enhanced the physical, chemical and microbial population of both FYM and vermicompost. Among all the manures, fortified vermicompost proved superior, exhibiting maximum nutrient concentration, microbial population and water retention

capacity. Comparable observations were also reported by Singh and Jha (2018) ^[6], who documented higher microbial biomass in nutrient-enriched organic manures.

Fortification improved the quality of both FYM and vermicompost. It increased the water holding capacity in FYM and also improved the organic carbon content in both FYM and vermicompost compared to their unfortified FYM and vermicompost. Fortification enhanced the nutrient composition of both FYM and vermicompost. Nitrogen content increased from 0.51% to 0.77% in FYM (51% increase) and from 0.77% to 1.12% in vermicompost (45% increase). Phosphorus content also improved markedly, doubling in FYM from 0.16% to 0.32% (100% increase) and from 0.69% to 0.90% in vermicompost (30% increase). Potassium content increased from 0.61% to 0.69% in FYM (13% increase) and from 1.07% to 1.09% in vermicompost (2% increase). sulphur content showed a considerable improvement in both FYM and vermicompost. Micronutrients, such as zinc, also increased remarkably, highlighting the efficacy of fortification in improving both macro and micronutrient availability. Total microbial counts of bacteria, fungi and actinomycetes were enhanced due to fortification of FYM and vermicompost.

3.2 Effect of fortified organic manures on yield of pigeonpea + sunflower intercropping system

The grain yield of pigeonpea (938 kg ha⁻¹), straw yield (2298 kg ha⁻¹), sunflower seed yield (523 kg ha⁻¹), sunflower stover yield (1267 kg ha⁻¹) and pigeonpea equivalent yield (1215 kg ha⁻¹) were recorded significantly highest under treatment T₁₁ [Fortified FYM + Fortified VC equivalent to 75% RDN + Panchagavya @ 3% followed by Vermiwash foliar spray @ 5%], which was followed by T₁₀ [Fortified VC equivalent to 75% RDN + Panchagavya @ 3% followed by Vermiwash foliar spray @ 5%] and T₉ [Fortified FYM equivalent to 75% RDN + Panchagavya @ 3% followed by Vermiwash foliar spray @ 5%] (Table 2). The lowest grain yield of pigeonpea (340 kg ha⁻¹), straw yield (1341 kg ha⁻¹), sunflower seed yield (258 kg ha⁻¹), sunflower stover yield (979 kg ha⁻¹) and pigeonpea equivalent yield (476 kg ha⁻¹) were recorded under the absolute control (T₁₂) (Fig. 1 and 2).

The pooled analysis across both years highlighted the higher PEY in the treatment T₁₁ (1215 kg ha⁻¹), treatment T₁₀ (1137 kg ha⁻¹) and treatment T₉ (1100 kg ha⁻¹) as the most productive treatments, reflecting the combined effect of nutrient

fortification and foliar bio-stimulants. Treatments comprising of non-fortified manures or without organic inputs, treatment T₁ (850 kg ha⁻¹), T₂ (768 kg ha⁻¹), T₃ (791 kg ha⁻¹) and T₁₂ (476 kg ha⁻¹) showed comparatively lower PEY. The superiority of treatment T₁₁ may be attributed to nutrient fortification and bio-enhancers, which improved microbial activity, nutrient mineralization and crop physiological efficiency (Tharmaraj *et al.*, 2011) ^[1]. The superior performance of T₁₁ may be attributed to the combined effect of fortified organic nutrient sources and foliar application of Panchagavya and Vermiwash, which enhanced nutrient availability, microbial activity, crop growth and yield attributes, resulting in higher productivity of both pigeonpea and sunflower and consequently greater system productivity

3.3 Effect of fortified organic manures on economics of pigeonpea + sunflower intercropping system

Economic returns were significantly influenced by different fortified organic manures and bio-enhancer treatments. The highest gross returns (Rs. 103,779 ha⁻¹), net returns (Rs. 56,069 ha⁻¹) and benefit-cost ratio (2.18) were recorded under treatment T₁₁ [Fortified FYM + Fortified VC equivalent to 75% RDN + Panchagavya @ 3% followed by Vermiwash foliar spray @ 5%], which was followed by T₁₀ (Rs. 97,041 ha⁻¹ gross returns) and T₉ (Rs. 94,008 ha⁻¹ gross returns). However, T₉ recorded net returns of Rs. 50,101 ha⁻¹ and a B ratio of 2.14, which were comparable to T₁₁ owing to its lower cost of cultivation (Table 3). The lowest gross returns (Rs. 38,946 ha⁻¹), net returns (Rs. 17,609 ha⁻¹) and benefit-cost ratio (1.83) were recorded under the absolute control (T₁₂). The higher profitability under T₁₁ was attributed to increased crop productivity and pigeonpea equivalent yield resulting from the combined application of fortified organic manures, Panchagavya and Vermiwash (Table 3). T₁₁ emerged as the best treatment both in terms of yield and economics, making it the most suitable option for sustainable and profitable pigeonpea + sunflower intercropping. Similarly, Bandiwaddar and Patil (2015) ^[8] recorded higher gross returns (Rs. 1,09,088 ha⁻¹), net returns (Rs. 71,266 ha⁻¹) and BC ratio (3.31) with application of RDF + enriched FYM fortified with micronutrients. Further, Choudhary *et al.* (2016) ^[9] also reported higher economic returns and benefit-cost ratio with enriched organic manures and micronutrient fortification compared to control treatments.

Table 1: Characterization of fortified and un-fortified organic manures

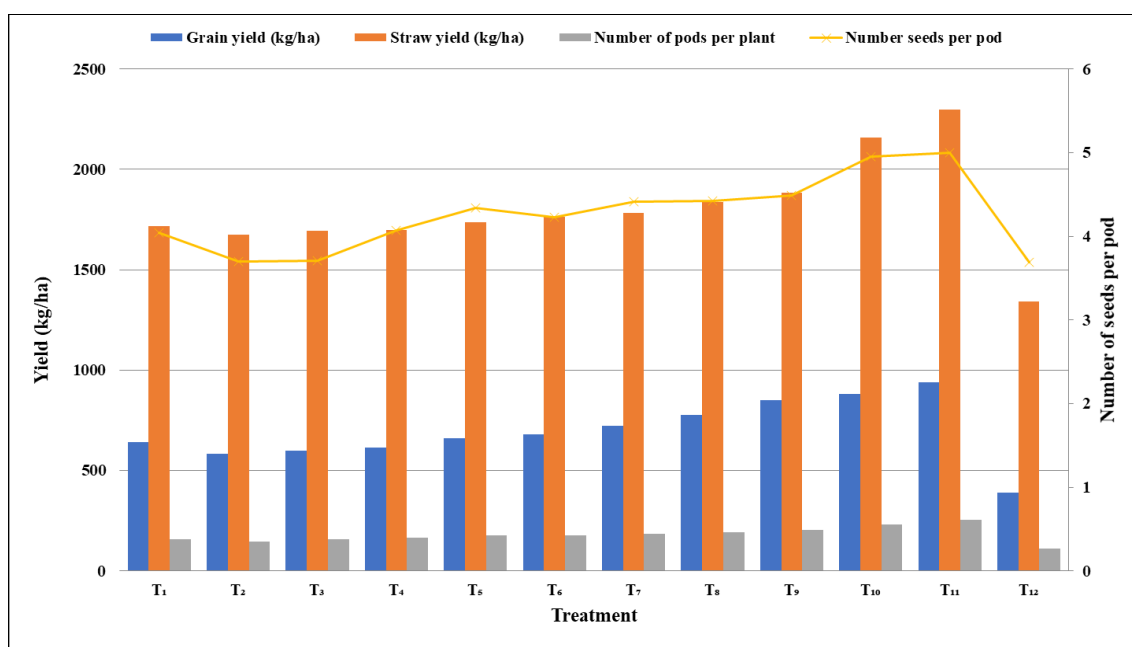
Parameter	FYM		Vermicompost	
	Without fortification	Fortification	Without fortification	Fortification
Physical Property				
Maximum water holding capacity (%)	89	98	113	112.4
Chemical Properties				
1. pH (1:5 soil to water ratio)	6.56	6.32	7.19	7.08
2. EC (1:5 soil to water ratio) (dS m ⁻¹)	1.12	3.17	0.45	3.98
3. Organic carbon (%)	13.87	14.71	19.25	19.45
4. Total N (%)	0.51	0.77	0.77	1.12
5. Total P (%)	0.16	0.32	0.69	0.90
6. Total K (%)	0.61	0.69	1.07	1.09
7. Total S (%)	0.29	0.55	0.41	0.63
8. Total micronutrients (mg kg ⁻¹)				
a. Zn	1.65	270.6	2.51	288.2
b. Fe	20.25	35.64	25.56	41.25
c. Cu	15.23	16.58	18.11	18.87
d. Mn	45.69	48.15	69.13	73.09
Total microbial count				
1. Bacterial population (CFU g ⁻¹)	37.53 × 10 ⁵	139.7 × 10 ⁵	41.11 × 10 ⁵	156.53 × 10 ⁵
2. Fungal population (CFU g ⁻¹)	12.18 × 10 ⁴	31.22 × 10 ⁴	17.05 × 10 ⁴	36.52 × 10 ⁴
3. Actinomycetes population (CFU g ⁻¹)	27.85 × 10 ³	35.06 × 10 ³	32.44 × 10 ³	41.64 × 10 ³

Table 2: Effect of fortified and un-fortified organic manures on yield of pigeonpea and sunflower and pigeonpea equivalent yield (pooled data of 2 years)

Treatment	Pigeonpea (kg ha ⁻¹)		Sunflower (kg ha ⁻¹)		Pigeonpea Equivalent yield (kg ha ⁻¹)
	Grain yield	Straw yield	Seed yield	Stover yield	
T ₁ : FYM + VC (1:1) equivalent to 100% RDN	643	1719	392	1141	850
T ₂ : FYM + VC (1:1) equivalent to 75% RDN	585	1673	345	983	768
T ₃ : Fortified FYM equivalent to 75% RDN	597	1694	367	1007	791
T ₄ : Fortified VC equivalent to 75% RDN	616	1698	377	1051	816
T ₅ : Fortified FYM + Fortified VC equivalent to 75% RDN	659	1737	408	1161	875
T ₆ : T ₃ + Cow urine @5% <i>fb</i> Vermiwash foliar spray@5%	682	1762	419	1175	903
T ₇ : T ₄ + Cow urine @5% <i>fb</i> Vermiwash foliar spray@5%	722	1782	435	1183	952
T ₈ : T ₅ + Cow urine @5% <i>fb</i> Vermiwash foliar spray@5%	775	1837	445	1208	1011
T ₉ : T ₃ + Panchagavya @3% <i>fb</i> Vermiwash foliar spray @5%	850	1882	474	1244	1100
T ₁₀ : T ₄ + Panchagavya @3% <i>fb</i> Vermiwash foliar spray @5%	880	2159	485	1265	1137
T ₁₁ : T ₅ + Panchagavya @3% <i>fb</i> Vermiwash foliar spray@5%	938	2298	523	1267	1215
T ₁₂ : Absolute control	340	1341	258	979	476
S.Em. ±	20.28	51.71	11.57	36.43	26.32
C.D. @ 5%	59	152	34	106	77.19

Table 3: Effect of different organic manures on economic returns of pigeonpea and sunflower intercropping system (pooled data of two years)

Treatment	Gross returns (Rs ha ⁻¹)	Cost of cultivation (Rs ha ⁻¹)	Net returns (Rs ha ⁻¹)	B:C
T ₁	72699	39482	33216	1.84
T ₂	65698	34817	30881	1.89
T ₃	67692	38247	29444	1.77
T ₄	69798	45867	23932	1.52
T ₅	74784	42050	32734	1.78
T ₆	77207	43947	33259	1.76
T ₇	81357	51567	29791	1.58
T ₈	86340	47750	38590	1.81
T ₉	94008	43907	50101	2.14
T ₁₀	97041	51527	45514	1.88
T ₁₁	103779	47710	56069	2.18
T ₁₂	38946	21338	17609	1.83
S.Em. ±	2250	-	2250	0.05
CD at 5%	6599	-	6599	0.16

**Fig 1:** Yield and yield attributes of of pigeonpea as influenced by different treatments

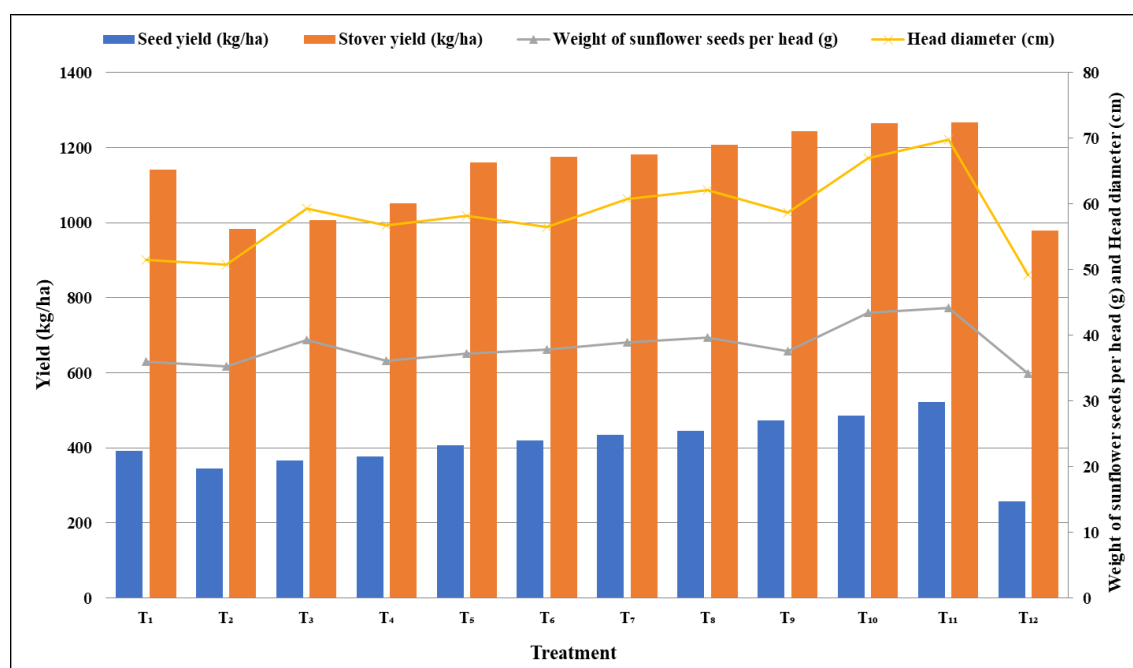


Fig 2: Yield and yield attributes of sunflower as influenced by different treatments

Conclusion

The study demonstrated that fortification of organic manures with microbial inoculants, cow urine and zinc sulphate substantially improved the physical, chemical and microbial population of FYM and vermicompost. These improvements translated into improved available nutrient status in soil and higher crop performance. Among the treatments, treatment T₁₁ (Fortified FYM + Fortified vermicompost equivalent to 75% RDN + Panchagavya 3% fb Vermiwash 5% foliar spray) consistently recorded the higher crop yield, gross and net returns and benefit-cost ratio, proving its superiority. Thus, the integrated use of fortified organic manures and panchagavya and vermiwash as foliar spray offers a sustainable and economically viable option for improving productivity and profitability of the pigeonpea + sunflower intercropping system while enhancing soil health.

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