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RESEARCH ARTICLE :

Influence of organic manures, micronutrients, Arbuscular Mycorrhiza and addition of crop residue enhance the soil organic carbon content and yield of maize-sunflower sequential cropping system

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SUMMARY : Field experiments were conducted to study the influence of organic manures, micronutrients and Arbuscular Mycorrhiza (AM) on the productivity of maize-sunflower cropping system at Tamil Nadu Agricultural University, Coimbatore during 2011-12 and 2012-13. The experiment was laid out in split plot design and replicated thrice for maize during winter 2011-12 and 2012-13 and the same experiment after dividing each plot into two was laid out in split-split plot design with three replications for sunflower during summer 2012 and 2013 to estimate the residual effects of organic manures. The popular maize hybrid NK 6240 was taken as test hybrid in maize and Co SFH2 as test hybrid in sunflower. Four sources of organic manures with RDF *viz.*, Farmyard manure 12.5 t ha^{-1}, sericulture waste 5 t ha^{-1}, poultry manure 5 t ha^{-1} and goat manure 5 t ha^{-1} were evaluated in main plot along with one control (RDF only). Arbuscular mycorrhiza 100 kg ha^{-1}, ZnSO4 37.5 kg ha^{-1}, TNAU Micronutrient mixture 30 kg ha^{-1} and a control without micronutrients and AM were studied in the sub plot. Organic manures, micronutrients and AM were applied to first crop of maize only and their residual effect was studied in the succeeding crop of sunflower with and without recommended dose of fertilizer. Enhanced yield attributes and higher grain and stover yields were recorded due to addition of organic manures compared to application of NPK alone. The yield attributes *viz.* cob length, cob girth, number of grain rows cob^{-1}, number of grains row^{-1}, cob weight, test weight, grain and stover yield, crude protein and starch content were significantly higher under application of poultry manure @ 5 t ha^{-1} with RDF followed by application of sericulture waste @ 5 t ha^{-1} with RDF. Among the micronutrients and AM, better yield attributes and higher grain and stover yields, crude protein and starch content were recorded with application of $ZnSO_4$ @ 37.5 kg ha^{-1} followed by TNAU MN mixture @ 30 kg ha^{-1}.The treatment combination of poultry manure @ 5t ha^{-1} with RDF along with $ZnSO_4$ @ 37.5 kg ha^{-1} recorded higher grain and stover yields followed by application of sericulture waste @ 5 t ha^{-1} with RDF along with $ZnSO_4$ @ 37.5 kg ha^{-1}.Hence, considering the overall performance in terms of growth, physiological attributes, yield attributes, yield, economics and system profitability of maize- sunflower cropping system, it is concluded that application of poultry manure @ 5 t ha^{-1} with RDF (150:75:75 kg $N:P_2O_5:K_2O$ ha^{-1}) along with $ZnSO_4$ @ 37.5 kg ha^{-1} to preceding maize and RDF to the succeeding sunflower can be recommended under irrigated condition to get higher yield, system profitability and also to maintain soil fertility.

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BACKGROUND AND OBJECTIVES

Maize (*Zea mays* L.) is the third most important cereal next to rice and wheat, at global level as well in India. It is a versatile crop and can be grown under diverse environmental conditions and has multidimensional uses. Besides its use as food, feed and fodder, maize is now gaining increased importance on account of its potential uses in manufacturing of wide array of products such as starch, plastic, rayon, textile, adhesive, dyes, resins, polish, syrups, ethanol, etc. It has got immense potential and is therefore, referred to as "**miracle crop**" and also "**queen of cereals"**. Maize, being a C_4 plant is an efficient converter of carbon and absorbed nutrients into food. Maize is one of the world's leading crops cultivated over an area of about

175.0 million hectares with a production of about 855.9 million tonnes and productivity of 4.89 tonnes of grain ha^{-1} (USDA, 2013) and per capita total maize grain consumption is 25.2 kg (Ito, 2013). In India, maize is cultivated over an area of 8.71 million hectares with a production of 21.57 million tonnes and the average productivity is 2476kg ha^{-1}. In Tamil Nadu, maize is cultivated in an area of 0.30 million hectares with a production of 1.57 million tonnes and the productivity is 5173 kg ha^{-1} (Agricoop, 2011 - 12). Micronutrient deficiencies in crop plants are widespread because of increased micronutrient demands due to intensive cropping practices and adaptation of high yielding cultivars which may have higher nutrient demand. Maize is one of the important crops sensitive to Zn deficiency with a high Zn demand that positively responds to Zn fertilization. Soil is the habitat for a vast complex and interactive community of the soil organisms whose activities determine the physical and chemical properties of the soil and in turn the growth and development of the crops. When specific microorganisms like Arbuscular Mycorrhiza (AM) fungi are applied to seed or roots, they cause an alteration in the composition of rhizosphere and such alterations have positive implication on nutrient mobilization especially P and Zn hence the growth and development of plants. Nutrients contained in organic manures are released more slowly and stored for a long time in the soil, ensuring a long residual effect (Sharma and Mittra, 2007). Safety of environment as well as public health is also important reasons for advocating increased use of organic sources of nutrients (Hazra, 2007). However, the use of organic manure alone, cannot sustain the cropping system due to unavailability of required quantities and their relatively low nutrient content on a long term basis (Palm *et al.*, 1997).

Hence, an attempt was made to study the influence of different organic sources with recommended dose of inorganic fertilizers in increasing the productivity and the quality of hybrid maize and possible carry-over residual effect on the succeeding sunflower sown immediately after harvest of maize under irrigated garden land conditions.

RESOURCES AND METHODS

Field experiments were conducted during winter and summer seasons of 2011-2012 and 2012-2013 at Eastern block of Tamil Nadu Agricultural University, Coimbatore to investigate the influence of different organic manures with inorganic fertilizers, micronutrients and Arbuscular Mycorrhiza on the growth and yield of maize and to assess their residual effect on the succeeding sunflower. The details of materials used and methods employed here.

Crop residue estimation:

To estimate the amount of crop residues added after each crop, the soil was dug upto 30 cm depth in an area of 0.25 m^2. The samples drawn by using the quadrate method was cleaned treatment wise in a drum with continuous flow of water as suggested by Long (1951). The crop residues were collected, dried and weighed. Residue added was calculated and expressed in kg ha^{-1}. The Soil organic carbon was estimated by the method is called wet chromic acid digestion by Walkey and Black (1934)

Treatments and experimental design :

Treatment details :

The experiments were laid out in split plot design. In the main plot, four organic nutrient treatments with

recommended dose of inorganic fertilizers to the maize crop only *viz.*, FYM, sericulture waste poultry manure, goat manure, along with a control (RDF only) and in the sub plot, four treatments *viz.*, AM, zinc sulphate and TNAU micro nutrient mixture were evaluated along with absolute control. The treatments were replicated thrice. For the second crop individual plots were further divided into two for raising sunflower, one plot without RDF and another plot with 100 % RDF for sunflower.

Statistical analysis :

The data collected were statistically analyzed as suggested by Gomez and Gomez (1984). Wherever the treatment differences were found significant, critical difference was worked out at five per cent probability level. The interaction effect was discussed wherever it was found significant.

OBSERVATIONS AND ANALYSIS

The results of the field experiments conducted at Tamil Nadu Agricultural University, Coimbatore during 2011-12 and 2012-13 to investigate the influence of organic manures, micronutrients and mycorrhizal inoculation on the productivity of maize based cropping system under irrigated condition.

Soil organic carbon :

Organic manures, micronutrients, AM and crop residues exerted significant and favourable influence on soil organic carbon content and improve the physio chemical properties of soil. During 2011-12, among the organic manures, poultry manure 5 t ha^{-1} registered significantly higher soil organic carbon of 0.56 per cent followed by sericulture waste5 t $ha^{-1,}$ goat manure 5 t ha^{-1} and FYM 12.5 t ha^{-1} and were comparable among themselves. The least organic carbon was recorded under control without organic manure. Among the micronutrients and AM, $ZnSO_4$ 37.5 kg ha^{-1} recorded significantly higher soil organic carbon (0.53) followed by TNAU MN mixture and AM and were comparable among themselves. The least organic matter was recorded under control. During 2012-13, the soil organic carbon content exhibited similar trend as that of the previous crop with regard to organic manures micronutrient and AM. The interaction effect was not significant during both 2011-12 and 2012-13. During 2011-12, among the organic manures, poultry manure 5 t ha^{-1} registered significantly higher soil organic carbon of 0.56 per cent followed by sericulture waste5 t $ha^{-1,}$ goat manure

Table 1 : Effect of organic manures, micronutrients and AM on soil organic carbon (%) and crop residue addition (kg ha^{-1}) of maize

Treatments	Soil organic carbon (%)		Crop residue (kg ha^{-1})	
	Winter, 2011-12	Winter, 2012-13	Winter, 2011-12	Winter, 2012-13
Organic manures (M)				
M_1 - RDF+ Farmyard manure @12.5 t ha^{-1}	0.50	0.61	1573	1487
M_2 - RDF+ Sericulture waste @ 5 t ha^{-1}	0.54	0.64	1657	1976
M_3 - RDF+ Poultry manure @ 5 t ha^{-1}	0.56	0.68	1707	2215
M_4 - RDF+ Goat manure @ 5 t ha^{-1}	0.51	0.62	1597	1766
M_5 - RDF alone (Control)	0.34	0.47	1518	1161
S.E. ±	0.03	0.03	62	99
C.D. (P=0.05)	0.06	0.07	143	229
Micronutrients and AM (S)				
S_1 - AM @ 100 kg ha^{-1}	0.50	0.62	1557	1656
S_2 - $ZnSO_4$ @ 37.5 kg ha^{-1}	0.53	0.64	1774	1930
S_3 - TNAU MN mixture @ 30 kg ha^{-1}	0.51	0.62	1599	1714
S_4 - Control	0.39	0.53	1512	1583
S.E. ±	0.02	0.03	57	94
C.D. (P=0.05)	0.04	0.06	116	191
Interaction	NS	NS	NS	NS

NS=Non-significant

5 t ha^{-1} and FYM 12.5 t ha^{-1} and were comparable among themselves. The least organic carbon was recorded under control without organic manure. Among the micronutrients and AM, $ZnSO_4$ 37.5 kg ha^{-1} recorded significantly higher soil organic carbon (0.53) followed by TNAU MN mixture and AM and were comparable among themselves. The least organic matter was recorded under control.

Crop residues :

During 2011-12, among the organic manures, poultry manure 5 t ha^{-1} registered significantly higher crop residue of 1707 kg ha^{-1} followed by sericulture waste compost 5 t ha^{-1} and both were comparable with each other. These treatments were followed by goat manure 5 t ha^{-1} and FYM 12.5 t ha^{-1}. The least crop residue was recorded under control without organic manure. Among the micronutrients and AM, $ZnSO_4$ 37.5 kg ha^{-1} recorded significantly higher crop residue (1774 kg ha^{-1}) than the other treatments. During 2012-13 also, the crop residue exhibited similar trend as that of the previous crop with regard to organic manures, micronutrient and AM. The

Table 2 : Effect of organic manures, micronutrients and AM on grain yield, stover yield (kg ha^{-1}) of maize (Winter, 2011-12)

Treatments	Grain yield	Stover yield
Organic manures (M)		
M_1 - RDF+ Farmyard manure @ 12.5 t ha^{-1}	6181	11939
M_2 - RDF+ Sericulture waste @ 5 t ha^{-1}	6593	12132
M_3 - RDF+ Poultry manure @ 5 t ha^{-1}	7230	12193
M_4 - RDF+ Goat manure @ 5 t ha^{-1}	6393	12032
M_5 - RDF alone (Control)	5453	11412
S.E. ±	207	64
C.D. (P=0.05)	476	147
Micronutrients and AM (S)		
S_1 - AM @ 100 kg ha^{-1}	6247	11695
S_2 - $ZnSO_4$ @ 37.5 kg ha^{-1}	7271	12677
S_3 - TNAU MN mixture @ 30 kg ha^{-1}	6555	12236
S_4 - Control	5406	11158
S.E. ±	125	61
C.D. (P=0.05)	254	125
Interaction	Sig	Sig

Table 3 : Effect of organic manures, micronutrients and AM on grain yield, stover yield (kg ha^{-1}) of maize (Winter, 2012-13)

Treatment	Grain yield	Stover yield
Organic manures (M)		
M_1 - RDF+ Farmyard manure @12.5 t ha^{-1}	6151	11984
M_2 - RDF+ Sericulture waste @ 5 t ha^{-1}	6953	12208
M_3 - RDF+ Poultry manure @ 5 t ha^{-1}	7635	12300
M_4 - RDF+ Goat manure @ 5 t ha^{-1}	6377	12103
M_5 - RDF alone (Control)	5514	11441
S.E. ±	219	69
C.D. (P=0.05)	506	159
Micronutrients and AM (S)		
S_1 - AM @ 100 kg ha^{-1}	6218	11734
S_2 - $ZnSO_4$ @ 37.5 kg ha^{-1}	7524	12838
S_3 - TNAU MN mixture @ 30 kg ha^{-1}	6562	12268
S_4 - Control	5800	11189
S.E. ±	201	66
C.D. (P=0.05)	411	134
Interaction	Sig	Sig

interaction effect was not significant during both 2011-12 and 2012-13. Application of organic manures with RDF improved the soil organic carbon content when compared to inorganic fertilizers alone. This could be ascribed to the higher organic matter content of the manures. Similar result of increase organic carbon content due to organic manures has been reported by Sharma and Mittra (2007). Among the organic manures, application of poultry manure with RDF to soil recorded significantly higher organic carbon which might be due to addition of organic matter and higher amount of crop residues as reported by Deksissa *et al.* (2008). Application

Table 4 : Interaction effect of organic manures, micronutrients and AM on grain yield of maize (kg ha^{-1})

Main plot / Sub plot	Winter 2011-12						Winter 2012-13					
	M_1	M_2	M_3	M_4	M_5	Mean	M_1	M_2	M_3	M_4	M_5	Mean
S_1	6173	6436	6575	6414	5641	6248	5947	6516	7090	5999	5538	6218
S_2	6785	7523	9104	7261	5681	7271	6784	8501	9310	7382	5645	7524
S_3	6361	6661	7759	6466	5529	6555	6285	6899	7631	6544	5450	6562
S_4	5406	5753	5484	5429	4961	5406	5588	5897	6507	5585	5423	5800
Mean	6181	6593	7230	6392	5453		6151	6953	7635	6377	5514	
	Source	S.E. ±	C .D. (P=0.05)				Source	S.E. ±	C .D. (P=0.05)			
	M	206	476				M	219	506			
	S	125	254				S	201	411			
	M at S	318	718				M at S	447	1012			
	S at M	279	569				S at M	450	919			

Table 5 : Residual effect of organic manures, micronutrients and AM applied to preceding maize and fertilizer level to sunflower on seed yield (kg ha^{-1}), stalk yield (kg ha^{-1}) of sunflower (Summer, 2012)

Treatment	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})
Organic manures (M)		
M_1 - RDF+ Farmyard manure @12.5 t ha^{-1}	1458	5573
M_2 - RDF+ Sericulture waste @ 5 t ha^{-1}	1882	6871
M_3 - RDF+ Poultry manure @ 5 t ha^{-1}	2086	7841
M_4 - RDF+ Goat manure @ 5 t ha^{-1}	1647	6162
M_5 - RDF alone (Control)	1300	5121
S.E. ±	73	220
C.D. (P=0.05)	169	508
Micronutrients and AM (S)		
S_1 - AM @ 100 kg ha^{-1}	1481	6193
S_2 - $ZnSO_4$ @ 37.5 kg ha^{-1}	2197	7357
S_3 - TNAU MN mixture @ 30 kg ha^{-1}	1544	6407
S_4 - Control	1477	5297
S.E. ±	43	85
C.D. (P=0.05)	88	174
Fertilizer levels (F)		
F_0 - Control	1650	6146
F_1 - 100 % RDF	1824	6481
S.E. ±	6	11
C.D. (P=0.05)	12	23
Interaction	Sig	Sig

of organic manures with RDF improved the soil organic carbon content when compared to inorganic fertilizers alone. This could be ascribed to the higher organic matter content of the manures. Similar result of increase organic carbon content due to organic manures has been reported by Sharma and Mittra (2007).

Among the organic manures, application of poultry manure with RDF to soil recorded significantly higher organic carbon which might be due to addition of organic matter and higher amount of crop residues as reported by Deksissa *et al.* (2008). All the organic manures applied to preceding maize exerted a positive influence on the yield of succeeding sunflower. Among the organic manures, seed and stalk yield of sunflower were higher with application of poultry manure to preceding maize. This positive response recorded could be due to mineralization of nutrients, as a result of which better growth was achieved. Higher vegetative production due to higher interception of light might have improved assimilate production and hence increased the yield as reported by Babaji *et al.* (2011). Similar result of increased crop yields due to residual effect of organic manures as reported by Jayanthi *et al.* (1997), Singh *et al.* (1999) and Babaji *et al.* (2011), lend support to the present finding.

Grain and seed yield of maize and sunflower :

The maize grain yield was significantly influenced by organic manures, micronutrients and AM during both the years. In general, all the organic manures tried recorded higher yield than control. In the first crop during 2011-12, among the organic manures, poultry manure 5 t ha^{-1} recorded the highest grain yield of 7230 kg ha^{-1}. This was followed by sericulture waste 5 t ha^{-1}, goat manure 5 t $ha^{-1}$and FYM 12.5 t ha^{-1} and they were comparable among themselves. Control recorded the least grain yield. Micronutrients and AM had a positive influence on grain yield of maize. Among the micronutrients, $ZnSO_4$ 37.5 kg ha^{-1} recorded the highest grain yield (7271 kg ha^{-1}) followed by TNAU MN mixture and AM. The yield increase under $ZnSO_4$ 37.5 kg ha^{-1} was 34.49 per cent, over control. In the second crop during 2012-13 also, similar trend of results as observed in the first crop during 2011-12 was observed. Regarding organic manures, higher yield of 7635 kg ha^{-1} was recorded by poultry manure 5 t ha^{-1} followed by sericulture

Table 6 : Residual effect of organic manures, micronutrients and AM applied to preceding maize and fertilizer level to sunflower on seed yield (kg ha^{-1}), stalk yield (kg ha^{-1}), harvest index and oil content (%) of sunflower (Summer, 2013)

Treatments	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})
Organic manures (M)		
M_1 - RDF+ Farmyard manure @12.5 t ha^{-1}	1663	6097
M_2 - RDF+ Sericulture waste @ 5 t ha^{-1}	1965	7346
M_3 - RDF+ Poultry manure @ 5 t ha^{-1}	2190	8116
M_4 - RDF+ Goat manure @ 5 t ha^{-1}	1787	6637
M_5 - RDF alone (Control)	1510	5745
S.E. ±	54	196
C.D. (P=0.05)	125	451
Micronutrients and AM (S)		
S_1 - AM @ 100 kg ha^{-1}	1651	5487
S_2 - $ZnSO_4$ @ 37.5 kg ha^{-1}	2228	8445
S_3 - TNAU MN mixture @ 30 kg ha^{-1}	1804	7655
S_4 - Control	1609	5565
S.E. ±	30	150
C.D. (P=0.05)	61	307
Fertilizer levels (F)		
F_0 - Control	1755	6646
F_1 - 100 % RDF	1891	6931
S.E. ±	5	9
C.D. (P=0.05)	9	19
Interaction	Sig	Sig

waste 5 t ha^{-1}, goat manure 5 t ha^{-1} and FYM 12.5 t ha^{-1}. Control recorded the least yield (5514 kg ha^{-1}).Regarding the micronutrients and AM treatments, $ZnSO_4$ 37.5 kg ha^{-1} recorded significantly higher yield (7524 kg ha^{-1}) than control (5800 kg ha^{-1}). Organic manures, micronutrients, AM and fertilizer levels had a significant influence on the seed yield of hybrid sunflower during 2012 and 2013.

During 2012, among the organic manures, higher seed yield of sunflower (2086 kg ha^{-1}) was recorded under poultry manure 5 t ha^{-1} applied to preceding maize followed by sericulture waste 5 t ha^{-1}, goat manure 5 t ha^{-1} and FYM 12.5 t ha^{-1}. The least seed yield of sunflower was recorded under control. During 2012, among the organic manures, higher seed yield of sunflower (2086 kg ha^{-1}) was recorded under poultry manure 5 t ha^{-1} applied to preceding maize followed by sericulture waste 5 t ha^{-1}, goat manure 5 t ha^{-1} and FYM 12.5 t ha^{-1}. The least seed yield of sunflower was recorded under control. Among the micronutrients and AM, $ZnSO_4$ 37.5 kg ha^{-1} to preceding maize recorded higher seed yield of 2197 kg ha^{-1} followed by TNAU MN mixture 30 kg ha^{-1} and AM applied to preceding maize. The least seed yield was recorded under control. With regard to fertilizer levels, 100% RDF to sunflower recorded higher seed yield (1824 kg ha^{-1}) than unfertilized control. The interaction between organic manures, micronutrients and AM was significant. The treatment combination of poultry manure 5 t ha^{-1} with $ZnSO_4$ 37.5 kg ha^{-1} applied to preceding maize recorded higher seed yield of 2859 kg ha^{-1} followed by sericulture waste 5 t ha^{-1} along with $ZnSO_4$ 37.5 kg ha^{-1} to preceding maize. The least seed yield (1264 kg ha^{-1}) was recorded under control without organic manures, micronutrients and AM.

Application of organic manures with RDF improved the soil organic carbon content when compared to inorganic fertilizers alone. This could be ascribed to the higher organic matter content of the manures. Similar result of increase organic carbon content due to organic manures has been reported by Sharma and Mittra (2007). Among the organic manures, application of poultry manure with RDF to soil recorded significantly higher organic carbon which might be due to addition of organic matter and higher amount of crop residues as reported by Deksissa *et al.* (2008). All the organic manures applied to preceding maize exerted a positive influence on the yield of succeeding sunflower Among the organic manures, seed and stalk yield of sunflower were higher with application of poultry manure to preceding maize. This positive response recorded could be due to mineralization of nutrients, as a result of which better growth was achieved. Higher vegetative production due to higher interception of light might have improved assimilate production and hence increased the yield as reported by Babaji *et al.* (2011). Similar result of increased crop yields due to residual effect of organic manures as reported by Jayanthi *et al.* (1997), Singh *et al.* (1999) and Babaji *et al.* (2011), lend support to the present finding. Among the organic manures, seed and stalk yield of sunflower were higher with application of

Table 7 : Interaction effect of residual organic manures, micronutrients and AM applied to preceding maize and fertilizer level to sunflower on seed yield of sunflower (kg ha^{-1})

Main plots / Sub plots	Summer, 2012						Summer, 2013					
	M_1	M_2	M_3	M_4	M_5	Mean	M_1	M_2	M_3	M_4	M_5	Mean
S_1	1391	1415	1859	1421	1319	1481	1474	1805	1866	1596	1513	1651
S_2	1604	2848	2859	2424	1248	2197	1978	2381	2931	2288	1562	2228
S_3	1448	1725	1731	1445	1371	1544	1807	1902	2078	1695	1541	1804
S_4	1389	1540	1894	1297	1264	1477	1392	1771	1887	1570	1426	1609
F_0	1372	1799	1986	1575	1206		1603	1897	2124	1728	1425	
F_1	1544	1965	2185	1719	1395		1723	2032	2257	1847	1596	
Mean	1458	1882	2086	1647	1300		1663	1965	2190	1787	1510	
	Source	S.E. ±	C.D. (P=0.05)				Source	S.E. ±	C.D. (P=0.05)			
	M	73	169				M	54	125			
	S	43	88				S	30	61			
	F	6	12				F	5	9			
	M at S	101	222				M at S	73	161			
	M at F	61	138				M at F	45	102			

poultry manure to preceding maize. This positive response recorded could be due to mineralization of nutrients, as a result of which better growth was achieved. Higher vegetative production due to higher interception of light might have improved assimilate production and hence increased the yield as reported by Babaji *et al.* (2011). Similar result of increased crop yields due to residual effect of organic manures as reported by Jayanthi *et al.* (1997), Singh *et al.* (1999) and Babaji *et al.* (2011), lend support to the present finding. The increased in yield in lieu of adding of crop residues in sunflower field and also improved the organic carbon content for the succeeding crop of sunflower.

Conclusion :

In maize – sunflower cropping system, application of poultry manure @ 5 t ha^{-1} with RDF along with zinc sulphate @ 37.5 kg ha^{-1} to maize and RDF to succeeding sunflower crop recorded the highest yield due to the addition of crop residues and in turn improvement of organic carbon in availability to succeeding sunflower crop.

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