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Straw residues in wild rice (*Zizania palustris* L.) stands in northern Saskatchewan

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Archibold, O. W. 1991. **Straw residues in wild rice (*Zizania palustris* L.) stands in northern Saskatchewan.** Can. J. Plant Sci. **71**: 337–345. Straw production in wild rice stands fluctuates markedly from year to year. In the short term, heavy straw accumulation may reduce grain yields by smothering seedlings; in the long term, the balance of nutrients in a lake may be affected. An aquatic weed harvester was used to remove standing straw from part of a wild rice stand at the end of the growing season. Compared to the control plot, grain production increased twofold in the following year. However, straw production also increased significantly and may exacerbate the problem in future years. Decomposition bags containing chopped and unchopped straw were submerged in a lake to assess the rate of straw breakdown: complete decomposition may require 3 yr. Decomposition occurred most rapidly during the early part of each growing season. No difference was noted in rates of decomposition or nutrient release between the chopped and unchopped straw. Reduced light levels under straw loadings up to 5000 kg ha^{-1} in laboratory trials did not affect seedling development. However, seedling survival was severely reduced under artificial straw loads and none survived straw additions equivalent to 5000 kg ha^{-1}.

Key words: Wild rice, *Zizania palustris*, Saskatchewan, straw production, nutrient content, decomposition rates

Archibold, O. W. 1991. **Résidus de paille dans les champs de riz sauvage (*Zizania palustris* L.) du nord de la Saskatchewan.** Can. J. Plant Sci. **71**: 337–345. La production de paille dans les champs de riz sauvage varie considérablement d'une année à l'autre. A court terme, une forte accumulation de paille peut réduire le rendement grainier en étouffant les semis; à long terme, cela peut modifier l'équilibre en éléments nutritifs. Une moissonneuse de mauvaises herbes aquatique a été utilisée pour éliminer la paille sur pied dans une section d'un petit lac à la fin de la saison de croissance. L'année suivante, la production de grains dans cette parcelle a été de deux fois supérieure à celle obtenue dans la parcelle témoin. Cependant, la production de paille a elle aussi augmenté de façon significative, ce qui pourrait aggraver les problèmes durant les années futures. Des sacs de décomposition contenant de la paille coupée et non coupée ont été immergés dans un lac pour déterminer le taux de décomposition de la paille: la décomposition complète peut nécessiter jusqu'à trois ans. La décomposition est la plus rapide au début de la saison de croissance. Aucune différence n'a été observée entre la paille coupée et non coupée, pour ce qui est du taux de décomposition ou de la libération d'éléments nutritifs. Des charges réduites de paille atteignant jusqu'à 5000 kg ha^{-1} n'ont eu aucun effet sur le développement des plants lors d'essais en laboratoire. Le taux de survie des semis a toutefois été grandement réduit avec des charges artificielles de paille et aucun n'a survécu à une addition de paille équivalant à 5000 kg ha^{-1}.

Mots clés: Riz sauvage, *Zizania palustris*, Saskatchewan, production de paille, teneur en éléments nutritifs, taux de décomposition

A considerable amount of straw is produced in a stand of wild rice (*Zizania* sp.) during the growing season. Lee (1986) has reported straw biomass as high as 17 000 kg ha^{-1} for wild rice in lakes in Ontario. The amount of nitrogen stored in this straw after harvest averaged 130 kg ha^{-1}, phosphorus 15 kg ha^{-1} and potassium 29 kg ha^{-1}: in the more productive lakes as much as 750 kg ha^{-1} nitrogen and 84 kg ha^{-1} phosphorus might be bound up in the straw. In paddy-grown wild rice the average nutrient content of the total crop (grain, leaves and stem) is calculated at 118 kg ha^{-1} nitrogen, 43 kg ha^{-1} phosphorus, and 291 kg ha^{-1} potassium (Oelke et al. 1982): of these amounts approximately 40% of the nitrogen, 60% of the phosphorus and 85% of the potassium is stored in the stems. Straw production in 20 lakes across northern Saskatchewan for the period 1984–1987 is shown in Fig. 1. The highest values, ranging from 1658 kg ha^{-1} to 5388 kg ha^{-1} occurred in 1984. The crop was much reduced in 1985 because of unusually high water levels (Archibold et al. 1989) and maximum straw production totalled only 1184 kg ha^{-1}. A progressive increase in straw production was noted at most sites during 1986 and 1987 when growing conditions improved.

Wild rice grain matures progressively from the top of the panicle and the stands are harvested about every 3 d over a 3- to 4-wk period. Delays in harvesting and windy conditions can result in as much as 40% of the crop being returned to the lake where the seed lies dormant over winter; thus, the stand is maintained, and its density increased, by natural reseeding. It is generally presumed by growers that there is a causal relationship between straw production and subsequent crop development. Often the straw will persist as a floating mat into the following spring. This could shade out new seedlings. If the straw sinks during the winter, seeds on the lake bed could be smothered. Straw accumulation is not a universal problem in wild rice stands. Slow moving currents will normally keep a site relatively straw free. Ice is particularly effective in uprooting the dead plants which are then carried off during the spring thaw. However, patchy production at a site can often be traced to submerged mats of straw. Straw decomposition is slow in northern lakes (Sain 1984).

Nutrient reduction within a lake as a result of straw being drifted to the shore has been noted by Keenan and Lee (1988): sediment nitrogen for example, decreased from a mean concentration of 1.5–0.2 g m^{-2} over a 5-yr period and potassium decreased from 1.3 to

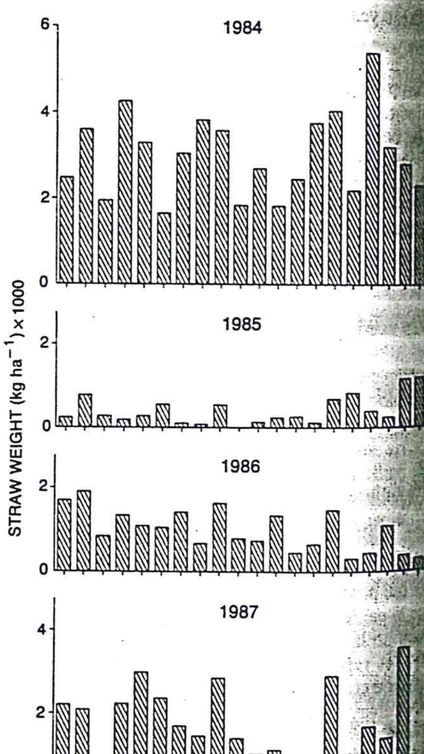

Fig. 1. Straw production (dry weight) at 20 sites across northern Saskatchewan for the period 1984 to 1987. The sites were distributed from Hanson Lake (site 1, 54.7°N, 102.8°W) in the east through La Ronge (site 5, 55.1°N, 105.3°W) to Buffalo Narrows (site 20, 55.9°N, 108.5°W) in the west.

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MATERIALS AND METHO...

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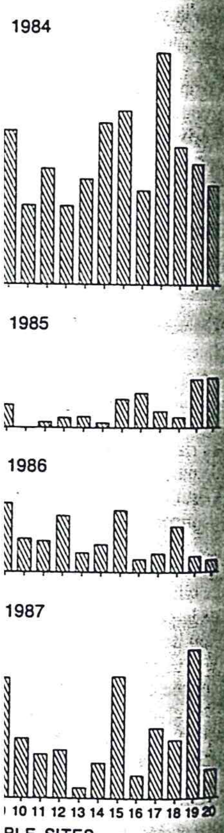

... g m^{-2}. Such processes could underlie the cyclical patterns seen in long-term production records of lake-grown wild rice across Canada (Archibold et al. 1989). Wild rice is grown in Saskatchewan under natural conditions without fertilizer or other chemical treatments. Thus, nutrient storage and rates of nutrient release from straw may become important to the industry as it attempts to increase and stabilise production.

Apart from broadcasting seed in the fall to increase acreage, most wild rice stands in Saskatchewan are visited only at harvest time. However, as readily accessible sites become more difficult to locate, local growers are becoming more interested in stand management as a means of increasing production. The objective of this study was to determine if straw removal affected wild rice yields in subsequent crop years. Nutrient storage in the straw and release during decomposition was also monitored along with the physical effect of straw on seedling development.

MATERIALS AND METHODS

Standing wild rice straw was removed from 1.5 ha at one end of a small lake near Ile-a-la-Crosse in northwestern Saskatchewan (55°27′N, 107°53′W) during the fall of 1987. An aquatic weed harvester, with a submerged cutting knife and conveyor system attached to the front of a 5-m-long steel barge, was used for this operation. The straw was cut approximately 10 cm above the lake bed in water that was about 0.8 m deep. A fence constructed from chicken wire (5-cm mesh) was erected around the plots to prevent straw from drifting into the cleared area. The adjacent, uncleared part of the lake was used as the control plot.

The effect of straw removal on plant performance was monitored during the 1988 growing season. Stem density was measured just prior to harvest in 50 0.25×0.25-m quadrats placed 10 m apart along two transects in both the control and test areas. Plant morphological characteristics, including number of tillers, stem length, stem diameter, stem weight and number of seeds per panicle were recorded for 100 plants collected from each area. The potential grain yield of each plot was calculated as the product of mean stem density × mean seed number per stem × mean seed weight. Straw production was calculated as stem density × mean stem weight. The effect of the depth of cut on the amount of straw removed was determined by weighing a sample of 40 oven-dried plants that had been cut into 30-cm lengths. Chemical analysis of each segment of plant tissue was performed on five samples each comprising material from five plants.

In 1986 a series of decomposition bags, prepared from straw collected at the end of harvest, was submerged in a lake near La Ronge (55°06′N, 105°17′W). The decomposition bags were constructed of nylon flyscreen (1.5-mm mesh) which was sown into pouches approximately 25 × 25 cm in size. The bags consisted of four pouches each containing 25 g of air-dried straw. Half of the sample was chopped in a horticultural shredder giving fragments approximately 3 cm in length. Chopped straw and whole, folded plants (unchopped) were used to fill alternate pouches. A total of 21 bags was submerged in October, 1986. Three bags were retrieved at approximately 3-mo intervals for dry weight determination and chemical analysis. The last set was collected in August 1988.

A laboratory experiment was conducted during the winter of 1988 to determine the effect of different straw loadings on plant performance. Eight 3-d-old seedlings were transplanted into growth tanks 30 × 30 × 25 cm deep containing 12 cm of soil. The surface of the soil was then covered with differing amounts of wet straw and the tanks filled with water to a depth of 30 cm. The tanks were set out in a growth room equipped with incandescent and fluorescent lights (temperature 21°C, 16 h photoperiod at 60 $\mu E\ m^{-2}\ s^{-1}$) and the performance of the seedlings monitored over a period of 6 wk. Six straw treatments were used each with six replicates. The treatments included adding chopped or whole wild rice straw at rates of 125, 250 and 500 g m^{-2}, these being equivalent to 1250, 2500 and 5000 kg of straw per hectare. Six control tanks, which contained no straw, were also distributed randomly amongst the samples.

RESULTS

Stand density in the growing season following clearing was 96 stems m^{-2} in the cleared plots; this represented an increase of 43% over the control plots which averaged 68 stems m^{-2}. Much of this increase in the cleared plot resulted from improved tillering (Table 1) since the actual number of plants established here was 28 m^{-2} compared to

Table 1. Morphological characteristics, potential grain yields and straw production of wild rice plants growing in the cleared and uncleared plots (mean ± SE, n=100; all values are significantly different between treatments, P<0.01, using Students t)

	Cleared	Uncleared
Stand density (stems m^{-2})	96.4±5.6	67.6±5.2
Number of tillers/plant	2.4±0.3	1.2±0.1
Stem length (cm)	157.0±2.3	137.8±2.4
Stem diameter (mm)	4.0±0.1	3.6±0.1
Stem weight (g)	14.4±1.6	8.1±0.8
Number of seeds/panicle	73.8±2.5	50.2±1.9
Potential grain yield (kg ha^{-1})	1992.0	950.2
Straw production (kg ha^{-1})	4108.1	2488.9

Table 2. The biomass (mean dry weight kg ha^{-1} ± SE, n=40) and nutrient content (mean kg ha^{-1} ± SE, n=5) of wild rice straw cut at different heights above the lake bed

Straw biomass and nutrient	Stem segments (cm above stem base) 0–30	31–60	61–90	>90	Total
	(kg ha^{-1})				
Straw biomass	1041±66	1268±70	995±69	804±82	4108
Nitrogen	5.79±0.36	9.51±0.51	10.26±0.51	7.67±0.13	33.23
Phosphorus	0.69±0.05	1.09±0.06	1.51±0.15	1.21±0.10	4.50
Potassium	5.48±0.36	9.13±0.62	10.72±0.55	7.06±0.25	32.39
Calcium	1.85±0.16	2.94±0.36	4.28±0.31	3.25±0.12	12.32
Magnesium	0.98±0.09	1.67±0.16	1.61±0.09	0.10±0.02	5.24
Manganese	1.30±0.13	1.38±0.24	0.33±0.11	0.07±0.01	3.08
Sulphur	0.83±0.04	1.27±0.04	1.15±0.07	0.85±0.03	4.10

31 m^{-2} in the uncleared plot. Straw clearing also increased stem length by over 20 cm, with corresponding increases noted for stem diameter and stem weight. Seed production, which averaged 74 seeds per panicle for the plants in the cleared plot, was 47% higher than for the control plants. Average seed weight was 28 mg and resulted in a potential yield of 1992 ka ha^{-1} compared to 950 kg ha^{-1}. However, the stimulative effect of straw removal on plant growth resulted in increased biomass at the end of the growing season: straw production was calculated at 4108 kg ha^{-1} in the cleared area: this represented an increase of 65% over the control plot.

Cutting off the plants at the lake bed (0 cm) would have removed a weight of straw equivalent to total stand production (4108 kg ha^{-1}, Table 2). By raising the cutting bar the amount of straw removed would have dropped to 3067 kg ha^{-1} at 30 cm, 1799 kg ha^{-1} at 60 cm, and 804 kg ha^{-1} at 90 cm above the lake bed. Corresponding amounts of nutrients that would be removed at these cutting heights is also given in Table 2. The greatest amounts of nitrogen, phosphorus and potassium are stored in the 61–90 cm segments which contain only 24% of the biomass; comparatively high concentrations of these nutrients are also found in the uppermost portion of the plants. A similar distribution was found for calcium, magnesium and sulphur. However, manganese tended to be concentrated in the lower portions of the plants.

The amount of straw remaining in the decomposition bags at various intervals during their submergence is shown in Fig. 2. About 65% of the bulk of the straw was lost over the 2-yr duration of this experiment. Initially the unchopped straw decomposed slightly faster than the chopped material, but during the second year weight loss was somewhat more rapid for the chopped straw. Although some decomposition occurred immediately after the straw was submersed, the bulk of the material was broken down in the first growing

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significantly different between treatments, $P<0.01$
t)

Cleared	Uncleared
6.4±5.6	67.6±5.2
2.4±0.3	1.2±0.1
7.0±2.3	137.8±2.4
4.0±0.1	3.6±0.1
4.4±1.6	8.1±0.8
3.8±2.5	50.2±1.9
1992.0	950.2
4108.1	2488.9

and nutrient content (mean kg ha^{-1} ± SE, n=5)
ights above the lake bed

s (cm above stem base)		
61–90	>90	Total
(kg ha^{-1})		
995±69	804±82	4108
10.26±0.51	7.67±0.13	33.23
1.51±0.15	1.21±0.10	4.50
10.72±0.55	7.06±0.25	32.39
4.28±0.31	3.25±0.12	12.32
1.61±0.09	0.10±0.02	5.24
0.33±0.11	0.07±0.01	3.08
1.15±0.07	0.85±0.03	4.10

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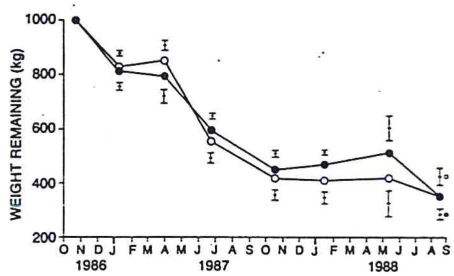

Fig. 2. The amount of chopped (○) and unchopped (●) straw (adjusted to a standard weight of 1000 kg, vertical lines indicate ±1 SE) remaining during the 2-yr decomposition trial.

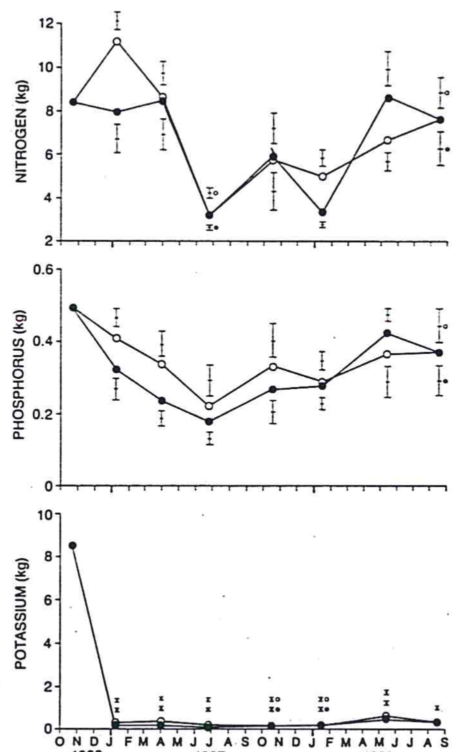

Fig. 3. The quantity of nitrogen, phosphorus and potassium remaining in the equivalent of 1000 kg of chopped (○) and unchopped (●) straw during decomposition over a 2-yr period (vertical lines indicate ±1 SE).

season. Microbe activity appeared to be negligible during the winter months, but further decomposition occurred in the second season. Complete decomposition should occur after three seasons irrespective of the straw treatment used.

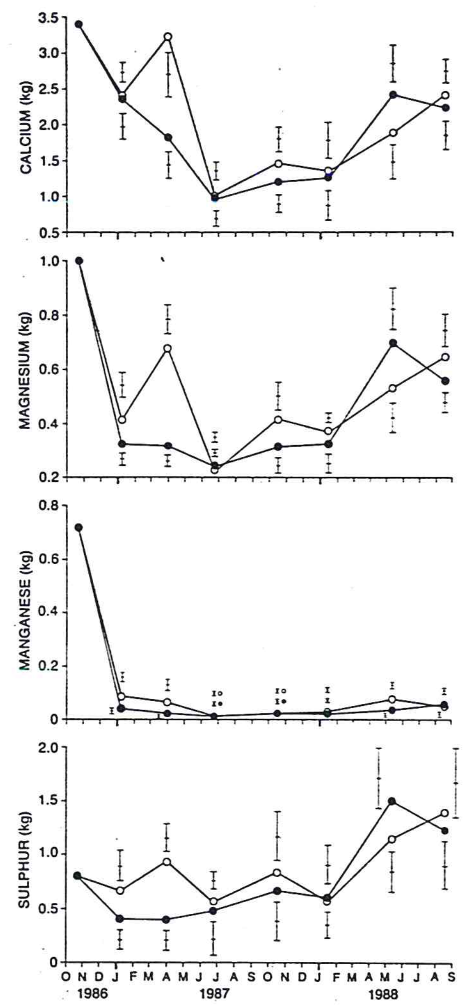

Fig. 4. The quantity of calcium, magnesium, manganese and sulphur remaining in the equivalent of 1000 kg of chopped (○) and unchopped (●) straw during decomposition over a 2-yr period (vertical lines indicate ± 1 SE).

The change in macronutrient concentration in the straw residues over the 2-yr period is shown in Fig. 3. Nitrogen was the most variable. For the unchopped material, nitrogen levels remained more or less constant through the first winter, then dropped markedly in the early part of the 1987 growing season. Values increased again in the second season and the final nitrogen content of the straw was calculated at 90% of the initial level. This suggests that algal growth or some other material was able to get established on the rotting straw. Trends in phosphorus concentrations were similar to those recorded for nitrogen. Concentrations were somewhat lower in the unchopped material. Phosphorus tends to get absorbed onto dead organic matter and this could account for the steady increase in phosphorus over the second winter. It is expected that this would be released during later growing seasons. Unlike the other two macronutrients, potassium concentrations dropped to very low levels over the first winter and remained stable for the duration of the experiment.

The concentration of secondary nutrients remaining in the decomposing straw is shown in Fig. 4. The amount of calcium stored in the dead tissue decreased steadily during the first growing season and parallels the breakdown and loss of organic material. The subsequent increase over the next year possibly reflects the development of algal and bacterial slimes within the residue. Magnesium tended to be released quickly from the wild rice straw and by the end of the first season about 80% of it had been lost. As with the other elements, the steady accumulation of magnesium during the second season is thought to reflect the increased micro-organism population which is harboured by the straw. The pattern of manganese release is similar to that noted for potassium with negligible amounts remaining after 3 mo submersion. Manganese is not considered to be an important nutrient for micro-organisms, and this probably accounts for the lack of accumulation in the decomposition bags that were removed later in the study. The gradual increase in sulphur noted in the straw residues suggests that the activities of sulphate reducing bacteria leads to the production of insoluble sulphur compounds which remain within the poorly oxygenated straw layer. The amount and state of sulphur in the sediment can greatly affect the availability of other nutrients and ultimately the productivity of a lake. Under anaerobic conditions sulphur is often immobilised as insoluble iron sulphide, but other sulphides which are toxic to plants can also be present and this could again result in poor wild rice yields in straw-choked sites if pH drops below 6.5.

The deleterious effect of the straw on the survival of wild rice seedlings is shown in Table 3. In the control tanks survival was better than 90%. The average number of plants surviving after 5 wk decreased as straw loading increased and none survived a load of 500 g m^{-2}: chopping the straw increased seedling survival and loads up to 250 g m^{-2} of chopped straw did not significantly reduce establishment compared to the 125 g m^{-2} treatment. Long-term survival appeared to be unaffected by straw loading. The effect of chopped and unchopped straw on light attenuation is shown in Fig. 5. Light intensities dropped off rapidly when the more densely packed chopped straw was used. The higher survival rates noted under chopped straw suggests that light may not be the most important factor in long-term plant performance. Indeed, seed germination will occur in murky lake water with depressed light levels.

Table 3. The effect of different straw treatments on the survival of wild rice seedlings (mean ± SE, n=6)

Straw treatment (g m^{-2})	Seedling survival (%) After 21 d	Seedling survival (%) After 35 d
Unchopped		
125	44±10*b*	41±6*b*
250	4±4*c*	2±2*c*
500	0*c*	0*c*
Chopped		
125	60±12*b*	56±10*b*
250	31±6*b*	27±5*b*
500	0*c*	0*c*
Control	94±4*a*	94±10*a*

a-c Mean values followed by the same letter in any horizontal row OR vertical column are not significantly different at $P \leq 0.05$.

DISCUSSION

The short-term effects of straw accumulation in a stand of wild rice are thought to be threefold. The straw can shade out the plants and the seedlings may die because of shortage of light, the straw may be too thick for the weak-stemmed seedlings to penetrate or, toxic conditions develop beneath the straw because atmospheric oxygen is prevented from mixing with the sediment. When straw is chopped it takes up far less volume than loosely folded stems and leaves. Perhaps, under poor growing conditions the weak-stemmed plants

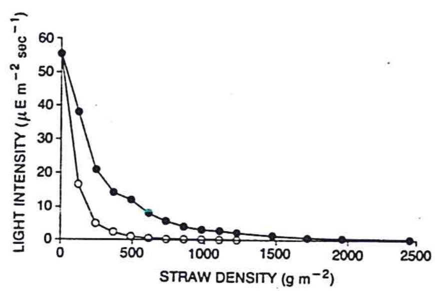

Fig. 5. The decrease in light intensity under varying densities of chopped (○) and unchopped (●) straw.

are less able to dislodge a great thickness of heavy, waterlogged straw and so continue their growth to the surface of the water. Loss of seedlings through physical suppression may be high. But in addition, poor stand establishment will probably result from the chemical conditions which develop beneath the straw. Anaerobic conditions can restrict germination of wild rice (Svare 1960), while in white rice aquaculture Ponnamperuma (1978) has noted that toxic chemical products can also inhibit seedling development. Painchaud and Archibold (1990) have noted a relationship between wild rice performance and sediment redox (Eh) levels: commercial stands develop in sediments with Eh readings above −150 mV while very poor growth occurs at sites with Eh readings below −200 mV.

Compared to other cereal crops, wild rice has a relatively high requirement for nitrogen, phosphorus and potassium (Oelke et al. 1982). Approximately 30% of the nitrogen and 20% of the phosphorus and potassium are taken up during the first 50 d of development. In the following 30-d period from jointing to early flower production this increases to approximately 80% for nitrogen and potassium and 70% for phosphorus. The remainder accumulates during the 20-d period when flowering and grain production occur (Oelke et al. 1982). The timing of nutrient release from decomposing straw could therefore affect long-term productivity in natural stands.

Maximum release of nitrogen occurs during the first season, but this is a time when straw bulk is high. Plant establishment may be smothered by the straw mat. Later, the denser microbial population could produce anaerobic conditions unsuitable for seed germination. Thus, it could take 3 yr before the effects of a dense mat of straw are eradicated and a good stand of wild rice becomes re-established. Phosphorus appeared to be retained by the straw in the decomposition bags. Production in aquatic ecosystems is significantly affected by phosphorus availability (Wetzel 1975), hence the subsequent release of this element following complete disintegration of the straw could lead to increased growth in the stand. Potassium is not normally considered to be limiting in aquatic ecosystems and the rapid release of this element from straw residues would suggest that it plays very little role as a regulator of wild rice productivity.

Nutrients tended to be concentrated in the upper part of the wild rice plant, the part most easily removed by straw-clearing operations. If possible, these nutrients should be preserved in the ecosystem. Although chopping has little effect on rates of straw breakdown and nutrient release, it does reduce the thickness of the straw mat which accumulates on the lake bed. This can increase the interaction between the organic debris and the decomposer organisms. The thin pouches used in the decomposition studies rested on the surface of the sediment where microbial populations are normally densest. Under heavy straw loadings decomposition rates would be expected to be lowered by increasingly anaerobic conditions. In such situations mulching the straw could accelerate decomposition or lessen its bulk resulting in a more rapid amelioration of the chemical environment.

Potential wild rice yields in the cleared area were more than double those in the uncleared plot. It is unlikely that all of this increase can be attributed to straw removal. However, as well as increasing grain yields, straw production also increased in the cleared patch. This suggests that straw clearing, once initiated, may need to be maintained if adverse growing conditions are to be avoided in the future. Aiken et al. (1988) suggest that wild rice

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obtains most of its nutrients from the soil. These would normally be replaced through decomposition of organic residues. Removal of nutrients in the straw and through harvesting can be significant (Keenan and Lee 1988). In the absence of chemical fertilizer applications straw removal, which at best is a costly and laborious process, therefore may not benefit production over the long term.

ACKNOWLEDGMENTS

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Aiken, S. G., Lee, P. F., Punter, D. and Stewart, J. M. 1988. Wild rice in Canada. NC Press Ltd., Toronto, ON. pp. 130.

Archibold, O. W., Good, A. G. and Sutherland, J. M. 1989. Annual variation in wild rice (*Zizania palustris* L.) growth and potential yield in Saskatchewan. Can. J. Plant Sci. **69**: 653–665.

Keenan, T. J. and Lee, P. F. 1988. Ecological relationships of wild rice, *Zizania aquatica*, 7. Sediment nutrient depletion following introduction of wild rice to a shallow boreal lake. Can. J. Bot. **66**: 236–241.

Lee, P. F. 1986. Summary report: The aquaculture of wild rice. Lakehead University, Thunder Bay, ON. pp. 42.

Oelke, E. A., Noetzel, D., Barron, D., Percich, J. Scherz, C., Strait, J. and Stucker, R. 1982. Wild rice production in Minnesota. Agriculture Extension Service Bulletin 464, University of Minnesota, St. Paul, MN.

Painchaud, D. L. and Archibold, O.W. 1990. The effects of sediment chemistry on the successful establishment of wild rice (*Zizania palustris* L.) in northern Saskatchewan water bodies. Plant Soil **129**: 198–116.

Ponnamperuma, F. N. 1978. Electrochemical changes in submerged soils and the growth of rice. Pages 421–441 *in* Soils and rice. International Rice Research Institute, Los Banos, Philippines.

Sain, P. 1984. Decomposition of wild rice (*Zizania aquatica*) straw in two natural lakes of northwestern Ontario. Can. J. Bot. **62**: 1352–1356.

Svare, C. W. 1960. The effects of various oxygen levels on germination and early development of wild rice. Game Investigation Report No. 3, Minnesota Department of Conservation.

Wetzel, R. G. 1975. Limnology. Saunders College Publishing, Philadelphia, PA. p. 743.