Weed Science. 1987. Volume 35:640–646

Effects of Giant Burreed (*Sparganium eurycarpum*) and Shade on Wild Rice (*Zizania palustris*)[1]

SHARON A. CLAY and ERVIN A. OELKE[2]

Abstract. Studies were conducted at Grand Rapids, MN, to determine the effect of giant burreed (*Sparganium eurycarpum* Engelm. #[3] SPGEU) planted at 6, 12, and 24 corms/m^2 on wild rice (*Zizania palustris* L. 'K2') growth and yield. Giant burreed, a spreading perennial, had shoot densities of 21, 29, and 42/m^2 at harvest for the 6, 12, and 24 corms/m^2 treatments, respectively. Wild rice yield and panicle number were reduced approximately 60% when giant burreed shoot density was 40/m^2 or higher when compared to the weed-free control. Giant burreed did not interfere with nutrient uptake of wild rice on a whole-plant basis, and increased N fertilizer application did not reduce losses in dry weight. Giant burreed reduced penetration of photosynthetically active radiation (PAR) from 2 to 35% in the wild rice canopy from the early tillering to the anthesis stage of wild rice development. In growth chamber studies, wild rice dry weight and panicle number were reduced by 46 and 65%, respectively, when wild rice was shaded for 12 weeks and compared to a full light treatment. Reduction of PAR penetration into the wild rice canopy appears to be the major mechanism of giant burreed interference with wild rice.

Additional index words. Weed population, interference, yield reduction, SPGEU.

INTRODUCTION

Giant burreed is a perennial aquatic monocotyledon plant that infests 90% of the wild rice fields in northern Minnesota (authors' unpublished data). High densities of giant burreed are localized at the present time. However, giant burreed has the potential to become a serious weed throughout the wild rice monoculture system due to its ability to reproduce by seeds, corms, and rhizomes, and by fall tillage operations spreading reproductive structures to noninfested areas.

Common waterplantain (*Alisma triviale* Pursh. # ALSPA) reduced wild rice yields by more than 90% (9) and caused a reduction in the number of wild rice panicles per plant even at low (5 plants/m^2) weed densities. High densities (11 plants/m^2) of this weed reduced the number of wild rice seeds/panicle. The authors speculated that shading of wild rice may have been a major cause for these reductions, although this hypothesis was not tested.

Weeds in crops interfere with water usage, light penetration into the canopy, and nutrient uptake (2, 8, 9, 10). Water is not limiting in wild rice production since fields are flooded in early spring and drained a few weeks before harvest[4]. Nitrogen may be limiting in wild rice production. Therefore, low levels of competition for N in wild rice may severely hamper wild rice development and reduce its yield potential. Rates of N recommended in wild rice are low (20 kg/ha for first-year fields and 40 kg/ha for fields in succeeding years) due to the tall stature of wild rice and its propensity to lodge[4].

Light may be a limiting factor in crop production (5, 8, 9, 10). Total dry matter production and shoot number of yellow nutsedge (*Cyperus esculentus* L. # CYPES) decreased in direct proportion to decreased amounts of light (6). Purple nutsedge (*Cyperus rotunuds* L. # CYPRO) reduced rice (*Oryza sativa* L.) yield by 43% (8). Applying soil N resulted in more vigorous growth of purple nutsedge and ultimately in greater yield loss due to increased shading of the rice plant.

The objectives of these experiments were to investigate the effect of giant burreed densities on the growth and yield of wild rice and to determine if giant burreed competes with wild rice for light and nutrients, or both.

MATERIALS AND METHODS

The effect of giant burreed on wild rice was evaluated in field studies at the North-Central Agricultural Experiment Station at Grand Rapids, MN, in 1984 and 1985. The influence of shade on wild rice was investigated in growth chamber experiments at St. Paul, MN, concurrently with the field studies.

Influence of giant burreed density on yield and growth of wild rice. The studies were conducted on an Indus clay loam soil (Typic Ochraqualf) with an organic matter content of 3% and a pH of 5.8 and 6.3 in 1984 and 1985, respectively. P (determined by using Bray-1 extractant solution) and K were 130 and 260 kg/ha, respectively, in both years. Experimental sites were fumigated with methyl bromide the fall prior to planting to eliminate volunteer wild rice and other weeds. The plot areas were cultivated and fertilized with N (see below) and 44 kg/ha K in the spring immediately before planting.

Field plots were established with a split-plot restriction in a randomized complete block design with nitrogen levels of 0 or 56 kg/ha N applied as urea to the main plots and giant burreed densities of 0, 6, 12, and 24 corms/m^2 as the

[1] Received for publication November 14, 1986, and in revised form April 6, 1987. Contribution from Dep. Agron. and Plant Genetics, Univ. Minnesota, St. Paul, MN 55108. Paper No. 15128, Scientific J. Ser.

[2] Former Grad. Res. Asst. and Prof., respectively, Dep. Agron. and Plant Genetics, Univ. Minnesota, St. Paul, MN 55108.

[3] Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 West Clark Street, Champaign, IL 61820.

[4] Oelke, E. A., J. Grava, D. M. Noetzel, D. D. Barron, J. A. Percich, C. E. Schertz, J. Strait, and R. E. Stucker. 1982. Wild rice production in Minnesota. Minnesota Agric. Ext. Serv. Bull. No. 464. 40 pp.

subplots. Each giant burreed density by N level treatment was replicated four times. Giant burreed corms were collected the previous fall from a production field near Aitkin, MN, and stored at 2 C until planting. The corms were planted 5 cm deep in a grid pattern in the center 2.5 by 2.5 m of a 4.9- by 4.9-m subplot to accomodate the spreading habit of giant burreed. Viability of the corms at planting was approximately 55% each year based on glasshouse tests. Wild rice seed was broadcast and raked into the top 0.5 cm of the entire plot area at a rate to achieve approximately 21 plants/m^2. The plots were planted May 2, 1984, and May 8, 1985, and flooded to a depth of 30 cm immediately after planting. In 1985, wild rice seedlings at the two-aerial-leaf (five-leaf) stage of crop development were transplanted into areas with poor wild rice stands to obtain 21 plants/m^2. Water was drained from the fields approximately one month before harvest each year.

Plant height, giant burreed density, and photosynthetically active radiation (PAR) in the wild rice canopy were measured at early- and late-tillering, boot, and anthesis stages of wild rice development in both years. A line sensor with a sensing area of 1 m by 12.7 mm was used to measure PAR from 400 to 700 nm at 5-cm increments from the top of the wild rice canopy to water level. Light intensity at the top of the canopy was approximately 1900 $\mu E \cdot m^{-2} \cdot s^{-1}$ at noon on a clear day.

Leaf area of five plants of each species was measured with a leaf area meter with conveyor belt assembly at the early- and late-tillering (1984) and boot stages (1984 and 1985) of wild rice development. Plant dry weights for aboveground portions of the plant sampled at the above stages were recorded after plant material was oven dried at 65 C for 3 days. Dried plant material was ground to pass through a 20-mesh screen, and total (micro) Kjehldahl N (1) and levels of P, K, Ca, and Mg for wild rice flag leaf, lower leaves, and stem and aboveground giant burreed plant material were measured by emission spectroscopy at the boot stage of wild rice development.

Wild rice was harvested from the center 1.8 by 1.8 m of the subplots at 40% seed moisture. Plant height, plant density, and wild rice panicle density were recorded at harvest. Wild rice plant and giant burreed shoot dry weights, and wild rice seed yield were determined as described previously. Data were subjected to analysis of variance. Yield and light penetration into the wild rice canopy data were subjected to regression analysis.

Influence of shade on growth and development of wild rice. A study to identify the effects of shade on wild rice was conducted in a growth chamber experiment with a split-plot treatment arrangement with light intensity as the main effect and time of shade removal (2, 4, 6, or 12 weeks) as the subplot. The plants were shaded with black shadecloth at shade levels of 30 or 47% or remained under full light. Pots were paired, with one set of plants harvested at each shade removal date and the other set harvested after 12 weeks of growth. The experiment was conducted three times with four replications each time.

Four wild rice seeds were planted in 30-cm-diameter pots lined with a 4-l plastic bag and filled to within 4 cm of the top with greenhouse soil mix of soil, sand, peat, and manure (4:3:3:3, v/v/v/v). Pots were placed in a growth chamber and immediately flooded to a 4-cm depth. Wild rice was thinned to two plants per pot after 2 weeks of growth. Plants were grown under 16-h days for the entire experiment with day/night temperatures of 19/7 C for the first 6 weeks and 24/12 C for the duration of the experiment. Full light in the growth chamber was measured by a line sensor at 800 $\mu E \cdot m^{-2} \cdot s^{-1}$.

At each shade removal date, plant height and growth stage were recorded from both shaded and full light treatments. Plants from one set of pots were harvested and dry weight was recorded after the plants were dried at 65 C for 3 days. The number of days from planting to panicle emergence was recorded for each plant remaining after the 6-week harvest. Plant height and number of wild rice panicles and tillers per plant were recorded at the 12-week harvest. Plants were divided into leaf and stem material and dry weights were recorded after oven-drying samples at 65 C for 3 days. The relative growth rate of (RGR) of wild rice under each treatment for each harvest date was calculated by the formula

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

where W_1 and W_2 are plant dry weights at times t_1 and t_2, respectively, and expressed in terms of $g \cdot g^{-1} \cdot day^{-1}$ (5). Data are reported as the mean ± (t × standard error).

RESULTS AND DISCUSSION

Influence of giant burreed density on the growth and yield of wild rice. Giant burreed is a spreading perennial plant, and shoot densities increased throughout the growing season (Table 1). At harvest, the number of giant burreed shoots for the 6, 12, and 24 corm/m^2 treatments were 20, 29, and 42 shoots/m^2, respectively, when averaged over years. This increase was a result of late development of lateral buds

Table 1. Giant burreed densities at three phenological stages of wild rice development in 1984 and 1985, Grand Rapids, MN.

	Giant burreed shoot density at wild rice phenological stage				
	Floating leaf[a]	Early tiller		Maturity	
Treatment	1985	1984	1985	1984	1985
(corms/m^2)	(shoots/m^2)				
0	0.0	0	0	0	0
6	0.5	4	2	21	20
12	1.0	7	4	30	28
24	2.0	16	8	44	40
LSD (0.05)	0.1	6	1	5	5

[a]Third leaf of wild rice.

on planted corms or rhizomatous shoot production by established plants, or both. The number of wild rice plants averaged $23/m^2$ in both years when averaged over all treatments. Total plant density, proportion of species, and the spatial arrangement of species are factors that influence yield to density responses (5). This study was conducted using an additive approach which varied the giant burreed density while wild rice density remained constant. This approach may limit interpretation but was selected because this was the nature of the high-density areas seen in producers' fields.

Wild rice dry weight and leaf area were not affected by giant burreed planting density at the early-tillering stage of development (data not shown). Giant burreed interference caused reductions in leaf area at late tillering (regression equation: $Y=-0.3X + 135.0$, $r^2=0.26$, significant at $P=0.01$); however, leaf dry weight was not reduced with increasing giant burreed density. Reductions in dry weight at late-tillering and boot stages of wild rice development also were measured when compared to the weed-free control (Figure 1). The reduction in dry weight was due to a loss of stem rather than leaf tissue (authors' unpublished data). This indicated that giant burreed interfered with wild rice tiller development. The reduction in stem tissue may have been due to decreased tiller production or increased tiller mortality, or both.

Best fit of regression lines for yield and components of yield had a negative linear correlation with number of giant burreed shoots/m^2 at harvest rather than with number of planted corms. Wild rice vegetative biomass per plant and seed yield per panicle at harvest were reduced by giant burreed interference (authors' unpublished data). High densities of giant burreed reduced the number of panicles per plant (Figure 2). The reduction of plant biomass and panicles was related to the decrease in stem tissue which was evident at the late-tiller and boot stages of wild rice development. This indicated that loss of tiller production early in the season was not compensated for later in development.

As giant burreed shoot density increased, wild rice yields decreased (Figure 3). Wild rice seed yield was reduced from 56 g/m^2 in the weed-free control to less than 20 g/m^2 in plots containing 40 or more giant burreed shoots/m^2. Each giant burreed shoot/m^2 resulted in a yield loss of approximately $1.5\%/m^2$. Wild rice yield also was correlated negatively with giant burreed shoot density in a production field[5]. A reduction in panicles per plant accounted for the majority of the yield loss in both studies while a reduction in seed yield per panicle was less important.

The mechanism by which giant burreed interfered with wild rice development and yield was investigated by measuring several environmental factors throughout the season. Water was not a limiting factor for wild rice growth through anthesis because fields are flooded during this time. Therefore, interference with water uptake and competition for a limited water supply were not major factors in this study. The two mechanisms of giant burreed interference investigated were nutrient and light availability to wild rice.

The critical nutrient content is the minimum tissue content of the nutrient associated with maximum growth or maximum yield (4). Potassium and N (in high-fertility plots) were applied in excess of recommended rates to insure

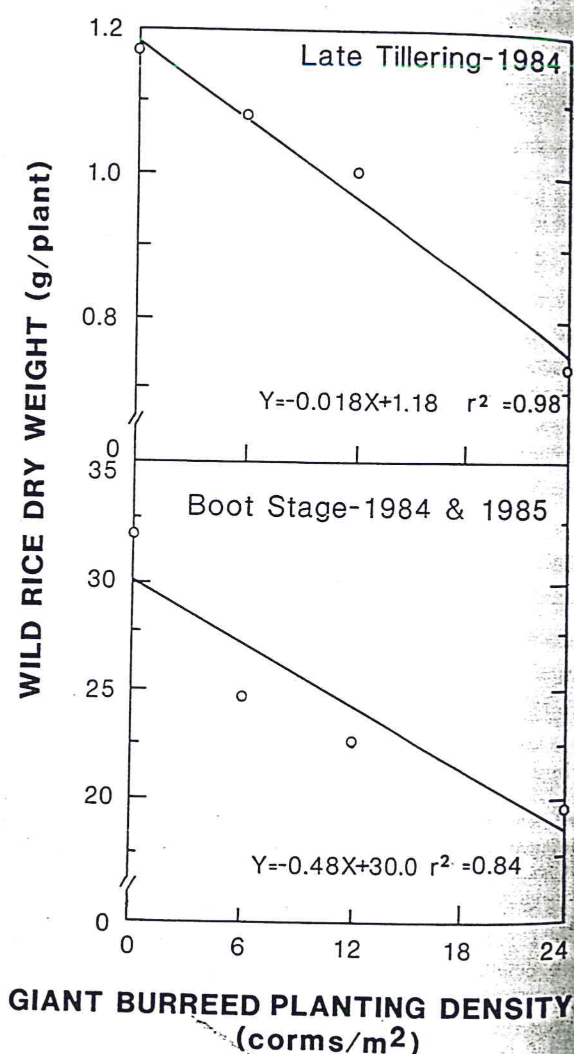

Figure 1. The effect of giant burreed interference on wild rice dry weight production.

[5]Clay, S. A. 1986. Interference and control of giant burreed (*Sparganium eorycarpum*) in wild rice (*Zizania palustris*). Ph.D. Thesis. Univ. Minnesota. 77 pp.

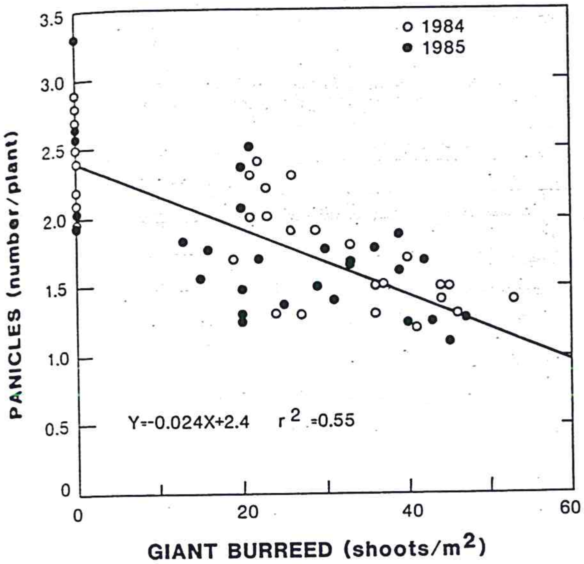

Figure 2. The effect of increasing giant burreed shoot density on wild rice panicle number/plant, Grand Rapids, MN, 1984 and 1985.

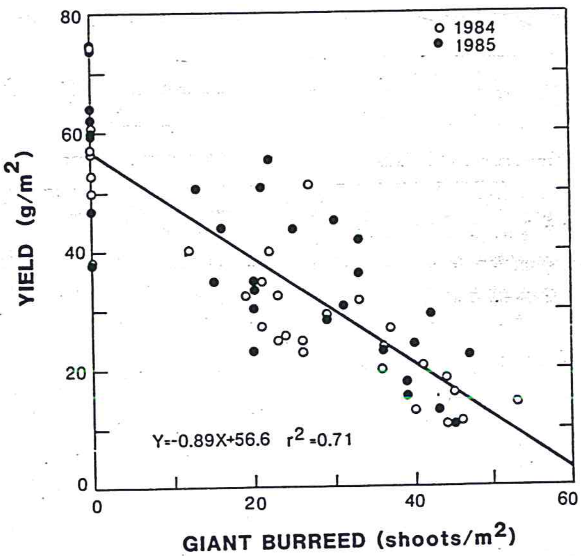

Figure 3. The effect of increasing giant burreed shoot density on wild rice seed yield, Grand Rapids, MN, 1984 and 1985.

adequate soil fertility for the wild rice crop. The urea form of N was applied to limit denitrification losses which occur in flooded soils.

Kern-Hansen and Dawson (7) reported whole-plant concentrations of N, P, and K for stream-growing narrowleaf burreed (*Sparganium emersum* Rehmann. # SPGEM) at 15.8, 1.9, and 14.0 mg/g dry weight, respectively. Critical concentrations of N and P for narrowleaf burreed were assumed to be 13.0 and 1.3 mg/g dry weight, respectively, based on data of other aquatic weeds [studied by Gerloff and Krombholz (4)] of comparable growth form and quantity of supporting tissue. Giant burreed in this experiment had concentrations of N, P, and K of 17.6, 4.8, and 37.0 mg/g dry weight, respectively, when averaged over treatments containing giant burreed. These amounts were above the levels assumed to be required for maximum growth of narrowleaf burreed, a related species; therefore, giant burreed growth should not have been limited by nutrient supply.

Critical nutrient levels for high-yielding wild rice on a whole-plant basis were reported as 1.5, 0.42, 3.5, 0.3, 0.24, and 0.025% for N, P, K, Ca, Mg, and Mn at the jointing stage of wild rice (3). Nitrogen, P, K, and Ca, Mg, and Mn contents in wild rice at the boot stage were 1.8, 0.54, 3.5, 0.58, 0.16, and 0.12%, respectively, when averaged over all treatments and years. The only element that had a concentration lower than the critical level was Mg when averaged over all treatments. Giant burreed density did not affect wild rice Mg content; therefore, interference with uptake was not measured. Percent Ca and Mg increased in wild rice with increased corm density (data not shown). However, wild rice in all treatments contained approximately 14.3 and 5.7 mg/g dry weight of Ca and Mg, respectively. This indicated that the increase in percent tissue content of these two nutrients was due to a reduction in plant dry weight rather than an increase in nutrient uptake.

Nitrogen application rate and N rate by weed density interactions were not observed for any of the measurements taken throughout the season except for N level in the upper leaves of wild rice plants in 1985. Therefore, the initial level of N in the field each year was above the level necessary for good development and high yield of wild rice.

Total plant N was 34% greater in 1984 than 1985. Transplanting of wild rice in 1985 may have restricted root growth, which resulted in limited N uptake. A year by N level by giant burreed corm density interaction was observed for N in upper plant leaves. Nitrogen levels were reduced in the upper leaves of wild rice plants grown in areas with low N and giant burreed when compared to the weed-free control in 1985 ($r=-0.42$, significant at $P=0.05$). This reduction was not apparent in 1984 due to higher N levels in the plant. Giant burreed interfered with N levels in the upper leaves of wild rice; however, nutrient levels on a total plant basis were not below reported critical nutrient levels for high-yielding wild rice. Therefore, the mechanism of giant burreed interference with wild rice development and yield was not interference with nutrient uptake.

Giant burreed emerged from the water approximately 20 days after planting (DAP). Wild rice floating-leaf and two-aerial-leaf stages were evident 30 and 45 DAP, respectively (Table 2). Giant burreed was taller than wild rice from

Table 2. Days after planting (DAP) to various wild rice phenological stages and height of wild rice and giant burreed at each phenological stage in 1984 and 1985, Grand Rapids, MN.

Phenological stage of wild rice	Days after planting: Wild rice 1984	Days after planting: Wild rice 1985	Plant height: Wild rice[a] 1984	Plant height: Wild rice[a] 1985	Plant height: Giant burreed[b] 1984	Plant height: Giant burreed[b] 1985
	(days)		(cm)			
Floating leaf[c]	30	26	...	...	40 ± 2	40 ± 2
2nd aerial leaf[d]	43	47	35 ± 2	40 ± 3	55 ± 3	55 ± 4
Early tiller	49	55	40 ± 1	50 ± 2	70 ± 1	80 ± 3
Late tiller	57	62	60 ± 3	65 ± 3	70 ± 4	85 ± 5
Boot	71	77	80 ± 2	75 ± 2	100 ± 5	90 ± 4
Anthesis	85	83	115 ± 4	130 ± 7	115 ± 6	105 ± 5
Maturity	112	111	175 ± 3	175 ± 4	130 ± 5	135 ± 5

[a]Each value is a mean value of 5 plants/plot averaged over all treatments.

[b]Each value is a mean value of 5 plants/plot averaged over all treatments containing giant burreed.

[c]Third leaf of wild rice.

[d]Five-leaf stage.

emergence to anthesis stage of wild rice development. This suggested that giant burreed may shade wild rice from early in development through anthesis.

The highest planted giant burreed density reduced PAR in the wild rice canopy from the early-tillering to the anthesis stages of wild rice development when compared to the weed-free control (Figures 4 and 5). Reduction of PAR at water level ranged from 2 to 30% throughout the season in plots containing giant burreed when compared to the weed-free control. A 10% reduction in PAR was measured at the early-tiller stage of development in high giant burreed densities (Figure 4). Giant burreed was 30 cm taller than wild rice at this stage of development (Table 2). Although not measured, PAR penetration into the water also would be reduced by giant burreed. Since tiller initiation occurs at the base of the wild rice plant, this light reduction may have decreased the number of tillers formed or increased tiller mortality, or both.

Wild rice was as tall or taller than giant burreed from anthesis to maturity; however, giant burreed continued to interfere with PAR penetration in the wild rice canopy as measured by a 17% reduction at water level in the high corm treatment compared with the weed-free control (Figure 5). Shade has been shown to limit flower production of yellow nutsedge (6). The shading that occurred late in the season may have limited wild rice flower production, seed set, or

Table 3. Relative growth rate (RGR) of wild rice at full light, 30, and 47% shade in a controlled environment.

Treatment	Relative growth rate: 14–28 DAP[a]	28–42 DAP[a]	42–84 DAP[a]
	($g \cdot g^{-1} \cdot day^{-1}$)[b]		
Full light	0.092 ± 0.037	0.106 ± 0.037	0.084 ± 0.009
30% shade	0.078 ± 0.037	0.136 ± 0.039	0.046 ± 0.016
47% shade	0.048 ± 0.025	0.118 ± 0.064	0.095 ± 0.009

[a]DAP = days after planting.

[b]Mean value of RGR ± (t X standard error of 12 samples at each treatment).

Table 4. The influence of shade on wild rice development at the 12-week harvest in a controlled environment.

Treatment: Shade	Treatment: Light	Total dry weight: Full light	Total dry weight: 30% shade	Total dry weight: 47% shade	Panicle/plant: Full light	Panicle/plant: 30% shade	Panicle/plant: 47% shade	Panicle emergence: Full light	Panicle emergence: 30% shade	Panicle emergence: 47% shade
(weeks)		(g/plant)[a]			(no.)[a]			(days after planting)[a]		
0	12	13.9 ± 2.7	...	...	5 ± 2	...	...	70 ± 4	...	...
2	10	...	10.3 ± 1.7	6.8 ± 8.2	...	2 ± 1	3 ± 2	...	74 ± 4	71 ± 10
4	8	...	9.0 ± 2.1	6.4 ± 4.7	...	2 ± 1	2 ± 2	...	77 ± 4	76 ± 10
6	6	...	11.8 ± 2.5	7.5 ± 2.0	...	3 ± 1	2 ± 2	...	73 ± 5	72 ± 12
12	0	...	5.9 ± 2.4	5.9 ± 4.0	...	1 ± 1	1 ± 1	...	79 ± 3	80 ± 5

[a]Mean value of each parameter ± (t X standard error of 12 samples at each treatment).

photosynthate supply to developing seeds, thus lowering the seed yield per panicle. Since water and nutrients were not affected by giant burreed density, it appeared that shading of wild rice throughout its development was the major mechanism causing yield reductions.

Influence of shade on growth and development of wild rice. The growth stages of wild rice at the 2-, 4-, and 6-week harvest dates were the floating-leaf (three leaves), two- to three-aerial leaf (five to six leaves), and early-tiller stage of development, respectively. Wild rice dry weight was

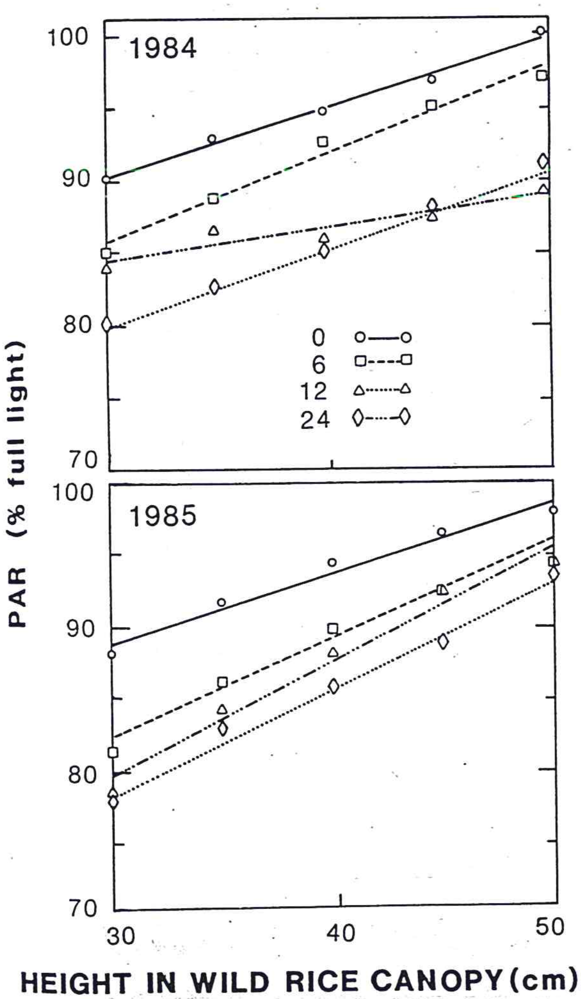

Figure 4. The effect of giant burreed interference on the penetration of photosynthetically active radiation (PAR) through the wild rice canopy at early tillering, at different heights of measurement, at Grand Rapids, MN. Curves denote giant burreed planting densities in corms/m^2. The regression equations for reduction of light penetration (Y) in the wild rice canopy (X=wild rice height) are: Y=0.47X+76.0 (r^2=0.94) with 0 corms/m^2, Y=0.60X+67.6 (r^2=0.97) with 6 corms/m^2, Y=0.22X+77.8 (r^2=0.86) with 12 corms/m^2, and Y=0.52X+64.1 (r^2=0.98) with 24 corms/m^2 in 1984; and Y=0.48X+74.4 (r^2=0.97) with 0 corms/m^2, Y=0.67X+62.3 (r^2=0.96) with 6 corms/m^2, Y=0.78X+56.4 (r^2=0.97) with 12 corms/m^2, and Y=0.73X+56.3 (r^2=0.98) with 24 corms/m^2 in 1985.

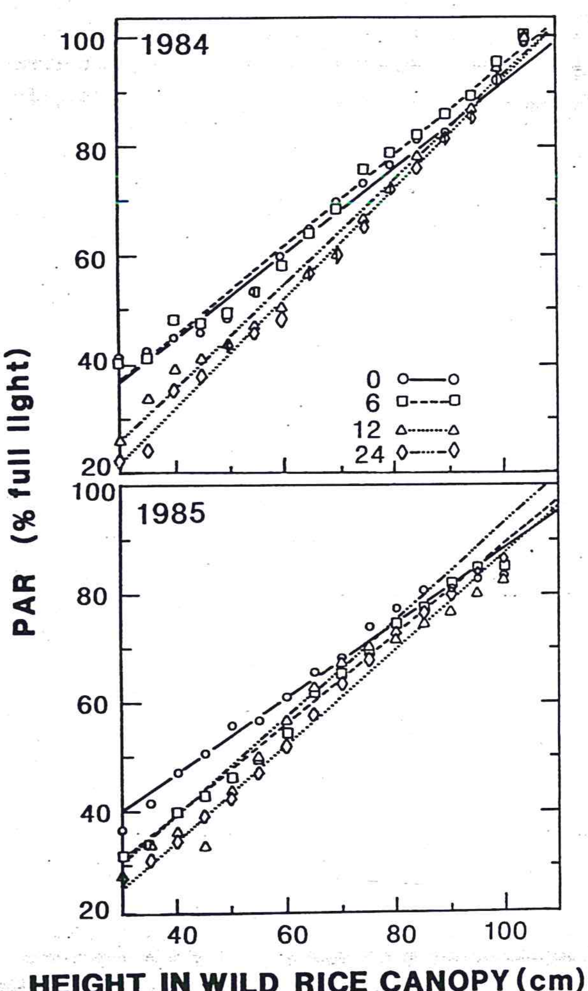

Figure 5. The effect of giant burreed interference on the penetration of photosynthetically active radiation (PAR) through the wild rice canopy at anthesis, at different heights of measurement at Grand Rapids, MN. Curves denote giant burreed planting density in corms/m^2. The regression lines for reduction of light penetration (Y) in the wild rice canopy (X=wild rice height) are: Y=0.77X+13.3 (r^2=0.98) with 0 corms/m^2, Y=0.82X+11.5 (r^2=0.98) with 6 corms/m^2, Y=0.94X−2.6 (r^2=0.98) with 12 corms/m^2, and Y=0.99X−8.3 (r^2=0.98) with 24 corms/m^2 in 1984; and Y=0.69X+19.2 with 0 corms/m^2, Y=0.83X+6.0 (r^2=0.99) with 6 corms/m^2, Y=0.89X+3.9 (r^2=0.96) with 12 corms/m^2, and Y=0.88X−0.9 (r^2=0.99) with 24 corms/m^2 in 1985.

reduced from the full light treatment by the 47% shade treatment at the 2-, 4-, and 6-week harvest dates and was due to a reduction in stem dry weight[5]. A reduction in dry weight also was measured in the field experiment early in the growing season.

The relative growth rate (RGR) of wild rice was reduced under 47% shade in the 14- to 28-DAP period when compared to the full light treatment (Table 3). Shading of 30% reduced the RGR of wild rice 50% in the last 6 weeks of growth when compared to the full light treatment. These reductions in RGR during the 12-week period corresponded to the reductions in total plant dry weight at harvest (Table 4). A 47% shade treatment of 2, 4, or 6 weeks followed by 10, 8, or 6 weeks of full light, respectively, reduced wild rice plant dry weight to a level comparable to 12 weeks 47% shade. However, a 30% shade treatment did not affect wild rice plant growth up to 6 weeks of growth when followed by 6 weeks of full light. These data indicated that shade intensity and duration must be considered in the assessment of shading influence on wild rice. Days to panicle emergence increased and plant dry weight and the number of panicles per plant decreased with both the 30 and 47% 12-week shade treatments. Although days to maturity in the field was not influenced by giant burreed, other weeds which have broader leaves and provide more shade such as common waterplantain may delay ripening of wild rice. A reduction in panicles/plant was observed in the field when wild rice was shaded by giant burreed. Although other factors such as light quality and timing of shade may be important, it appeared that shade and giant burreed interference had comparable effects on wild rice development. Reduction of PAR penetration into the wild rice canopy appears to be the major mechanism of giant burreed interference in wild rice.

ACKNOWLEDGMENTS

Dr. D. Linden, USDA-ARS, University of Minnesota, provided graphics software for the figures.

LITERATURE CITED

1. Bremner, J. M. 1965. Total nitrogen. Pages 1149–1178 *in* C. A. Black, ed. Methods of Soil Analysis, Part 2. Agron. Monogr. No. 9. Am. Soc. Agron., Madison, WI.
2. Dawson, J. H. and J. T. Holstun, Jr. 1970. Estimating losses from weeds in crop. Pages 3.2.2/1–3.2.2/4 *in* Crop Loss Assessment Methods. FAO. Rome.
3. Grava, J. and K. A. Raisanen. 1978. Growth and nutrient accumulation and distribution in wild rice. Agron. J. 70:1077–1081.
4. Gerloff, G. C. and P. H. Krombholz. 1966. Tissue analysis as a measure of nutrient availability for the growth of angiosperm aquatic plants. Limnol. Oceanogr. 11:529–537.
5. Harper, J. L. 1977. Population biology of plants. Academic Press, New York.
6. Keeley, P. E. and R. J. Thullen. 1978. Light requirements of yellow nutsedge (*Cyperus esculentus*) and light interception by crops. Weed Sci. 26:10–16.
7. Kern-Hansen, U. and F. H. Dawson. 1978. The standing crop of aquatic plants of lowland streams in Denmark and the inter-relationships of nutrients in plant, sediment, and water. Pages 143–150 *in* 5th International Symposium on Aquatic Weeds. EWRS. Amsterdam. A. Wheaton and Co., Ltd., Exter, Great Britain.
8. Okafor, L. I. and S. K. DeDatta. 1976. Competition between upland rice and purple nutsedge for nitrogen, moisture, and light. Weed Sci. 24:43–46.
9. Ransom, J. K. and E. A. Oelke. 1982. Common waterplantain (*Alisma triviale*) interference with wild rice (*Zizania palustris*). Weed Sci. 30:10–14.
10. Zimdahl, R. L. 1980. Weed-Crop Competition: A Review. Int. Plant Prot. Ctr. Oregon State Univ., Corvallis, OR. 195 pp.