ARCTIC
VOL. 35, NO. 2 (JUNE 1982), P. 307-311

Factors Associated with Growth of Wild Rice in Northern Saskatchewan

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ABSTRACT. Six growth measurements of wild rice (*Zizania aquatica L.*) were made in 17 stands near La Ronge, northern Saskatchewan. Sediment depth, water depth, and 19 substrate chemical factors were measured. Panicle development was primarily related to available P, pH, and concentrations of Na, Ca, Zn, soluble K, Cu, Mn, SO_4, Cl, and Fe in the sediment. It was also related to water and substrate depths. Shoot length was related to water and mud depths. Shoot weight was related to substrate mud depth, and to the concentration of soil Ca and Mn. Changes in the chemical composition of sediment may have been the cause for decreased production of wild rice. Substrate properties may be useful for identifying potential seeding sites for wild rice.

Key words: wild rice, *Zizania,* northern Saskatchewan

RÉSUMÉ. La croissance de dix-sept plants de zizanie (*Zizania aquatica L.*) près de La Ronge, dans le nord de la Saskatchewan, a été suivie au moyen de six prises de mesures de la profondeur des sédiments et de l'eau et des facteurs chimiques sous-terrains. La croissance des panicules était reliée principalement à la présence de P et de pH et aux concentrations dans les sédiments de Na, de Ca, de Zn, de K soluble, de Cu, de Mn, de SO_4, de Cl et de Fe. La profondeur de l'eau et de la sous-strate touchaient aussi la croissance. La longueur des pousses variait selon la profondeur de l'eau et de la boue, tandis que leur poids variait en fonction de la profondeur de la sous-strate de boue et de la concentration dans le sol de Ca et de Mn. Les changements dans la composition chimique des sédiments ont peut-être entraîné une baisse dans la production de zizanie. Les propriétés des sous-strates peuvent être utiles dans l'identification des sites possibles d'ensemencement de zizanie.

Mots clés: zizanie, *Zizania,* nord de la Saskatchewan
Traduit pour le journal par Maurice Guibord.

INTRODUCTION

Wild rice (*Zizania aquatica* L.) is not native to Saskatchewan (Dore, 1969). The first seeding occurred in streams and lakes of northern Saskatchewan in 1935 and today there is sufficient acreage to support a small commercial harvesting program in the vicinity of La Ronge. La Ronge Industries and the Department of Northern Saskatchewan are seeding wild rice to increase acreage and grain production.

Wild rice strains appear to vary greatly in their responses to various environmental conditions (Steeves, 1952; Rogosin, 1951). One cannot be certain whether these variations reflect physiological tolerance of individual plants or the response of a diversified gene pool. Nevertheless previous studies have suggested that water depth, water sulphate levels, pH, and oxygen concentrations influence the presence, germination and growth of wild rice (Steeves, 1952; Dore, 1969; Weber and Simpson, 1967). Water depths of <10 cm or >110 cm and rapid changes in water level appear to reduce wild rice production (Thomas and Stewart, 1969). Water sulphate retards growth and concentrations >50 ppm prevent growth (Dore, 1969). Maximum growth of wild rice generally occurs betwen pH levels of 7.5 and 8.5 (Dore, 1969; Neilson, 1964). Other factors which may reduce wild rice growth include winter kill of seed by frozen water and soil (Rogosin, 1951), and insect, waterfowl and muskrat foraging (Dore, 1969; Rogosin, 1951; Stoudt, 1944). Neilson (1964) suggested that wild rice needs at least 45 cm of loose mud or ooze but other workers have reported that various soils are suitable (Dore, 1969; Weber and Simpson, 1967). Turbidity, alkalinity, plant competition, and water colour may also influence growth (Dore, 1969; Neilson, 1964; Rogosin, 1951; Moyle, 1944).

The introduction of wild rice into northern Saskatchewan has created locally important habitat for waterfowl (Peden, 1977) and provided a locally important cash-crop industry. It now appears that established stands are experiencing a decline (La Ronge Industries, pers. comm.) in annual grain production. In order to determine the cause of this decline and to identify potential habitat for wild rice, there is a need to discover those factors that influence the growth and development of wild rice in northern Saskatchewan. This is the purpose of this report.

MATERIALS AND METHODS

Seventeen wild rice stands near La Ronge, Saskatchewan, located on Brabant Lake, Potato Lake, Nemeiben Lake, Pisew Lake and the Pine Branch River were selected to represent the range of growth observed in wild rice during previous years. The wild rice stands at Pisew Lake and Nemeiben Narrows on Nemeiben Lake were seeded during the previous autumn whereas the rest of the stands were well established (La Ronge Industries, pers. comm.). Each transect was placed perpendicular to the depth contours of the stand. Five circular plots each with a radius of 2 m were evenly spaced 5 m apart along each transect.

During the last two weeks of August, 1975, five wild rice plants were harvested from within each plot. Not all plots contained plants so that from a total of 85 plots only 59 sets

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of wild rice plants were taken. At Brabant Lake fewer than five plants were available at some plots.

For each set of wild rice samples, the following growth characteristics were measured: the average number of pistillate spikelets per panicle (NPSP); the percent of pistillate spikelets displaying some visual sign of grain development (PG); the average dry weight of the grains from each panicle (AGW); and the length of the plant shoots (defined as the culms, leaves, and inflorescences of each plant). Before weighing, all plants were dried for 48 hours at 60°C. The roots were not included since much of the root biomass was lost during sampling.

A combined growth index was calculated to give the estimated total weight of grain production per panicle (TGW) by the following equation:

$$TGW = \frac{(NPSP)\ \ (PG)\ \ (AGW)}{100\%}$$

This calculation assumes that if grain exists it must be visible. Thus pistillate spikelets without grain did not contribute to the total grain production estimate.

From each plot, lake bottom samples were collected from the first 10 cm of sediment. The sediment samples from each plot on a transect were air dried and then combined in equal proportions and thoroughly mixed to give one sample for each transect. The high cost of sediment analyses necessitated this pooling of substrate samples. The Saskatchewan Soil Testing Laboratory, Saskatoon, following the methods of Hamn and Cooney (1977), analysed the samples for nitrate (ppm), available phosphorus (ppm), potassium (ppm), % organic matter, % total nitrogen, % total phosphorus, copper (ppm), iron (ppm), manganese (ppm), zinc (ppm), soil pH, and conductivity (MMHOS). Concentrations of water-soluble sodium, calcium, magnesium, potassium, chloride and sulphate were also measured (ppm). The sodium-absorption-ratio was calculated. From each plot, soil and water depths at the time of harvesting plant samples in August were measured.

A one-way analysis of covariance (ANOCOVA) was used to test for differences among the 17 transects and to test for correlations with soil depth and water depth of each growth parameter. Eliminating site-to-site variation by including the effect of transect was done primarily to maximize the power of the tests of the effects of soil and water depths. However, the mean values for each transect of the total grain weight were ranked and the differences among them were compared using Duncan's New Multiple Range Test (Li, 1964).

The growth data from within each transect for each growth parameter were averaged. Step-wise multiple regressions were used to explain variability among the 17 transect means in each of the six growth parameters in terms of the soil characters. Only those soil factors or independent variables generating a significant F statistic ($P<0.05$) were accepted as being of importance in explaining the variation observed in wild rice growth. The three soil parameters having the lowest correlation coefficients with respect to each growth parameter were eliminated from the step-wise regression, since the number of soil measurements exceeded the number of transects (otherwise the number of regression coefficients to be estimated would have exceeded the number of equations in the least-squares method).

RESULTS

Significant differences ($P<.001$) in five of the six growth parameters of wild rice were found by the ANOCOVA among the 17 transects. Shoot length was the only growth measurement for which significant differences among transects were not observed. Three of the four highest estimates of total grain weight described newly seeded areas, while the lower estimates from the remaining 14 transects described established stands (Table 1). The lowest weights from the newly seeded areas were not significantly different from the highest weights for the established stands. Total grain weight in the newly seeded areas ranged from 113 to 216 mg per panicle and from 2 to 122 mg per panicle in the established stands. The transect means for the other five growth parameters are given in Table 1.

Testing for significance of covariates in the ANOCOVA suggests that at least one was correlated with each wild rice growth parameter (Table 2) except for average seed weight. Water depth was significantly ($P<.05$) and positively correlated with the % grain, total grain weight, and shoot length. Sediment depth was negatively correlated with NPSP, PG, shoot weight and shoot length. After pooling the non-significant effects of transect and of covariates with the residual mean square in the ANOCOVA, partial coefficients of determination were calculated. With the exception of shoot length, the effect of variability among transects was greater than the effects of water depth and sediment depths. Thirty-four percent of the variability in shoot length was attributable to water depth and none to among-transect variation. The low multiple coefficient of determination indicates that other unexplained factors account for most of the variability in shoot length.

The chemical profile of the sediment in each transect is summarized in Table 3. Five of the six step-wise regressions revealed significant ($P<.05$) correlations between the growth parameters of wild rice and these substrate chemistry measurements (Table 4). Only shoot length was not correlated to any of the measured soil characteristics. Number of pistillate spikelets per panicle (NPSP) was positively correlated with available phosphorus and pH, and negatively correlated with sodium. Average grain weight (AGW) was positively related to pH and zinc but negatively to available phosphorus, calcium and soluble potassium. Percent grain (PG) was negatively related to available phosphorus, copper and chloride but positively related to pH, manganese and sulphate. Total grain weight

TABLE 1. Mean growth estimates for wild rice plants in 17 stands in northern Saskatchewan

Transect Location	Shoot length (cm)	Dry weight shoot (g)	NPSP[1]	AGW[2] (mg)	PG[3]	TGW[4] (mg)	Sets of TGW means which are not significantly different
*Pisew Lake - Stand 1	146	345	39	13.2	42	216	
*Pisew Lake - Stand 2	165	471	36	11.5	34	142	a
Potato Lake - Stand 1	111	385	44	9.5	29	122	a b
*Nemeiben Narrows	129	249	27	8.7	48	113	a b
Pine Branch River - Stand 1	131	179	19	11.2	44	95	b c
Potato Lake - Stand 2	124	585	33	10.2	28	93	b c
Potato Lake - Stand 3	141	324	39	8.9	25	86	b c
Pine Branch River - Stand 2	134	157	20	7.9	43	66	d c
Jackfish Bay, Nemeiben Lake - Stand 1	108	129	13	13.6	38	64	d c
Pine Branch River - Stand 3	157	239	21	8.4	33	58	d e c
Potato Lake - Stand 4	143	385	38	11.1	13	52	d e
Jackfish Bay, Nemeiben Lake - Stand 2	124	205	19	8.6	28	47	d e
Potato Lake - Stand 5	111	585	22	5.0	20	21	e f
Brabant Lake - Stand 1	114	484	42	4.2	11	19	e f
Jackfish Bay, Nemeiben Lake - Stand 3	118	173	17	4.2	11	8	f
Mud Bay, Nemeiben Lake	101	223	23	4.2	4	4	f
Brabant Lake - Stand 2	147	918	47	1.6	1	2	f

* Newly seeded.
[1]NPSP = number of pistillate spikelets per panicle.
[2]AGW = average dry weight of grains from each panicle.
[3]PG = percent of pistillate spikelets with observable development of grain.
[4]TG = total grain dry weight per panicle.

TABLE 2. Significant ($P<.05$) partial coefficients of determination and regression coefficients (in parentheses) relating wild rice growth to effects of among-transect variability, water depth and sediment depth

Growth Parameter	Partial Coefficient of Determination: Effect of Transect	H_2O Depth	Sediment Depth	Multiple R^2
NPSP*	0.63	—	0.05 (−.056)	0.71
AGW*	0.61	—	—	0.65
PG*	0.53	0.09 (.199)	0.04 (−0.63)	0.75
TGW*	0.47	0.11 (.881)	—	0.58
Shoot wt.	0.54	NS	0.07 (−1.36)	0.73
Shoot length	—	0.34 (.769)	0.03 (−0.11)	0.37

*Defined in Table 1.

(TGW) was positively correlated with calcium, zinc and iron and was negatively related to chloride. The multiple coefficients of determination (R^2) for the growth parameters related to panicle development ranged from 0.87 to 0.97. Since the sediment chemistry estimates were averaged for each transect, the high R^2 values indicate that much of the among-transect variation in panicle development (Table 2) can be explained in terms of 11 chemical measurements. However, the vegetative measurements of shoot length (R^2 = 0) and shoot weight (R^2 = .59) cannot so readily be explained in the same way.

DISCUSSION

The concentrations of certain plant nutrients in the soil sediments were highly correlated to panicle development. Previous studies of wild rice considered water chemistry so that the results were not directly comparable. However, the data support previous observations that water depth (Thomas and Stewart, 1969), mud depth, sulphate, and pH (Dore, 1969; Steeves, 1959) affect the growth of wild rice. In addition phosphorus, sodium, calcium, zinc, soluble potassium, copper, manganese, chloride, and iron were correlated to wild rice growth (Table 4.)

Since the methods (Hamn and Cooney, 1977) of analyses of soil chemistry used in this study were developed for and are appropriate for Saskatchewan farmland, caution is needed in interpreting the results. Flooded soils are characterized by anaerobism, a reduced chemical state, toxic substances, and increased availability of Na, K, Ca, and Mg (Mikkelsen, 1974). These conditions make questionable any interpretation of the mechanisms underlying the observed correlations. However Mikkelsen (1974) does note that for rice "zinc deficiency is the most widespread [micronutrient] disorder followed by Fe, Mn, and Cu". The results from this study support that view for Zn, Fe, and Mn but not for Cu (Table 4).

Vegetative growth and panicle development were related to different factors. Panicle development was primarily correlated to among-transect differences which were large-

TABLE 3. Sediment chemistry profiles describing only those characteristics which were significantly correlated to differences in wild rice production among transects

Transect location	Available P (ppm)	pH	Water-soluble Ions (ppm) Na	Ca	Zn	K	Cu	Mn	SO_4	Cl	Fe
Pisew Lake - Stand 1	11	6.7	22	260	10	13	4	108	575	55	40
Pisew Lake - Stand 2	4	6.8	22	200	4	13	1	40	280	39	24
Potato Lake - Stand 1	15	5.6	11	65	16	10	6	222	180	20	180
Nemeiben Narrows	16	5.7	26	140	13	13	7	88	540	29	88
Pine Branch River - Stand 1	4	5.4	10	45	13	8	6	240	160	10	160
Potato Lake - Stand 3	18	5.8	18	85	14	13	6	75	310	23	55
Pine Branch River - Stand 2	8	5.4	13	50	13	13	6	304	170	14	164
Jackfish Bay, Nemeiben Lake - Stand 1	6	5.6	24	80	15	7	10	188	330	23	172
Pine Branch River - Stand 3	11	5.4	14	45	11	14	8	208	150	13	132
Potato Lake - Stand 4	15	5.8	15	95	16	13	13	40	280	32	44
Jackfish Bay, Nemeiben Lake - Stand 2	11	5.6	22	45	12	11	12	236	200	18	124
Potato Lake - Stand 5	15	5.8	15	95	6	13	2	14	230	23	20
Brabant Lake - Stand 1	22	5.4	15	25	5	11	10	68	110	11	132
Jackfish Bay, Nemeiben Lake - Stand 3	8	5.7	30	55	9	21	13	96	210	26	76
Mud Bay, Nemeiben Lake	12	5.5	22	200	10	30	10	60	440	53	80
Brabant Lake - Stand 2	28	5.4	12	30	8	11	11	88	105	11	96

TABLE 4. Standardized regression coefficients relating wild rice growth to significant ($P<.05$) chemistry characteristics of sediment

Sediment characteristics	NPSP*	AGW*	PG*	TGW*	Shoot length	Shoot weight
P	.81	−.27	−.22	—	—	—
pH	.64	.74	.43	—	—	—
Na	−.36	—	—	—	—	−.50
Ca	—	−.09	—	1.46	—	—
Zn	—	.64	—	.21	—	—
Solk	—	−.32	—	—	—	—
Cu	—	—	−.24	—	—	—
Mn	—	—	.54	—	—	−.72
SO_4	—	—	1.0	—	—	—
Cl	—	—	−.99	−.61	—	—
Fe	—	—	—	.25	—	—
Multiple coefficient of determination	0.87	0.87	0.97	0.92	0.0	0.59

*Defined in Table 1.

ly explained in terms of variation in substrate characteristics (P, pH, Na, Ca, Zn, soluble K, Cu, Mn, SO_4, Cl and Fe). In contrast, shoot length was not correlated to any substrate character while shoot weight was correlated with a small coefficient of determination (R^2 = .59) to sodium and manganese (Table 4). In this study, there was no observed correlation between organic matter in the sediment and the growth of wild rice. In other studies, a lack of dissolved oxygen associated with the accumulation of organic matter is thought to have limited growth (Dore, 1969).

The growth measurements reported in this study should not be confused with biomass estimates or actual grain harvest. Rather they represent the performance of only certain aspects of single plants and do not consider the density of plants or panicles per unit area. Measures of wild rice biomass and grain production per unit area are needed but are difficult to obtain because of the tendency for rice to shatter and because of the difficulty of sampling from a canoe.

The observation (La Ronge Industries, pers. comm.) that wild rice grain production declines over the years following seeding was in accord with our findings that the three estimates of total grain weight from newly seeded stands (Table 1) exceeded the estimates from most of the well-established ones. Between 87% and 97% of the variability among all wild rice transects was attributable to differences in the chemical composition of sediment, which suggests that changes in these nutrients may reduce the vigour of wild rice over a sequence of years. These high coefficients of determination for the relationship between sediment chemical composition and among-transect variation also suggest that these 11 sediment properties may be useful keys for identifying potential wild rice planting sites in northern Saskatchewan.

ACKNOWLEDGEMENTS

The author is grateful for the field assistance of Eric Whiting, for the manpower and facilities provided by Oral Young, Economic Development Branch, Department of Northern Saskatchewan and Kaz Parada, La Ronge Industries, for manuscript reviews by R.T. Coupland and E.A. Driver, and for E.H. Halstead's comments and criticisms. The Canadian Wildlife Service supported this project.

REFERENCES

DORE, W.G. 1969. Wild Rice. Canada Department of Agriculture Research Publication No. 1393. 84 p.

HAMN, J.W. and COONEY, G.R. 1977. Saskatchewan Soil Testing Laboratory procedures manual. Department of Soil Science, University of Saskatchewan, Saskatoon.

LI, J.C.R. 1964. Statistical Inference I. Ann Arbor: Edwards Brothers. 270-273.

MIKKELSEN, D.S. 1974. Micronutrient nutrition of rice in flooded soils. In: Isotope-Aided Micronutrient Studies in Rice Production with Special Reference to Zinc Deficiency. International Atomic Energy Agency Document No. I AEA-172, Vienna. 141-158.

MOYLE, J.B. 1944. Wild rice in Minnesota. Journal of Wildlife Managment 8:177-184.

NEILSON, J.D. 1964. Wild rice identification and propagation in northern Saskatchewan. Saskatchewan Department of Agriculture, Prince Albert. 13 p.

PEDEN, D.G. 1977. Waterfowl use of exotic wild rice habitat in northern Saskatchewan. Canadian Field-Naturalist 91(3):286-287.

ROGOSIN, A. 1951. An ecological history of wild rice. Minnesota Department of Conservation, Game Research Unit. 29 p.

STEEVES, T.A. 1952. Wild rice — Indian food and a modern delicacy. Economic Botany 6:107-142.

STOUDT, J.H. 1944. Food preferences of mallards on the Chippewa National Forest, Minnesota. Journal of Wildlife Management 8:100-112.

THOMAS, A.G. and STEWART, J.M. 1969. The effect of different water depths on the growth of wild rice. Canadian Journal of Botany 47:1525-1531.

WEBER, R.P. and SIMPSON, G.M. 1967. Influence of water on wild rice (*Zizania aquatica* L.) grown in a prairie soil. Canadian Journal of Plant Science 47:657-663.