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Research Article

Influence of organics and inorganics on yield, quality, nutrient uptake and economics of sunflower + greengram intercropping system

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Background: To investigate the combined effects of organics and inorganics on the yield, quality, nutrient uptake and economics of sunflower + greengram intercropping system, field investigations were conducted from July - October 2023 and January - April 2024 at the Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalai Nagar, 608 002.

Methods: The experiments were laid out in split plot design with three replications. The main plot treatments include M_1 - Sole sunflower, M_2 - sunflower + greengram and subplot treatments include S_1 - RDF alone (60:90:60 kg of NPK ha^{-1}), S_2: RDF + Poultry manure compost @ 6t ha^{-1}, S_3: RDF + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45 kg ha^{-1} through gypsum, S_4: RDF + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45kg ha^{-1} + AM Fungi @12 kg ha^{-1}.

Results: The experiment's findings showed that the yield, quality, nutrient uptake and economics of sole sunflower were significantly influenced by RDF + Poultry manure compost @ 6t ha^{-1} + sulphur @ 45 kg ha^{-1} + AM fungi @ 12 kg ha^{-1} (M_1S_4). In terms of economics, sunflower + greengram intercropping system along with the application of RDF + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45 kg ha^{-1} + AM Fungi @ 12 kg ha^{-1} (M_2S_4) recorded the highest BCR of 2.74.

Conclusion: Based on the results, it could be concluded that sunflower + greengram intercropping with the application of RDF (60:90:60 kg of NPK ha^{-1}) + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45 kg ha^{-1} through Gypsum + AM Fungi @ 12 kg ha^{-1} (M_2S_4) was agronomically sound and economically feasible practice to maximize the productivity and profitability of sunflower growing farmers in Tamil Nadu.

Keywords: *organics, inorganics, quality, nutrient uptake, Intercropping of sunflower*

Introduction

Sunflower (*Helianthus annuus*) is an important member of the Asteraceae family. Sunflowers are commercially significant because their seeds are used to make oil and as a food source. Sunflower oil is highly esteemed in the culinary world, equivalent to olive or almond oil. According to Kumbhar et al. (2017), Sunflower oil provides 20-25% oleic acid and adequate levels of vitamins A, D, and E. Because of its high linoleic acid content (64%), which benefits heart patients. In India during 2022 - 2023, sunflower cultivation covered around 0.36 million hectares giving a yield of 0.36 million tonnes and productivity of 996 kg ha^{-1}. Tamil Nadu has an area of 0.10 lakh hectares, with production and productivity of 0.10 lakh tonnes and 1050 kg ha^{-1}, respectively (Department of Agriculture & Farmers Welfare, 2024). It is widely acknowledged that intercropping is a very successful way to increase crop yield per unit of land. It has been proposed that intercropping with sunflower is more favourable than growing sunflower alone and that intercropping

pulses is especially useful for increasing total productivity (Pragatheeswaran et al., 2021). Pulses are rich in nutrients and can also help maintain and improve soil fertility by fixing atmospheric nitrogen in the soil through a symbiotic relationship with root nodules. According to Mukherjee et al. (2019), sunflowers require adequate nutrition to grow to their maximum potential and maintain soil health. Achieving maximum crop yield with minimal inputs requires an integrated and balanced usage of nutrients from both organic and inorganic fertilizer sources to maintain soil fertility and supply nutrients at optimal levels (Dambale et al., 2018). Sunflowers exhibit a significant need for nitrogen, which concurrently affects the oil concentration in their seeds. Furthermore, nitrogen has a crucial role in increasing the surface area for photosynthesis, which allows for more efficient transport of photosynthates to the growing parts of the plant, resulting in increased production (Deepika et al., 2022).

The application of organic manure greatly enhances the accumulation of dry matter, as well as the height and girth of the plant at all stages of growth. Poultry manure is esteemed as a great organic manure owing to its elevated concentrations of nitrogen (N), phosphorous (P), potassium (K), and other vital nutrients. The sunflower grown with poultry manure has superior performance as it efficiently distributes phosphorus to plants compared to other organic manures (Mokgolo et al., 2019). Sulphur has become widely recognised as the fourth vital element for plants, after nitrogen, phosphorus, and potassium. Because of its mobility, sulphur leaches rapidly from the soil. Such depleted soils cannot supply sufficient sulphur to meet crop demands, resulting in suboptimal yields. In soil, sulphur exists in organic and inorganic forms, and plants absorb the sulphate form through their roots (Thakur et al., 2021). Sulphur applications have an advantageous effect on oilseed crops, particularly in oil synthesis, as well as growth and production. The application of sulphur combined with the prescribed nitrogen, phosphorus, and potassium is a suitable strategy for improving sunflower seed yield and oil yield (Saleem et al., 2019). Arbuscular mycorrhizal (AM) fungi, also called vesicular-arbuscular mycorrhizae (VAM), are symbiotic fungi that create mutually beneficial relationships with the roots of most terrestrial plants. One of the key advantages of Arbuscular mycorrhizal fungi is improved nutrient uptake, particularly phosphorus, which is frequently deficient in soil. This greater uptake can be due to multiple ways, such as increased soil contact surface area, accelerated nutrient flow into the mycorrhizae, change of the root environment, and increased nutrient storage (Wahab et al., 2023). Keeping this in consideration, the current study has to be carried out to improve yield, quality, nutrient uptake, and economics in the sunflower + greengram intercropping system through the application of organic and inorganics.

Materials and Methods

The field experiments were carried out at Experimental Farm, Department of Agronomy, Annamalai University, Annamalai Nagar, Tamil Nadu during July - October, 2023 and January - April, 2024. The experimental farm is located at 11° 24' N latitude and 79° 44' E longitude with an elevation of +5.79m above mean sea level. The soil of the experimental field had a clay loam texture with initial soil fertility status of low available nitrogen (215.4 kg ha^{-1}), medium available phosphorus (19.3 kg ha^{-1}), high available potassium (302.6 kg ha^{-1}), and low available sulphur (9.2 kg ha^{-1}). The experiment was laid out in Split plot design with three replications. The details of the treatment in main plot are M_1-sole sunflower, M_2-sunflower + greengram and subplots are S_1: RDF alone (60:90:60 kg of NPK ha^{-1}), S_2: RDF + Poultry manure compost @ 6t ha^{-1}, S_3: RDF + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45 kg ha^{-1} through gypsum and S_4: RDF + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45kg ha^{-1} + AM Fungi @ 12kg ha^{-1}. The seeds of sunflower hybrid COSFH-4, greengram (VBN-I) were chosen for this study. The recommended NPK dose of 60:90:60 kg ha^{-1} is applied in the form of urea, DAP, and potassium muriate. The mycorrhiza inoculum was applied to the corresponding plots at a rate of 12 kg ha^{-1}, mixed with 50 kg FYM and sand. The harvested plant sample was chopped into pieces, dried in a hot air oven at 80°C ± 5°C for 8 hours, and then ground into powder in a Willey mill. The powdered samples were then chemically analysed.

Results

Yield attributes and yield

Among the different main plot treatments tried, sole cropping of sunflower (M_1) significantly recorded the maximum head diameter (18.32 cm), total number of seeds $head^{-1}$ (969.06), number of filled seeds $head^{-1}$ (752.92), percentage of filled seeds (76.93), test weight (4.45 g), seed yield (2169.25 kg ha^{-1}) and stalk yield (4009 kg ha^{-1}) in both the crop seasons. Among the different subplot treatments tried, application of RDF (60:90:60 kg of NPK ha^{-1}) + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45kg ha^{-1} + AM Fungi @ 12 kg ha^{-1} (S_4) significantly registered maximum head diameter (22.05 cm), total number of seeds $head^{-1}$ (1112.91), number of filled seeds $head^{-1}$ (939.54), percentage of filled seeds (84.07 %), test weight (4.75 g), seed yield (2400.50 kg ha^{-1}) and stalk yield (4126.50 kg ha^{-1}) in both the crop seasons. Regarding interaction, sole cropping of sunflower along with RDF (60:90:60 kg of NPK ha^{-1}) + Poultry

manure compost @ 6t ha^{-1} + Sulphur @ 45kg ha^{-1} + AM Fungi @ 12 kg ha^{-1} (M_1S_4) significantly registered the maximum head diameter (22.60 cm), total number of seeds head^{-1} (1134.36), number of filled seeds head^{-1} (954.64), percentage of filled seeds (84.15), test weight (4.78 g), seed yield (2428 kg ha^{-1}) and stalk yield (4186 kg ha^{-1}) in both the crop seasons. This was followed by intercropping of greengram in sunflower along with RDF (60:90:60 kg of NPK ha^{-1}) + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45kg ha^{-1} + AM Fungi @ 12 kg ha^{-1} (M_2S_4). The least values of head diameter (13.56 cm), total number of seeds head^{-1} (805.34), number of filled seeds head^{-1} (486.28), percentage of filled seeds (60.38), test weight (4.02 g), seed yield (1725 kg ha^{-1}) and stalk yield (3816 kg ha^{-1}) in both the crop seasons were recorded under intercropping of greengram in sunflower along with RDF alone (60:90:60 kg of NPK ha^{-1}) (M_2S_1) (Table 1).

Table 1. Effect of Intercropping System and co-application of organics and inorganics on yield attributes and yield of sunflower. (Mean values of two seasons)

Treatments	Head diameter (cm)	Total number of seeds head^{-1}	Number of filled seeds head^{-1}	Percentage of filled seeds head^{-1}	Test weight (g)	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})
Main plot							
M_1	18.32	969.06	752.92	76.93	4.45	2169.25	4009
M_2	17.22	934.97	712.88	75.15	4.37	2074.50	3937
S. Ed	0.12	5.90	5.57	0.51	0.10	14.10	21.43
CD (P=0.05)	0.25	11.85	11.14	1.02	NS	28.23	42.86
Subplot							
S_1	14.25	824.34	511.22	61.98	4.07	1775.50	3853.50
S_2	16.11	894.37	691.50	77.31	4.29	2067	3907
S_3	18.69	976.44	789.34	80.81	4.54	2244.50	4005
S_4	22.05	1112.91	939.54	84.07	4.75	2400.50	4126.50
S. Ed	0.37	19.85	15.70	1.59	0.09	44.50	82.21
CD (P=0.05)	0.75	39.92	31.39	3.19	0.18	88.99	164.42

Quality parameters

Among the different main plot treatments tried, sole cropping of sunflower (M_1) significantly recorded the maximum oil yield (833.46 kg ha^{-1}) in both crop seasons. Among the different subplot treatments tried, application of RDF (60:90:60 kg of NPK ha^{-1}) + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45kg ha^{-1} + AM Fungi @ 12 kg ha^{-1} (S_4) significantly registered maximum oil content (41.55 %), oil yield (967.93 kg ha^{-1}) and crude protein content (18.20 %) in both crop seasons (Table 2).

Table 2. Effect of Intercropping System and co-application of organics and inorganics on quality of sunflower. (Mean values of two seasons)

Treatments	Oil content (%)	Oil yield (kg ha^{-1})	Crude protein content (%)
Main plot			
M_1	40.30	833.46	17.73
M_2	39.98	790.59	17.60
S. Ed	0.11	5.26	0.09
CD (P=0.05)	NS	10.53	NS
Subplot			
S_1	38.65	663.19	17.10
S_2	39.60	756.88	17.55
S_3	40.75	860.09	17.80
S_4	41.55	967.93	18.20
S. Ed	0.33	17.15	0.11
CD (P=0.05)	0.66	34.29	0.21

Regarding interaction, sole cropping of sunflower along with RDF (60:90:60 kg of NPK ha^{-1}) + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45kg ha^{-1} + AM Fungi @ 12 kg ha^{-1} (M_1S_4) significantly registered the maximum oil content (41.60 %), oil yield (992.57 kg ha^{-1}) and crude protein content (18.30 %) in both crop seasons. This was followed by intercropping of greengram in sunflower along with RDF (60:90:60 kg of NPK ha^{-1}) + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45kg ha^{-1} + AM Fungi @ 12 kg ha^{-1} (M_2S_4). The least values of oil content (38.40 %),

oil yield (650.11 kg ha^{-1}) and crude protein content (17 %) in both crop seasons were recorded under intercropping of greengram in sunflower along with RDF alone (60:90:60 kg of NPK ha^{-1}) (M_2S_1).

Nutrient uptake

Among the different main plot treatments tried, sole cropping of sunflower (M_1) significantly recorded higher N uptake (54.56 kg ha^{-1}), P uptake (18.89 kg ha^{-1}), K uptake (70.02 kg ha^{-1}) and S uptake (9.88 kg ha^{-1}) in both crop seasons. Among the different subplot treatments tried, application of RDF (60:90:60 kg of NPK ha^{-1}) + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45 kg ha^{-1} + AM Fungi @ 12 kg ha^{-1} (S_4) significantly recorded higher N uptake (60.06 kg ha^{-1}), P uptake (21.04 kg ha^{-1}), K uptake (74.47 kg ha^{-1}) and S uptake (11.69 kg ha^{-1}) in both crop seasons. Regarding interaction, sole cropping of sunflower along with RDF (60:90:60 kg of NPK ha^{-1}) + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45kg ha^{-1} + AM Fungi @ 12 kg ha^{-1} (M_1S_4) significantly recorded higher N uptake (61.36 kg ha^{-1}), P uptake (21.43 kg ha^{-1}), K uptake (75.68 kg ha^{-1}) and S uptake (11.95 kg ha^{-1}) in both crop seasons. This was followed by intercropping of greengram in sunflower along with RDF (60:90:60 kg of NPK ha^{-1}) + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45kg ha^{-1} + AM Fungi @ 12 kg ha^{-1} (M_2S_4). The least values of N uptake (47.16 kg ha^{-1}), P uptake (16.24 kg ha^{-1}), K uptake (63.47 kg ha^{-1}) and S uptake (7.92 kg ha^{-1}) in both crop seasons were recorded under intercropping of greengram in sunflower along with RDF alone (60:90:60 kg of NPK ha^{-1}) (M_2S_1) (Table 3).

Table 3. Effect of Intercropping System and co-application of organics and inorganics on nutrient uptake (kg ha^{-1}) of sunflower. (Mean values of two seasons)

Treatments	N - uptake (kg ha^{-1})	P - uptake (kg ha^{-1})	K - uptake (kg ha^{-1})	S - uptake (kg ha^{-1})
Main plot				
M_1	54.56	18.89	70.02	9.88
M_2	52.47	18.31	68.61	9.52
S. Ed	0.78	0.11	0.37	0.06
CD (P=0.05)	1.56	0.23	0.78	0.12
Subplot				
S_1	47.76	16.61	63.90	8.03
S_2	51.20	17.39	67.82	9.09
S_3	55.06	19.37	71.07	9.99
S_4	60.06	21.04	74.47	11.69
S. Ed	1.12	0.35	1.42	0.20
CD (P=0.05)	2.24	0.78	2.88	0.41

Economics

The treatment combination of M_2S_4 that is intercropping of sunflower + greengram along with RDF (60:90:60 kgs of NPK ha^{-1}) + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45 kg ha^{-1} + AM Fungi @ 12 kg ha^{-1} recorded the higher net return of Rs. 121604. This was followed by M_2S_3 that is intercropping of sunflower + greengram along with RDF + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45 kg ha^{-1} with a net return of Rs. 105791(Table 4).

Table 4. Effect of Intercropping System and co-application of organics and inorganics on economics of sunflower. (Mean values of two seasons)

Treatments	Total cost of cultivation	Gross income	Net income	BCR
M_1S_1	58185	116864	58679	2.01
M_1S_2	65385	135040	69655	2.07
M_1S_3	68685	148032	79347	2.16
M_1S_4	69045	155392	86347	2.25
M_2S_1	59185	140722	81537	2.38
M_2S_2	66385	163262	96877	2.46
M_2S_3	69685	175476	105791	2.52
M_2S_4	70045	191649	121604	2.74

The least net return of Rs. 58679 was recorded under sole sunflower with RDF alone (M_1S_1). With respect B:C ratio, M_2S_4 recorded maximum value with 2.74 and the least value was recorded in M_1S_1.

Discussion

Yield attributes and yield

The yield attributes and yield increase in sole sunflower could be due to enhanced nutrient absorption, better photosynthetic production, and more efficient distribution of resources from source to sink, resulting from the lack of competition from intercropping. The improved movement of photosynthetic products to growth sites contributed to better growth and yield outcomes. The best results were obtained from the combined application of inorganic fertilizer and organic manures. This might be applied to achieve better yield parameters for sunflower plants. These results are in agreement with findings of Alauddin et al. (2021) and Mahapatra et al. (2021). The greater values of yield attributes and yield were recorded with the application of RDF (60:90:60 kgs of NPK ha^{-1}) + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45kg ha^{-1} + AM Fungi @ 12 kg ha^{-1} (S_4). This might be the result of improved crop growth, which is driven by effective fertilizer and moisture use. This allows plants to create more photosynthate, which accumulates in the sink (Bhusari et al., 2018). Higher applications of nitrogen and sulphur are considered to increase seed yield because of the availability of sufficient nutrients and improved growth. In particular, increased seed setting and filling is facilitated by the build-up of amino acids and amides and their effective transfer to reproductive organs. Similar finding was observed by Deepika et al. (2022). The application of poultry manure had a notable impact on both the size of the flower head and the number of seeds $head^{-1}$. This might be attributed to increased photosynthetic efficiency during the vegetative phase, which results in higher head dry matter accumulation and increased nutrient availability, particularly in the case of nitrogen and phosphorus supply due to the application of composted poultry manure. Similar finding was observed by Khan et al. (2022).

Quality parameters

Whereas both oil content (%) and crude protein content (%) recorded no significant variation in sole crop or intercropped with greengram. The increase in oil content and oil yield were recorded with application of RDF (60:90:60 kgs of NPK ha^{-1}) + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45kg ha^{-1} + AM Fungi @ 12 kg ha^{-1} (S_4). This might be due to the greater synthesis of sulphur-containing amino acids and fatty acid biosynthesis, particularly the conversion of acetyl CO-A to malonyl CO-A may be the reason for higher oil content and oil production. This is due to thiokinase enzyme activity is dependent on the availability of sulphur. The percentage of sunflower oil content increased with higher S dosage. Similar findings were reported by Ravikumar et al. (2016) and Amin et al. (2020).

Nutrient uptake

The increased nutrient uptake in sole cropping of sunflower may be due to the lack of competition from intercropping, which allows the sunflower to fully utilize the available resources. As a result, the nutrient uptake by the sole sunflower crop was significantly improved. Higher nutrient uptake was recorded with application of RDF (60:90:60 kgs of NPK ha^{-1}) + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45kg ha^{-1} + AM Fungi @ 12 kg ha^{-1} (S_4). This could be due to combining organic and inorganic fertilizers provides a steady and reliable supply of nutrients in forms that are easily available to plants. This approach supports the specific nutrient needs of the crop throughout its different growth stages. Similar findings were observed by Ramesh & Elankavi (2017) and Mehta et al. (2024). The AM fungi inoculation significantly increased the nutrient uptake in plants because it facilitates the crop to easily absorb more nutrients especially phosphorus and increase the microbial activity. Similar findings were earlier reported by Kalaiyarasan et al. (2017).

Conclusion

Based on the above results, it could be concluded that sunflower + greengram intercropping with application of RDF (60:90:60 kgs of NPK ha^{-1}) + Poultry manure compost @ 6t ha^{-1} + Sulphur @ 45 kg ha^{-1} through Gypsum + AM Fungi @ 12 kg ha^{-1} (M_2S_4) was agronomically sound and economically feasible practice to maximize the productivity and profitability of sunflower growing farmers in Tamil Nadu.

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Author contributions

Dharanidharan. V conducted research trials, collection, analysis of data, and thesis writing. C. Kalaiyarasan contributed as a research guide, guided to conduct trial, observation, analysis, and thesis writing. S. Kandasamy and D. Venkatakrishnan contributed to writing the manuscript of the research article.

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Ethics approval

Not applicable

AI tool declaration

It is declared that the authors didn't use AI and related tools to write this manuscript.

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