deep-rooted perennial plants would also be of importance in killing plants.

**LITERATURE CITED**


Common Waterplantain (*Alisma triviale*) Interference with Wild Rice (*Zizania palustris*)

J. K. RANSOM and E. A. OELKE

**Abstract.** Three cultivars of wild rice (*Zizania palustris L.*) were grown with various densities of common waterplantain (*Alisma triviale* Pursh) established from seeds and from rootstocks during 1979 and 1980. Wild rice cultivars did not differ in their response to common waterplantain interference. Common waterplantain grown from seeds at densities up to 82/m² did not significantly reduce wild rice yield. Common waterplantain established from rootstocks significantly reduced wild rice yield at densities as low as 3/m². A density of 43/m² reduced wild rice yield by 91%. The yield component most susceptible to interference from common waterplantain was panicles per plant. The number of seeds per panicle was reduced by densities as low as 11/m² and seed weight was reduced by densities of 22/m² or greater. Only a density of 43/m² reduced the stand of wild rice. Common waterplantain established from rootstocks at a density of 17 plants/m² did not reduce wild rice yield if removed by 7 weeks after planting. Interference from common waterplantain for 9 weeks or longer reduced wild rice yield by approximately 50%.

**Additional index words.** Competition, yield.

**INTRODUCTION**

Wild rice (*Zizania palustris* L.) (previously classified as *Z. aquatica* var. *angustifolia*) is an annual aquatic cereal native to the Great Lakes Region. It grows naturally in lakes and rivers in Minnesota, Wisconsin, and Canada and was once a major source of food for the Sioux and Chippewa Indians of this region (9). Wild rice is undergoing domestication and is presently cultivated on approximately 11,000 ha in Minnesota. Most of the land used for wild rice production is situated in low-lying areas not previously used as farmland. Because of the high capital investment associated with dike construction and irrigation equipment, and because land cultivated with wild rice is poorly suited for alternate crops, wild rice is commonly grown in the same field year after year. This continuous monoculture has permitted the establishment of common waterplantain at competitive levels in many fields.

Common waterplantain is an emergent, erect aquatic perennial that may grow to a height of 1 m. It reproduces by rootstocks and by seeds (Figure 1). Common waterplantain seed remains dormant after maturation until subjected to a period of cold temperature (below 2°C) for 1 or 2 months (4). They can remain viable in the soil for many years (8). Rootstock buds also become dormant in the fall. This dormancy is broken by a cold period similar to that required by the seeds. In California, common waterplantain is troublesome on the banks and edges of irrigation and drainage canals and in fields of rice (*Oryza sativa* L.) where crop stands are thin (8).
Cultivars within a crop species can vary in their ability to compete with weeds. Rice cultivars that required a longer time of maturing were more competitive with barnyardgrass [Echinochloa crus-galli (L.) Beauv.] than did earlier-maturing cultivars (7). Burnside et al. (1) found that tall, early-maturing soybean [Glycine max (L.) Merr.] cultivars were generally better able to compete with weeds than were short, early-maturing cultivars. Competitive ability of grain sorghum [Sorghum bicolor (L.) Moench] cultivars was associated with plant vigor during early growth stages.

The objectives of this study were to investigate the effect of common waterplantain densities on the growth and yield of wild rice cultivars and to determine the maximum length of time that common waterplantain may interfere with wild rice cultivars before yields are reduced.

MATERIALS AND METHODS

General — Experiments were conducted in 1979 and 1980 at the University of Minnesota's North Central Agricultural Research Station at Grand Rapids, Minnesota. The soil was an Indus clay loam (Typic Ochraqualf) with a pH of 5.8. An experimental area was fallowed and fumigated the year before cropping. The fumigant, methyl bromide, was applied at the rate of 360 kg/ha to eliminate residual wild rice and weed seeds. Prior to planting, 25 kg/ha of N was applied as urea. The soil had high levels of extractable phosphorous (160 ppmw) and exchangeable potassium (300 ppmw).

On May 21, 1979, and April 30, 1980, wild rice was hand broadcast at a rate of 50 kg/ha of viable seeds. The seeds were incorporated into the soil by a shallow rototilling. A randomized complete block design with a split-plot arrangement was used for both experiments conducted. Wild rice cultivars ('Netum', 'K2', and 'Johnson') were whole plots. Subplots were 2 by 2 m.

Common waterplantain was established by hand-planting small individual rootstocks, which had one viable bud, or by lightly raking the seeds into the soil after seeds of wild rice had been incorporated. Rootstocks and seeds were collected from growers' fields the previous fall and stored at 2°C.

Immediately after planting, the field was flooded to a depth of 20 cm. This depth was maintained until 1 week before harvesting, when the water was drained. Malathion (0.0, dimethyl phosphorodithioate of diethyl mercaptosuccinate) was applied at 1.1 kg/ha when wild rice had reached the floating-leaf stage to control a midge (Cricotopus spp.) and during grain filling to control the wild rice worm (Acapa amplus Guenee). Zinc ion-maneb complex (zinc ion + manganese ethyl-bisdithiocarbamate) at 1.8 kg/ha was applied early in August for prevention of leaf spot caused by Helminthosporium spp.

Wild rice was harvested from the center 2.25 m² of each plot when approximately 30% of the kernels were dark. Plants and panicles were counted from each harvested area before threshing the grain with a plot thresher. The threshed grain was weighed immediately. Netum, K2, and Johnson were harvested on August 28, September 4, and September 11, respectively, in 1979. All cultivars were harvested on August 25 in 1980. Seed weights were determined by weighing 200 kernels, which had been oven-dried at 50°C for 48 h. The dried grain was heated at 100°C for 1 hr, dehulled, and weighed to determine processed yield. Percent recovery was calculated by dividing the processed grain weight by the harvested grain weight.

Plant density. In 1979, common waterplantain densities were: 0, 5, 11, 22, and 43 rootstocks/m² and 54, 108, and 215 seedlings/m². The highest rootstock density and the two lowest seedling densities were omitted in 1980. The appropriate 2-by 2-m plots were seeded with 6, 12, and 24 g of common waterplantain seed in 1979 to establish 54, 108, and 215 seedlings/m², respectively. These weights represented the amount of seed needed to establish the three seedling densities in glasshouse experiments. Because of poor establishment in 1979, 218 g/plot of common waterplantain seed were planted in 1980 in order to establish 215 seedlings/m².

At harvest, five waterplantain plants were pulled from each plot and weighed (combined above ground portions and rootstocks) after drying at 50°C for 96 h. The treatments were replicated three times in 1979 and twice in 1980.

Duration of interference. Subplots were uniformly planted with common waterplantain rootstocks at a rate of 17/m².
with the exception of the weed-free control. After planting, common waterplantain was allowed to grow with wild rice for 0, 3, 5, 7, 9 weeks, and all season (an average of 15 weeks) in 1979 and for 0, 3, 5, 7, 9, 11 weeks, and all season (approximately 17 weeks) in 1980. At the end of each interference period, common waterplantain plants were removed by hand, and in 1980 dry weights were obtained on five random plants/plot. All plots were free from other weed species throughout the growing season. All treatments were replicated twice each year.

RESULTS AND DISCUSSION

Plant density. The three wild rice cultivars respond similarly to common waterplantain interference averaged over all densities of waterplantain grown from rootstocks or seed yields did not differ significantly (data not shown). Moreover, cultivars did not interact with weed densities.

The densities of common waterplantain established from seeds ranged between 7 and 82/m² in 1979 and between 0 and 40/m² in 1980, and did not correlate with the numbered A regression analysis indicated that densities of common waterplantain grown from seeds did not affect wild rice growth or yield \( r^2 = 0.01 \) for yield both years. The lack of harmful interference to wild rice from relatively high densities of common waterplantain seedlings may be due to the slow rate of seedling growth. Wild rice was over 40 cm tall and in the late tillering stage before most of the common waterplantain seedlings had reached the surface of the water. Even though seedlings do not affect wild rice yield they may produce perennial rootstocks that have the potential for rapid regrowth the following spring (Figure 2).

All densities of common waterplantain grown from rootstocks significantly reduced wild rice yield (Table 1). R

<table>
<thead>
<tr>
<th>Common waterplantain</th>
<th>Wild rice</th>
<th>Vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (plants/m²)</td>
<td>Yield</td>
<td>Grain</td>
</tr>
<tr>
<td></td>
<td>Harvested</td>
<td>Processed</td>
</tr>
<tr>
<td></td>
<td>(kg/ha)</td>
<td>(%)</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2030a</td>
<td>1391a</td>
</tr>
<tr>
<td>11</td>
<td>3420c</td>
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<tr>
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<td>4980b</td>
<td>741c</td>
</tr>
<tr>
<td>43</td>
<td>9500a</td>
<td>579c</td>
</tr>
</tbody>
</table>

Table 1. Common waterplantain dry weight and wild rice yield and yield components averaged over three wild rice cultivars as influenced by densities of common waterplantain grown from rootstocks in 1979 and 1980.

\(^a\) Values within a column and year followed by the same letter do not differ at the 5% level according to Duncan's multiple range test.

\(^b\) Includes both shoot and rootstock dry weights.
action in harvested yield varied between 22% and 91% with densities between 5 and 43/m² in 1979 and between 26% and 77% with densities between 3 and 22/m² in 1980. Harvested and processed wild rice yield responded similarly to interference except at the highest common waterplantain density, which decreased the percent recovery significantly from all other densities in 1979. Yield reductions attributable to common waterplantain interference at comparable densities were greater in 1980 than 1979, probably because of the warmer spring in 1980, which favored rapid growth. Common waterplantain establishment and growth. Water and air temperatures averaged 3°C and 2°C higher, respectively, in 1980 during the first 6 weeks of growth.

In 1980, maximum wild rice plant density was only half the density established in 1979 because of poor germination. Common waterplantain interference did not, however, alter wild rice plants per hectare except at the highest density established from rootstocks in 1979. Panicles per plant decreased linearly with increased densities of common waterplantain established from rootstocks and was the component that yielded the most reduced by interference. Moreover, panicles per plant was the only yield component significantly affected at the lowest levels of weed competition. Smith et al. (6) found that panicles per plant and seeds per panicle were the components most influenced by intraspecific competition spring oats (Avena sativa L.). In contrast, Vesey et al. (7) found that competition from wild cane (Sorghum bicolor .) Moench reduced the number of seeds per panicle at a much greater rate than reduced other yield components.

The number of wild rice seeds per panicle was reduced only by the highest densities of common waterplantain from rootstocks in 1979 and by 11 and 22/m² in 1980. Seeds per panicle were consistently higher in 1980 than in 1979, possibly because of the lower wild rice population. Common waterplantain densities of 22/m² were required to decrease seed weight. The kernels on individual panicles ripened unevenly and some were shed before all were ripe. Consequently, wild rice had to be harvested before all kernels were mature (5). Therefore, the reduction in seed weight by high levels of competition is largely due to a reduction in the number of fully mature kernels, because high densities of common waterplantain from rootstocks tended to delay maturity (data not given).

Wild rice shoot dry matter declined sharply as densities of common waterplantain from rootstocks increased (Table 1). The greatest reduction exceeded 90% in 1979. Plant height was reduced by common waterplantain to densities of 11/m² or more in 1979 and 22/m² in 1980. Common waterplantain dry matter increased as its plant density increased. Common waterplantain grown from rootstocks at a density of 11/m² or more in competition with wild rice produced more dry matter than did wild rice; a density of 22/m² of common waterplantain produced much dry matter as wild rice grown weed free.

Duration of interference. Wild rice cultivars did not differ in their response to the length of interference from common waterplantain grown from rootstocks. The effect of duration of competition, therefore, was averaged across cultivars (Table 2).

<table>
<thead>
<tr>
<th>Duration of interference</th>
<th>Dry wt</th>
<th>Grain</th>
<th>Vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(wks)</td>
<td>(kg/ha)</td>
<td>Harvested</td>
<td>Processed</td>
</tr>
<tr>
<td>0</td>
<td>1447a</td>
<td>501ab</td>
<td>35a</td>
</tr>
<tr>
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<td>1542a</td>
<td>544a</td>
<td>35a</td>
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<td>9</td>
<td>1356a</td>
<td>427b</td>
<td>32a</td>
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<tr>
<td>11</td>
<td>1357a</td>
<td>487b</td>
<td>36a</td>
</tr>
<tr>
<td>136c 1500b 255a 0.9ab</td>
<td>1406c 1200b 329a 1.3b</td>
<td>0 5</td>
<td>204a</td>
</tr>
<tr>
<td>181a 2300a 187a 2.5ab</td>
<td>165ab 1100b 116a 2.4ab</td>
<td>0 5</td>
<td>398a</td>
</tr>
<tr>
<td>9 1804b 1229c 116a 2.4ab</td>
<td>170ab 1100b 156a 1.8b</td>
<td>0 5</td>
<td>11 3441c</td>
</tr>
</tbody>
</table>

Values within a column for each year followed by the same letter do not differ at the 5% level according to Duncan's multiple range test.

Includes both shoot and rootstock dry weights.
not reduce harvested yield if removed by 7 weeks in both years. Nine weeks of interference, however, reduced harvested yield by 46% and 52% in 1979 and 1980, respectively. Interference beyond 9 weeks did not reduce yields further. Processed yield responded similarly to harvested yield except in 1980 when only 5 weeks of interference reduced processed yield significantly. Interference for 9 weeks reduced wild rice dry matter by half. Both vegetative and reproductive growth were sensitive to this period of interference.

The number of panicles per plant was the first yield component influenced by competition, with reductions noted after 7 weeks in 1979 and 5 weeks in 1980. Seeds per panicle varied greatly from treatment to treatment and were significantly reduced only by season-long competition in 1980. Seed weight was reduced by season-long competition in 1979 by 16%.

These data indicate that, between 7 and 9 weeks after seeding, wild rice is extremely sensitive to competition from common waterplantain. This sensitivity might be due in part to the rapid growth of common waterplantain during this period. Between week 7 and week 9, common waterplantain increased more than 4-fold in dry weight in 1980. Common waterplantain also maintained a height advantage over wild rice until after about 9 weeks of growth and shaded it during this period. Fisher (2) found that shading during the 30-day period just before anthesis in spring wheat (Triticum aestivum L. em Thell.) reduced yield more than shading in any other growth stage. Information from this study—indicates that yield losses can be avoided if common-waterplantain from rootstocks is controlled within 7 weeks after planting.

LITERATURE CITED


Adsorption, Bioactivity, and Evaluation of Soil Tests for Alachlor, Acetochlor, and Metolachlor

JEROME B. WEBER and C. JOHN PETER

Abstract. Alachlor [2-chloro-2',6'-diethyl-N-(methoxy-methyl)acetanilide], acetochlor [2-chloro-N-(ethoxy-methyl)-6'-ethyl-o-acetotoluidide] and metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylthylethyl)acetamide] were adsorbed in similar amounts, approximately one-third that of the reference compound prometryn [2,4-bis(isopropylamino)-6-(methylthio)-s-triazine] by Ca-organic matter and seven soils. Adsorption isotherms for the four herbicides by Ca-organic matter were of the same shape, but different bonding mechanisms were involved. Adsorption and bioactivity of the acetanilide herbicides were correlated with organic matter, clay content and other soil parameters as determined by two different soil-testing laboratories.

Additional index words. Herbicide inactivation, adsorpti mechanisms, soil testing, organic-matter analysis, prometry adsorption.

INTRODUCTION

The acetanilide herbicides are nonionizable, moderate