Directions for Management of Annual Broad-Leaved Weeds in Lowland Rice

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The annual broad-leaved weed species of rice in rain-fed and irrigated lowlands is the largest group of species. Some of the most frequently encountered ones include: *Trianthema portulacastrum*, *Alternanthera nodiflora*, *Alternanthera pungens*, *Amaranthus spinosus*, *Amaranthus viridis*, *Acmella uliginosa* (syn. *Spilanthes uliginosa*, *Spilanthes acmella*), *Ageratum conyzoides*, *Bidens pilosa*, *Conyza bonariensis*, *Conyza sumatrensis*, *Eclipta prostrata*, *Sphaeranthus senegalensis*, *Sphaeranthus suaveolens*, *Synedrella nodiflora*, *Tridax procumbens*, *Vernonia cinerea*, *Coldenia procumbens*, *Murdannia nudiflora* (syn. *Aneilema nudiflorum*, *Aneilema malabaricum*; annual/perennial), *Momordica charantia*, *Caperonia palustris*, *Chamaesyce hirta*, *Chamaesyce hyssopifolia*, *Croton hirtus*, *Euphorbia heterophylla*, *Phyllanthus amarus*, *Phyllanthus niruri*, *Phyllanthus niruroides*, *Phyllanthus urinaria*, *Aeschynomene sensitiva*, *Crotalaria retusa*, *Sesbania pachycarpa*, *Uraria picta*, *Aeschynomene afraspera* (annual/perennial), *Chamaecrista mimosoides* (syn. *Cassia mimosoides*; annual/perennial), *Crotalaria goreensis* (annual/perennial), *Melilotus officinalis* (bi-annual), *Senna obtusifolia*, *Senna occidentalis*, *Hydrolea glabra*, *Hyptis lanceolata*, *Hyptis spicigera*, *Hyptis suaveolens*, *Basilicum polystachyon* (annual/perennial), *Ammania auriculata*, *Ammania baccifera*, *Ammania prieureana*, *Corchorus aestuans*, *Melochia corchorifolia*, *Boerhavia diffusa*, *Ludwigia hyssopifolia*, *Ludwigia abyssinica*(syn. *Jussiaea abyssinica*, *Ludwigia prostrata*, annual/perennial), *Ludwigia octovalvis* (syn. *Jussiaea suffruticosa*; annual/perennial), *Ceratopteris cornuta*, *Fagopyrum tataricum*, *Polygonum senegalense* (syn. *Polygonum lanigerum* var. africanum), *Polygonum salicifolium* (annual/perennial), *Heteranthera callifolia*, *Portulaca oleracea*, *Oldenlandia corymbosa*, *Spermacoce verticillata*, *Pentodon pentandrus* (annual/perennial), *Bacopa floridunda*, *Scoparia dulcis*, *Bacopa crenata* (annual/perennial), *Physalis angulata*, *Physalis lagascae* (syn. *Physalis micrantha*), *Solanum nigrum*, *Sphenoclea zeylanica*, *Tribulus terrestris*, *Stachytarpheta indica* (annual/perennial).

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 *Sphenoclea 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

Common name	Example of product	Rates (kg a.i. ha^{-1})	Timing
• 2,4-D	• Dacamine • Fernoxone • Herbazol	0.5-1.5	Late post
• 2,4-D + dichlorprop	Weedone	1-1.5 (l ha^{-1})	Post
• bensulfuron	Londax	0.05-1.0	Post
• bentazon	Basagran	1.0-3.0	Post
• bifenox	As a mixture= Foxpro D	1.5-2.4	Pre
• butachlor*	Machete	1.0-2.5	Pre/early post
• dymrone (K-223)	Dymrone	3.0-5.0	Pre
• fluorodifen	Preforan	2.0-3.5	Pre
• MCPA	Herbit	0.5-1.5	Post

• molinate	Ordram	1.5-4.0	Pre/early post
• oxadiazon**	• Ronstar 25EC • Ronstar 12L	0.6-1.5	Pre/early post
• Pendimethalin***	• Stomp 500 • Prowl	0.5-1.5	Pre
• pretilhachlor + o dimethametryne	Rifit extra 500 EC	1.5/0.5	Pre
• propanil +			
o bentazon	Basagran PL2	6-8 (l ha^{-1})	Post
o triclopyr	Garil	5 (l ha^{-1})	Post
o 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*

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