Directions for Management of Annual Broad-Leaved Weeds in Lowland Rice
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Annual weed species depend on seed production and seed dissemination for their distribution and persistence (Zimdahl, 2007). Hence control strategies, in particular strategies aiming at reducing future infestations, should aim at avoiding seed production and dispersal (Johnson, 1997). The most effective way to avoid seed production is to target the weeds before flowering. They should be physically removed, by hand or hoe, or killed by effective, lethal doses of the right choice of herbicide at the right time (e.g. Wopereis et al., 2007, Rodenburg and Johnson, 2009, Ampong-Nyarko, 1996). Suitable herbicides for annual broad-leaved species in lowland rice are listed in Table 1.

On the short term, within a cropping season, recruitment from the existing seed bank should be avoided. This can be achieved by using pre-emergence herbicides, or by ploughing the soil such that seeds are buried to depths from where they cannot germinate anymore. The
latter principle has been sown effective against, for instance, *Chromolaena odorata* and *Tridax procumbens*, two of the most noxious broad-leaved weeds which show no emergence when seed are buried at more than 3 cm depth (Chauhan and Johnson, 2008a). Some annual broad-leaved species, such as *Eclipta prostrata* for instance, only germinate when seeds are on the soil surface (Chauhan and Johnson, 2008b). Another method to prevent weed seeds to germinate is by using mulches or cover crops, but these technologies are less compatible to systems where a water layer is present. The seed bank can be actively reduced by preparing a so-called ‘false’ or ‘stale’ seed bed (Mortimer et al., 1997). The weed seed bank is reduced prior to sowing by preparing a seed bed but delaying the actual sowing/planting. Land is properly prepared, flooded and drained, then weeds are allowed to emerge for 2 weeks or so and then removed or killed (for instance using herbicide). After this the crop can be sown or transplanted followed by flooding. The false seed bed can be repeated a second time before the crop is sown/planted to recruit and kill more weeds. Increasing the competitiveness of the crop by increasing planting densities or the use of competitive varieties (e.g. Saito et al., 2010, Rodenburg et al., 2009, Haefele et al., 2004), as well as flooding, is an effective method to control many of the broad-leaved weed species. Some noxious weed species, like *Sphenolea zeylanica* and *Ageratum conyzoides* are relatively tolerant to submergence (Rodenburg and Johnson, 2009). If flooding can be used as a control measure it should be used form the early stages onwards (as soon as the rice is in its 3 –leave stage). The crop’s competitiveness can also be increased by transplanting (see references in: Rodenburg and Johnson, 2009). given the rice plants a time advantage over the weeds. Transplanting in rows will also facilitate weed recognition and mechanical weeding operations for instance with push-weeders (a.k.a. rotary hoes). The most effective weed-control can be achieved when the rice is transplanted in a 5-cm water layer, drained for 2-3 days directly thereafter and flooded again to at least 5 cm until about 2 weeks before maturity with a gradual increase of the water level to 10 cm (e.g. Wopereis et al., 2007).

Table 1 Suitable herbicides for broad-leaved weed species in rain-fed and irrigated lowland rice

<table>
<thead>
<tr>
<th>Common name</th>
<th>Example of product</th>
<th>Rates (kg a.i. ha⁻¹)</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D</td>
<td></td>
<td>0.5-1.5</td>
<td>Late post</td>
</tr>
<tr>
<td>2,4-D + dichlorprop</td>
<td>Weedone</td>
<td>1-1.5 (l ha⁻¹)</td>
<td>Post</td>
</tr>
<tr>
<td>bensulfuron</td>
<td>Londax</td>
<td>0.05-1.0</td>
<td>Post</td>
</tr>
<tr>
<td>bentazon</td>
<td>Basagran</td>
<td>1.0-3.0</td>
<td>Post</td>
</tr>
<tr>
<td>bifenox</td>
<td>As a mixture= Foxpro D</td>
<td>1.5-2.4</td>
<td>Pre</td>
</tr>
<tr>
<td>butachlor*</td>
<td>Machete</td>
<td>1.0-2.5</td>
<td>Pre/early post</td>
</tr>
<tr>
<td>dymrone (K-223)</td>
<td>Dymrone</td>
<td>3.0-5.0</td>
<td>Pre</td>
</tr>
<tr>
<td>fluorodifen</td>
<td>Preforan</td>
<td>2.0-3.5</td>
<td>Pre</td>
</tr>
<tr>
<td>MCPA</td>
<td>Herbit</td>
<td>0.5-1.5</td>
<td>Post</td>
</tr>
</tbody>
</table>
- molinate  
  Ordram  
  1.5-4.0  
  Pre/early post
- oxadiazon**  
  - Ronstar 25EC  
  0.6-1.5  
  Pre/early post
  - Ronstar 12L
- Pendimethalin***  
  - Stomp 500  
  0.5-1.5  
  Pre
  - Prowl
- pretilachlor +  
  - dimethametryne  
  Rifit extra 500 EC  
  1.5/0.5  
  Pre
- propanil +  
  - bentazone  
  Basagran PL2  
  6-8 (l ha⁻¹)  
  Post
  - triclopyr  
  Garil  
  5 (l ha⁻¹)  
  Post
  - oxadiazon  
  Ronstar PL  
  5 (l ha⁻¹)  
  Post
- thiobencarb****  
  Saturn  
  1.5-3.0  
  Pre/early post

* Known exceptions are Eclipta prostrata and Trianthema portulacastrum
** Exception is Eclipta prostrata
*** Exception is Euphorbia heterophylla
**** Exceptions are Eclipta prostrata and Ageratum conyzoides

References