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Effect of integrated nutrient and weed management practices on weeds, growth and yield of sunflower

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Abstract
A comprehensive study was made in irrigated sunflower to optimise the integrated nutrient and weed management practices for augmenting sunflower productivity, at Annamalai University Experimental Farm, Annamalai Nagar, Tamil Nadu, India. The experiment was laid out in split plot design with three replications. The details of the treatment in main plots are M_1-Control, M_2-RDF(40:20:20 kg NPK ha^{-1}) + FYM @ 12.5 t ha^{-1}, M_3-RDF+ Vermicompost @ 5 t ha^{-1}+seed treatment with Azospirillum (600 g ha^{-1})+ $ZnSo_4$ @ 25 kg ha^{-1}+ foliar spray of 1% KH_2PO_4 (twice at 25 and 55 DAS), M_4- RDF+ FYM @ 12.5 t ha^{-1}+seed treatment with Azospirillum (600 g ha^{-1})+ $ZnSo_4$ @ 25 kg ha^{-1}+ foliar spray of 1% KH_2PO_4 (twice at 25 and 55 DAS) M_5- RDF+ Vermicompost @ 5 t ha^{-1}+seed treatment with Azospirillum (600 g ha^{-1})+ $ZnSo_4$ @ 25 kg ha^{-1}, M_6- RDF+ FYM @ 12.5 t ha^{-1}+seed treatment with Azospirillum (600 g ha^{-1})+ $ZnSo_4$ @ 25 RDF+ FYM @ 12.5 t ha^{-1}+seed treatment with Azospirillum (600 g ha^{-1})+ $ZnSo_4$ @ 25 kg $ha^{-1}$and the subplots are S_1- Unweeded control, S_2- Pre EMG. Oxyfluorfen @ 0.1 kg ha^{-1} + HW at 30 DAS, S_3- Pre sowing fluchloralin @ 1 kg ai ha^{-1} + HW at 30 DAS, S_4- Pre EMG. Pendimethalin @1 kg ai ha^{-1}+ HW at 30 DAS and S_5- HW twice at 15 and 30 DAS. The results of the study evidently proved that application of recommended NPK+ vermicompost +Azospirillum+ $ZnSo_4$ + foliar spray of KH_2PO_4 along with fluchloralin + HW at 30 DAS (M_3S_5) as an agronomically efficient, eco-friendly and economically viable technology for improving sunflower yield and quality. This treatment (M_3S_5) combination registered lowest values for weed density, nutrient removal by weeds, weed biomass and maximum weed control index and maximum values for growth and yield attributes and yield of sunflower in both the crops.

Keywords: Integrated nutrient, practices, weeds, growth, yield, sunflower

Introduction
The cultivated sunflower (*Helianthus annuus* L.) is an annual oilseed plant of *compositae* family. Sunflower has many advantages over other oilseeds crops. The crop is endowed with short growth period, photo-sensitiveness and presence of high degree of poly unsaturated fatty acid (PUFA) content. The sunflower oil has a pleasant flavour and excellent keeping quality when refined. Cholesterol lowering factor constitutes around 85-90% of the total fatty acid (Silver *et al*., 1984) [9]. Fertilizer application as the major input through which the productivity can be increased by exploiting varietal potential. Chemical fertilizers have had a substantial impact on yield increments in the recent past and are today an indispensable part of modern agricultural practices (Reddy and Raja Reddy, 2002) [8]. Integration of organic manures and biofertilizers with chemical fertilizers is more emphasised not only to boost the production of sunflower from limited land resource but also for its sustainability. There is need to promote use of organics in addition to inorganic fertilizers for sustained maintenance of soil fertility (Devidayal and Agarwal, 1999) [2]. Sunflower which grows slowly during its initial stage provides congenial environment for weed growth in abundance. The weeds cause drastic reduction in seed yield of sunflower upto 83% (Legha *et al*., 1992) [4]. The critical period of weed competition is upto 30 DAS in sunflower (Muthusankaranarayan *et al*., 1995) [5]. The most promising single approach to weed control in land reported is to combine manual, cultural and mechanical methods with herbicides (Yaduraju and Mishra, 2003) [10].

Material and Methods
The field experiments were conducted to study the effect of integrated nutrient and weed management on sunflower at Experimental Farm, Department of Agronomy,

Annamalai University, Annamalai Nagar (TN). The soil of experimental field was clayey loam with low in available nitrogen (212.4 kg ha^{-1}), medium in available phosphorus (28.3 kg ha^{-1}) and high in available potassium (348.1 kg ha^{-1}). The pH and E.C. were 7.5 and 0.45 dsm^{-1} respectively. The experiment was laid out in a split plot design with three replication. The details of the treatment in main plots are M_1-Control, M_2-RDF(40:20:20 kg ha^{-1}) + FYM @ 12.5 t ha^{-1}, M_3-RDF+ Vermicompost @ 5 t ha^{-1}+seed treatment with Azospirillum (600 g ha^{-1})+ $ZnSo_4$ @ 25 kg ha^{-1}+ foliar spray of 1% KH_2PO_4 (twice at 25 and 55 DAS), M_4- RDF + FYM @ 12.5 t ha^{-1}+seed treatment with Azospirillum (600 g ha^{-1})+ $ZnSo_4$ @ 25 kg ha^{-1} + foliar spray of 1% KH_2PO_4 (twice at 25 and 55 DAS) M_5- RDF+ Vermicompost @ 5 t ha^{-1} + seed treatment with Azospirillum (600 g ha^{-1}) + $ZnSo_4$ @ 25 kg ha^{-1}, M_6- RDF+ FYM @ 12.5 t ha^{-1}+seed treatment with Azospirillum (600 g ha^{-1}) + $ZnSo_4$ @ 25 RDF+ FYM @ 12.5 t ha^{-1}+seed treatment with Azospirillum (600 g ha^{-1}) + $ZnSo_4$ @ 25 kg $ha^{-1}$and the subplots are S_1- Unweeded control, S_2-Pre EMG. Oxyfluorfen @ 0.1 kg ha^{-1} + HW at 30 DAS, S_3-Pre sowing fluchloralin @ 1 kg ai ha^{-1} + HW at 30 DAS, S_4-Pre EMG. Pendimethalin @1 kg ai ha^{-1}+ HW at 30 DAS, S_5-HW twice at 15 and 30 DAS. Recommended dose of 40:20:20 kg of NPK ha^{-1} was applied. N was applied in the form of urea while phosphorus and potassium were applied in the form of SSP and MOP respectively. Entire dose of P_2O_5, K_2O and half of N was applied as basal and remaining "N" at 30 DAS. Weed management practices were carried out as per the treatment schedule. The pre emergence herbicides (Pendimethalin, oxyfluorfen and metolachlor) at required quantities were taken and sprayed at 3 DAS using the hand operated knapsack sprayer fitted with a flood a jet nozzle. A spray volume of 500 litres of water was used per hectare.

Results and Discussion

Weeds (Table 1 and 2)

The nutrient management treatments significantly influenced the weed characters in sunflower. Among the nutrient management practices tried, the treatment M_3 (RDF+vermicompost+azospirillum+$ZnSO_4$+KH_2PO_4) recorded lower weed population (378.20 and 448.60 m^{-2}) and (390.00 and 462.00m^{-2}), lesser weed biomass (97.23 and 107.26 kg ha^{-1}) and (104.34 and 102.47 kg ha^{-1}), higher weed control index (77.01 and 80.45 %) and (76.63 and 81.73 %) at 15 and 30 DAS in first and second crop respectively. This treatment also record lesser nitrogen removal by weeds (16.10 and 17.20 kg ha^{-1}), phosphorus removal by weeds (4.03 and 4.20 kg ha^{-1}), potassium removal by weeds (13.44 and 12.56 kg ha^{-1}) at 30 DAS in first and second crop respectively. The reason for low weed population under these treatments might be due to better uptake of nutrients by the crop from the initial stage and did not provide enough time for the weeds to utilise the nutrients and other factors. Similar result was reported by Patel *et al*. (1995) [7]. This was followed by M_4 (RDF+FYM+Azospirillum+$ZnSO_4$+KH_2PO_4). Highest values for weed density, weed biomass and nutrient removal were recorded in M_1 (No NPK/ Organics).

Profound influence on weed count was noticed due to weed management treatments. Among the different weed management practices tried, S_3 (fluchloralin + HW at 30 DAS) registered the lowest weed count (263.83 and 279.16 m^{-2}) and (338.5 and 350.00m^{-2}), lowest weed biomass (89.12 and 95.01 kg ha^{-1}) and (79.21 and 85.2kg ha^{-1}),highest weed control index (78.93 and 78.72%) and (85.56 and 81.79 %) at 15 and 30 DAS in first and second crop respectively.S_5 (HW twice at 15 and 30 DAS) recorded a lesser nutrient removal nitrogen removal by weeds (14.54 and 15.54 kg ha^{-1}), phosphorus removal by weeds (3.70 and 3.70 kg ha^{-1}) and potassium removal by weeds (13.52 and 12.62 kg ha^{-1}) at 30 DAS in first and second crop respectively. It may be due to the efficiency of the sowing herbicide in supporting germination of weed seeds. This findings is in conformity with the studies of Rodrique *et al*. (1982). The unweeded control (S_1) treatment recorded higher weed density, weed biomass, poor weed and maximum NPK removal the crops at all the stages. This is due to poor weed management.

Significant interactions were noticed between the nutrient and weed management practices in both the crops. The Interaction between nutrient management (M_3) with the weed management treatment (S_5) proved efficiency by registering lowest weed density, biomass, Nutrient removal by weeds and maximum weed control index. This might be due to the herbicidal effect of fluchloralin might be due to the inhibition of cell division through tubulin inactivation mechanism which might have curtailed the density and growth of weeds Krishne Gowda *et al*. (1985) [3].

Crop Growth Attributes (Table 3)

Among the nutrient management practices tried, the treatment M_3 (RDF+vermicompost+azospirillum+$ZnSO_4$+KH_2PO_4) recorded maximum plant height (145.34 cm) at harvest stage, leaf area index (6.46) at flowering stage and dry matter production (4449.13 kg ha^{-1}) at harvest stage, root length (27.9cm), root volume (17.20 cm^{-3} $plant^{-1}$). Lowest plant height, leaf area index and dry matter production recorded under M_1 (control) in all stages of crop growth.

Among the weed management treatments, S_5 (HW twice at 30 DAS) recorded maximum plant height (141.37 cm) at harvest stage, leaf area index (6.22) at flowering stage and dry matter production (4006.97 kg ha^{-1}) at harvest stage, root length (27.02cm), root volume (16.7cm^{-3} $plant^{-1}$). This was followed by the treatment S_3 (fluchloralin + HW at 30 DAS). The plant height, leaf area index and dry matter production recorded under S_1 (unweeded control) in all stages of crop growth.

The Interaction effect between the nutrient and weed management on plant growth attributes is significant. Treatment M_3 (RDF+vermicompost+azospirillum+ZnSO4+KH_2PO_4) with S5 (HW twice at 30 DAS) maximum plant height, leaf area index (7.35) at flowering stage and dry matter production (4521.13 kg ha^{-1}) at harvest stage, root length (31.2cm), root volume (18.6 cm^{-3} $plant^{-1}$). Lowest plant height, leaf area index and dry matter production recorded under M_1S_1 (control) in all stages of crop growth.

This might be due to the effective interaction between the nutrients and weed management treatments, which could have increased the availability of better nutrition from vermicompost and other components along with the efficient control of weeds by the respective treatments. Similar trend of results was reported by Patel *et al*. (1994) [6].

Yield Attributes (Table 4 and 5)

Among the nutrient management practices tried M_3 (RDF+vermicompost+azospirillum+$ZnSO_4$+KH_2PO_4) recorded maximum values for head diameter (18.5cm),total number of seeds $head^{-1}$ (866.2$head^{-1}$), number of filled seeds $head^{-1}$ (513.7), seed filling percentage (94.8), test weight (7.73g), seed yield (1671kg ha^{-1}) and stalk yield (5752kg ha^{-1}) over other treatments. This was followed by M_4 (RDF+FYM+azospirillum+$ZnSO_4$+KH_2PO_4). M_1 (control)

recorded lower value for head diameter (14.03cm), total number of seeds head^{-1} (827.18.head^{-1}), number of filled seeds gead^{-1} (466.22), seed filling percentage, test weight(6.10g), seed yield (503kg ha^{-1}) and stalk yield.

Among the weed management treatments S_5 (HW twice at 30 DAS) registered higher head diameter (18.7cm),total number of seeds head^{-1} (837.4 head^{-1}), number of filled seeds head^{-1}(786.4), seed filling percentage (93.5), test weight(7.60g), seed yield (1201kg ha^{-1}) and stalk yield (5622kg ha^{-1}) over other treatments. This was followed by S_3 (fluchloralin + HW at 30 DAS). Unweeded control (S_1) recorded lowest head diameter, total number of seeds head^{-1}, number of filled seeds head^{-1}, seed filling percentage, test weight, seed yield and stalk yield.

Table 1: Effect of integrated nutrient and weed management practices on weed characters of sunflower

Treatments	Mean Weed population (M^2)				Weed biomass (Kg ha^{-1})			
	I Crop		II Crop		I Crop		II Crop	
Main Plot	**15 DAS**	**30 DAS**	**15 DAS**	**30 DAS**	**15 DAS**	**30 DAS**	**15 DAS**	**30 DAS**
M_1	417.00 (20.29)	529.60 (22.84)	448.40 (21.03)	543.40 (23.14)	387.7	435.7	384.8	436.5
M_2	403.60 (19.95)	516.00 (22.54)	420.80 (20.38)	532.20 (22.89)	345.9	386.6	343.1	388.25
M_3	378.20 (19.25)	448.60 (20.97)	390.00 (19.56)	462.00 (21.30)	97.23	107.3	104.3	102.5
M_4	386.00 (19.47)	456.60 (21.18)	401.00 (19.86)	469.00 (21.47)	134.5	115.9	116.6	114.6
M_5	394.00 (19.69)	486.20 (21.84)	411.00 (20.12)	495.20 (22.04)	303.2	356.6	317.9	360.6
M_6	397.40 (19.79)	503.40 (22.23)	414.80 (20.23)	517.80 (22.56)	328.3	374.4	327.8	367.9
SEd	0.038	0.41	0.55	0.05	3.90	1.95	4.88	3.96
CD (P=0.05)	0.08	0.093	0.12	0.12	7.85	3.92	7.70	7.96
Sub Plot								
S_1	505.83 (22.49)	695.16 (26.36)	524.16 (22.90)	710.66 (26.55)	422.9	548.73	446.7	560.9
S_2	393.00 (19.81)	573.66 (23.94)	422.16 (20.50)	588.66 (24.25)	291.9	416.87	301.3	412.9
S_3	263.81 (16.24)	373.33 (19.50)	279.16 (16.71)	386.00 (19.63)	89.1	108.9	95.0	96.4
S_4	310.83 (17.64)	469.66 (21.67)	326.33 (18.07)	481.00 (21.93)	180.6	326.6	165.2	319.8
S_5	506.66 (22.51)	338.50 (18.39)	519.83 (22.80)	350.00 (18.70)	346.0	79.2	307.2	85.3
S.Ed	0.05	0.05	0.073	0.005	2.76	1.38	3.45	3.26
CD (P=0.05)	0.101	0.11	0.14	0.011	6.16	3.08	9.82	

*: Figures in parenthesis are arc sin transformed values.

Table 2: Effect of integrated nutrient and weed management practices on weed control index (WCI) and Nutrient removal by weeds on Sunflower

	WCI (%)				Nutrient removal by weeds (kg ha^{-1}) at 30 DAS					
Treatments	I Crop		II Crop		I Crop			II Crop		
Main plot	**15**	**30 DAS**	**15**	**30 DAS**	**N**	**P**	**K**	**N**	**P**	**K**
M_1	8.33	20.60	13.85	22.18	22.7	5.51	19.94	23.9	5.73	18.5
M_2	18.22	29.55	23.19	30.77	18.1	4.68	16.93	19.5	4.64	15.64
M_3	77.01	80.45	76.63	81.73	16.1	4.03	13.44	17.2	4.20	12.6
M_4	68.19	78.87	73.90	79.56	16.7	4.19	15.78	17.8	4.35	14.8
M_5	28.31	35.01	28.83	35.76	17.0	4.29	15.86	18.2	4.42	14.9
M_6	22.38	31.76	26.61	34.40	17.4	4.43	16.06	18.8	4.50	15.02
S. Ed					0.078	0.09	0.0039	0.043	0.011	0.017
CD (P=0.05)					0.157	0.019	0.007	0.086	0.023	0.0035
Sub Plot										
S_1	-	-	-	-	28.7	6.72	25.09	29.9	6.86	23.7
S_2	30.97	24.03	32.55	26.37	17.1	4.56	15.45	18.7	4.66	14.2
S_3	78.93	30.16	78.72	82.81	14.8	3.76	13.72	15.9	3.92	12.8
S_4	57.29	41.047	63.01	42.97	15.0	3.85	13.90	16.1	4.0	12.9
S_5	18.19	85.56	31.22	84.79	14.5	3.70	13.52	15.5	3.76	12.6
S. Ed					0.055	0.006	0.0027	0.030	0.008	0.0012
CD (P=0.05)					0.123	0.015	0.006	0.067	0.018	0.0027

Table 3: Effect of integrated nutrient and weed management practices on growth attributes of sunflower

Treatments	Plant height (cm) (At harvest)		LAI (At flowering)		DMP (Kg ha^{-1}) (At harvest)		Root length (cm) (At 60 DAS)		Root volume (Cm^{-3}/ plant) (At 60 DAS)	
	I	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**
Main plot										
M_1	103.0	79.9	4.15	4.06	3297	2954	20.5	18.2	13.7	12.9
M_2	125.8	105.0	5.41	5.28	3958	3637	25.1	22.8	15.9	15.4
M_3	145.3	124.9	6.46	6.31	4449	4103	27.9	26.2	17.2	16.9
M_4	138.6	118.6	6.10	6.03	4291	3953	26.4	24.5	16.6	16.4
M_5	135.6	116.2	5.95	5.88	4230	3898	26.0	24.2	16.4	16.2
M_6	131.7	112.1	5.75	5.65	4099	3756	25.6	23.9	16.2	15.9
S.Ed	0.409	0.37	0.002	0.003	14.9	16.3	0.19	0.15	0.043	0.048
CD (P=0.05)	0.91	0.84	0.051	0.01	29.8	32.7	0.39	0.32	0.088	0.098
Sub Plot										

S_1	111.8	88.9	4.69	4.64	3509	3250	22.3	20.8	14.7	14.1
S_2	121.9	101.7	5.27	5.15	3848	3481	24.2	21.9	15.4	15.1
S_3	139.1	118.9	6.08	5.98	4219	3951	26.5	24.8	16.7	16.3
S_4	135.9	116.4	5.93	5.81	4220	3879	26.2	24.4	16.5	16.1
S_5	141.4	121.3	6.22	6.09	4402	4006	27.0	25.4	16.9	16.5
S. Ed	0.213	0.07	0.018	0.003	12.7	14.1	0.20	0.09	0.036	0.039
CD (P=0.05)	0.42	0.15	0.037	0.001	25.5	28.3	0.40	0.19	0.073	0.079

Table 4: Effect of integrated nutrient and weed management practices on yield attributes of sunflower

Treatments	50% flowering		Head diameter (cm)		Total no. of seeds head^{-1}		Number of filled Seeds head^{-1}		Seed filling (%)		Test Wt. (g)	
	I	II	I	II	I	II	I	II	I	II	I	II
Main Plot												
M_1	56.0	58.5	14.0	13.8	578.7	479.8	466.2	365.6	79.5	78.8	6.10	6.07
M_2	51.8	52.8	16.4	16.2	753.7	643.5	683.5	574.7	90.4	89.1	7.29	7.28
M_3	50.2	50.9	18.5	18.2	866.2	774.0	513.7	721.2	94.8	93.7	7.73	7.70
M_4	50.8	51.5	18.1	17.8	826.1	734.3	770.9	676.5	93.0	91.8	7.58	7.56
M_5	51.0	51.7	17.8	17.4	814.0	718.7	753.2	651.8	92.6	91.3	7.51	7.48
M_6	51.4	52.3	17.2	17.0	785.6	678.9	723.7	614.4	92.0	90.1	7.41	7.39
S. Ed	0.25	0.029	0.005	0.0057	3.82	3.44	2.29	1.48	0.058	0.054	0.020	0.019
CD (P=0.05)	0.51	0.06	0.0112	0.0166	8.53	6.92	4.61	2.98	0.126	0.109	0.041	0.04
Sub Plot												
S_1	53.9	55.9	14.7	14.6	648.3	546.4	544.3	453.5	83.0	82.1	6.60	6.58
S_2	52.3	53.8	15.8	15.6	727.3	622.7	653.7	544.9	89.7	88.0	7.13	7.10
S_3	50.9	51.9	18.41	17.9	827.2	731.4	772.2	676.8	93.2	91.9	7.54	7.52
S_4	51.3	51.9	18.44	17.6	814.1	712.2	752.9	653.5	92.5	91.3	7.47	7.46
S_5	50.7	51.4	18.7	18.1	837.4	744.9	786.4	691.4	93.5	92.2	7.60	7.58
S. Ed	0.19	0.024	0.004	0.0056	3.53	2.94	0.129	1.21	0.056	0.046	0.016	0.014
CD (P=0.05)	0.39	0.05	0.009	0.0114	7.1	6.55	2.61	2.43	0.118	0.093	0.033	0.03

Table 5: Effect of integrated nutrient and weed management practices on yield and quality of sunflower

Treatments	Seed yield (Kg ha^{-1})		Stalk yield (Kg ha^{-1})		Oil Content (%)		Protein Content %	
	I	II	I	II	I	II	I	II
Main Plot								
M_1	503	489	4279	4121	37.30	37.31	18.26	17.14
M_2	826	817	5160	5054	38.48	38.34	18.63	17.61
M_3	1671	1591	5752	5536	39.18	39.03	18.82	18.04
M_4	1263	1212	5550	5368	38.83	38.81	18.75	17.90
M_5	182	1085	5471	5311	38.73	38.68	18.73	17.85
M_6	988	979	5326	5187	38.63	38.50	18.69	17.76
S. Ed	22.96	16.37	17.46	83.94	0.0069	0.0029	0.0079	0.003
CD (P=0.05)	46.24	32.91	34.97	19.93	0.014	0.006	0.016	0.006
Sub Plot								
S_1	833	801	4644	4544	37.79	37.74	18.45	17.27
S_2	1009	967	4987	4903	38.29	38.33	18.54	17.55
S_3	1169	1128	5546	5352	38.83	38.76	18.76	17.92
S_4	1116	1088	5483	5278	38.76	38.66	18.72	17.87
S_5	1201	1161	5622	5404	38.95	38.74	18.78	17.96
S. Ed	15.57	15.35	15.94	17.40	0.0059	0.0019	0.071	0.002
CD (P=0.05)	31.31	30.86	31.92	34.99	0.012	0.004	0.014	0.004

The Interaction effect between the nutrient and weed management was significant. Treatment M_3 (RDF+vermicompost+azospirillum+$ZnSO_4$+KH_2PO_4) with S_5 (HW twice at 30 DAS) registered higher head diameter (20.31cm),total number of seeds head^{-1} (946.21 head^{-1}), number of filled seeds head^{-1}(929.25), seed filling percentage, test weight(8.13g), seed yield (1901kg ha^{-1}) and stalk yield (6225kg ha^{-1}) over other treatments. This was followed by M_3S_3 and lowest yield was recorded by M_1S_1 head diameter, total number of seeds head^{-1}, number of filled seeds head^{-1}, seed filling percentage, test weight, seed yield and stalk yield. These findings are in conformity with the findings of Babusasravanan (1992) [1] in groundnut. These results indicated that integrated nutrient management under comparatively weed free environment can influence the sunflower yield components and seed yield significantly.

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