Variation in wild rice (*Zizania palustris*) stands across northern Saskatchewan

O. W. ARCHIBOLD AND B. J. WEICHEL

Department of Geography, University of Saskatchewan, Saskatoon, Sask., Canada S7N 0W0

Received June 25, 1985

ARCHIBOLD, O. W., and B. J. WEICHEL. 1986. Variation in wild rice (*Zizania palustris*) stands across northern Saskatchewan. Can. J. Bot. **64**: 1204–1211.

Variations in wild rice (*Zizania palustris* L.) morphology and stand productivity have been evaluated for 20 sites across northern Saskatchewan. Although considerable within-stand variation occurred, significant between-site differences were also detected, and regional trends were clearly evident. Plant development was more rapid in the eastern part of the province, and harvest began about 1 week earlier here. However, in the west, individual plants were typically more robust, tillering was more common, and the number of florets borne on the panicle was generally larger. Consequently, potential seed production from an individual plant was highest in these western districts, although differences in stem density and seed weight at the various sites offset individual plant performance to some extent. Differences in water temperature and water depth occurred across the province in July, while in August, water depth, pH, and conductivity were significantly correlated with longitude. Water depth and pH were most strongly related to plant performance, shallower water and higher pH being characteristic of the western sites.

ARCHIBOLD, O. W., et B. J. WEICHEL. 1986. Variation in wild rice (*Zizania palustris*) stands across northern Saskatchewan. Can. J. Bot. **64**: 1204–1211.

Les variations de la morphologie et de la productivité du riz sauvage (*Zizania palustris* L.) ont été évaluées sur 20 sites à travers le nord de la Saskatchewan. Des variations significatives entre les sites et à l'intérieur de chacun furent observées. Le développement des plantes était plus rapide à l'est de la province et la récolte y a débuté 1 semaine plus tôt. Cependant, les plantes individuelles étaient typiquement plus vigoureuses à l'ouest, le tallage plus fréquent et le nombre de fleurettes portées par la panicule, plus élevé. En conséquence, la production potentielle des semences des plantes individuelles était plus élevée dans les districts à l'ouest. Mais les différences dans la densité des tiges et le poids des semences aux différents sites ont dépassé jusqu'à un certain point la performance des plantes individuelles. Les différences dans la température et l'épaisseur de l'eau ont été observées à travers la province en juillet, alors qu'en août, l'épaisseur d'eau, le pH et la conductivité étaient correlés significativement avec la longitude. L'épaisseur d'eau et le pH étaient plus fortement reliés à la performance des plantes: une épaisseur moindre d'eau et un pH plus élevé caractérisant les sites à l'ouest.

[Traduit par le revue]

Introduction

Originally an eastern North American species, wild rice (*Zizania palustris* L.) was introduced to Saskatchewan about 1935. However, it was not until the late 1970s that its economic potential was fully appreciated, with seeding programmes and other assistance being offered by the provincial government to encourage the development of new stands across the northern part of Saskatchewan (Fig. 1). By 1984 an estimated 7000 ha had been established yielding 475 000 kg with a market value exceeding $2 million after processing. Saskatchewan thus became the largest producer of wild rice in Canada, accounting for 61% of the national crop. Despite this increased production, the provincial harvest amounted to only 8% of the world production of wild rice from lakes and paddies (P. Orcajada, personal communication). Archibold *et al.* (1985) and Weichel (1985) provide a general account of the ecology of the species and of the expansion of the industry in Saskatchewan.

Noticeable morphological differences can be seen across the province (Weichel and Archibold 1984*a*). In addition, the growth, flowering, and maturation of stems within a stand can vary appreciably as some individuals come into flower while others are ready for harvest. An understanding of the nature and causes of such intersite and intrasite variation and the selection of wild rice varieties best suited to specific habitats could lead to more uniform stands and higher crop production. The purpose of this study is to determine if existing wild rice stands vary significantly with respect to plant morphology, the timing of flowering, and seed production. The relationship between plant performance and selected environmental parameters is examined in the context of geographic location within the province.

Field and laboratory methods

The initial field studies were conducted in late July 1984. During this 4-day period 20 study sites were established across the province (Fig. 1). At each wild rice stand, stem density was evaluated using twenty-five 0.5 × 0.5 m quadrats placed 10 m apart along two randomly located transects which started 15 m within the stand perimeter. The maturity of all stems in the quadrats was also recorded based on four flowering stages, referred to here as floret emergence, the pistillate stage, the staminate stage, and full panicle development (Fig. 2). In the floret emergence stage the upper female florets were visible above the leaf sheath; by the pistillate stage all of the female florets had appeared. The staminate stage was characterised by the appearance of some male florets on the panicle, with the entire flower almost completely extended by the full panicle development stage.

Stem density and flowering stage assessments were repeated during a second period of fieldwork conducted in late August. In addition, a sample of wild rice plants, totalling between 50 and 60 stems, was collected at random from each stand and air dried, and the following variables were measured: number of tillers, stem length, basal diameter of stem, and number of female florets. The plants were then oven-dried and shoot and root weights determined. Also, random, composite samples of mature seed still enclosed in their paleas and lemmas were gathered, oven-dried, and weighed. The potential commercial yield of grain at each site was then calculated by multiplying mean stem density at the end of August by the mean number of female florets per panicle and mean ovendry seed weight. The resulting values greatly exceed actual commercial yields since they assume 100% pollination, favourable climatic conditions for seed maturation, and no loss of seed by wind shattering or through inefficient harvesting techniques.

Printed in Canada / Imprimé au Canada

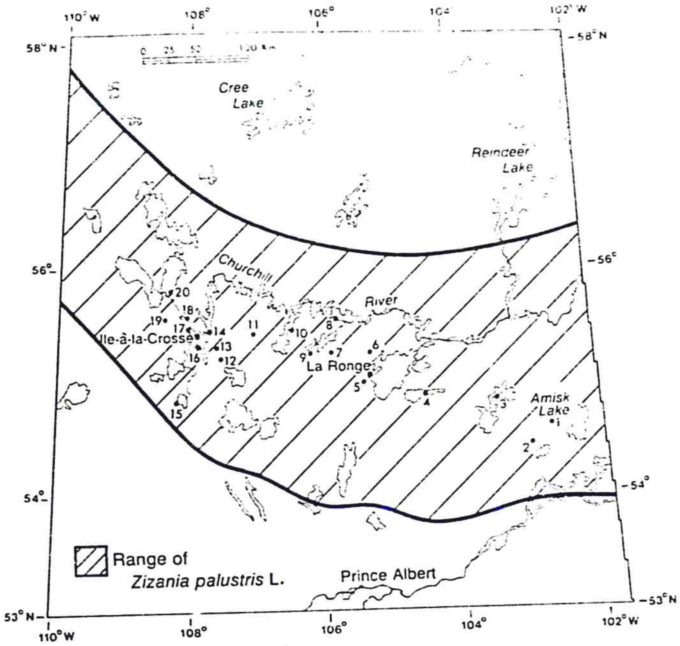

FIG. 1. Location of the sample sites and the range of *Zizania palustris* L. in northern Saskatchewan.

Floret emergence

Pistillate stage

Staminate stage

Full panicle development

FIG. 2. Sequential stages of panicle development in wild rice.

Water temperature and conductivity (YSI model 33 S-C-T conductivity meter), depth, and pH (Metrohm-Herisau model E 488 pH meter) were measured in the field at 12 points along the transects during each sampling period. Daily weather data for the period April to September 1984, obtained for 41 climate stations throughout northern Saskatchewan and adjacent areas in Alberta and Manitoba, were used to establish the length of the frost-free period and cumulative growing degree-days (base 5°C (Hare and Thomas 1979)) for the growing season.

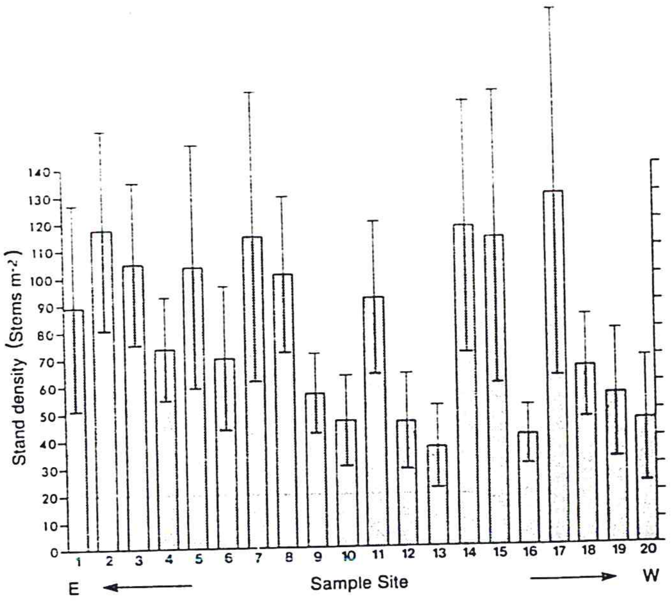

FIG. 3. Mean stem density in the 20 sample sites in late July. Site 1 is located in the eastern part of the province and site 20 to the west. The vertical lines represent standard deviations of the mean.

Results

Mean stem density of the wild rice stands recorded at the 20 study sites in July is given in Fig. 3. Mean density was highest at site 17, with stem counts averaging 133 ± 80 m^{-2}. Mean densities were similarly high at sites 14 (119 ± 55 stems m^{-2}), 2 (118 ± 44 stems m^{-2}), and 7 (117 ± 63 stems m^{-2}). The stand at site 13 was the thinnest with only 37 ± 18 stems m^{-2}; low counts were also recorded at sites 16, 12, 20, and 10 (41 ± 13, 45 ± 21, 46 ± 27, and 47 ± 20 stems m^{-2}, respectively). However, this regional variation in stem density was not significantly related to latitude or longitude (Table 1).

The total number of stems in flower was highest in the eastern part of the province At site 2 this averaged 97 ± 36 m^{-2}, with 76 ± 39 m^{-2} recorded at site 1 and 73 ± 25 m^{-2} recorded at site 3. Average flowering counts were considerably lower in the western part of the province with only 5 ± 4 flowering stems m^{-2} recorded at site 13; at sites 18, 19, and 20 the counts were 11 ± 5, 10 ± 5, and 9 ± 4 m^{-2}, respectively. The total number of stems in flower decreased significantly towards the west ($r = -0.628$, $p < 0.01$). In addition, the stage of flower development reached in July also exhibited an east–west gradient with the percentage of panicles in the full stage ranging from over 40% at site 2 to less than 2% at 20 (Fig. 4). For the eastern sites (sites 1–4) the mean percentage of stems in each of the flowering categories was 15.8 ± 6.5 at floret emergence, 11.8 ± 6.7 in the pistillate stage, 16.7 ± 8.4 in the staminate stage, and 27.7 ± 22.5% with fully developed florets. In the central region (sites 5–11) flowering was less advanced: mean flowering performance here was 8.9 ± 6.9 at floret emergence, 8.8 ± 7.5 pistillate, 9.8 ± 10.2 staminate, and 6.2 ± 7.5% at full panicle development. This group was the most variable; the stand at site 5, for example, was noticeably later than adjacent stands. In the west (sites 12–20) most plants were still in the early stages of flowering, the group means being 9.4 ± 7.9 at floret emergence, 2.7 ± 3.5 pistillate, and 2.8 ± 5.0% staminate, with only 1.8 ± 3.3% having reached full panicle development. Although all stages of flower development were significantly related to

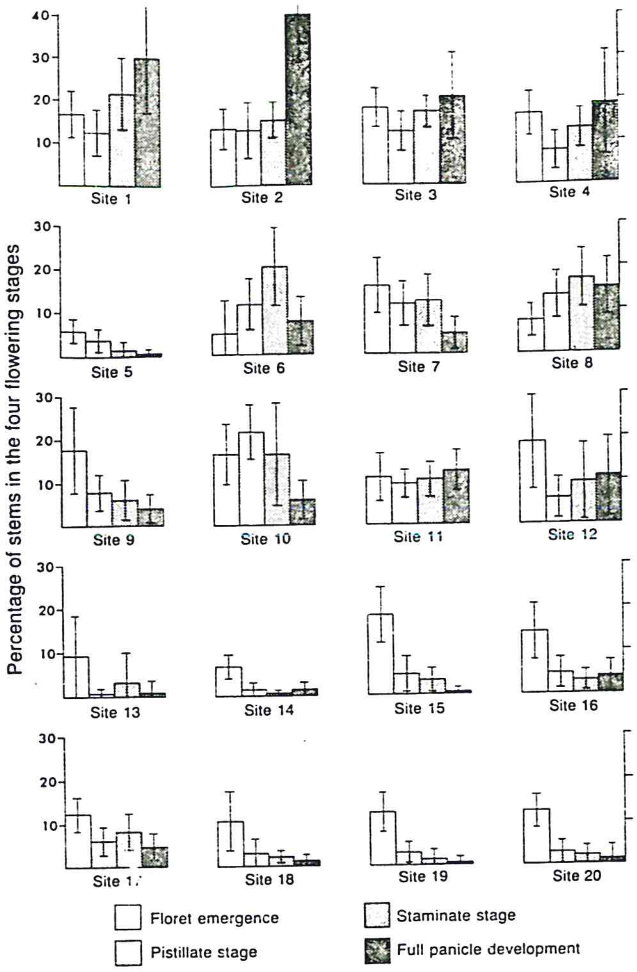

FIG. 4. Mean percentage of stems in each of the four flowering stages in late July. The east–west gradient and standard deviations of the mean are given.

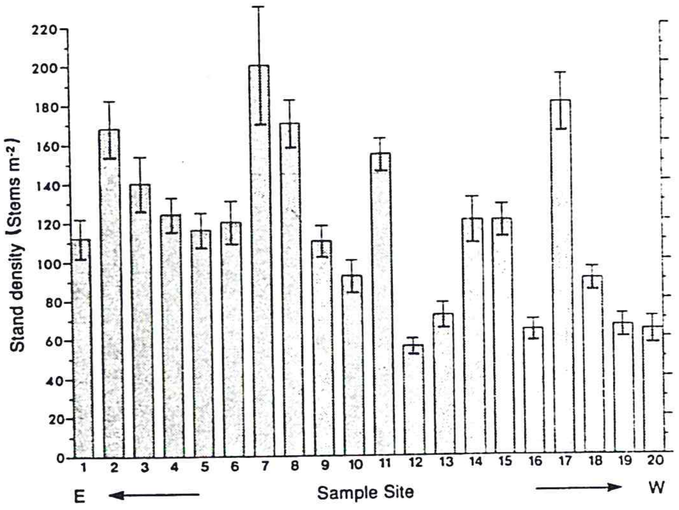

FIG. 5. Mean stem density across the province in late August. The east–west gradient and standard deviations of the mean are given.

longitude, the relationship was strongest for the staminate and fully developed stages (Table 1). Flowering in the more northerly sites was also delayed with the number of panicles fully developed exhibiting a negative correlation with latitude ($r = -0.482$, $p < 0.05$).

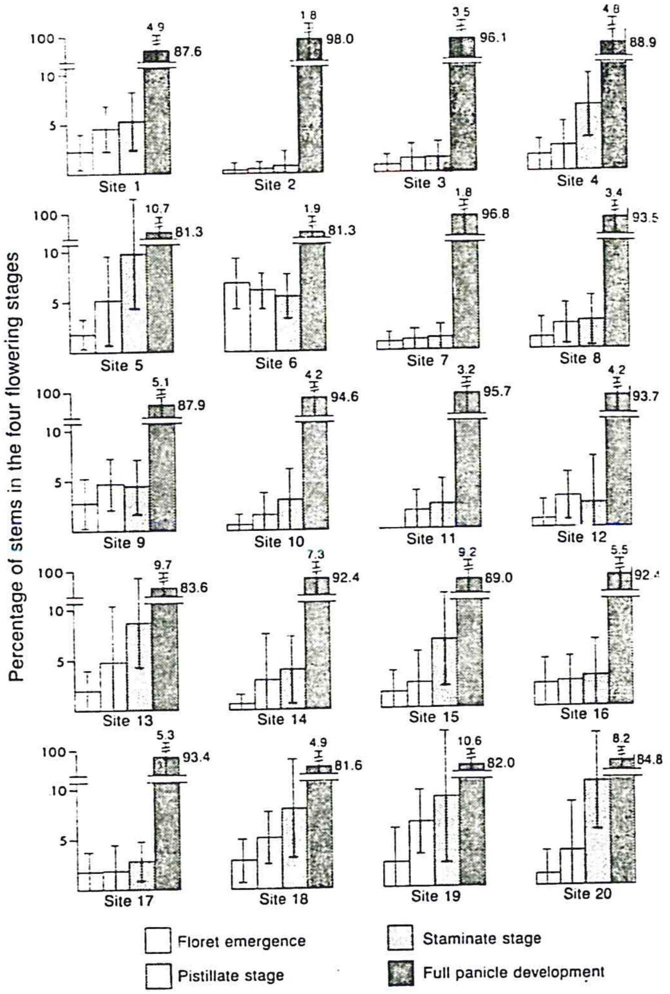

FIG. 6 Mean percentage of stems in each of the four flowering stages in late August. The east–west gradient and standard deviations of the mean are given.

Mean stem densities at the end of August are shown in Fig. 5; these ranged from 57 ± 3 at site 12 to 207 ± 25 stems m^{-2} at site 7. At all sites the mean stem density of the wild rice stands had increased as a result of tillering and through the elongation of stems previously below water level. The percentage increase in mean stem density between July and August ranged from 3% at site 14 to 116% at site 6. Large increases were also recorded at sites 9, 10, and 13. Flowering data for August are presented in Fig. 6. Despite the significant increase in mean stem density during August, the overall flowering rate was very close to 100% at all sites. The highest percentage of stems which were fully developed was recorded at site 2 (98.0%), with 96.8 recorded at site 7 and 96.1% at site 3. Conversely, the lowest percentage was recorded at site 5 (81.3%), with sites 6, 18, 19, and 20 generally later than the other sites. This pattern was again significantly correlated with longitude (Table 1), although the latitudinal component was now absent.

The structure of the wild rice plants varied considerably with respect to the number of tillers arising from both the basal root plate and from nodes higher up the stem (Fig. 7). At site 7, 97% of the plants consisted of single stems. Similarly, over 94% of the stands at sites 2 and 17 was accounted for by

TABLE 1. Correlation coefficients between stand characteristics and latitude and longitude ($n = 20$)

	Latitude	Longitude
July		
Stem density	−0.095	−0.196
Floret emergence	−0.344	−0.368*
Pistillate stage	−0.197	−0.499**
Staminate stage	−0.273	−0.541**
Full panicle development	−0.482**	−0.643**
Total stems in flower	−0.061	−0.643**
August		
Stem density	−0.061	−0.460
Floret emergence	−0.022	0.039
Pistillage stage	−0.004	0.239*
Staminate stage	−0.034	−0.354*
Full panicle development	0.078	−0.234*
Total stems in flower	−0.059	−0.376*

NOTE: *, $p < 0.05$; **, $p < 0.01$.

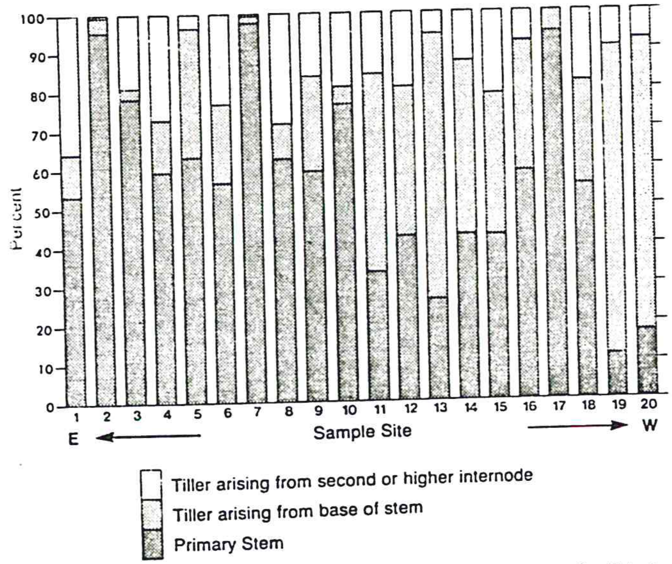

FIG. 7. The importance of tillering in the composition of wild rice stands across Saskatchewan. The east–west gradient and standard deviations of the mean are given.

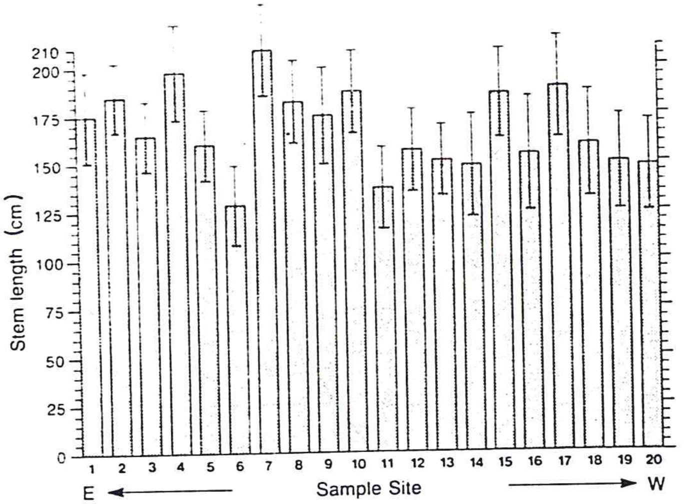

FIG. 8. Mean length of all wild rice stems growing at each sample site. All measurements were made to the root mass; for stems arising from the second or higher nodes the additional distance to the root mass was added. The east–west gradient and standard deviations of the mean are given.

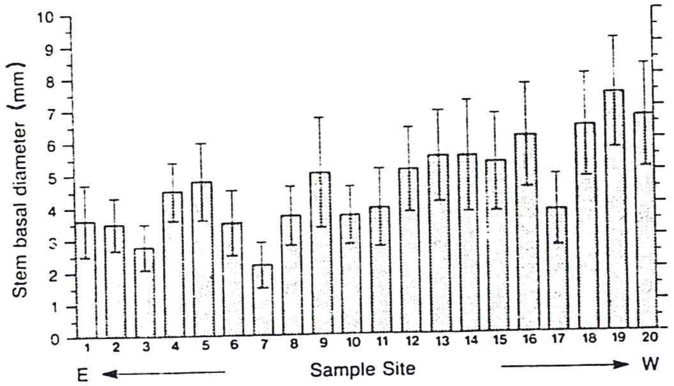

FIG. 9. Mean basal stem diameter. Stems arising from the second or higher nodes were not included in these measurements. The east–west gradient and standard deviations of the mean are given.

single-stemmed plants. However, at site 19 most of the stems (79%) arose from the basal plate; this was also the case at sites 20 (75%), 13 (68%), and 11 (51%). At the remaining sites the primary shoots comprised the highest percentage of the stand, but whereas in the eastern part of the study region these were generally supplemented by tillers arising from the second or third nodes, in the west tillers arising from the basal plate were more abundant. Overall tillering activity was strongly related to longitude ($r = 0.496$, $p < 0.01$). The maximum number of tillers developing partway along the stem was 3 per plant (recorded at sites 11, 13, 15, and 19), but as many as 11 tillers growing from the stem base were found on individual plants at site 20 and up to 10 were found on plants at site 19.

The average length of the plant stems can be seen in Fig. 8. The tallest stems were found at sites 7 (207 ± 24 cm) and 4 (197 ± 26 cm); the shortest occurred at sites 6 (127 ± 22 cm), 11 (137 ± 22 cm), and 20 (147 ± 24 cm): no significant geographic trends were evident in stem length. However, plants in the eastern part of the study region produced more slender stems than those in the west (Fig. 9). Basal diameters were smallest at sites 7 (2.2 ± 0.7 mm) and 3 (2.8 ± 0.7 mm), with the largest stems found at sites 19 and 20 having diameters of 7.4 ± 1.7 and 6.7 ± 1.6 mm, respectively. This pattern of variation was significantly correlated with longitude ($r = 0.476$, $p < 0.05$).

Ovendry aerial and root biomass are presented in Fig. 10. The largest plants were found at sites 19 and 20 with mean aerial biomass of 42.2 ± 14.4 and 25.2 ± 15.3 g, respectively; corresponding root biomass was 26.2 ± 25.2 and 10.3 ± 8.1 g. Plants from site 13 were also comparatively large with mean aerial biomass of 16.7 ± 13.2 and a mean root biomass of 5.6 ± 4.2 g. Plants in the western region were generally larger than those from the eastern and central regions, where aerial biomass was typically less than 5.0 g. The smallest plants, with mean aerial biomass of 1.7 ± 0.9 g, were found at site 7. Mean root biomass throughout the study region was 1.7 ± 3.1 g, the variation being largely accounted for by the bulky root masses previously noted for sites 13, 19, and 20.

Figure 11 shows the average number of female florets per plant and, assuming complete pollination, would therefore indicate the maximum number of seeds that potentially could be

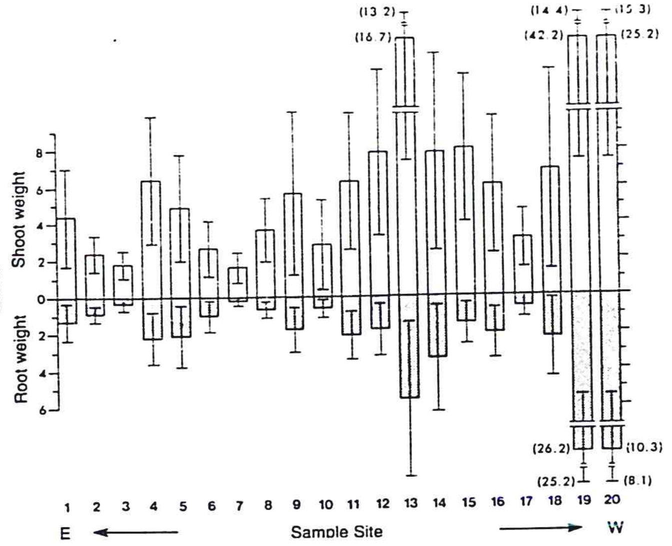

FIG. 10. Mean ovendry shoot and root biomass for entire wild rice plants. The east–west gradient and standard deviations of the mean are given.

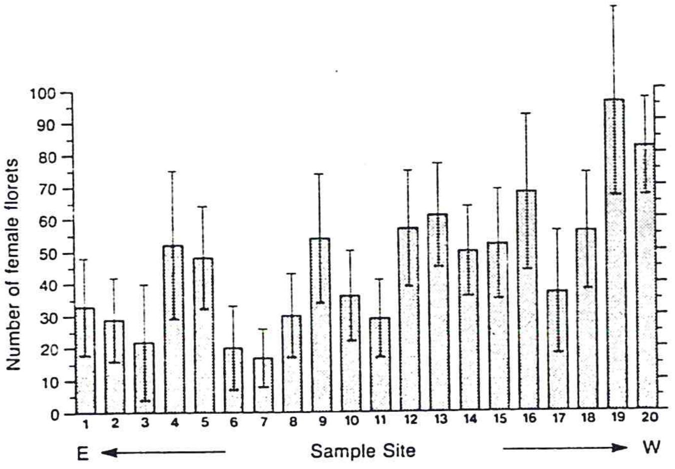

FIG. 11. Mean number of female florets per stem. The east–west gradient and standard deviations of the mean are given.

produced. Plants at site 19 produced the largest number of florets, with a mean count of 96 ± 29 per panicle. At site 20 the mean count was 82 ± 15, decreasing to 68 ± 24 at site 16 and 61 ± 16 at site 13. The lowest mean number of florets occurred at site 7 with only 17 ± 9 florets per panicle; low values also were recorded at sites 6 and 3 (20 ± 13 and 22 ± 18 florets per panicle, respectively). This pattern was strongly correlated with longitude ($r = 0.632$, $p < 0.01$). The dry weights of the seeds are presented in Fig. 12. The heaviest seed was found at site 11 with a mean weight of 52 ± 1 mg. Sites 1 and 8 similarly produced heavy seed, with mean weights of 50 ± 1 and 50 ± 2 mg, respectively. At most of the remaining sites average seed weight was in excess of 40 mg, with a range of standard deviations from 1 to 4 mg. However, at site 2 unusually small seeds weighing only 25 ± 1 mg were produced.

An estimate of the potential commercial yield of seed at each site is given in Fig. 13. The most productive stand was at site 15 with a potential commercial yield averaging 3342 ± 222 kg ha^{-1}. Although the sites in the west were potentially the most productive, high-yielding sites were found throughout the study region. At site 4 the potential commercial yield was estimated at 3205 ± 419, at site 5, 2959 ± 220, at site 9, 27 ± 587, and at site 8, 2734 ± 366 kg ha^{-1}. Stands with the lowest potential commercial yield were found at sites 3, 2, and 6 (1133 ± 214, 1159 ± 182, and 1303 ± 411 kg ha^{-1}, respectively). At sites 3 and 6 this resulted from the small number of florets per flower head, while at site 2 it reflected the light weight of the seed. Site 12 was also low at 1358 ± 268 kg ha^{-1}; here the stand was rather open with a mean density of only 57 stems m^{-2}. Despite this marked variation, potential commercial yield exhibited a significant longitudinal gradient ($r = 0.434$, $p < 0.05$).

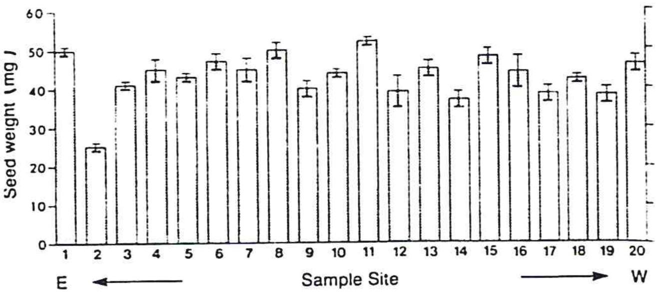

FIG. 12. Mean ovendry seed weight at each sample site. The east–west gradient and standard deviations of the mean are given.

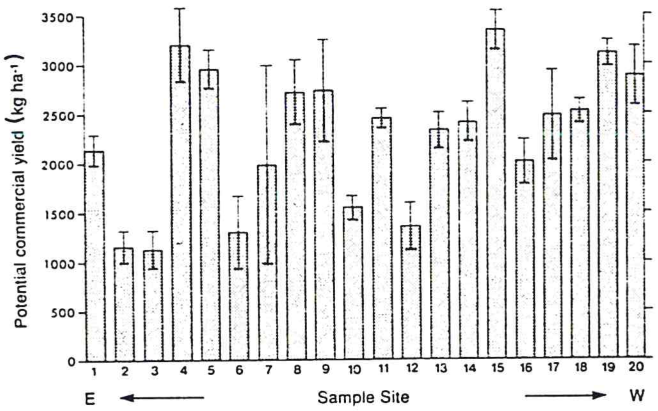

FIG. 13. Potential yield of wild rice based on mean stem density in August, mean floret number, and mean ovendry seed weight. The east–west gradient and standard deviations of the mean are given.

At the end of July water temperatures averaged 20.3 ± 1.0°C in the eastern part of the study region (sites 1–4). In the central region (sites 5–11) the mean water temperature was 20.6 ± 1.3°C, while in the west (sites 12–20) the water was somewhat cooler at 19.5 ± 1.6°C. Water depth varied markedly between sites, ranging from a mean of 1.38 ± 0.16 at site 7 to 0.50 ± 0.07 m at site 11. The water was slightly alkaline in the western region, where pH averaged 7.6 ± 0.4, but was as high as 9.28 ± 0.1 at site 20. Approximately neutral conditions were recorded in the central (pH 7.3 ± 0.5) and eastern regions (pH 7.2 ± 0.4). Similarly, the conductivity of the water was lowest in the central region, where a mean reading of 96 ± 49 μS cm^{-1} was recorded. Mean conductivity increased to 126 ± 21 in the east and 149 ± 46 μS cm^{-1} in the west. However, only water temperature and water depth were correlated to longitude with coefficients of −0.498 ($p < 0.01$) and −0.402 ($p < 0.05$), respectively. No significant relationship with latitude was detected.

TABLE 2. Matrix of correlation coefficients between plant morphological characteristics and stem density in August ($n = 20$)

	Stem length	Stem basal diam.	No. of basal stem tillers	No. of nodal stem tillers	Root biomass	Shoot biomass	No. of female florets	Seed weight
Stem basal diam.	−0.45*							
No. of basal stem tillers[a]	−0.44*	0.70**	—					
No. of nodal stem tillers[b]	−0.48*	0.35**	0.54**	—				
Root biomass	−0.34	0.68**	0.95**	0.51**	—			
Shoot biomass	−0.37*	0.75**	0.99**	0.53**	0.97**	—		
No. of female florets	−0.32	0.95**	0.79**	0.34	0.78**	0.85**	—	
Seed weight	0.13	0.08	−0.03	0.48*	−0.13	−0.07	−0.11	—
August stem density	0.53**	−0.78**	−0.53**	−0.35	−0.47*	−0.56**	−0.78**	−0.03

NOTE: *, $p < 0.05$; **, $p < 0.01$.

[a] Tillers arising from the basal plate.

[b] Tillers arising from the second or higher nodes.

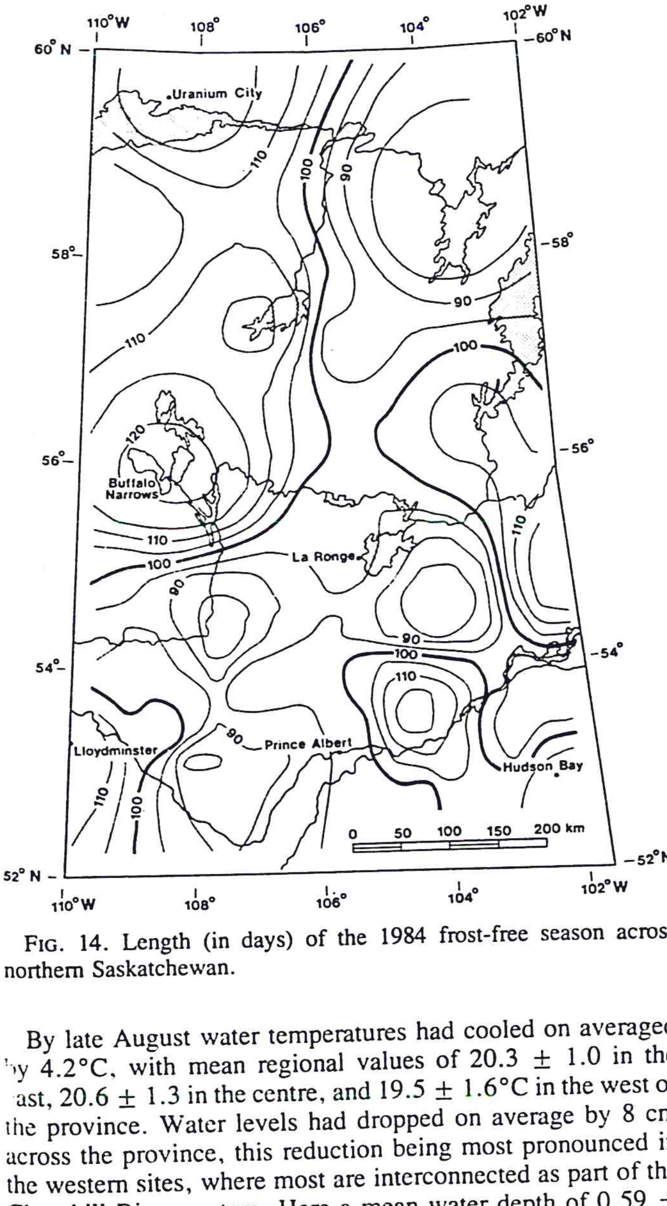

FIG. 14. Length (in days) of the 1984 frost-free season across northern Saskatchewan.

By late August water temperatures had cooled on averaged by 4.2°C, with mean regional values of 20.3 ± 1.0 in the east, 20.6 ± 1.3 in the centre, and 19.5 ± 1.6°C in the west of the province. Water levels had dropped on average by 8 cm across the province, this reduction being most pronounced in the western sites, where most are interconnected as part of the Churchill River system. Here a mean water depth of 0.59 ± 0.16 m was recorded; in the east of the province water depths averaged 0.91 ± 0.12 and in the central regions 0.94 ± 0.29 m. August pH readings dropped throughout the region averaging 7.2 ± 0.4 in the east, 7.3 ± 0.6 in the centre, and 7.6 ± 0.4 in the west. Conversely, conductivity increased during August with mean values of 110 ± 31 in the east, 149 ± 52 in the centre, and 198 ± 61 $\mu S\ cm^{-1}$ in the west. Regional trends in water properties were more pronounced in August and significant correlations with longitude resulted for depth ($r = -0.532$, $p < 0.01$), pH ($r = 0.396$, $p < 0.05$), and conductivity ($r = 0.560$, $p < 0.01$).

Analysis of weather data indicated that spring frosts occurred latest in the northeast part of the province, with below-freezing temperatures recorded at Reindeer Lake as late as June 12. The first autumn frosts occurred approximately 2 weeks earlier in the east side of the province. Consequently, the frost-free season was some 15 to 20 days longer in the west, exceeding 120 days at Buffalo Narrows (Fig. 14). Cumulative growing degree-days (GDD) for the growing season in the western and central areas were similar, with 1155 GDD recorded both at Buffalo Narrows and La Ronge. Heat accumulation in the area to the east of La Ronge was somewhat lower at 915 GDD, although this increased to 1100 GDD in the Cumberland House district in the southeast corner of the region. Approximately 62% of the regional heat accumulation for the growing season had been received by the end of July when the initial fieldwork was conducted.

Discussion

The interrelationships between the various plant characteristics are shown in Table 2. Shoot length was not significantly associated with either the number of female florets on the panicle or the weight of the seeds. This may be due to the fact that additional stem elongation simply reflects the necessity for shoots to emerge above the surface of the water should water levels rise during the growing season. However the other measures of robustness, including stem basal diameter, and shoot and root weights were strongly correlated with the number of seeds per panicle, although no such relationship was detected for seed weight. Increased plant performance was related to tillering activity; tillers arising from the base of the stem were significantly correlated with the number of florets borne on a panicle.

The morphology of wild rice grown in northern Saskatchewan is similar to that reported for the species elsewhere. However, the mean ovendry seed weight reported here, 43 mg, is somewhat heavier than that recorded in Ontario: Garrod (1984) reported a mean seed weight of 31 and Counts (1984) a maximum seed weight of 25 mg. This is consistent with an acknowledged latitudinal cline of larger seeds in more northerly sites (Lee 1979) which is attributed to the relative predominance of *Z. palustris* L. var. *palustris* Dore farther north. Within a given species, seed weight is considered to be the

TABLE 3. Correlation coefficients between plant characteristics and environmental parameters in August (n = 20)

	Depth	Temp.	pH	Conductivity	GDD
Stem length	0.76**	−0.06	−0.18	−0.15	−0.27
Stem basal diam.	−0.75**	−0.20	0.58**	0.47*	0.20
No. of basal stem tillers[a]	−0.59**	0.14	0.58**	0.43*	0.25
No. of nodal stem tillers[b]	−0.38*	0.17	0.20	0.19	−0.05
Root biomass	−0.47*	0.10	0.59**	0.27	0.24
Shoot biomass	−0.55**	0.16	0.60**	0.41*	0.21
No. of female florets	−0.63**	−0.15	0.61**	0.46*	0.16
Seed Weight	0.05	0.07	−0.13	−0.10	−0.15
Potential yield[c]	−0.32	−0.13	0.48*	0.32	0.01
August stem density	0.59**	0.13	−0.35	−0.36	0.00

NOTE: *, $p < 0.05$; **, $p < 0.01$.

[a] Tillers arising from the basal plate.

[b] Tillers arising from the second or higher nodes.

[c] Assuming 100% pollination and floret maturation.

TABLE 4. Correlation coefficients between flowering stages in July and stem density and environmental parameters (n = 20)

	Floret emergence	Pistillate stage	Staminate stage	Full floret development	Total stems in flower
Stem density (July)	−0.28	0.25	0.08	0.26	0.59**
Depth	−0.45*	0.51*	0.38*	0.15	0.47*
Temperature	−0.40*	−0.06	0.07	0.66**	0.54**
pH	0.49*	−0.70**	−0.53**	0.01	−0.23
Conductivity	0.67**	−0.28	−0.79**	−0.34	−0.27
GDD	−0.34	0.67**	0.42*	−0.15	0.00

NOTE: *, $p < 0.05$; **, $p < 0.01$.

least plastic characteristic of a plant (Harper 1977) showing, as in this study, relatively little variation compared with most other morphological traits. These data also tend to confirm earlier conclusions (Weichel and Archibold 1984*b*) that specimens matching the taxonomic descriptions of both *Z. palustris* L. var. *palustris* Dore and *Z. palustris* L. var. *interior* (Fassett) Dore can be found in Saskatchewan and that there is an identifiable eastward gradient of decreasing plant robustness.

Considerable within-stand variation for several phenological and morphological characteristics has been shown to occur. Subsequent analysis for between-site variation was carried out using analysis of variance; for every plant characteristic the resulting *F*-value was highly significant ($p < 0.01$). The effects of environmental variables on plant performance are presented in Table 3. Greater water depth clearly exerted the anticipated negative effects on robustness, tillering, and the capacity of shoots to produce seeds (Rogosin 1958; Dore 1969; Counts 1983). Interestingly, high density was positively correlated with depth, thereby offsetting lower potential seed production per panicle and reducing the significance of the relationship between depth and potential commercial yield per unit area. Both pH and conductivity, as indicators of general nutrient status of the water bodies (Wetzel 1975), were shown to be positively correlated with increased performance. Neither water temperature nor growing degree-days appeared to have any significant effect on plant morphology or seed production. However, interpretation of the results is restricted by the fact that only two visits were made to each site. As well, climatic conditions were not monitored at the specific study sites; hence growing degree-days could only be estimated by interpolation.

A significant correlation ($r = -0.454$, $p < 0.05$) was found between stem density in July and percent increase in stem density between sampling periods. Also a strong relationship was detected between July and August stem densities ($r = 0.832$, $p < 0.01$). Thus stands which were thinnest in late July, while they exhibited the greatest increase in stem density, remained the thinnest in late August. However, these open stands characteristically produced higher numbers of female florets per panicle, with a correlation of $r = -0.781$ ($p < 0.01$) resulting for stem density in August with floret number. Late-July density is included in Table 4, where along with water depth and temperature, it is significantly correlated with a higher proportion of stems already in flower; lower pH and lower conductivity are similarly associated with earlier flowering, diminished vegetative development, and reduced seed production potential (Table 3).

Conclusion

This research has shown that noticeable differences exist within and between stands of wild rice presently established in Saskatchewan. High-yielding plants were characteristic of sites 11 and 15, whereas site 2 was distinguished by early maturity. Such variations could reflect the combined effects of genotypic heterogenity and phenotypic plasticity in response to local environmental conditions. The underlying cause of such differential growth and performance might be established using trial seedings under uniform habitat conditions. Careful selection of genetically different seed could form an important initial step in more reliable seeding programmes in the province. In areas where the risk of early fall frost is low, the use of higher yielding forms would benefit the industry. In areas with a marginal climate early maturity would be a desirable quality that might optimize long-term yields.

Acknowledgments

We thank Mr. Pab. Orcajada, wild rice agrologist with Saskatchewan Agriculture, for making funds available for this study, Ms. A. E. Paterson for assisting with the computer analysis, and Mr. Keith Bigelow for the cartographic work.

Archibold, O. W., B. J. Weichel, and J. E. Fitzgibbon. 1985. Factors in the ecology of wild rice in northern Saskatchewan. Can. Geogr. **29**: 100–112.

Counts, R. 1983. Variations in the growth of wild rice in Ontario. The aquaculture of wild rice: progress year 2. *Edited by* P. F. Lee. Biology Department, Lakehead University, Thunder Bay. pp. 66–85.

——— 1984. Variation in wild rice in Ontario. The aquaculture of wild rice: progress year 3. *Edited by* P. F. Lee. Biology Department, Lakehead University, Thunder Bay. pp. 172–224.

Dore, W. G. 1969. Wild-rice. Can. Dep. Agric. Res. Branch, Publ. No. 1393.

Garrod, R. C. 1984. Ecology of wildrice (*Zizania palustris* L.): fruit production and habitat relationships. M.Sc. thesis, Department of Botany, University of Manitoba, Winnipeg.

Hare, F. K., and M. K. Thomas. 1979. Climate Canada. Wiley, New York.

Harper, J. L. 1977. Population biology of plants. Academic Press, London.

Lee, P. F. 1979. Biological, chemical and physical relationships of wild rice, *Zizania aquatica* L., in northwestern Ontario and northeastern Minnesota. Ph.D. thesis, Department of Botany, University of Manitoba, Winnipeg.

Rogosin, A. 1958. Experimental growth of wild rice in relationship to water levels, seeding densities and fertiliser application. Proc. Minn. Acad. Sci. **25**: 95–97.

Weichel, B. J. 1985. An evaluation of habitat potential for wild rice (*Zizania palustris* L.) in northern Saskatchewan. M.Sc. thesis, Department of Geography, University of Saskatchewan, Saskatoon.

Weichel, B. J., and O. W. Archibold. 1984*a*. Habitat potential of wild rice (*Zizania palustris*) in northern Saskatchewan. Wild rice research in Saskatchewan. Report No. 3. Department of Geography, University of Saskatchewan, Saskatoon.

——— 1984*b*. Wild rice—environment relationships and the regional potential for northern Saskatchewan. Saskatchewan Wild Rice Research 1984. Saskatchewan Department of Agriculture, Regina. pp. 4–32.

Wetzel, R. G. 1975. Limnology. Saunders, Philadelphia.