Weed management in direct-seeded rice (*Oryza sativa*) + *brahmi* (*Bacopa monnieri*) intercropping system

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ABSTRACT

An investigation was carried out to evaluate the effect of weed management on yield, yield attributes and eco-

nomics of direct seeded rice (*Oryza sativa* L.) and herb of grace or *brahmi* [*Bacopa monnieri* (L.) Pennell] intercropping system at Pantnagar, Uttarakhand, during rainy seasons of 2015 and 2016. The lowest weed density, dry weight and the highest weed-control efficiency were recorded with pendimethalin followed by (fb) cyhalofop-butyl fb 1 hand-weeding 45 days after sowing (DAS) or days after planting (DAP) in 2 : 1 row ratio. Dry-herbage yield of *brahmi* (2.07 and 2.35 t/ha) and grain yield (5.30 and 6.56 t/ha) were highest in sole direct-seeded rice (pendimethalin fb cyhalofop-butyl fb 1 hand-weeding at 45 DAS/DAP) and sole *brahmi* (3 hand-weedings 30, 45 and 60 DAP). The highest land-equivalent ratio was found with pendimethalin fb cyhalofop-butyl fb 1 hand-weeding at 45 DAS or DAP in alternate row ratio (1 : 1) of direct-seeded rice and *brahmi* during both the years. The higher net returns and benefit: cost ratio were found with pendimethalin fb cyhalofop-butyl fb 1 hand-weeding at 45 DAP in alternate row ratio (1:1) of rice and *brahmi* intercropping system.

Key words: *Brahmi*, Direct-seeded rice, Intercropping, Weed, Yield

Rice is primarily grown by transplanting of seedling in puddled field which is very cumbersome and labour-intensive (Prasad, 2004). It is imperative to identify alternative methods of rice cultivation to overcome these constraints. Direct-seeded rice (DSR) offers the advantage of faster and easier planting, reduce labour and hence less drudgery and more efficient water use. Weeds are the greatest yield-limiting constraint to rice. The risk of yield loss from weeds in DSR is greater than transplanted rice (Rao et al., 2007). In DSR, yield penalty is as high as 50–91% (Rao et al., 2007). Different weed-control options are available for rice. Physical control are eco-friendly but tedious and labour-intensive. Nowadays, intercropping has become one of the popular methods in agricultural system owing to the more efficient use of resources and its role in reduction in weeds interference and other pests.

Herb of grace or *brahmi* is one of the medicinal plants which can be grown like rice in upland as well as in low-land conditions and the crop will be ready after 90 days. As a pure crop, fresh yield is 22.5 t/ha, reduced to approximately 5.5 t/ha on drying. As an intercrop with rice, dry-matter production of *Bacopa* is estimated to be about 3.75 t/ha. Therefore, to overcome the problem of weeds in DSR, a field investigation was carried out by using *brahmi* as an intercrop along with different weed-management practices.

MATERIALS AND METHODS

The experiment was carried out during the rainy seasons of 2015 and 2016 at N.E. Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, on direct-seeded rice + *brahmi* intercropping system under different weed management practices. The soil was loam. The experiment was carried out in a randomized complete-block design by taking 10 treatments with 3 replications. Intercropping treatments were rice + *brahmi* (1:1) in additive series (where *brahmi* crop was sown at the spacing of 40 cm and 1 row of rice was sown between 2 rows of *brahmi* at 20 cm) and rice + *brahmi* (2 : 1) in replacement series (where *brahmi* crop was sown at the spacing of 40 cm after 2 rows of rice at 20 cm) along with 4 weed management practices viz.,
pendimethalin 1 kg/ha + 2 hand-weedings (H.W.), pendimethalin 1 kg/ha, pendimethalin 1 kg/ha + cyhalofop-butyl 20 g/ha + 1 hand-weeding) and weedy check. Sole crop of rice and sole brahmi were also kept for comparison. Furrows were opened manually with the help of liners at a specified row-to-row distance of 20 cm. The rice variety ‘Pant-18’ was sown on 9 June, 2015 and 7 June, 2016 and brahmi variety ‘CIM Jagriti’ was sown on 10 June, 2015 and 8 June, 2016 using a seed rate of 17 kg/ha and 3.3 t/ha in additive series and 21 kg/ha and 2.5 t/ha in replacement series respectively. Pre-emergence herbicides were applied on day 3 of sowing and planting and post-emergence on day 20 after sowing or planting. The recommended fertilizer doses of rice (120 : 60 : 40 N : P : K/ha) were applied uniformly through N : P : K (12 : 32 : 16) mixture and rest through urea and the irrigation was given accordingly. Plant-protection measures and irrigations were provided as and when required. Weedy check plots remained infested with native population of weeds till harvesting. Data of density of complex weed flora (no./m²) were collected from each individual plot from one side of the plot, leaving the 2 border rows with the help of a quadrate. For weed biomass (g/m²), weeds were removed from the sampling rows above the ground with the sickle, sun-dried then kept in hot-air oven at 60±10°C till constant dry weight was obtained. Different yield-attribute parameters and yield were recorded at crop harvesting. Economics was calculated on the basis of prevailing market prices of input used and output obtained. Weed population data were subjected to square-root transformation √(x+1) before statistical analysis, adapted in statistical package STPR 2 developed by the GBPUA and T, Pantnagar.

Weed-control efficiency

The weed-control efficiency (WCE) taken at 30 DAS was calculated by using the following formula and expressed on per cent basis:

\[
WCE (%) = \frac{W_d - W_d^t}{W_d} \times 100
\]

where,

- \(W_d\) : weed dry weight in control plot (weedy check), and
- \(W_d^t\) : weed dry weight in treated plot (treatment).

Land-equivalent ratio (LER):

It was calculated as:

\[
LER = \frac{Y_{AB}}{Y_{AA} + Y_{BA}} \div \frac{Y_{BB}}{Y_{BA}}
\]

where \(Y_{AB}\), yield of intercrop (rice); \(Y_{AA}\), yield of sole crop (rice); \(Y_{BA}\), yield of intercrop (brahmi); and \(Y_{BB}\), yield of sole crop (brahmi).

RESULTS AND DISCUSSION

Weeds

The experimental plots were infested with mixed weed flora and hand-weeding was manually done every 10 days after sowing. The plots were divided into seven treatments as given in Table 1.

Table 1. Effect of different intercropping treatments on total weed density, total weed dry weight and weed-control efficiency in rice + brahmi intercropping at 30 DAS/DAP (pooled data of two years)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dose (kg/ha)</th>
<th>Total weed density (no./m²)</th>
<th>Total weed dry weight (g/m²)</th>
<th>Weed-control efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSR + brahmi (1:1) Pendi (PE)</td>
<td>1.00</td>
<td>4.89 (23.00)</td>
<td>4.04 (15.33)</td>
<td>32.86</td>
</tr>
<tr>
<td>DSR + brahmi (1:1) Pendi (PE) fb 2 HW</td>
<td>1.00 fb 30 and 45 DAS/DAP</td>
<td>4.44 (18.75)</td>
<td>3.40 (10.58)</td>
<td>54.30</td>
</tr>
<tr>
<td>DSR + brahmi (1:1) Pendi (PE) fb Cyhalo (PoE) fb H.W.</td>
<td>1.00 fb 0.02 fb 45 DAS/DAP</td>
<td>3.74 (73.00)</td>
<td>2.94 (7.63)</td>
<td>67.00</td>
</tr>
<tr>
<td>DSR + brahmi (1:1) Weedy</td>
<td>-</td>
<td>5.87 (33.50)</td>
<td>4.91 (23.13)</td>
<td>0.00</td>
</tr>
<tr>
<td>DSR + brahmi (2:1) Pendi (PE)</td>
<td>1.00</td>
<td>4.71 (21.25)</td>
<td>3.62 (11.90)</td>
<td>49.20</td>
</tr>
<tr>
<td>DSR + brahmi (2:1) Pendi (PE) fb 2 HW</td>
<td>1.00 fb 30 and 45 DAS/DAP</td>
<td>4.24 (17.00)</td>
<td>3.24 (9.53)</td>
<td>59.32</td>
</tr>
<tr>
<td>DSR + brahmi (2:1) Pendi (PE) fb Cyhalo (PoE) fb H.W.</td>
<td>1.00 fb 0.02 fb 45 DAS/DAP</td>
<td>3.53 (11.50)</td>
<td>3.13 (8.82)</td>
<td>76.84</td>
</tr>
<tr>
<td>DSR + brahmi (2:1) Weedy</td>
<td>-</td>
<td>5.87 (33.50)</td>
<td>4.94 (23.43)</td>
<td>0.00</td>
</tr>
<tr>
<td>Sole rice Pendi (PE) fb Cyhalo (PoE) fb H.W.</td>
<td>1.00 fb 0.02 fb 45 DAS</td>
<td>3.35 (10.25)</td>
<td>2.72 (6.25)</td>
<td>73.00</td>
</tr>
<tr>
<td>Sole brahmi (3 HW)</td>
<td>30 fb 45 fb 60 DAP</td>
<td>4.12 (16.00)</td>
<td>3.34 (10.18)</td>
<td>56.00</td>
</tr>
</tbody>
</table>

Where, DSR, Direct-seeded rice; Pendi, pendimethalin; Cyhalo, cyhalofop-butyl; HW, hand-weeding; PE, pre-emergance; PoE, post-emergence; DAS, days after sowing; DAP, days after planting; fb, followed by. Figures in parentheses are the means of original values. Data were subjected to square-root transformation.

\[
\text{SEm±} = 0.02, \ 0.01, \ 0.78, \ 2.33
\]
flora during both the years. The major weed flora observed in the experimental field during the rainy seasons of 2015 and 2016 were: *Echinochloa crus-galli* (10.0, 8.63%), *Echinochloa colona* (9.2, 8.45%), *Alternanthera sessilis* (11.74, 11.63%), *Caesulia axillaris* (5.35, 4.45%) and *Cyperus rotundus* (56.2, 60.1%) and others (7.5, 6.7%).

**Weed density and dry weight**

The total weed density and weed dry weight recorded at 30 days after sowing/days after planting (DAS/DAP) were influenced significantly by different intercropping and weed-management practices during both the years (Table 1). The lowest total weed density and dry weight were found under sole rice (pendimethalin fb cyhalofop-butyl fb 1 hand-weeding at 45 DAS/DAP), followed by intercropping of rice with *brahmi* in paired (2:1) ratio along with pendimethalin 1 kg/ha fb cyhalofop-butyl 100 g/ha fb 1 hand-weeding at 45 DAS/DAP treatment during both the years (Table 1). The maximum weed-control efficiency was recorded in rice with *brahmi* in paired (2:1) ratio along with pendimethalin 1 kg/ha fb cyhalofop-butyl 100 g/ha fb hand-weeding at 45 DAS/DAP. This might be owing to suppression of weeds more effectively through sequential application of pre-emergence and post-emergence herbicide along with 1 hand-weeding and integrated approach of weed-control, resulting in the minimum biomass production, hence offering efficient and prolong WCE (Bhurer *et al.*, 2013).

**Intercropping parameters**

The LER values were always higher than unity, signifying yield advantages of intercropping over monoculture (Table 2). The highest value was observed in additive treatment of *brahmi* in 1 : 1 ratio in which pendimethalin fb cyhalofop-butyl fb 1 hand-weeding at 45 DAS/DAP treatment was applied. The value of area-time equivalent ratio (ATER) was recorded to be unity in sole rice and sole *brahmi* treatment which was the highest value and was followed by alternate planting of rice and *brahmi* in 1 : 1 ratio along with pendimethalin fb cyhalofop-butyl fb 1 hand-weeding at 45 DAS/DAP treat-
**Table 3.** Effect of different intercropping treatments on yield of rice and *brahmi* and economics (pooled data of 2 years)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dose (kg/ha)</th>
<th>Grain yield (t/ha)</th>
<th><em>Brahmi</em> fresh yield (t/ha)</th>
<th>Sytem productivity (t/ha)</th>
<th><em>Brahmi</em> dry yield (t/ha)</th>
<th>Net returns (×10^3 ₹/ha)</th>
<th>Benefit: cost ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSR + <em>brahmi</em> (1:1) Pendi (PE)</td>
<td>1.00</td>
<td>3.2</td>
<td>6.9</td>
<td>4.9</td>
<td>1.7</td>
<td>221.3</td>
<td>8.8</td>
</tr>
<tr>
<td>DSR + <em>brahmi</em> (1:1) Pendi (PE) fb 2 HW</td>
<td>1.00 fb 30 and 45 DAS/DAP</td>
<td>3.6</td>
<td>7.4</td>
<td>5.4</td>
<td>1.8</td>
<td>250.6</td>
<td>7.8</td>
</tr>
<tr>
<td>DSR + <em>brahmi</em> (1:1) Pendi (PE) fb Cyhalo (PoE) fb H.W.</td>
<td>1.00 fb 0.02 fb 45 DAS/DAP</td>
<td>4.2</td>
<td>8.1</td>
<td>6.2</td>
<td>2.0</td>
<td>293.4</td>
<td>10.2</td>
</tr>
<tr>
<td>DSR + <em>brahmi</em> (2:1) Pendi (PE)</td>
<td>1.00 fb 0.02 fb 45 DAS/DAP</td>
<td>-</td>
<td>0.0</td>
<td>1.7</td>
<td>0.4</td>
<td>92.5</td>
<td>0.6</td>
</tr>
<tr>
<td>DSR + <em>brahmi</em> (2:1) Pendi (PE) fb 2 HW</td>
<td>1.00 fb 30 and 45 DAS/DAP</td>
<td>4.3</td>
<td>4.8</td>
<td>5.5</td>
<td>1.2</td>
<td>189.6</td>
<td>5.9</td>
</tr>
<tr>
<td>DSR + <em>brahmi</em> (2:1) Pendi (PE) fb Cyhalo (PoE) fb H.W.</td>
<td>1.00 fb 0.02 fb 45 DAS/DAP</td>
<td>-</td>
<td>0.3</td>
<td>2.0</td>
<td>0.8</td>
<td>27.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Sole rice Pendi (PE) fb Cyhalo (PoE) fb H.W.</td>
<td>1.00 fb 0.02 fb 45 DAS</td>
<td>5.3</td>
<td>0.0</td>
<td>5.3</td>
<td>0.0</td>
<td>96.6</td>
<td>3.4</td>
</tr>
<tr>
<td>Sole <em>brahmi</em> (3 HW)</td>
<td>30 fb 45 fb 60 DAP</td>
<td>0.0</td>
<td>8.3</td>
<td>2.07</td>
<td>2.1</td>
<td>191.5</td>
<td>5.6</td>
</tr>
</tbody>
</table>

SEm± (P<0.05) - 0.04 0.07 0.02
CD (P<0.05) - 0.12 0.21 0.06

Where, DSR, Direct-seeded rice; Pendi, pendimethalin; Cyhalo, cyhalofop-butyl; HW, hand-weeding; PE, pre-emergence; PoE, post-emergence; DAS, days after sowing; DAP, days after planting; fb, followed by

Among the yield attributes of rice, the highest number of grains/panicle was recorded in 2 : 1 row ratio along with pendimethalin fb cyhalofop-butyl fb 1 hand-weeding at 45 DAS/DAP treatment, whereas the highest number of panicles and 1,000-grain weight were recorded in sole rice treatment (pendimethalin fb cyhalofop-butyl fb 1 hand-weeding at 45 DAS/DAP). Among the yield attributes of *brahmi*, highest number of branches/spread material, number of sub-branches/spread material and dry-matter accumulation were recorded in sole *brahmi* treatment (3 hand-weedicings at 30, 45 and 60 DAS/DAP) (Table 2).

**Yield**

Sole stand of rice recorded significantly higher grain yield which was followed by additive and replacement series in both 1 : 1 and 2 : 1 ratio along with pendimethalin fb cyhalofop-butyl fb 1 hand-weeding at 45 DAS/DAP during both the years. This might be owing to less competition for sunlight, space, water and nutrients for sole crop as compared to intercropping treatments (Table 3). However, between additive and replacement treatments, significantly higher herbage yield of *brahmi* was recorded under additive series (1 : 1) along with pendimethalin fb cyhalofop-butyl fb 1 hand-weeding at 45 DAS/DAP, which might be owing to significantly higher plant population than replacement series (2:1). Tripathi *et al.* (2005) also realized similar results for grain yield for chickpea in chickpea + Indian mustard intercropping system. Among the other herbicidal treatments, the lowest grain yield of rice was obtained with application of pendimethalin alone in both ratios.

**Economics**

During both the years, the intercropping and weed-management practices affected the net returns and benefit: cost ratio. The highest net returns and benefit: cost ratio were found in the treatment pendimethalin fb cyhalofop-butyl fb 1 hand-weeding at 45 DAS/DAP in alternate (1 : 1) ratio of rice and *brahmi* during both the years (Table 3). Matusso *et al.* (2014) reported that, maize + cowpea intercropping was more profitable than their sole crops. These results indicate that intercropping could improve the system’s productivity, increase the income for smallholder farmers, and compensate losses.

From the above study, it can be concluded that direct seeded rice + *brahmi* in 1 : 1 row ratio along with pendimethalin fb cyhalofop-butyl fb 1 hand-weeding at 45 DAS/DAP proved to be the most productive and remunerative cropping system.

**REFERENCES**