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 (F0 - control, F1 - 2.5 t/ha enriched compost and F2 - 5.0 t/ha enriched compost) as the main factor and weed management (W0 - no weeding, W1 - hand hoeing and earthing up 20 and 50 days after sowing, W2 - in situ cowpea mulching up to 50 days after sowing and W3 - in situ blackgram mulching up to 50 days after sowing) as the sub factor in maize and its residual effects tested in subsequent sesamum crop. It was found that W1 resulted in the least weed NPK content (%) at 60 days after sowing (DAS). In case of NPK uptake (kg/ha), W1 resulted in the least at 60 DAS and harvest. It was also noticed that W2 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 W1, F2 and W1F2 resulted in significantly the best LAI of maize for both the years. Treatments W1 (3014.59 kg/ha and 2849.24 kg/ha in 2013 and 2014, respectively), F2 (2322.33 kg/ha and 2178.29 kg/ha during 2013 and 2014, respectively) and W1F2 (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...
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-rapeseed 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 sesame crop, an important oilseed crop of India which have a low nutrient requirement.9 Researcher10,11 have noticed residual effect of compost application in different cropping sequence. Researches on non-herbicidal 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<sub>0</sub> - control, F<sub>1</sub> - 2.5 t/ha enriched compost and F<sub>2</sub> - 5.0 t/ha enriched compost) and the sub factor was weed management (W<sub>0</sub> -no weeding, W<sub>1</sub> - hand hoeing and earthing up 20 and 50 days after sowing, W<sub>2</sub> - in situ cowpea mulching upto 50 days after sowing and W<sub>3</sub> - 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 sesame. 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<sub>2</sub>O<sub>5</sub> was 32.95 kg/ha and available K<sub>2</sub>O was 167.54 kg/ha.9,12
Crop Varieties Used
Varieties used in the experiment were as follows, maize variety-Dekalb 900 m Gold, sesame-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 sesame. 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:

\[
\text{Nutrient uptake} = \frac{\text{Nutrient content}}{100} \times \text{Biomass (kg/ha)}
\]

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 sesame were calculated by dividing the leaf area/plant by the land area occupied by single plant. In sesame, 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% sesame 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 sesame, 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, W, 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, W, 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
Table 1: Effect of weed management and fertility management on NPK content (%) and uptake (kg/ha) of weeds in maize at 60 DAS

| Treatment                  | N Content (%) | P Content (%) | K Content (%) | N Uptake (kg) | P Uptake (kg) | K Uptake (kg) |
|----------------------------|---------------|---------------|---------------|---------------|---------------|---------------|
|                            | 2013 2014     | 2013 2014     | 2013 2014     | 2013 2014     | 2013 2014     | 2013 2014     |
| **F Fertility management** |               |               |               |               |               |               |
| F0: 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   |
| F1: 2.5 t/ha Enriched Compost | 1.63 1.61     | 0.252 0.245   | 1.30 1.26     | 13.73 13.42   | 2.10 2.02     | 10.81 10.39   |
| F2: 5.0 t/ha Enriched Compost | 1.64 1.61     | 0.251 0.246   | 1.24 1.23     | 13.28 12.84   | 2.02 1.95     | 10.11 9.89    |
| 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   |
| 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**      |               |               |               |               |               |               |
| W0: 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   |
| W1: Hand hoeing and earthing up to 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 |
| W2: In situ cowpea mulching up to 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 |
| W3: In situ blackgram mulching up to 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 |
| 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   |
| 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   |
| **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 4.019   | 4.16 6.74     | 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     |

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 Content (%) | P Content (%) | K Uptake (kg) | N Uptake (kg) | P Uptake (kg) | K Uptake (kg) |
|-----------|--------------|---------------|---------------|---------------|---------------|---------------|
|           | 2013 2014    | 2013 2014     | 2013 2014     | 2013 2014     | 2013 2014     | 2013 2014     |
| F Fertility management | | | | | | |
| F₀: 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 | | |
| F₁: 2.5 t/ha | 1.54 1.53 0.261 0.253 | 1.28 1.54 | 19.29 18.91 3.24 3.10 | 15.64 19.29 | | |
| Enriched Compost | | | | | | |
| F₂: 5.0 t/ha | 1.57 1.55 0.258 | 0.251 1.26 1.57 19.61 19.14 3.21 3.10 | 15.35 19.61 | | |
| Enriched Compost | | | | | | |
| SEm (±) | 0.025 0.026 0.003 0.003 | 0.016 0.025 | 0.054 0.342 0.101 0.080 0.312 0.554 | | | |
| CD (P=0.05) | NS NS NS NS NS NS NS NS NS NS NS NS | NS NS NS NS NS NS NS NS NS NS NS NS | |
| W Weed management | | | | | | |
| W₀: 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 | | |
| W₁: Hand hoeing and earthing up 20 and 50 DAS | 1.83 1.82 0.303 | 0.294 1.58 1.83 | 7.14 6.89 1.18 1.11 | 6.16 7.14 | | |
| W₂: In situ cowpea mulching upto 50 DAS | 1.24 1.21 0.230 | 0.224 1.03 1.24 | 14.77 14.29 2.74 2.64 | 12.23 14.77 | | |
| W₃: In situ blackgram mulching upto 50 DAS | 1.55 1.53 0.244 | 0.241 1.19 1.55 | 25.63 25.06 4.04 3.96 | 19.65 25.63 | | |
| SEm (±) | 0.020 0.026 0.003 | 0.003 0.018 0.020 | 0.580 0.613 0.089 0.073 0.368 0.368 0.580 | | | |
| CD (P=0.05) | 0.059 0.076 0.009 | 0.008 0.054 0.059 | 1.723 1.822 0.264 0.216 1.095 1.723 | | | |
| F X W | NS NS NS NS NS NS NS NS NS NS NS NS | NS NS NS NS NS NS NS NS NS NS NS NS | |
| CV (%) | 5.67 5.90 4.436 4.178 | 4.42 5.67 | 9.85 6.24 10.89 8.99 7.05 9.85 | | | |
|         | 3.82 5.01 3.596 | 3.077 4.38 | 8.93 9.68 8.31 7.06 7.22 8.93 | | | |

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 Content (%) 2013 | N Content (%) 2014 | P Content (%) 2013 | P Content (%) 2014 | K Content (%) 2013 | K Content (%) 2014 | N Uptake (kg) 2013 | P Uptake (kg) 2013 | K Uptake (kg) 2013 | N Uptake (kg) 2014 | P Uptake (kg) 2014 | K Uptake (kg) 2014 |
|----------------------------------|-------------------|-------------------|-------------------|-------------------|--------------------|--------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| **F Fertility management**       |                   |                   |                   |                   |                    |                    |                   |                   |                   |                   |                   |                   |
| F₀: 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              |
| F₁: 2.5 t/ha                    | 2.26              | 2.24              | 0.325             | 0.321             | 1.90               | 1.88               | 7.66              | 7.32              | 1.10              | 1.05              | 6.43              | 6.14              |
| Enriched Compost                |                   |                   |                   |                   |                    |                    |                   |                   |                   |                   |                   |                   |
| F₂: 5.0 t/ha                    | 2.25              | 2.23              | 0.326             | 0.325             | 1.90               | 1.89               | 7.64              | 7.32              | 1.11              | 1.06              | 6.46              | 6.21              |
| Enriched Compost                |                   |                   |                   |                   |                    |                    |                   |                   |                   |                   |                   |                   |
| **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**            |                   |                   |                   |                   |                    |                    |                   |                   |                   |                   |                   |                   |
| W₀: 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              |
| W₁: 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 |
| W₂: 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 |
| W₃: 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**                        |                   |                   |                   |                   |                    |                    |                   |                   |                   |                   |                   |                   |
| 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              |
| CV (%)                           | 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 4: NPK content (%) and uptake (kg) of weeds in sesame at 60 DAS as affected by weed management and fertility management

| Treatment                      | N       | P       | K       | N       | P       | K       | N       | P       | K       | N       | P       | K       |
|--------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
|                                | 2013    | 2014    | 2013    | 2014    | 2013    | 2014    | 2013    | 2014    | 2013    | 2014    | 2013    | 2014    |
|                                | Content (%) | Uptake (kg) |
|                                |         |         |         |         |         |         |         |         |         |         |         |         |
| F Fertility management         |         |         |         |         |         |         |         |         |         |         |         |         |
| F<sub>0</sub>: 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<sub>1</sub>: 2.5 t/ha        | 2.26    | 2.24    | 0.325   | 0.321   | 1.90    | 1.88    | 7.66    | 7.32    | 1.10    | 1.05    | 6.43    | 6.14    |
| Enriched Compost              |         |         |         |         |         |         |         |         |         |         |         |         |
| F<sub>2</sub>: 5.0 t/ha        | 2.25    | 2.23    | 0.326   | 0.325   | 1.90    | 1.89    | 7.64    | 7.32    | 1.11    | 1.06    | 6.46    | 6.21    |
| Enriched Compost              |         |         |         |         |         |         |         |         |         |         |         |         |
| 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<sub>0</sub>: 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<sub>1</sub>: Hand hoeing and | 2.24    | 2.22    | 0.325   | 0.321   | 1.91    | 1.89    | 7.64    | 7.31    | 1.11    | 1.06    | 6.51    | 6.23    |
| earthing up 20 and 50 DAS      |         |         |         |         |         |         |         |         |         |         |         |         |
| W<sub>2</sub>: In situ cowpea  | 2.26    | 2.24    | 0.326   | 0.322   | 1.91    | 1.90    | 7.76    | 7.42    | 1.12    | 1.07    | 6.56    | 6.27    |
| mulching upto 50 DAS           |         |         |         |         |         |         |         |         |         |         |         |         |
| W<sub>3</sub>: In situ blackgram| 2.26    | 2.24    | 0.324   | 0.322   | 1.90    | 1.89    | 7.67    | 7.37    | 1.10    | 1.06    | 6.45    | 6.21    |
| mulching upto 50 DAS           |         |         |         |         |         |         |         |         |         |         |         |         |
| 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                          |         |         |         |         |         |         |         |         |         |         |         |         |
| 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 sesame

| Treatment | 30 DAS LAI | 60 DAS LAI | 90 DAS LAI | Days to 50% tasseling | Grain yield (kg/ha) | 30 DAS LAI | 60 DAS LAI | 90 DAS LAI | Days to 50% flowering | Seed yield (kg/ha) |
|-----------|------------|------------|------------|-----------------------|---------------------|------------|------------|------------|-----------------------|-------------------|
| Control   | 0.27       | 0.26       | 1.03       | 0.98                  | 0.77                | 0.76       | 59.25      | 60.33      | 380.18                | 314.31             |
| F1        | 0.37       | 0.35       | 1.88       | 1.8                  | 1.75                | 1.65       | 58.17      | 59.08      | 1779.74               | 1681.83            |
| F2        | 0.43       | 0.4        | 2.3        | 2.24                 | 2.14                | 1.98       | 58.17      | 58.83      | 2322.33               | 2178.29            |
| W0        | 0.34       | 0.32       | 1.58       | 1.4                  | 1.31               | 1.4        | 59         | 60         | 1050.43               | 944.64             |
| W1        | 0.43       | 0.41       | 2.52       | 2.46                 | 2.33                | 2.15       | 56.44      | 57.56      | 3014.59               | 2849.24            |
| W2        | 0.32       | 0.3        | 1.37       | 1.31                 | 1.21               | 1.12       | 59.78      | 60.56      | 917.44                | 854.06             |
| W3        | 0.33       | 0.31       | 1.49       | 1.43                 | 1.27               | 1.26       | 58.89      | 59.56      | 993.88                | 917.96             |
| SEm (±)   | 0.005      | 0.004      | 0.027      | 0.019                | 0.025              | 0.022      | 0.096      | 0.132      | 17.602                | 16.414             |
| CD (P=0.05) | 0.018   | 0.016      | 0.105      | 0.077                | 0.097              | 0.086      | 0.378      | 0.517      | 69.113                | 64.45              |
| CV (%)    | 4.58       | 4.65       | 5.32       | 4.04                 | 5.49               | 5.19       | 0.57       | 0.77       | 4.08                  | 4.09               |

**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 up to 50 DAS, W3 - In situ blackgram mulching up to 50 DAS
Table 6 Interaction effects of weed management and fertility management on growth, yield of maize and sesame

| Treatment | Maize LAI 30 DAS | Maize LAI 60 DAS | Maize LAI 90 DAS | Sesamum LAI 30 DAS | Sesamum LAI 60 DAS | Sesamum LAI 90 DAS | Days to 50% tasseling in maize | Days to 50% flowering in sesame |
|-----------|------------------|------------------|------------------|---------------------|-------------------|-------------------|-------------------------------|--------------------------------|
|           | 2013             | 2014             | 2013             | 2014                | 2013              | 2014              | 2013                      | 2014                           |
|           | $W_0$ $W_1$ $W_2$ $W_3$ | $W_0$ $W_1$ $W_2$ $W_3$ | $W_0$ $W_1$ $W_2$ $W_3$ | $W_0$  | $W_1$  | $W_2$  | $W_3$  | $W_0$ | $W_1$ | $W_2$ | $W_3$ | $W_0$ | $W_1$ | $W_2$ | $W_3$ | $W_0$ | $W_1$ | $W_2$ | $W_3$ | $W_0$ | $W_1$ | $W_2$ | $W_3$ | $W_0$ | $W_1$ | $W_2$ | $W_3$ | $W_0$ | $W_1$ | $W_2$ | $W_3$ | $W_0$ | $W_1$ | $W_2$ | $W_3$ | $W_0$ | $W_1$ | $W_2$ | $W_3$ | $W_0$ | $W_1$ | $W_2$ | $W_3$ | $W_0$ | $W_1$ | $W_2$ | $W_3$ |
| $F_0$    | 0.27 0.28 0.26 0.26 | 0.27 0.28 0.26 0.26 | 0.25 0.26 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 |

| $D_1$ | 0.006 | 0.018 | 0.006 | 0.017 | 0.035 | 0.104 | 0.031 | 0.091 | 0.029 | 0.086 | 0.035 | 0.103 |
| $D_2$ | 0.009 | 0.024 | 0.022 | 0.023 | 0.049 | 0.137 | 0.037 | 0.109 | 0.045 | 0.121 | 0.042 | 0.122 |

| Treatment | 2013 Maize yield | 2014 Maize yield | 2013 Sesamum yield | 2014 Sesamum yield |
|-----------|------------------|------------------|-------------------|-------------------|
|           | $W_0$ $W_1$ $W_2$ $W_3$ | $W_0$ $W_1$ $W_2$ $W_3$ | $W_0$ $W_1$ $W_2$ $W_3$ | $W_0$ $W_1$ $W_2$ $W_3$ |
| $F_0$    | 226.63 | 851.83 | 219.8 | 222.46 | 173.63 | 747.32 | 168.55 | 167.73 |
| $F_1$    | 1331.78 | 3468.14 | 1104.97 | 1242.08 | 1210.54 | 3293.16 | 1043.88 | 1179.74328.87 |
| $F_2$    | 1620.88 | 4723.81 | 1517.11 | 1449.75 | 4507.24 | 1349.75 | 1406.42 | 461.43 |
| $D_1$    | 44.409 | 131947 | 30.53 | 90.71 | 13.228 | 370.32 |
| $D_2$    | 37.716 | 132665 | 32.269 | 100.732 | 12.472 | 47.371 |

F: Fertility management, W: Weed management, $F_0$: Control, $F_1$: 2.5 t/ha Enriched Compost, $F_2$: 5.0 t/ha Enriched Compost, $W_0$: No weeding, $W_1$: Hand hoeing and earthing up 20 and 50 DAS, $W_2$: In situ cowpea mulching up to 50 DAS, $W_3$: In situ blackgram mulching up to 50 DAS

$D_1$, Difference of two W means at the same level of F; $D_2$, 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 Total cost of production (`/ha) | Net return (`/ha) | B:C ratio | Gross 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                  | 122160.50 | 61856.00 | 60304.50 | 0.97 | 93413.84 | 61856.00 | 31557.84 | 0.51 |
| F1W0                  | 121660.50 | 65048.80 | 56511.20 | 0.99 | 94615.00 | 65048.80 | 32106.20 | 0.50 |
| F1W1                  | 228693.50 | 101768.00 | 126925.50 | 1.87 | 255858.67 | 101768.00 | 154090.67 | 1.51 |
| 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 | 32062.20 | 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 level**
- F0: Control
- F1: 2.5t/ha Enriched compost
- F2: 5.0t/ha Enriched compost

**Weed level**
- 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

**Price (`)**
- Maize grain: 50.00/kg
- Sesamum seed: 100.00/kg

**Interaction**
No significant interaction effect between fertility management by organic nutrition and non-herbicidal 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. 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.

**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 sesame crop was quite obvious. No residual effect of herbicides as well as hand weeding twice applied in rice on succeeding blackgram was observed.\textsuperscript{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 yield\textsuperscript{12} (2322.33 kg/ha and 2178.29 kg/ha during 2013 and 2014, respectively) were as a result of F\textsubscript{2} application. Application of F\textsubscript{1} was the second best in this regard. In case of days to 50% tasseling, F\textsubscript{2} (58.17 and 58.83 DAS) and F\textsubscript{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\textsubscript{0}.

**Weed Management**

Effect of non-herbicidal 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 yield\textsuperscript{12} (3014.59 kg/ha and 2849.24 kg/ha for 2013 and 2014, respectively) were recorded with W\textsubscript{1}. Days to 50% tasseling was found to be significantly decreased due to W1 (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\textsubscript{1} outperform the other treatments and at the same or different level of non-herbicidal weed management (W), F\textsubscript{2} showed better result than the other treatments in respect of both LAI and days to 50% tasseling. Among the various treatment combination, application of F\textsubscript{1}W\textsubscript{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\textsubscript{1}W\textsubscript{1} was the second best treatment in this regard. The treatment combinations, F\textsubscript{2}W\textsubscript{1}, F\textsubscript{1}W\textsubscript{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\textsubscript{1} produced the highest grain yield. Taking into account the same or different level of non-herbicidal weed management (W), F\textsubscript{2} resulted in the highest maize grain yield.\textsuperscript{12} Amongst the treatment combinations, F\textsubscript{2}W\textsubscript{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-herbicidal weed management. This was due to the fact that non-herbicidal weed management by W\textsubscript{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\textsubscript{2}W\textsubscript{1} was found to be significantly the best followed by F\textsubscript{1}W\textsubscript{1} in respect of the growth attributing characteristic and yield. Weed management by W\textsubscript{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 all4. The efficacy of non-herbicidal methods in managing the weeds and increasing the yield in maize was highlighted by several workers.\textsuperscript{20,21,22} Efficiency of organic nutrition in improving the growth and yield of maize was reported by various workers.\textsuperscript{23,24} In case of \textit{in situ} cowpea live mulching, even though the weed NPK content and uptake were significantly reduced compared to \textit{in situ} blackgram live mulching upto 50 DAS and weedy check, \textit{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.

**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 F₂ 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 F₂ (37.67 and 38.00 DAS during 2013 and 2014, respectively) and F₁ (38.08 and 38.50 DAS during 2013 and 2014, respectively) were at par and caused lesser days to 50% flowering than F₀. Considering the yield of sesamum, F₂ (589.08 kg/ha) and F₁ (556.28 kg/ha) being at par were better than F₀ in 2013 while in 2014, F₂ (402.78 kg/ha) was the best than the rest. Weed management: No significant residual effect due to non-herbicidal 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-herbicidal 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 F₂₀, non-herbicidal 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, W₁ could significantly increase the LAI in succeeding sesamum crop in comparison with the other treatments. Similar results were obtained at F₁. Now with F₂ application in maize, W₀, W₂ and W₅ could significantly increase the LAI at 30 DAS and significantly decrease the days to 50% flowering compared with W₁. At 60 DAS, W₀ and W₅ were similar but significantly better than W₁ and W₅ in respect of LAI whereas at 90 DAS, no non-herbicidal treatments proved to be significantly more effective than W₀. A perusal of the data indicated that at the same or different level of non-herbicidal weed management (W), F₁W₀, F₁W₁, F₂W₀, F₂W₁ and F₃W₀ 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.

No residual effect of non-herbicidal 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-herbicidal, 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. 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. Taking into account the same level of fertility (F₂₀), in terms of seed yield of sesamum, W₁ was the best treatment. At the same level of F₁, W₁ and W₀ being at par, both recorded significantly more seed yield of sesamum. At F₂₀, W₀ and W₁, both being statistically similar, was the best. F₂₀W₀, F₂₀W₁ and F₂₀W₁ being statistically similar, produced the highest sesamum seed yield than the rest of the combinations.

Therefore, growth characteristics and seed yield of sesamum showed significant improvement due to residual effect of application of enriched compost at 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 (INR 292078.33/ha and INR 255858.67/ha in 2013 and 2014, respectively) and net return (INR 190310.33/ha and INR 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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