



Non-herbicidal Weed and Organic Nutrient Management in Maize under Rainfed Maize-Sesamum Cropping Sequence

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Abstract

During 2013 and 2014, a field experiment was performed in the Instructional-Cum-Research Farm, Assam Agricultural University, Jorhat to study the effect of weed and nutrient management in maize on weeds and maize, sesamum yield. The field experiment was conducted in split plot design (SPD) and the treatments comprised of fertility management (F_0 - control, F_1 - 2.5 t/ha enriched compost and F_2 - 5.0 t/ha enriched compost) as the main factor and weed management (W_0 -no weeding, W_1 - hand hoeing and earthing up 20 and 50 days after sowing, W_2 -*in situ* cowpea mulching upto 50 days after sowing and W_3 - *in situ* blackgram mulching upto 50 days after sowing) as the sub factor in maize and its residual effects tested in subsequent sesamum crop. It was found that W_1 resulted in the least weed NPK content (%) at 60 days after sowing (DAS). In case of NPK uptake (kg/ha), W_1 resulted in the least at 60 DAS and harvest. It was also noticed that W_2 caused the least weed NPK content (%) at harvest during both the years. Organic nutrition had no effect on the above mentioned parameters. The residual effect of weed management and organic nutrition in the subsequent sesamum crop was nil in terms of weed suppression. It was found that W_1 , F_2 and W_1F_2 resulted in significantly the best LAI of maize for both the years. Treatments W_1 (3014.59 kg/ha and 2849.24 kg/ha in 2013 and 2014, respectively), F_2 (2322.33 kg/ha and 2178.29 kg/ha during 2013 and 2014, respectively) and W_1F_2 (4723.81 kg/ha and 4507.24 kg/ha during 2013 and 2014, respectively) too resulted in significantly the highest grain yield of maize. No residual effect of weed management was found while organic nutrition had residual effect in sesamum crop. The best LAI in



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sesamum was due to fertility management, F_2 during both the years while F_1 and F_2 both at par resulted in the least number of days needed for 50% flowering in sesamum. In sesamum, significant interaction effect was found only during 2014 for LAI, days to 50% flowering and yield. In terms of seed yield of sesamum, F_2 (589.08 kg/ha) and F_1 (556.28 kg/ha) being at par were better than F_0 in 2013 while in 2014, F_2 (402.78 kg/ha) was the best treatment. More benefit: cost ratio (2.56 and 2.16 during 2013 and 2014, respectively) of the maize-sesamum cropping sequence was due to F_1W_1 .

Introduction

Maize is the third most important food grain followed by rice and wheat in India. Maize is used for human consumption both with and without industrial processing, as animal feeds and bio-chemical industries. Maize is called as the queen of cereals due to its high yielding ability. Maize is mostly cultivated during rainy season in our country and weeds are a major problem during this period of time because of ample availability of growth factors during this season. Several research workers had observed that if weed competition in maize was left unchecked it would result in serious yield loss.^{1,2,3} Weed management strategies are focused on reducing the deleterious competition of weeds growing with crop plants for growth factors.⁴ It is a well documented fact that due to rise in environment pollution, various human health related issues have arisen which have led the human race to advocate for reduction in the pollution for a greener earth. Agriculture too has a share in the contribution towards environment pollution through the indiscriminate use of synthetic agro-chemicals. Researchers are constantly working on bringing out techniques that would curtail the agriculture dependence on synthetic agro-chemicals while not compromising with the issue of feeding the ever growing population on earth. Manual weeding followed by earthing up,⁵ hoeing twice⁶ and live mulching combined with hand weeding⁷ were documented to be effective in suppressing the weeds in maize. In India, maize-wheat or maize-rape seed rotations are prevalent. Maize is usually mono cropped or in cultivated in rotation with greengram or blackgram in Assam.⁸ The farming in the North eastern region is organic by default as the application of fertilizers and pesticides are limited compared to the other regions of the country. Maize organically cultivated may be followed by sesamum crop, an

important oilseed crop of India which have a low nutrient requirement.⁹ Researcher^{10,11} have noticed residual effect of compost application in different cropping sequence. Researches on non-herbicide weed and organic nutrient management in maize-sesamum cropping sequence in Assam are lacking. Considering all the points discussed above, the present experiment was done.

Materials and Methods

Site Location

During the year 2012-2013 and 2013-2014, the field experiment was done at the Instructional-Cum-Research (ICR) farm, Assam Agricultural University, Jorhat.

Treatments, Layout and Initial Soil Chemical Status of the Experimental Field

The experiment was conducted in split plot design. The main factor was fertility management (F_0 - control, F_1 - 2.5 t/ha enriched compost and F_2 - 5.0 t/ha enriched compost) and the sub factor was weed management (W_0 -no weeding, W_1 -hand hoeing and earthing up 20 and 50 days after sowing, W_2 -*in situ* cowpea mulching upto 50 days after sowing and W_3 - *in situ* blackgram mulching upto 50 days after sowing). The treatments were incorporated in maize and its effects were carried over to the succeeding crop sesamum. The enriched compost was procured from the department of soil science, Assam Agricultural University, Jorhat. Enrichment was done by addition of rock phosphate. The research plot soil was sandy loam in texture with acidic in reaction (pH 5.33). The soil organic C value was 0.51%, available N was 318.93 kg/ha, available P_2O_5 was 32.95 kg/ha and available K_2O was 167.54 kg/ha.^{9,12}

Crop Varieties Used

Varieties used in the experiment were as follows, maize variety-Dekalb 900 m Gold, sesamum-Koliabor Til, cowpea-UPC-212, blackgram-T9.^{9,12}

Weed Analysis

The weeds present within a quadrat (50 cm x 50 cm) placed randomly at four locations in each individual plot were removed at 60 days after sowing (DAS) and during harvest of maize and sesamum. The weeds were cleaned and oven-dried at 60±5°C to constant dry weight, finely grounded with a grinding machine and chemically analysed for NPK content. The methods of chemical analysis followed were-

- Nitrogen-Micro Kjeldahl method¹³
- Phosphorus-Vanadomolybdate yellow colour (colorimetric) method¹³
- Potassium-Flame photometer method¹³

For the total NPK uptake by weeds, it was calculated using the following formula:

Nutrient uptake = [Nutrient content/100] × Biomass (kg/ha)

Growth Analysis

In case of maize, length of the fully opened leaf lamina was measured from the base to the tip. Leaf breadth was taken at the widest point of the leaf lamina. The product of the leaf length and breadth were multiplied by the factor 0.75¹⁴ and the sum of all the leaves were expressed as leaf area in cm²/plant. Finally the average was calculated to get the data of each plot. This observation was recorded at 30, 60 and 90 DAS. Leaf area index (LAI) for maize and sesamum were calculated by dividing the leaf area/plant by the land area occupied by single plant. In sesamum, length of the leaf lamina was measured from the base to the tip. Leaf breadth was taken at the widest point of the leaf lamina. The product of the leaf length and breadth was multiplied by the factor 0.709¹⁵ and the sum of all the leaves was expressed as leaf area in cm²/plant. Finally the averages were calculated out. This observation was recorded at 30, 60 and 90 DAS. Days to 50% tasseling was recorded on the day when 50 % maize plants had attained tasseling stage. This data was recorded for individual plot. Days to 50% flowering was recorded on the day when 50% sesamum plants had attained

flowering stage. This data was recorded for individual plot.

Yield Analysis

At physiological maturity, maize cobs from each net plot were harvested. Cobs were separated, air dried, shelled, cleaned and weighed. Grain yield per ha was worked out and expressed in kg/ha. In sesamum, during harvest, net plot was harvested separately and bundled. Bundles were dried in sunshine. Later seeds were separated from the bundles separately for each individual plot manually by tapping with a stick. The produce was dried, winnowed, cleaned and weight of seeds obtained from each net plot was recorded expressed in kg/ha.

Benefit:Cost Ratio Analysis

This was calculated by dividing the net return by total cost of cultivation.

Statistical Analysis

All the data pertaining to the present investigation was analysed following the procedure of analysis of variance.¹⁶ Significance or non-significance of variance was determined by calculating respective 'F' values. Whenever the variance ratio (P) was found significant, critical difference (CD) was worked out at 5% probability level.

Results and discussion

Content (%) and Uptake (kg/ha) of NPK by Weeds in Maize at 60 days and at Harvest

Fertility management: The data given in Table 1 and Table 2 revealed no significant effect of fertility management by organic nutrition in maize on content (%) and uptake (kg/ha) of NPK of weeds in maize at 60 days and harvest.

Weed Management

Non-herbicidal weed management in maize resulted in significant effect (Table 1 and Table 2). It was noted that at 60 DAS, W₁ resulted in the least nutrient content of N (1.50%, 1.47% during 2013 and 2014, respectively), P (0.232%, 0.227% during 2013 and 2014, respectively) and K (1.15%, 1.12% during 2013 and 2014, respectively). At harvest of maize, W₂ resulted in the least content of N (1.24%, 1.21% at harvest during 2013 and 2014, respectively), P (0.230%, 0.224% at harvest during 2013 and 2014, respectively) and K (1.03%, 1.24% K at harvest

during 2013 and 2014, respectively). In terms of uptake, during 60 DAS and harvest, W_1 resulted in the least uptake of N (0.49 kg/ha and 0.47 kg/ha at 60 days, 7.14 kg/ha and 6.89 kg/ha at harvest during 2013 and 2014, respectively), P (0.08 kg/ha and 0.07 kg/ha at 60 days, 1.18 kg/ha and 1.11 kg/

ha at harvest during 2013 and 2014, respectively) and K (0.38 kg/ha, 0.36 kg/ha at 60 days, 6.16 kg/ha and 7.14 kg/ha at harvest during 2013 and 2014, respectively). Highest content (%) and uptake (kg/ha) at 60 days and at harvest by weeds in maize was recorded in case of W_0 during 2013 and 2014.

Table1: Effect of weed management and fertility management on NPK content (%) and uptake (kg/ha) of weeds in maize at 60 DAS

Treatment	N			P			K			N			P			K		
	2013		2014	2013		2014	2013		2014	2013		2014	2013		2014	2013		2014
	Content (%)			Uptake (kg)			Content (%)			Uptake (kg)			Content (%)			Uptake (kg)		
F Fertility management																		
F_0 : Control	1.65	1.62	0.249	0.242	1.26	1.23	13.85	13.45	2.07	1.98	10.66	10.28	13.73	13.42	2.10	2.02	10.81	10.39
F_1 : 2.5 t/ha	1.63	1.61	0.252	0.245	1.30	1.26	13.73	13.42	2.10	2.02	10.81	10.39	13.73	13.42	2.10	2.02	10.81	10.39
Enriched Compost																		
F_2 : 5.0 t/ha	1.64	1.61	0.251	0.246	1.24	1.23	13.28	12.84	2.02	1.95	10.11	9.89	13.28	12.84	2.02	1.95	10.11	9.89
Enriched Compost																		
SEm (±)	0.021	0.024	0.003	0.002	0.015	0.024	0.319	0.263	0.060	0.036	0.188	0.147	NS	NS	NS	NS	NS	NS
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
W Weed management																		
W_0 : Weedy check	1.78	1.75	0.269	0.262	1.38	1.35	27.09	26.33	4.08	3.93	20.92	20.23	27.09	26.33	4.08	3.93	20.92	20.23
W_1 : Hand hoeing and earthing up 20 and 50 DAS	1.50	1.47	0.232	0.227	1.15	1.12	0.49	0.47	0.08	0.07	0.38	0.36	0.49	0.47	0.08	0.07	0.38	0.36
W_2 : In situ cowpea mulching upto 50 DAS	1.54	1.52	0.240	0.233	1.19	1.15	7.87	7.60	1.22	1.17	6.09	5.78	7.87	7.60	1.22	1.17	6.09	5.78
W_3 : In situ blackgram mulching upto 50 DAS	1.74	1.71	0.261	0.256	1.34	1.33	19.04	18.55	2.87	2.77	14.71	14.39	19.04	18.55	2.87	2.77	14.71	14.39
SEm (±)	0.022	0.024	0.003	0.003	0.014	0.023	0.405	0.434	0.063	0.059	0.258	0.209	0.405	0.434	0.063	0.059	0.258	0.209
CD (P=0.05)	0.065	0.073	0.008	0.008	0.042	0.069	1.202	1.289	0.186	0.177	0.767	0.621	1.202	1.289	0.186	0.177	0.767	0.621
F X W	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	4.40	5.24	3.842	3.019	4.16	6.74	8.12	6.88	10.07	6.23	6.19	4.99	8.12	6.88	10.07	6.23	6.19	4.99
	4.03	4.55	3.246	3.489	3.38	5.63	8.91	9.83	9.11	8.99	7.36	6.16	8.91	9.83	9.11	8.99	7.36	6.16

NS Not significant; DAS Days after sowing

Table 2: Effect of weed management and fertility management on NPK content (%) and uptake (kg/ha) of weeds in maize at harvest

Treatment	N						P						K											
	2013		2014		2013		2014		2013		2014		2013		2014									
	Content (%)		Content (%)		Uptake (kg)		Uptake (kg)		Content (%)		Content (%)		Uptake (kg)		Uptake (kg)									
F Fertility management																								
F ₀ : Control	1.56	1.53	0.256	0.250	1.23	1.56	19.56	18.99	3.17	3.08	14.95	19.56	19.29	18.91	3.24	3.10	15.64	19.29						
F ₁ : 2.5 t/ha Enriched Compost	1.54	1.53	0.261	0.253	1.28	1.54	19.61	19.14	3.21	3.10	15.35	19.61	19.61	19.14	3.21	3.10	15.35	19.61						
F ₂ : 5.0 t/ha Enriched Compost	0.025	0.026	0.003	0.003	0.016	0.025	0.554	0.342	0.101	0.080	0.312	0.554	NS	NS	NS	NS	NS	NS						
SEM (±)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS						
W Weed management																								
W ₀ : Weedy check	1.59	1.58	0.254	0.246	1.22	1.59	30.40	29.81	4.85	4.66	23.21	30.40	7.14	6.89	1.18	1.11	6.16	7.14						
W ₁ : Hand hoeing and earthing up 20 and 50 DAS	1.83	1.82	0.303	0.294	1.58	1.83	14.77	14.29	2.74	2.64	12.23	14.77	14.77	14.29	2.74	2.64	12.23	14.77						
W ₂ : In situ cowpea mulching upto 50 DAS	1.24	1.21	0.230	0.224	1.03	1.24	25.63	25.06	4.04	3.96	19.65	25.63	25.63	25.06	4.04	3.96	19.65	25.63						
W ₃ : In situ blackgram mulching upto 50 DAS	1.55	1.53	0.244	0.241	1.19	1.55	0.580	0.613	0.089	0.073	0.368	0.580	1.723	1.822	0.264	0.216	1.095	1.723						
SEM (±)	0.020	0.026	0.003	0.003	0.018	0.020	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS						
CD (P=0.05)	0.059	0.076	0.009	0.008	0.054	0.059	9.85	6.24	10.89	8.99	7.05	9.85	9.85	6.24	10.89	8.99	7.05	9.85						
F X W	NS	NS	NS	NS	NS	NS	8.93	9.68	8.31	7.06	7.22	8.93	8.93	9.68	8.31	7.06	7.22	8.93						
CV (%)	5.67	5.90	4.436	4.178	4.42	5.67																		
	3.82	5.01	3.596	3.077	4.38	3.82																		

NS Not significant; DAS Days after sowing

Table 3: NPK content (%) and uptake (kg) of weeds in sesamum at 60 DAS as affected by weed management and fertility management

Treatment	N			P			K			N			P			K		
	Content (%)			Uptake (kg)			Content (%)			Uptake (kg)			Content (%)			Uptake (kg)		
	2013	2014	2014	2013	2014	2014	2013	2014	2014	2013	2014	2014	2013	2014	2014	2013	2014	2014
F Fertility management																		
F ₀ : Control	2.25	2.23	0.324	0.320	1.92	1.90	7.84	7.48	1.13	1.07	6.35	7.66	7.32	1.10	1.05	6.43	6.14	
F ₁ : 2.5 t/ha Enriched Compost	2.26	2.24	0.325	0.321	1.90	1.88	7.64	7.32	1.11	1.06	6.21	0.077	0.112	0.021	0.021	0.069	0.130	
F ₂ : 5.0 t/ha Enriched Compost	2.25	2.23	0.326	0.325	1.90	1.89	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
SEM (±)	0.034	0.024	0.005	0.005	0.025	0.032	0.077	0.112	0.021	0.021	0.069	NS	NS	NS	NS	NS	NS	
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
W Weed management																		
W ₀ : Weedy check	2.26	2.24	0.325	0.322	1.91	1.88	7.78	7.39	1.12	1.06	6.21	7.64	7.31	1.11	1.06	6.51	6.23	
W ₁ : Hand hoeing and earthing up 20 and 50 DAS	2.24	2.22	0.325	0.321	1.91	1.89	7.76	7.42	1.12	1.07	6.27	7.67	7.37	1.10	1.06	6.45	6.21	
W ₂ : In situ cowpea mulching upto 50 DAS	2.26	2.24	0.326	0.322	1.91	1.90	0.151	0.118	0.019	0.013	0.133	0.151	0.118	0.019	0.013	0.133	0.106	
W ₃ : In situ blackgram mulching upto 50 DAS	2.26	2.24	0.324	0.322	1.90	1.89	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
SEM (±)	0.036	0.036	0.005	0.004	0.029	0.028	0.036	0.036	0.005	0.004	0.028	NS	NS	NS	NS	NS	NS	
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
F X W	5.17	3.72	4.98	5.22	4.56	5.89	3.47	5.27	6.48	6.97	3.67	3.47	5.27	6.48	6.97	3.67	7.24	
CV (%)	4.74	4.84	4.20	3.41	4.58	4.51	5.85	4.80	5.13	3.67	5.11	5.85	4.80	5.13	3.67	6.13	5.11	

NS Not significant; DAS Days after sowing

Table 4: NPK content (%) and uptake (kg) of weeds in sesamum at 60 DAS as affected by weed management and fertility management

Treatment	N			P			K			N			P			K		
	Content (%)			Uptake (kg)			Content (%)			Uptake (kg)			Content (%)			Uptake (kg)		
	2013	2014	2014	2013	2014	2014	2013	2014	2014	2013	2014	2014	2013	2014	2014	2013	2014	2014
F Fertility management																		
F ₀ : Control	2.25	2.23	0.324	0.320	1.92	1.90	7.84	7.48	1.13	1.07	6.67	6.35						
F ₁ : 2.5 t/ha Enriched Compost	2.26	2.24	0.325	0.321	1.90	1.88	7.66	7.32	1.10	1.05	6.43	6.14						
F ₂ : 5.0 t/ha Enriched Compost	2.25	2.23	0.326	0.325	1.90	1.89	7.64	7.32	1.11	1.06	6.46	6.21						
SEm (±)	0.034	0.024	0.005	0.005	0.025	0.032	0.077	0.112	0.021	0.021	0.069	0.130						
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS						
W Weed management																		
W ₀ : Weedy check	2.26	2.24	0.325	0.322	1.91	1.88	7.78	7.39	1.12	1.06	6.57	6.21						
W ₁ : Hand hoeing and earthing up 20 and 50 DAS	2.24	2.22	0.325	0.321	1.91	1.89	7.64	7.31	1.11	1.06	6.51	6.23						
W ₂ : In situ cowpea mulching upto 50 DAS	2.26	2.24	0.326	0.322	1.91	1.90	7.76	7.42	1.12	1.07	6.56	6.27						
W ₃ : In situ blackgram mulching upto 50 DAS	2.26	2.24	0.324	0.322	1.90	1.89	7.67	7.37	1.10	1.06	6.45	6.21						
SEm (±)	0.036	0.036	0.005	0.004	0.029	0.028	0.151	0.118	0.019	0.013	0.133	0.106						
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS						
F X W	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS						
CV (%)	5.17	3.72	4.98	5.22	4.56	5.89	3.47	5.27	6.48	6.97	3.67	7.24						
	4.74	4.84	4.20	3.41	4.58	4.51	5.85	4.80	5.13	3.67	6.13	5.11						

NS Not significant; DAS Days after sowing

Table 5 Effect of weed management and fertility management on growth, yield of maize and sesamum

Treatment	Maize												Sesamum							
	30 DAS						60 DAS						90 DAS				60 DAS			
	LAI	2013	2014	2013	2014	2013	2014	LAI	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014		
F	0.27	0.26	1.03	0.98	0.77	0.76	59.25	60.33	380.18	314.31	0.21	0.14	1.46	0.84	0.33	0.2	39.42	39.83	445.06	226.92
F ₀	0.37	0.35	1.88	1.8	1.75	1.65	58.17	59.08	1779.74	1681.83	0.25	0.17	1.52	1.18	0.34	0.23	38.08	38.5	556.28	353.91
F ₁	0.43	0.4	2.3	2.24	2.14	1.98	58.17	58.83	2322.33	2178.29	0.28	0.19	1.6	1.27	0.36	0.26	37.67	38	589.08	402.78
F ₂	0.005	0.004	0.027	0.019	0.025	0.022	0.096	0.132	17.602	16.414	0.002	0.003	0.021	0.012	0.004	0.006	0.241	0.304	9.823	6.105
SEm (±)	0.018	0.018	0.105	0.077	0.097	0.086	0.378	0.517	69.113	64.45	0.009	0.013	0.083	0.048	0.015	0.024	0.945	1.195	38.57	23.97
CD (P=0.05)																				
W	0.34	0.32	1.58	1.49	1.4	1.31	59	60	1050.43	944.64	0.26	0.18	1.56	1.15	0.36	0.24	38.22	38.56	541.71	339.42
W ₀	0.43	0.41	2.52	2.46	2.33	2.15	56.44	57.56	3014.59	2849.24	0.24	0.17	1.51	1.07	0.34	0.23	38.44	38.89	529.02	334.53
W ₁	0.32	0.3	1.37	1.31	1.21	1.12	59.78	60.56	917.44	854.06	0.25	0.17	1.53	1.07	0.35	0.22	38.22	38.89	531.17	313.96
W ₂	0.33	0.31	1.49	1.43	1.27	1.26	58.89	59.56	993.88	917.96	0.24	0.17	1.5	1.09	0.34	0.23	38.67	38.78	518.67	323.56
W ₃	0.003	0.003	0.02	0.018	0.017	0.02	0.2	0.164	25.64	17.627	0.005	0.006	0.021	0.02	0.008	0.006	0.292	0.248	10.29	7.637
SEm (±)	0.010	0.010	0.060	0.052	0.050	0.059	0.595	0.486	76.179	52.371	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CD (P=0.05)	***	***	***	***	***	***	***	***	***	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F X W	4.58	4.65	5.32	4.04	5.49	5.19	0.57	0.77	4.08	4.09	3.14	6.94	4.77	3.88	3.87	9.25	2.17	2.72	6.42	6.45
CV (%)	2.92	2.96	3.50	3.16	3.24	4.09	1.03	0.83	5.15	3.80	5.85	9.88	4.19	5.60	7.02	7.64	2.28	1.92	5.82	6.99

** Significant; NS Not significant

F - Fertility management, W - Weed management F₀ - Control, F₁ - 2.5 t/ha Enriched Compost, F₂ - 5.0 t/ha Enriched Compost; W₀ - No weeding, W₁ - Hand hoeing and earthing up 20 and 50 DAS, W₂ - In situ cowpea mulching upto 50 DAS, W₃ - In situ blackgram mulching upto 50 DAS

Table 6 Interaction effects of weed management and fertility management on growth, yield of maize and sesame

Treatment	Maize LAI																								
	30 DAS					60 DAS					90 DAS														
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014									
	W ₀ *	W ₁	W ₂	W ₃	W ₀ *	W ₁	W ₂	W ₃	W ₀ *	W ₁	W ₂	W ₃	W ₀ *	W ₁	W ₂	W ₃	W ₀ *	W ₁	W ₂	W ₃					
F ₀	0.27	0.28	0.26	0.26	0.26	0.27	0.25	0.26	1.06	1.14	0.92	0.99	1.01	1.08	0.88	0.95	0.77	0.85	0.71	0.73	0.74	0.82	0.71	0.76	
F ₁	0.34	0.48	0.32	0.33	0.33	0.45	0.3	0.31	1.65	3.01	1.39	1.50	1.50	2.94	1.31	1.46	1.51	2.88	1.3	1.34	1.38	2.79	1.12	1.30	
F ₂	0.4	0.53	0.38	0.39	0.37	0.51	0.35	0.36	2.03	3.41	1.80	1.97	1.97	3.35	1.73	1.90	1.91	3.28	1.62	1.74	1.80	2.85	1.54	1.73	
	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	
D ₁	0.006	0.018	0.006	0.017	0.035	0.035	0.104	0.031	0.091	0.029	0.086	0.103	0.086	0.103	0.086	0.103	0.086	0.103	0.086	0.103	0.086	0.103	0.086	0.103	
D ₂	0.009	0.024	0.008	0.023	0.049	0.049	0.137	0.037	0.109	0.045	0.121	0.042	0.121	0.042	0.121	0.042	0.121	0.042	0.121	0.042	0.121	0.042	0.121	0.042	
	Days to 50% tasseling in maize																								
	30 DAS					60 DAS					90 DAS					Days to 50% flowering in sesame									
	Sesamum LAI					Sesamum LAI					Sesamum LAI					Days to 50% flowering in sesame									
	30 DAS					60 DAS					90 DAS					Days to 50% flowering in sesame									
	2014					2014					2014					Days to 50% flowering in sesame									
	W ₀ *	W ₁	W ₂	W ₃	W ₀ *	W ₁	W ₂	W ₃	W ₀ *	W ₁	W ₂	W ₃	W ₀ *	W ₁	W ₂	W ₃	W ₀ *	W ₁	W ₂	W ₃	W ₀ *	W ₁	W ₂	W ₃	
F ₀	0.14	0.16	0.14	0.13	0.85	0.99	0.8	0.73	0.19	0.22	0.19	0.19	59.67	56.67	60.33	61.00	58.00	61.00	61.00	61.00	61.00	61.00	61.00	61.00	61.00
F ₁	0.17	0.18	0.16	0.18	1.19	1.25	1.05	1.21	0.23	0.25	0.22	0.24	59.00	56.33	59.67	57.67	59.67	57.33	60.67	58.67	58.67	58.67	58.67	58.67	58.67
F ₂	0.21	0.15	0.21	0.20	1.4	0.98	1.37	1.32	0.30	0.21	0.26	0.26	58.33	56.33	59.33	58.67	59.33	57.33	60.00	58.67	58.67	58.67	58.67	58.67	58.67
	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	
D ₁	0.01	0.029	0.035	0.026	0.010	0.028	0.010	0.037	0.0347	0.0347	1.031	0.283	0.842	0.430	1.279	0.430	1.279	0.430	1.279	0.430	1.279	0.430	1.279	0.430	1.279
D ₂	0.008	0.033	0.028	0.025	0.012	0.038	0.241	0.965	0.269	0.887	0.569	1.731	0.569	1.731	0.569	1.731	0.569	1.731	0.569	1.731	0.569	1.731	0.569	1.731	
	Sesamum yield																								
	2013					2014					2014					Sesamum yield									
	2013					2014					2014					Sesamum yield									
	W ₀ *	W ₁	W ₂	W ₃	W ₀ *	W ₁	W ₂	W ₃	W ₀ *	W ₁	W ₂	W ₃	W ₀ *	W ₁	W ₂	W ₃	W ₀ *	W ₁	W ₂	W ₃	W ₀ *	W ₁	W ₂	W ₃	
F ₀	226.63	851.83	219.8	222.46	173.63	747.32	168.55	167.73	227.97	312.67	191.57	175.47	376.28	418.93	425.77	418.93	376.28	418.93	425.77	418.93	376.28	418.93	425.77	418.93	
F ₁	1303.78	3468.14	1104.97	1242.08	1210.54	3293.16	1043.88	1179.74328.87	385.97	324.53	376.28	418.93	376.28	418.93	425.77	418.93	376.28	418.93	425.77	418.93	376.28	418.93	425.77	418.93	
F ₂	4723.81	1427.54	1517.11	1449.75	4507.24	1349.75	1406.42	461.43	304.97	425.77	418.93	376.28	418.93	425.77	418.93	376.28	418.93	425.77	418.93	376.28	418.93	425.77	418.93	376.28	
	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)	
D ₁	44.409	131.947	30.53	132.665	90.71	100.732	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	
D ₂	37.716	132.665	32.269	132.665	90.71	100.732	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	12.472	

F₀ - Fertility management, W₀ - Weed management, F₁ - 2.5 t/ha Enriched Compost, F₂ - 5.0 t/ha Enriched Compost; W₀ - No weeding, W₁ - Hand hoeing and earthing up 20 and 50 DAS, W₂ - In situ cowpea mulching upto 50 DAS, W₃ - In situ blackgram mulching upto 50 DAS
 D₁ Difference of two W means at the same level of F; D₂ Difference of two F means at the same or different level of W

Table 7: Comparative economics of the treatments in maize-sesamum cropping sequence

Treatment combination	2013				2014			
	Gross return	Total cost of production (₹/ha)	Net return (₹/ha)	B:C ratio (₹/ha)	Gross return (₹/ha)	Total cost of production (₹/ha)	Net return (₹/ha)	B:C ratio
F0W0	55654.66	24356.00	31298.66	1.29	31478.00	24356.00	7122.00	0.29
F0W1	90121.50	26768.00	63353.50	2.37	68632.50	26768.00	41864.50	1.56
F0W2	54481.50	32760.70	21720.80	0.66	27584.34	32760.70	-5176.36	-0.16
F0W3	53803.17	27008.80	26794.37	0.99	25933.34	27008.80	-1075.46	-0.04
F1W0	122160.50	61856.00	60304.50	0.97	93413.84	61856.00	31557.84	0.51
F1W1	228693.50	64268.00	164425.50	2.56	203254.50	64268.00	138986.50	2.16
F1W2	111437.17	70260.70	41176.47	0.59	84647.16	70260.70	14386.46	0.20
F1W3	116170.50	64508.80	51661.70	0.80	96615.00	64508.80	32106.20	0.50
F2W0	142260.50	99356.00	42904.50	0.43	118631.00	99356.00	19275.00	0.19
F2W1	292078.33	101768.00	190310.33	1.87	255858.67	101768.00	154090.67	1.51
F2W2	131049.17	107760.70	23288.47	0.22	110064.34	107760.70	2303.64	0.02
F2W3	134710.17	102008.80	32701.37	0.32	112214.33	102008.80	10205.53	0.10

Fertility levelF₀: ControlF₁: 2.5t/ha Enriched compostF₂: 5.0t/ha Enriched compost**Weed level**W₀: No weedingW₁: Hand hoeing and earthing up 20 and 50 DASW₂: In situ cowpea mulching upto 50 DASW₃: In situ blackgram mulching upto 50 DAS**Price (₹)**

Maize grain: 50.00/kg

Sesamum seed: 100.00/kg

Interaction

No significant interaction effect between fertility management by organic nutrition and non-herbicide weed management in maize on NPK content (%) and uptake (kg/ha) of weeds in maize at 60 DAS and harvest.

No significant effect due to fertility management on weeds was found in the present experiment. Organic manures had no significant effect on dicot weeds while significant effect was observed only on monocot weeds in fennel.¹⁷ A study of the results on NPK content (%) of weeds revealed that the trend at harvest of maize were totally different as compared to that made at 60 DAS. Significantly more NPK content (%) of weeds at harvest of maize in case of W₁ compared to other treatments. The soil disturbances at 50 DAS due to W₁ might have encouraged emergence of new weeds later on and their density being less at harvest of maize resulted in more NPK content of weeds. However, it was not detrimental to maize as the critical period of crop-weed competition was over after 50 DAS.

Significantly the lowest NPK content of weeds in case of W₂ was due to smothering of weeds. The findings regarding NPK uptake (kg/ha) of weeds at harvest in maize as described above reflected the similar trend as observed at 60 days. Though low NPK content of weeds was observed in W₂ it could not reduce the weeds NPK uptake. It was due to the fact that this treatment was unable to substantially decrease the weeds density and dry weight. As the density and dry weight of weeds were significantly lesser due to W₁, uptake of NPK in weeds was found to be significantly lesser too as compared to other treatments. No weeding resulted in the maximum uptake of NP nutrients by weeds in maize as compared to two hand weeding.¹⁸

Content (%) and Uptake (kg/ha) of NPK by Weeds in Sesamum at 60 Days and Harvest

Fertility, weed management and their interaction in maize could not significantly influence the NPK content (%) and uptake (kg/ha) of weeds in sesamum at 60 days and at harvest (Table 3 and Table 4). As in the preceding crop maize fertility

management with enriched compost application did not have significant effect on weeds, therefore similar effect in respect of weeds during the sesamum crop was quite obvious. No residual effect of herbicides as well as hand weeding twice applied in rice on succeeding blackgram was observed.¹⁹

LAI, days to 50% Tasseling and Yield of Maize Fertility Management

The LAI, days to 50% tasseling and yield of maize were found to be significantly affected due to fertility management by organic nutrition (Table 5). Best LAI (0.43 and 0.40 at 30 DAS, 2.30 and 2.24 at 60 DAS and 2.14, 1.98 at 90 DAS during 2013 and 2014, respectively) and maize grain yield¹² (2322.33 kg/ha and 2178.29 kg/ha during 2013 and 2014, respectively) were as a result of F_2 application. Application of F_1 was the second best in this regard. In case of days to 50% tasseling, F_2 (58.17 and 58.83 DAS) and F_1 (58.17 and 59.08 DAS) were statistically at par and resulted in the least number of days for the maize plants to attain 50% tasseling as compared with F_0 .

Weed Management

Effect of non-herbicide weed management was significant (Table 5). It was noticed that highest LAI (0.43 and 0.41 at 30 DAS, 2.52 and 2.46 at 60 DAS and 2.33, 2.15 at 90 DAS in 2013 and 2014, respectively) and grain yield¹² (3014.59 kg/ha and 2849.24 kg/ha for 2013 and 2014, respectively) were recorded with W_1 . Days to 50% tasseling was found to be significantly decreased due to W_1 (56.44 and 57.56 DAS at 2013 and 2014, respectively).

Interaction

Interaction of the weed and nutrient management had significant effect on the LAI, days to 50% tasseling and maize grain yield (Table 6). At the same level of organic nutrition (F), W_1 outperforms the other treatments and at the same or different level of non-herbicide weed management (W), F_2 showed better result than the other treatments in respect of both LAI and days to 50% tasseling. Among the various treatment combinations, application of F_2W_1 caused significantly the highest LAI (0.53, 0.51 at 30 DAS, 3.41, 3.35 at 60 DAS and 3.28, 2.85 at 90 DAS in the 2013 and 2014, respectively) than the rest of the treatments. Application of F_1W_1 was the second best treatment in this regard. The treatment combinations,

F_2W_1 , F_1W_1 , both being statistically at par among themselves (56.33 days in 2013 and 57.33 days in 2014 for both the treatment combinations) were able to significantly decrease days to 50% tasseling in maize.

While considering the same level of organic nutrition (F), W_1 produced the highest grain yield. Taking into account the same or different level of non-herbicide weed management (W), F_2 resulted in the highest maize grain yield.¹² Amongst the treatment combinations, F_2W_1 was the best in terms of grain yield of maize during both the years.

Perusal of the results on the effects of the treatments of the present experiment on revealed that LAI, days to 50% tasseling and yield of maize were significantly improved due to application of enriched compost and non-herbicide weed management. This was due to the fact that non-herbicide weed management by W_1 could significantly reduce the weed infestation in maize, and therefore, the growth attributes and ultimately the yield of maize significantly improved by organic nutrition through application of enriched compost in maize. Thus, the combination of F_2W_1 was found to be significantly the best followed by F_1W_1 in respect of the growth attributing characteristic and yield. Weed management by W_1 could significantly reduce the weed infestation till the critical period of crop-weed competition in maize thereby giving the opportunity to the maize plants to tap the growth factors from their environment with less stress from the weeds compared to other treatments. The benefits of organic nutrition through enriched compost @ 2.5 t/ha and 5.0 t/ha could only be realised by the effective management of the weeds which were evident by the data obtained. Two hand weeding applied in maize resulted in better growth attributes as compared to no weeding at all. The efficacy of non-herbicide methods in managing the weeds and increasing the yield in maize was highlighted by several workers.^{20,21,22} Efficiency of organic nutrition in improving the growth and yield of maize was reported by various workers.^{23,24} In case of *in situ* cowpea live mulching, even though the weed NPK content and uptake were significantly reduced compared to *in situ* blackgram live mulching upto 50 DAS and weedy check, *in situ* cowpea live mulching proved to be detrimental to the maize plants because it competed with the crop for growth factors thereby negating its weed suppressing

ability which was reflected in poor growth of maize plants. *In situ* blackgram live mulching was poor in suppressing the weeds and thus the combined effect of blackgram plants and weeds depressed the growth of the maize plant. Competition from live mulches for growth factors with the main crop thereby causing yield loss of the main crop had been reported.²⁵

Lai, Days To 50% Flowering and Yield Of Sesamum

Fertility Management

The data revealed significant residual effect of fertility management by organic nutrition in maize on LAI, days to 50% flowering and yield of sesamum (Table 5). Application of F_2 resulted in significantly more LAI (0.28, 0.19 at 30 DAS; 1.60, 1.27 at 60 DAS; 0.36, 0.26 at 90 DAS during 2013 and 2014, respectively). It was found that F_2 (37.67 and 38.00 DAS during 2013 and 2014, respectively) and F_1 (38.08 and 38.50 DAS during 2013 and 2014, respectively) were at par and caused lesser days to 50% flowering than F_0 . Considering the yield of sesamum,¹² F_2 (589.08 kg/ha) and F_1 (556.28 kg/ha) being at par were better than F_0 in 2013 while in 2014, F_2 (402.78 kg/ha) was the best than the rest. Weed management: No significant residual effect due to non-herbicide weed management in maize on LAI, days to 50% flowering and seed yield in the succeeding crop sesamum was observed (Table 5). Interaction: Interaction between fertility management and non-herbicide weed management in maize on LAI, days to 50% flowering and seed yield in sesamum had significant residual effect only in 2014 (Table 6). During that year, at the same level of F_0 , non-herbicide weed management treatments in maize could not significantly change the LAI in sesamum as observed at 30 and 90 DAS and similarly days to 50% flowering also, but at 60 DAS, W_1 could significantly increase the LAI in succeeding sesamum crop in comparison with the other treatments. Similar results were obtained at F_1 . Now with F_2 application in maize, W_0 , W_2 and W_3 could significantly increase the LAI at 30 DAS and significantly decrease the days to 50% flowering compared with W_1 . At 60 DAS, W_0 and W_2 were similar but significantly better than W_1 and W_3 in respect of LAI whereas at 90 DAS, no non-herbicide treatments proved to be significantly more effective than W_0 . A perusal of the data indicated that at the same or different level of non-herbicide

weed management (W), F_1W_0 , F_1W_1 , F_1W_3 , F_2W_0 , F_2W_2 and F_2W_3 combinations were statistically similar and resulted in significantly more LAI at 30 DAS and significantly lesser days to 50% flowering in sesamum than the other combinations. On the other hand, at 60 DAS, F_2W_0 and F_2W_2 , both being statistically at par, resulted in significantly more LAI whereas at 90 DAS, F_2W_0 , F_2W_2 and F_2W_3 being statistically similar resulted in significantly more LAI in sesamum.

Taking into account the same level of fertility (F_0), in terms of seed yield of sesamum,¹² W_1 was the best treatment. At the same level of F_1 , W_1 and W_3 being at par, both recorded significantly more seed yield of sesamum. At F_2 , W_0 and W_2 , both being statistically similar, was the best. F_2W_0 , F_2W_2 and F_2W_3 being statistically similar, produced the highest sesamum seed yield than the rest of the combinations.

No residual effect of non-herbicide weed management on growth characteristics and yield of the succeeding crop sesamum were observed due to weed management of maize. As the weed management during the preceding crop maize was non-herbicide, its residual effect on weeds of the next crop sesamum was not observed obviously. No residual effect of hand weeding twice applied in rice on succeeding blackgram was observed.¹⁹ On the other hand, distinct residual effect due to fertility management in maize with enriched compost application was observed which was reflected in significantly improved LAI, significantly lesser days to 50% flowering and higher grain yield in sesamum. Positive residual effects of organic manures in succeeding crops following maize have been reported.^{26,10,27} Regarding the significant residual effect of fertility management during maize on growth characteristics of sesamum, it may be explained that due to slow release of nutrients from enriched compost during maize, the residual effect might have been obtained during sesamum. Manures have manifold benefits on the soil physical, chemical and biological characters²⁸ and have the ability to supply plant nutrient for two or more crop seasons.²⁹

Therefore, growth characteristics and seed yield of sesamum showed significant improvement due to residual effect of application of enriched compost @ 2.5 and 5.0 t/ha compared to non application of enriched compost.

Comparative Economics of the Treatments In Maize-Sesamum Cropping Sequence

The comparative economics of the treatments in respect of maize-sesamum cropping sequence has been presented in Table 7. It revealed that higher gross return (₹292078.33/ha and ₹255858.67/ha in 2013 and 2014, respectively) and net return (₹190310.33/ha and ₹154090.67/ha) of the sequence were due to application of F_2W_1 , but benefit: cost ratio (2.56 and 2.16 in 2013 and 2014, respectively) was more due to application of F_1W_1 .

The efficacy of fertility management with application of enriched compost at either 2.5 or 5.0 t/ha and weed management by non-herbicidal methods especially hand hoeing and earthing up at 20 and 50 days in maize-sesamum cropping sequence in controlling weeds and improving growth and yield of the crops has already been highlighted. That is why, application of enriched compost associated with hand hoeing and earthing up at 20 and 50 days proved to be better than the other treatment

combinations in this regard. More benefit: cost ratio obtained with application of 2.5 t/ha enriched compost as compared with 5.0 t/ha application may be attributed to the lesser cost of production incurred in case of the former.

Conclusion

Management of weeds by hand hoeing and earthing up twice coupled with organic nutrition by enriched compost in maize would result in profitable maize grain yield while beneficial residual effect of enriched compost application in maize would be observed in subsequent sesamum in terms of better growth and higher seed yield.

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Conflict of interest

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