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# A GUIDE TO WILD RICE PRODUCTION

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A Guide to Wild Rice Production

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# INTRODUCTION

Wild rice is native to Manitoba and attracts much interest because of its history and potential economic value. This production handbook provides information to prospective growers of wild rice. The Governments of Canada and Manitoba have cooperated in supporting this publication financially.

## Historical Background

Wild rice is known to have grown since prehistoric times with the discovery of preserved wild rice grains in excavations. Known prehistoric growing areas include the Mississippi headwaters of Minnesota.

Research has also shown that North American Indians actively produced wild rice in North America. The Indians used the rice as an important dietary source. Cree Indians who lived east of Lake Winnipeg and Ojibwa Indians who replaced them, both produced wild rice. The Indians introduced the European fur traders to wild rice.

Today, most wild rice in Manitoba is produced on Crown Lands which are leased to wild rice producers.

Until recent times, only naturally growing wild rice was available for harvest. Management of lakes and streams, seeding, and thinning of crops were unknown. As harvest time approached, Indians would scout for productive areas.

Whole families took part in the harvest which lasted about three weeks. One person paddled the canoe while another harvested. The harvester had two sticks, with one the high straw was bent over the canoe and a light blow with the other caused the ripe grain to fall into the canoe. Immature kernels remained in the heads. Care was taken not to break the straw so that harvesters could return several days later to collect more ripe grain. A yield of 56 kg/ha (50 lbs/acre) of grain can be harvested by this method. The remainder of the grain would fall into water to reseed the lake or stream.

The Great Lakes Indians employed three different methods of curing the mature green wild rice: prolonged sun drying, smoking and heating over a slow fire, and parching in a vessel.

Parching was accomplished by heating the green wild rice on a rack of willows or in a large open kettle. The parched wild rice was put into stone or clay hollows lined with clean new skins, where boys "danced the rice" so the outer husk was loosened. The husk was separated from the grain by placing the rice in birch bark dishes. Then, it was tossed into the air for the wind to blow away the husks. Some Chippewas and Menomini used flailing to dehull the rice although treading was preferred.

As the demand for wild rice grew, a number of white men in the rice district began to buy processed wild rice from the Indians. Buyers frequently encountered complaints about the variable nature of rice so they began to buy it "green" and process it themselves. In some cases they sold it to processors.

Processors in the United States bought Canadian green wild rice from the pickers. Pickers, or harvesters, had little control of the market, as dealers, processors and cooperatives directed the industry.

## Paddy Wild Rice Development

Attempts to grow wild rice as a cultivated crop in Minnesota began in 1950. By 1958, there were 50 hectares (120 acres) dyked for growing wild rice. Uncle Ben, Inc. started contracting for wild rice in 1965.

Wild rice is grown as a field crop primarily in Minnesota, with some paddies in Wisconsin, Northern California, southeastern Manitoba and northwestern Ontario. Wild rice paddy construction expanded rapidly in Minnesota from 1968 to 1973, but declined sharply in 1977 due to cost/price comparison, dry years and problems with insects and diseases. Paddy production in Manitoba has not developed beyond trial commercial ventures in part due to a lack of research funding, and also the abundant natural wild rice stands.

Early paddies were planted with seed collected from the wild rice growing lakes. Floating harvesters, similar to those developed for lake harvesting were used. Later, following selection and establishment of shatter resistant varieties, the paddies were drained before harvesting and combines were used to harvest the grain.

Paddy production has made the supply of wild rice more dependable and research has reduced the risk of crop failure. However, a stabilized price above the cost of production has not been assured.

## Botany

### Nomenclature

English explorers called the aquatic plant wild rice or Indian rice, while the French saw the resemblance to oats and called it folle avoine. Wild rice, the common name for the plant, belongs to the grass family. It is of the genus *Zizania*, a different but closely related tribe to rice which belongs to the genus *Oryza*. Wild rice is not closely related to oats of the genus *Avena*.

Some confusion about the naming of the species exists. Four species, *aquatica, palustris, texana* and *latifolia,* are written about but in other references, *aquatica* and *palustrics* are considered one species, as they interbreed and are not distinct.

The northern wild rice, of interest in this publication, is called *Zizania palustris L.*, or *Zizania aquatica var. angustifolia* Hitchcock. Fassett further divided the species *palustris* into the varieties *palustris* and *interior*, the former having narrower leaves and growing in deeper water than the latter. *A. palustris var. interior* (Fasset) Dore grows on muddy shores and in water up to 30 cm (1 foot) deep along rivers in southeastern Manitoba, northwestern Ontario, New Brunswick and the North Central States. This variety is also known as *Z. aquatica var. interior* Fassett.

### Distribution

*Zizania aquatica* (including *Z. palustris*) distributed extensively in eastern North America, reaching from the northern end of Lake Winnipeg, eastward along the northern shore of the Great Lakes and the St. Lawrence River to eastern New Brunswick, from the central

Dakotas, western Nebraska and eastern Texas to the Atlantic Ocean, and along the coast as far south as Florida. It also appears in places west of this range, such as at Lac la Ronge, Saskatchewan and in the Rocky Mountains.

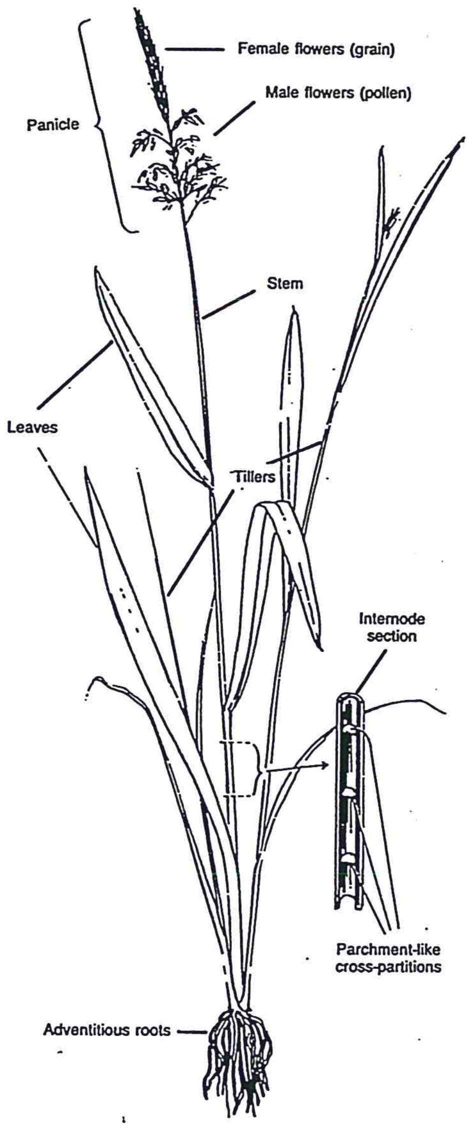
*Zizania aquatica var. aquatica* is the original variety identified by Linnaeus as *Z. aquatica*. Commonly called southern wild rice, it grows in natural stands along the St. Lawrence River, eastern and southeastern U.S. coastal areas, and south into Louisiana. Its seeds are very slender and are not harvested for food. *Z. aquatica var. brevis* Fassett grows on the tidal flats of the St. Lawrence estuary, and is also known as estuarine wild rice.

The species *Z. texana* Hitchcock and *Z. latifolia* (Grisec) Turcz are perennials, the former native to a small area of Texas, and the latter native to Asia.

### The Plant and Its Life History

Wild rice is an annual aquatic grass with a terminal panicle made up of unisexual spikelets (Figure 1). Cross pollination normally occurs because the female flowers become pollinated before the male flowers on the same panicle have released their pollen.

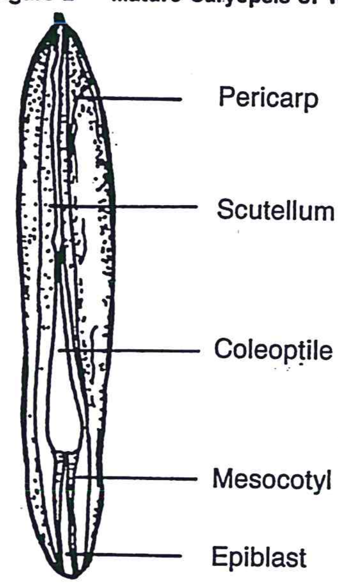
**Figure 1 — The Wild Rice Plant.**




In late August, and throughout September, the ripe grain falls from the plant into the water and sinks by its own weight, pointed end first. The barbs or bristles on the lemma and awn attach the kernel to the soft mud. It becomes buried out of the sight of the waterfowl which would feed upon it. The seed remains dormant over winter and germinates in spring.

The wild rice fruit is a caryopsis which is a single seed fused with the wall of the ripened ovary (pericarp) to form a seed-like grain (Figure 2). The seed is 1 to 1.5 cm (0.4 to 0.6 inches) long. The caryopsis structure of wild rice is similar to kernels of other cereal grains, the large endospern surrounded by a thin layer of pericarp and aleurone. The embryo which contains a cotyledon, or seed leaf is at the caryopsis' base. The endosperm makes up 77 percent of the caryopsis, the hulls (lemma and palea) 14 percent, the pericap four percent and the embryo four percent.

**Figure 2 — Mature Caryopsis of Wild Rice.**




Wild rice seeds need three to four months storage in cold (2°C) water before they germinate. During this time the seed is dormant. Dormancy is caused by an impermeable and tough outer covering, and by an imbalance of growth promoters and inhibitors.

The seed can be forced to germinate without going through the long dormancy period by removing (scraping) the pericarp directly above the embryo. These scraped seeds must be germinated in water and the resulting seedlings transplanted.

A sprouted embryo is called a seedling. A hypocotyl covered by a sheath emerges through the pericarp toward the base of the seed to provide the first evidence of germination.

The hypocotyl, which grows into a root, is below the point of attachment of the cotyledon. The coleoptile emerges later and includes the epicotyl which develops into the shoot. The single primary root grows from the base of the seed about seven to ten days after the coleoptile emerges. The primary root system dies when the permanent root system (adventitious roots, Figure 1) develops.

Buds are located at the juncture of the stem and leaves, and if they appear elsewhere on the stem are called adventitious. The node is the point on a stem where a bud grows. The length of stem between two successive nodes is an internode. The first internode of the germinated wild rice seed elongates up to 5 cm (2 inches), allowing wild rice seedlings to emerge through 7.5 cm (3 inches) of flooded soil. There is little first internode elongation if the seeds germinate in water. Adventitious roots grow from the first node and occasionally the second and third nodes.

The first seed plant stem develops from the epicotyl, or shoot apex. The terminal bud terminates in an inflorescence, or panicle (Figure 2). Germination takes place about the middle of May or early June, and floating leaves appear on the surface of the water by mid-June. The first three leaves produced remain submerged. Their surfaces have no wax and they are narrow, limp and delicate in texture.

The next two leaves float on the water surface and are waxy. In early July, up-right aerial leaves appear and extend above the water, the seedling foliage withers and disappears. Until the aerial leaves, which can eventually number three to five, appear, the plant is extremely susceptible to a sudden rise in water level. Drowning can result.

Aerial leaves have a waxy surface. Blades vary in length from 40 to 76 cm (16 to 30 inches) and are about 2.5 cm (1 inch) wide. Stem diameter varies from 0.5 to 1.2 cm (0.2 to 0.5 inches) depending on the variety, plant density, fertility level and water depth. Plant height also depends on water depth, for example a plant growing in 60 cm (2 feet) of water may be 1.2 m (4 feet) from base to flower heads. The lower internodes of the stem are about 30 cm (1 foot) while the top one can be 75 cm (2½ feet). The upper three to five internodes of the mature stem are hollow and divided by their parchment-like partitions. These provide water tight compartments which enhance buoyancy of the stem.

**Tillers:** Up to 50 tillers per plant can be produced from the basal node of the main stem and tiller stems. Many tillers have panicles. In paddies, plants will have three to six tillers, with a plant population of 40 plants/$m^2$ (4 plants/$ft^2$). Their root system is shallow with a spread of 20 to 30 cm (8 to 12 inches).

**Flowering Plants:** Flowering plants may be found from the middle of July through August. The spikelets occur on a terminal panicle and are uni-sexual and one-flowered. The pistillate (female) spikelets are on the upper, nearly erect branches of the panicle, close to the stem, with the pendulous staminate (male) spikelets on the lower branches.

Maturation proceeds from the tip downwards and each pistillate spikelet remains fertile for three to four days, so not all grains in one panicle mature at once.

The staminate spikelets shed pollen just as the last pistillate spikelets have been pollinated. This makes self-pollination very unlikely. The panicle averages 45 to 50 cm (18 inches to 20 inches) with the seed bearing (female) part being 25 to 30 cm (10 to 12 inches). The staminate (male) inflorescence with 12 to 15 branches are wide spreading, about 10 cm (4 inches) long with 50 to 60 staminate florets per branch.

Wild rice is ready for harvest the last half of August and into September. A growing season of 106 to 130 days depending on growing season temperatures and variety, is required. Canadian lake types of wild rice planted in Minnesota mature two to three weeks earlier than Minnesota varieties. When the base temperature of 4°C is used to calculate growing degree days, wild rice requires a minimum of 1600 growing degree days to mature, according to Minnesota findings.

**Habitat:** Wild rice is found along the borders of sluggish streams, in marshes and shallow lakes. It is adapted to marginal soils, a growing season considered normal in eastern Manitoba, and needs an ample water supply.

The prime requirement is a suitable water depth. Northern wild rice is often found in water as deep as 60 to 200 cm (2 to 6 feet). In deeper water, plants do not grow or tend to be slender, single stemmed and widely spaced. They are weaker and flower later.

Where the water may be 15 to 30 cm (6 to 12 inches) the plants grow densely together, have several tillers from each root, and produce ample panicles. Severe losses in natural stands have resulted from flooding in mid-summer. A sudden drop in the water level in mid-season can cause plants to topple over and lodge. However, a gradual decline in water level during the latter part of summer is not detrimental to production.

The lakes in which wild rice is found are broadenings of otherwise regular river channels, where there is always a certain flow of water. Small landlocked lakes and still ponds are seldom locations of wild rice. Wild rice needs a constant flow and gentle movement of water.

Streams and rivers containing deep, loose soil, well supplied with mineral salts and other nutrients are needed by the wild rice plant. Brackish water that contains so much salt that it can be tasted is not good for wild rice culture.

**Sediment:** For wild rice growth, mud, sand or gravel can be the sediment under the water — bare and rocky sediment can support growth. The densest beds are found in soft textured sediments such as silts, muds and oozes. Anything which cultivates or disturbs the bottom sediments increases the oxygen supply needed for root system development.

**Water Quality:** Turbid water eliminates the light required by the newly germinated seed. It is also an attractive environment for competing plants. Hard, carbonate water is a good medium, but no species are listed for alkali waters. The soil and water west of Lake Winnipeg are alkaline, not conductive to wild rice growth. Marl lakes, containing lime, are unsuitable for wild rice because the high pH levels make the iron and manganese unavailable to the plant. Plants will die if summer heat dries the habitat. Excessive heat speeds up development of the plant and results in seeds too small for good food usage.

# PADDY WILD RICE DEVELOPMENT AND PRODUCTION

## Production Zone Characteristics

### Location

The major natural stand producing areas in Manitoba are east of Lake Winnipeg and the Red River, from the United States border on the south to the 53rd parallel north. Wild rice has been found in some areas west of this zone. (Figure 3). Paddies situated where wild rice is presently found would be a logical extension of the natural habitat. Large areas of organic, or peat soils and class 3 or higher soils are present. Class 3 soils have moderately severe limitations that restrict the growth of a wide range of crops. As the class number increases, the limitations become more severe.

Inexpensive and marginal land has been used successfully in both Manitoba and Minnesota for wild rice production. Guidelines for Paddy site selection are:

- level topography
- water availability
- drainage availability
- workable soil
- easily cleared plant cover

### Soil

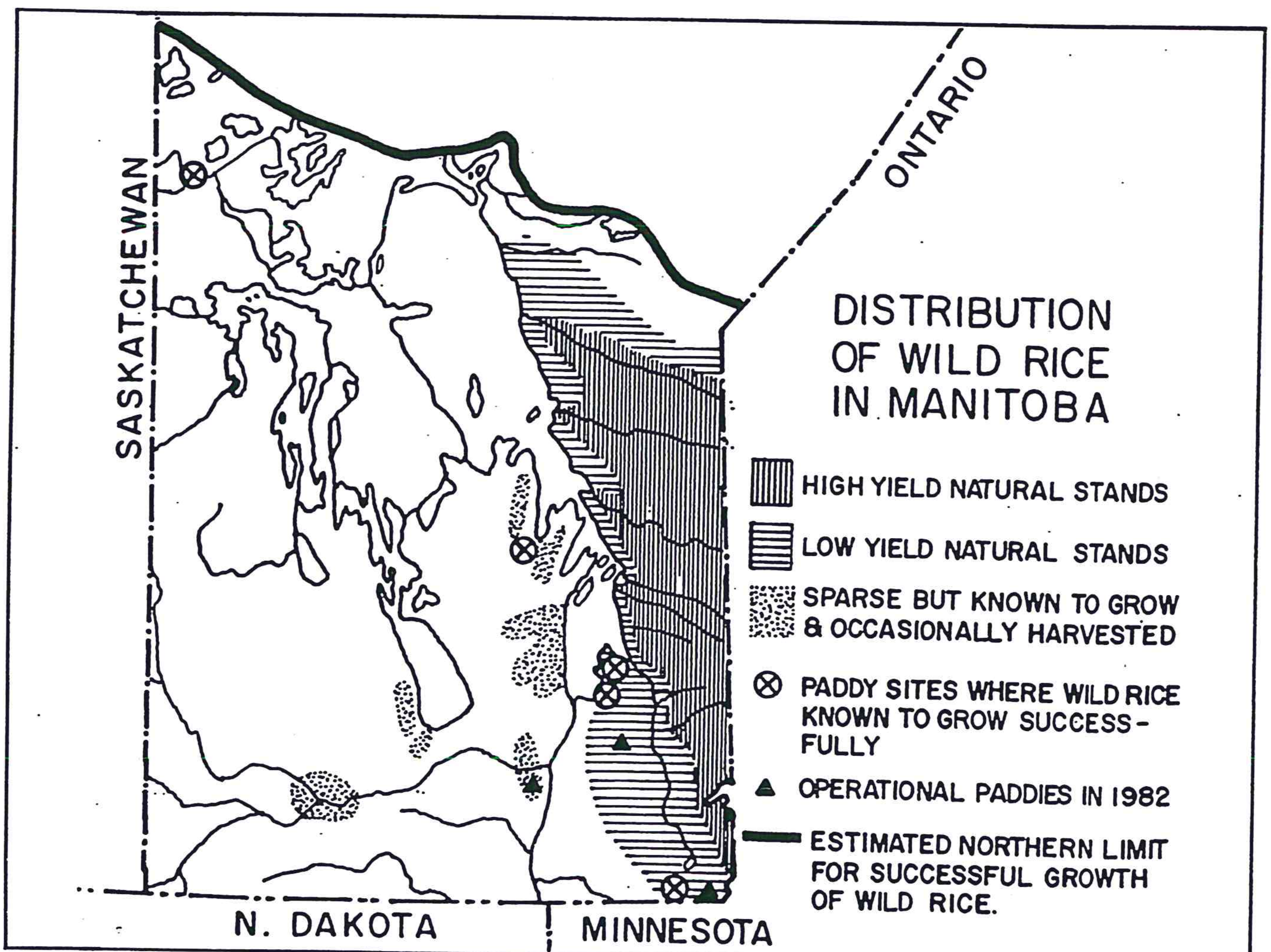
Wild rice grows well on shallow peat soils, mineral and sandy loams. Avoid deep or sphagnum peats because these peats tend to float. Dolomitic soils have also presented some difficulties for production.

The soils most often used for paddy development are shallow peats overlying clay subsoils. The clay acts as an impervious layer which retains water, and is a solid footing for heavy harvest machinery. It is also a good source of dyke building material.

Precambrian rock country may have some suitable areas. These may have been developed to the wet meadow or dryland stage and are capable of being dyked and used for paddies. Beavers often build dams on streams with considerable flat land along the banks. These areas may create a suitable site provided water depth control is adequate. Potholes are most difficult to develop as many have a very low pH (high acidity).

The properties and environment of soil submerged in water are different from those of well-drained upland soils. As the air in the soil is displaced by water during

**Figure 3 — Distribution of Wild Rice in Manitoba.**




*Map courtesy of Dr. J. Stewart, Department of Botany, University of Manitoba*

submergence, the root zone changes from an oxygen-rich, or aerobic, to an oxygen-lacking, or anaerobic environment. The root zone is essentially anaerobic although there is a thin aerobic layer at the soil water interface. The thickness of the layer is determined by the difference between the oxygen supplying rate through the water, and the oxygen consumption rate of the soil. In peat soils there may be no oxidized layer and reducing conditions extend to the soil-water interface. After oxygen has disappeared, nitrate and nitrite nitrogen are rapidly reduced to gaseous forms of nitrogen unavailable to the crop (nitrogen gas and nitrous oxide). Manganese compounds are reduced next to manganous forms, which are more soluble than the oxidized forms. Reduced iron, or ferrous compounds are also more soluble than ferric oxide, or oxidized forms of iron. If reduction becomes intense enough, sulphate will be reduced to the extremely toxic sulphide form.

Measured in terms of oxidation-reduction potential ie., redox potential, 200 to 300 mV at pH 7, or neutrality, is considered the dividing line between oxidized and reduced conditions. Reasonable predictions concerning the behaviour of several important plant nutrients can be made when the redox potential (Eh) is known because the intensity of reducing conditions can be assessed. In several Minnesota paddies, a redox potential of -215 to -315 mV has been measured, indicating severely reducing conditions.

Bacterial activity is responsible for the oxygen depletion leading to reduction. This is affected by the soil temperature.

In reducing conditions, mineralization of organic nitrogen goes to the ammonium stage and can be used by the plant. Waterlogging increases the soil phosphate availability by diverting ferric phosphate to ferrous ions and freeing phosphate. Although flooding increases the amount of potassium in the soil solution, a large leaching loss can result, particularly in organic soils.

The probable availability of boron and molybdenum (possibly copper and zinc), should increase slightly because of greater solubility. Soil pH values are shifted to neutral (acid becomes less acidic and alkaline becomes less alkaline) by flooding and there are more soluble salts as well as increased silicon solubility.

In intensely reducing conditions, sulphate can be changed to toxic sulphides, including the sulphide of iron, which then produces an iron deficiency in the root zone and ultimately in the plant.

### Water

Wild rice prefers water with less than 10 ppm sulphate, but can survive with much higher levels if reducing conditions are not intense enough to produce the toxic sulphide compounds. Low "alkali salt" levels in water encourage good wild rice growth. An acceptable water source must be available from a stream or lake. There is considerable variation in hardness of water and pH levels tolerated by wild rice plants. Wild rice grows in water which is very hard (300 parts per million $CaCO_3$) and alkaline (pH 8) or in relatively soft (22 ppm $CaCO_3$) and acid (pH 4.2-5.7).

### Nutrients

Water in well fertilized production areas may have a relatively high concentration of nitrogen, phosphorous and potassium. Phosphorus is considered the nutrient most likely to have a detrimental effect on public waters. Addition of phosphorus increases growth of aquatic plants because phosphorus is usually the limiting nutrient for plant growth. Phosphate retention by peat is low.

If organic soils are overfertilized, quantities of nutrients will appear in the drainage waters. A paddy producer must be concerned about rates of nutrients applied to paddies and the nutrient content of the effluent from the paddy. The potential for loss of plant nutrients from paddies appears high, but actual losses are low.

Using an airboat for thinning increases the turbidity and total phosphorus in the water for less than an hour. Water loss from seepage through dykes does not harm the water quality because of prolonged soil contact and the small volumes concerned. Efficient water management necessitates minimal return flow of paddy water at the close of the production season.

## Development and Planning

If the initial guidelines for site selection produce a positive evaluation, detailed planning should be undertaken. This includes:

- detailed land surveys
- obtaining the required water acquisition and disposal rights
- planning the development of paddies — dykes, drains, roadways
- planning initial and follow-up production operations

### Land Clearing

Land covered with trees and boulders is the most expensive to clear. The least expensive is recently cultivated land while clearing land covered by brush is intermediate.

Compact rectangular shaped paddies are preferred to irregular or elongated fields. This makes harvesting, tillage, and seeding operations easier and minimizes wave action of the water. The maximum distance across a paddy should be 400 m (1300 feet).

Brush and small trees are often cleared in the winter with a bulldozer, and later burned. On the first pass with a rototiller over a freshly cleared area, have the back gates of the rototiller open. A forward speed of 5 km/h (3 m.p.h.) is suggested. On the second pass, the back gates should be closed and the speed reduced to about 1.6 km/h (1 m.p.h.). This provides for thorough tillage of the soil in preparation for a detailed topographical

survey to establish contour lines for dykes and drainage locations. Plows have been used to prepare areas, but may cause problems, particularly with peat soils covered with grass. Organic soils which are plowed can float when flooded.

### Land Survey

The PFRA (Prairie Farm Rehabilitation Assistance) district in Morden, will provide engineering services to survey the paddy area and advise on dyke construction. The Morden office serves the area presently known for wild rice production, but there are other district offices at Brandon and Dauphin. A detailed survey is necessary so that dyke location combined with land forming, can provide a maintained water depth differential of 30 cm (12 inches) within the production area of each paddy.

Access roads should be located and integrated as part of a system that provides transportation, diverts or collects water, and divides drainage area. Where roads cross drainageways, incorporate culverts or other permanent structures into the plan. Other advantages for paddy site selection include having power lines near the site, supply and repair facilities close at hand.

### Dyke Building

A topographical survey will determine dyke height and location of culverts, and which parts of the growing area should be levelled. Small sites will have a perimeter dyke and water outlet at the channel or downside. Large sites will have cross dykes with water gates in addition to the main dyke. A slight slope of the growing area is beneficial for pre-harvest drainage. The slope should be less than 0.5 percent or 15 cm/30 m (6 inches/100 feet).

The best time to build dykes is in the spring or summer prior to fall seed bed preparation and seeding.

Before dyke construction, strip the area for the dyke below the root zone to minimize water seepage. Construction can then begin on this stripped area. A ditch is constructed immediately inside the dyke so water can flow around in the paddy and the proper water level is retained. This ditch will also assist in drainage of the paddy. These ditches may have to be cleaned periodically to maintain proper drainage. Backhoes are used in dyke construction, especially in very soft ground. Bulldozers are often used and road graders have been effective on mineral soils.

A dyke must be impervious to water. A dyke made of clay soil is best. If peat content is unavoidable the dyke must be much wider. The top width of the main dyke should be 2.5 m (8 feet) or half this width for an inner dyke. Locate dykes so that the water depth at the shallow end can be maintained at 15 cm (6 inches) and 45 cm (18 inches) at the deep end of the paddy.

In clay soils the dykes should have a 1.5 to 2:1 slope (a 1m drop for every 2m horizontal), (1 foot drop for every 2 feet horizontal), and in peat soils at least a 3:1 slope. The side slopes may need to be flatter than the minimums to give wave protection or fill stability. Evaluate each side individually.

If the dykes are clay, they should be 15 to 30 cm (0.5 to 1.0 feet) higher than the water level. Peat dykes 30 to 60 cm (1 to 2 feet) higher than the water level. Organic soil dykes need to be higher than mineral soil dykes to allow for settling. Sufficient compaction can be attained during dyke construction if earth is added in layers of no more than 15 cm (6 inches). Bulldozers can be used for trimming.

Dykes are used to divert water, collect water and divide drainage areas. Access roads should be integrated into the dyke system, graded and crowned to provide high and dry travel. Use culverts or other permanent structures where roads cross drainageways to provide the necessary drainage. There should be access roads to every paddy for ease of observation and moving equipment. Decide the location and size of culverts, as well as pump size before building. Place pump stations and water gates so that the desired water control is achieved.

Dykes must have a vegetation cover and should be seeded down, and the ground cover cut regularly. There is a problem of finding a suitable species which grows well and is not an alternative host for diseases. As wild rice is a grass, any grasses do present the possibility of acting as alternative hosts. In particular, avoid brome grass, barnyard grass, foxtail barley and cereals. Creeping rooted alfalfa is a possible cover crop.

Limit individual paddy cells to 12 hectares (30 acres) because of the potential for wave action on large areas.

### Water Supply and Management

The Water Resources Branch of the Manitoba Department of Natural Resources must be contacted regarding use of the water from rivers or streams and drainage of water from paddies.

To make application for water use or drainage, estimates must be provided of the quantities needed and rate at which the water will be drawn and returned. A certain amount of water per year is allocated to each approved application. The effect of an individual application on neighboring areas is a prime consideration.

Paddies should be managed so that a minimum of waste water is drained. Terminate water application as early as possible so that crop utilization will begin water drawback in the paddy. Slow drainage, if any is needed, is most desirable to preserve the quality of the receiving water. Irrigation, water management and maintenance operations should minimize soil erosion.

One layout for the water system is to use a central water supply ditch from which various paddies can be flooded. Another system allows water to flow from one paddy to another. Under the second system adjacent paddies cannot be fallowed for a year or two thus limiting the flexibility of the system.

The size of pump necessary to control water levels depends on the specific conditions at individual sites. Control structures should be designed to regulate the water level up to a height of at least 30 cm (1 foot) above the highest point in the paddy. A minimum delivery head of 10 cm (4 inches) above this elevation should be provided in the pump design.

Water permits should allow for pumping the amount of water necessary to provide the maximum quantity that will be needed to fill and maintain water levels. However, on the average about half the water necessary is supplied by rainfall. The water supply and pumping system should allow a grower to flood a paddy in seven to ten days. If a grower has 12 ha (30 acres), 67,000,000 litres (15,000,000 gallons) of water are required for the initial flooding. The initial flooding includes saturation of the soil and filling of the ditches. A 30 cm (12 inch) pump which delivers 18,200 litres per minute (4,000 gal/min.), and runs 24 hours per day, provides 26,200,000 litres per day (5,760,000 gal/day). To flood a 12 ha (30 acre) paddy to a depth of 28 cm (11 inches) on average, would take the described pump two and a half days. A pump which delivers 18,200 litres per minute (4000 gal/min.) could pump enough water for an area containing four 12 ha (30 acre) paddies. If the water gates are closed in the fall subsequent winter snow and spring rains, will be retained and less water will be required to obtain the required depth.

During the first eight to ten weeks of the season, a constant water depth is critical. Weeds are more easily controlled by water levels early in the season, and fluctuating water depths could disturb the wild rice plants. Water should be added daily, or as needed, to compensate for percolation, evaporation and transpiration. Water does not need to be added continuously. The water level in the paddies can be allowed to decrease slowly during flowering so that very little water needs to be drained from the paddies two or three weeks before harvest.

## Production of Wild Rice in Paddies

### Paddy Seedbed Preparation

Once the paddy is constructed, the seedbed preparation follows. Usually a rotovator is used and rototilling 10 to 15 cm (4 to 6 inches) deep is most satisfactory. A disc can be used for seedbed preparation but existing vegetation is not as easily incorporated and destroyed as with a rotovator.

In peat soil, a normal moldboard plow is not satisfactory if there is vegetation cover because the turned over soil layer can float when the paddy is flooded. Large breaker plows do not cause as much of a flotation problem but if the peat layer is shallow, underlaying clay can be brought to the surface. This makes wild rice establishment difficult. For good drainage, the final seedbed should not leave any ridges or hollows.

Where much vegetation is to be tilled under, a year or more of cultivation is desirable before planting. The use of Roundup or paraquat herbicides before the initial tillage will kill many species of plants. Sometimes small grains are planted for a year or two before planting wild rice. Oats has been used as an initial crop. Canola or rapeseed is a possible alternative with less danger of diseases common to wild rice.

Keeping the paddy in upland conditions for one or two years allows vegetation to decompose. Fewer problems then result from gas formation and floating peat when the paddy is flooded. Peat soils are usually low in phosphorus and potassium, and if this is the case, 67 kg/ha (60 lb/acre) of each should be applied and incorporated five to 10 cm deep (2 to 4 inches) with a disc or rotovator during seedbed preparation.

### Varieties

Pioneers of wild rice paddy growing used seed from native stands. Several characteristics of the native stand wild rice are undesirable. Native wild rice shatters readily and combined with the extended time over which the seed matures, the characteristics make necessary several passes at harvest to recover a good yield of mature seed. Heavy losses through shattering reseeds the area.

The primary concern of plant breeders initial work was the production of early maturing varieties. Also harvested yield could be increased and harvesting completed with a single pass of a combine if non-shattering varieties were established.

There have been several varieties developed in Minnesota, but there is still a major problem with seed shattering. The mature seed of the present varieties will fall off if not harvested soon after the stage of maturity called "40 percent dark seed". Shatter resistant lines were introduced by Algot Johnson and the first variety with some shatter resistance was named Johnson.

The first varieties developed in Minnesota were Johnson, M1, M3, K2 and Netum. All five varieties have some shatter resistance.

Johnson
- tall, lodging and disease susceptible
- has wide leaves with panicle colour ranging from pale green to purple — too late maturing for Manitoba

M1
- medium height
- medium to late maturing
- lodging and disease susceptibility
- medium width leaves
- panicle colour mainly purple

M3
- medium height
- medium to late maturing
- lodging and disease susceptible
- medium width leaves with a variety of panicle colours and a mixture of all female and female-male panicles

K2
- medium height
- early to medium maturity

- lodging and disease susceptible
- medium width leaves with mostly purple panicles

Netum
- medium height
- early maturing
- lodging and disease susceptible
- medium to narrow width leaves with a mixture of panicle colours from pale green to purple probably the best for Manitoba.

The M varieties were developed by Manomin Development Co., the K variety, by Kosbau Bros. and Netum by the Minnesota Agriculture Experiment Station.

The average yields of these varieties are not significantly different in small plot tests. (Table 1). In small plot yield trials at the University of Minnesota testing sites, yields varied from 1150 to 2250 kg/ha (1050 to 2000 lb/acre). Testing procedures varied considerably. Netum is preferred for Manitoba conditions because of its early maturity, but it tended to yield less than the other varieties. Provided that the longer maturing varieties can mature successfully, K2 would be advantageous to grow.

Table 1
Summary Of Yield Tests in Minnesota[1]

| Variety | Average 1978 and 1979[2] | | Average 1980 | |
|---|---|---|---|---|
| | kg/ha | lb/acre | kg/ha | lb/acre |
| Netum | 1511 | 1348 | 1590 | 1419 |
| K2 | 1809 | 1614 | 1480 | 1319 |
| M3 | 1962 | 1750 | 1770 | 1579 |
| Johnson | 1665 | 1458 | 1480 | 1319 |

1 Average yield weight expressed at 40% moisture.
2 Average yields are not significantly different.
In a growing season when the later varieties can mature, Netum is likely to be the lowest in yield. When the growing season is cut short by frost or harvest losses due to storms Netum is likely to be the best yielding variety.

Yields can be reduced by frost, increased incidence and severity of winds, build up of disease, and bird foraging late in the season. All varieties are susceptible to brown spot and other diseases, and all will lodge if over-fertilized or grown in deep water.

Shattering of wild rice decreases yields, diseases destroy stands, and dormancy makes it difficult to change to superior varieties. Late maturing varieties are susceptible to late season production hazards. Also, shorter plants stand better and are adapted to machine harvesting. Plant breeders are presently trying to develop superior, domesticated varieties of wild rice to incorporate shatter resistance, disease resistance, early maturity, and short plant characteristics. A recently developed material, called Voyager (formerly K2E) combines the yield of K2 with the earliness of Netum in Minnesota. To date it has not been tried in Manitoba.

Plant new paddies which are to be combine harvested with varieties that are of an acceptable maturity range and have good shatter resistance. Some certified seed is available from Minnesota. Some lake rice leaseholders will keep seed if requested in advance. In many cases the seed will be shatter susceptible. For direct purchase from Minnesota growers, contact the Wild Rice Growers Association, Box 366, Aitkin, Minnesota 56431.

### Seed and Seeding

Seed should be free of weed seeds. This is most easily attained if the paddy producing seed is weed free. An air or gravity cleaner can be used after harvest. Cleaned seed should be kept above 28 percent moisture or submerged in water. Germination will be severely reduced if seed dries below 28 percent moisture.

Wild rice for fall seeding is usually placed in water permeable containers such as polypropylene or polyethylene sacks. It can be kept in livestock tanks filled with water. The water in the stock tanks should be changed regularly.

Seed stored for spring planting can be put into 200 litre (45 gallon) drums with numerous small holes to permit water circulation. The drums can be placed in pits 3 m (10 feet) deep filled with water, or in streams below the winter ice level. Mud should not cover the seed as oxygen is necessary for seed respiration during storage. Water temperature should be 1 or 2°C. It is best if the water surrounding the seed does not freeze. The one advantage of spring seeding is that the germination can be tested before using the seed. Optimum germination occurs at 17°C, and high quality seed will have at least 70 percent germination at room temperature when placed in a pan of water for three weeks. Change the water in the germinating tray every two days.

Fall seeding is preferred to spring seeding. After seedbed preparation and surface water is drained from the seed, mix the moist seed with oats in a ratio of two or three units of oats to one of wild rice. Oats are mixed with the wild rice seed to encourage the seed to flow more uniformly through mechanized seeding equipment. Seeding to a uniform depth with a grain drill or similar equipment gives the best stand. Wild rice seed will emerge from depths of 2.5 to 7.5 cm (1 to 3 inches) with firm clay requiring a shallower seed depth than loosely packed peat. Seeding can also be done with a bulk fertilizer spreader. Incorporation of the broadcast seed with a harrow should immediately follow spreading. The paddies should then be flooded to protect the seeds from birds and to maintain a satisfactory germination percentage.

Spring seeding should be done as early as possible before the stored seed begins to sprout. Seeding directly into water by airplane or broadcasting equipment is the recommended method. Increase the seeding rate 15 to 20 percent, when using these techniques.

Work done at the University of Minnesota has shown that the highest yields are obtained with a plant population of 40 plants/m² (4 plants/square foot). Higher plant populations resulted in more lodging and higher incident of leaf disease. The seeding rate required to

provide proper plant population is about 35 kg/ha (30 lb/acre). The amount of seed needed to obtain optimum population varies with seed quality, and more particularily, germination. Germination of seed averages from 30 to 65 percent.

### Nutrient Requirements

The amount of various nutrients in a plant may reflect its nutrient requirement. Nitrogen, potassium, calcium and magnesium are required in greater quantities than other nutrients (Table 2). The grain contains about 37 percent nitrogen, 22 percent phosphorus and 3 percent potassium compared to the whole plant. Many of the nutrients present in the whole wild rice plant remain in the stem and leaves, and are returned to the soil.

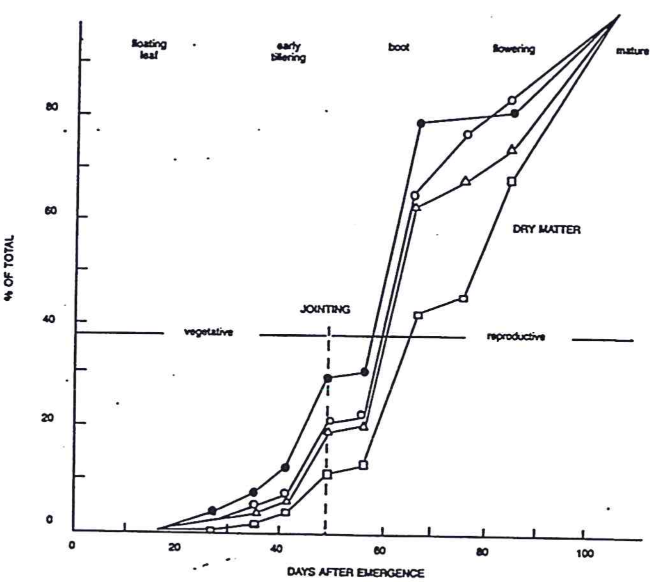
Table 2
Amounts Of Plant Nutrients In Wild Rice

| Plant | Leaves[1] (dry weight) | Grain, Leaves and Stems[2] kg/ha | lb/acre |
|---|---|---|---|
| Nitrogen | — | 118 | 105 |
| Phosphorus | 0.08% | 43 | 38 |
| Potassium | 2.2% | 291 | 260 |
| Calcium | 1.2% | 295 | 263 |
| Magnesium | 0.18% | 232 | 207 |
| Iron | 0.09% | 2 | 2 |
| Manganese | 0.03% | 2 | 2 |

1 P.F. Lee (1979)
2 University of Minnesota (E.A. Oelke) 1981

Wild rice assimilates 118 kg/ha (105 lb/acre) nitrogen in the grain, leaves and stems of a 0.9 tonne (2000 lb) crop dry weight at maturity. The accumulation of nitrogen, phosphorus and potassium in relation to the amount of dry matter, takes place in stages (Figure 4). A topdress nitrogen application has been found effective if applied at jointing stage, partly because wild rice accumulates 70 percent of its total nitrogen during flowering and grain formation.

**Figure 4 — Accumulation of Dry Matter, Nitrogen, Phosphorus and Potassium in Wild Rice.**




A soil test is the best way to determine how much fertilizer is needed, although plant nutrients may also be supplied by the water. After draining the paddy, or during seedbed preparation, take samples one for each 2 to 3 hectares (5 to 8 acres), in the paddy. The core samples should be taken at two depths, 0 to 15 cm (0 to 6 inches) and 15 to 60 cm (6 to 24 inches). Thoroughly mix the samples from the same level from all locations in the field in a clean container. The samples should be air dried then forwarded to the Soil Testing Laboratory, Ellis Building, University of Manitoba.

The Manitoba Department of Agriculture Soil Testing Laboratory has recommended amounts of nitrogen, phosphate and potash for wild rice paddies (Table 3). Plants lacking nitrogen are lighter green in colour and shorter than plants receiving sufficient nitrogen. Lower leaves of affected plants have yellow tips and margins. A slight deficiency of nitrogen in wild rice results in less lodging, reduced vegetative growth, and less brown spot damage, with increased yields and easier combining.

Ammonium phosphate or urea are about equally effective as a source of nitrogen for wild rice. Nitrate is not maintained in a flooded soil, and losses through leaching and denitrification can amount to 70 percent of the total amount applied. All or part of the nitrogen, as ammonium phosphate or urea, and all the phosphate and potash should be applied during the seedbed preparation in the fall. The best response in Minnesota has been obtained by broadcasting the fertilizer followed by incorporation to a depth of 8 to 10 cm (3 to 4 inches). Spring application of phosphate can cause algae problems and may also be lost in water run off.

Urea or ammonium nitrate are good sources of nitrogen for topdress application at joining when the internodes start to elongate.

### Paddy Management

Wild rice will germinate at 4°C, but best germination occurs at 18°C. Paddies with either shattering or shatter resistant varieties reseed themselves resulting in dense stands after the initial establishment year.

*Thinning*

Thinning the plant population brings higher yields as more panicles will have a good seed set due to less competition. Low population plantings can produce up to 30 tillers per plant, while high density populations may not tiller. When the plant is at the floating leaf stage, thin the population by cutting off a percentage of the total plant population, near the soil-water line.

A cutting bar has been devised for an airboat that travels about 56 km/h (35 m.p.h.) on the water surface. V-shaped knives are spaced 15 to 20 cm (6 to 8 inches) apart on a toolbar attached to the rear of the airboat. The knives ride on the soil surface and remove 70 percent of the plants, leaving the remainder for further growth. When additional thinning is needed a second series of passes are made.

## Table 3

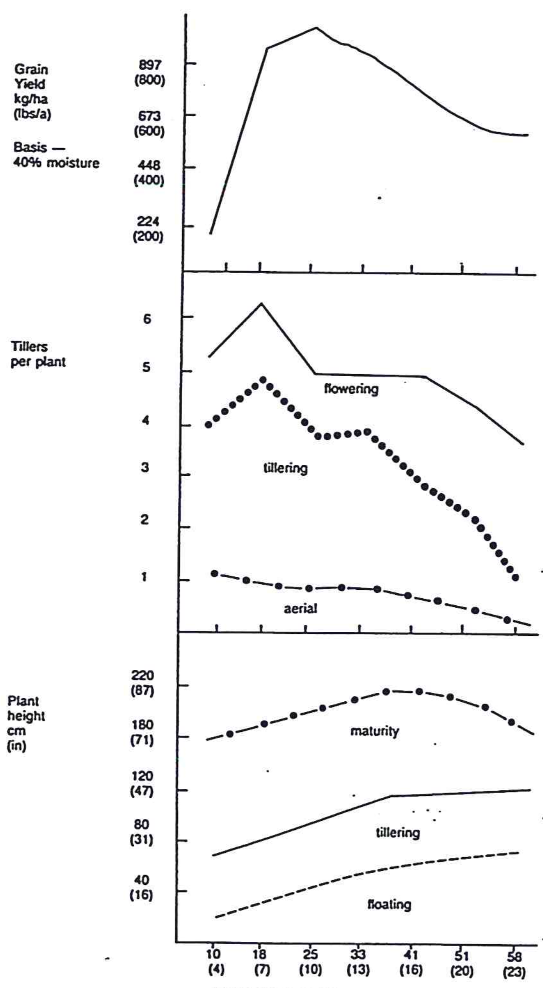
Fertilizer Rates Recommended By
The Manitoba Department of Agriculture Soil Testing Laboratory

| Nutrient | Criteria | | Amount kg/ha (lb/acre) | |
|---|---|---|---|---|
| Nitrogen | | | Mineral soils | Organic soils |
| | First year only | | 22 (20) | 17 (15) |
| | 2nd year and older | | 45 (40) per year | 34 (30) per year |
| Phosphorus ($P_2O_5$) | Soil Test | | Amount | |
| | kg/ha | lb/acre | kg/ha | lb/acre |
| | 0-17 | 0-15 | 45 | 40 |
| | 18-34 | 16-30 | 22 | 20 |
| | over 34 | over 30 | 0 | 0 |
| Potassium (potash) ($K_2O$) | 0-112 | 0-100 | 67 | 60 |
| | 113-224 | 101-200 | 45 | 40 |
| | 225-336 | 201-300 | 22 | 20 |
| | over 336 | over 300 | 0 | 0 |

*Water Depth*

Grain yield, tillering and plant height are affected by the depth of water during plant growth (Figure 5). A minimum depth of 15 cm (6 inches) should be maintained on the shallow parts of the paddy. Wild rice will not grow in unsaturated soil. Any germination will result in small seedlings and plants that are yellow.

**Figure 5 — Influence of Water Depth on Plant Height, Tillering and Yield of Wild Rice.**




The deep part of the growing area should not be more than 45 cm (18 inches) of water. Deeper water reduces plant population and causes lodging when the water level is reduced before harvest as the tall plant stems offer insufficient support for the grain. Best weed control, adequate plant population, no delay in maturity and good yield were obtained with 33 cm (13 inches) of water in a three year water depth trial at Grand Rapids, Minnesota.

Paddy water level can be allowed to decrease slowly during flowering. This means that very little, if any water needs to be drained from the area two to three weeks before harvest or one to two weeks after flowering. Keep soils saturated with water for most of the grain filling period. Pay particular attention to the saturation of mineral soils during hot weather otherwise, yield losses will result from prematurely dry plants.

*Water Shed*

Wild rice paddies are often filled using spring runoff water which in turn reduces the potential of spring flooding by some rivers. A reservoir can provide assurance of water supply and can also serve to recycle discharges from paddies. If paddy water is suspected of contributing undesirable nutrients such as phosphorus loads to lakes, use a reservoir to store drained paddy water.

Less water is needed in the second and subsequent years than in the first year of operation. This is because the ground is thoroughly saturated with water after the first year.

## Insects

*Wild Rice Worm*

The larval stage of this insect can cause significant yield loss. The life cycle of the insect is timed to coincide with the development of the crop. The adult moth uses milkweed as its initial feeding host. Later eggs are deposited in the wild rice flowers for a period of 4 to 6 weeks. Larvae hatch, develop through several instars or stages and feed as they grow. First they feed on the glumes of the developing seed head, later on the rice kernels. Both activities reduce yield potential.

As their growth pattern approaches completion the worms tend to migrate and bore into wild rice stems or the stems of plants bordering the production area where they overwinter. The winter is passed in the seventh instar stage and in spring, after a final molt and some additional feeding, the larvae pupate and complete the cycle by developing into a moth in late June or early July. Work in Minnesota has shown that one larva per plant will reduce yield by 10%. In addition, processors encourage growers to reduce worm numbers in grain to be processed since the processing plants are considered as food processors.

Control of the wild rice worm has been experimentally successful, but there are no registered chemicals recommended in Manitoba to date.

*Midge*

Several midges are capable of developing in flooded wild rice paddies. One in particular *Cricotopus* has caused severe injury to first year stands.

The adult stage is an inconspicuous, small mosquito-like fly which lays its eggs in moist soil. Hatching occurs when the area is flooded. The larva spins a silken webbing attached to wild rice seedlings. Mud is often found in the webbing and this, combined with feeding interferes with the development of the small wild rice plants. Many fail to reach the floating leaf stage, thus thinning the stand.

Second and subsequent year fields do not usually suffer economic loss. This is because of high plant population rather than lack of insects.

Chemical control measures, although effective in Minnesota are not registered for use in Manitoba.

*Other Insects*

Several other insects are known to feed off wild rice plants. These include rice stalk borers, rice water weevil, rice leaf miners and rice stem maggot. Studies in Minnesota have been unable to confirm economic injury from these insects.

**Diseases**

*Brown Spot*

This disease is caused by two fungi that survive on a wide variety of grass plants including wild rice. Fungal spores are produced in the spring and are wind borne. Hot daytime temperatures (23-35°) warm nights (20°C) high relative humidity (90%) and free water on leaf surfaces for 11-16 hours favor infections. The disease causes infections on all parts of the plant. Leaf spots are typically oval and small having brown centers with higher colored, yellow margins. As the disease develops the spots tend to grow together killing large areas of leaf, stem and panicle tissue. Yield losses can range from slight to 100%.

Sanitation is an essential part of control. Incorporate or burn all crop residue into the soil after harvest. Sow disease free seed in new fields and use nonsusceptible crops or summerfallow in the rotation. Use of non-susceptible material to seed dykes is also recommended. Use of a balanced fertility program is also part of the control package. Excessive nitrogen tends to promote lush dense growth and enhance conditions for disease development.

*Photo 1 — Brown spot.*

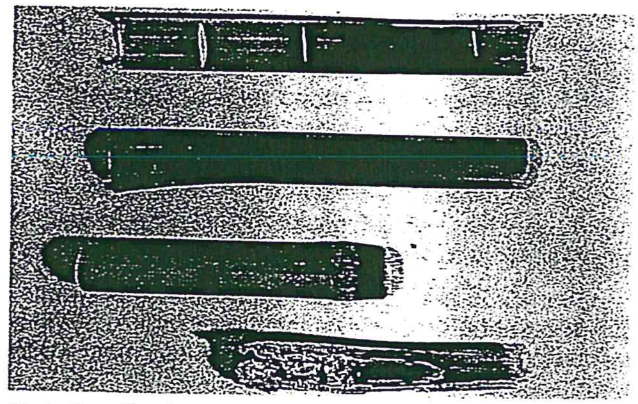


*Photo 2 — Fusarium.*

*Stem Rot and Stem Smut*

These two fungal diseases are known to cause damage. Stem rot results in weak stems and plants lodge, thus their production is lost. Stem smut infection occurs in the heads, clums and stems, causing yield loss.

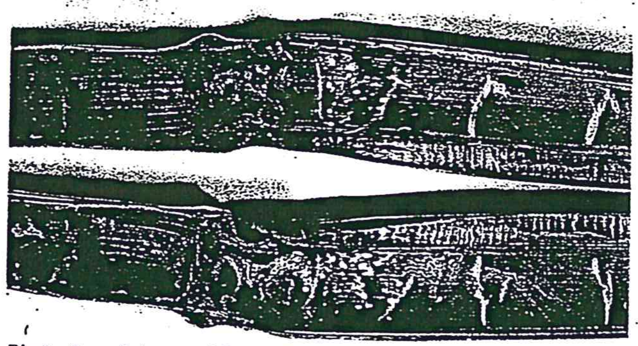


*Photo 3 — Advanced Stem Rot.*

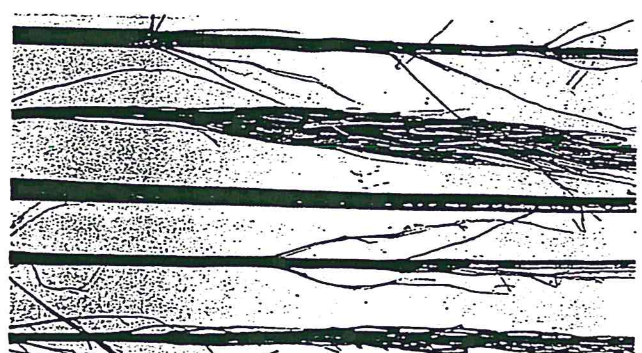


*Photo 4 — Black Postules.*

As is the case with brown spot, adequate sanitation and alternate host management are useful control measures.

*Ergot*

Plants in natural stands appear to have a higher resistance to infection. Ergot in some years causes failure in a particular natural stand. The worst stand of ergot infestation reported caused a 40 percent reduction in yield.

In summary, sanitation is the most essential part of the disease control. Hosts of pathogens, other than the wild rice should be removed from the area. Thoroughly incorporate crop residue into the soil in the fall tillage process. Using clean, healthy seed in new paddies avoids the introduction of foreign pathogenic species. Other practices to control disease are:

- planting rotation crops resistant to wild rice pathogens
- summerfallow as a rotation practice
- selecting of non-hosts for use on dykes

## Weeds

Wild rice is not able to compete with other plants. Initial seedbed preparation combined with rotovation or discing of paddies after harvest reduces most weed populations.

*Weed Seedlings*

Maintaining water levels over 15 cm (6 inches), prevents the establishment of most weeds from seed. (Table 4). First year seedlings are usually too small and late developing to provide competition to the wild rice plants. In the second year, however, they develop further and compete with the wild rice. Thus, it is important to control seedling populations.

*Water Plantain*

The most frequent weed problem associated with wild rice is common water plantain. It has been shown that water plantain developed from rootstocks will cause yield losses of 43 percent with a population of 10 plants per square meter (1 plant/square foot). Some fields have been reported with the above density of infestation.

*Broadleaf and Submerged Weeds*

Weed control measures for the most serious broadleaf and submerged water weeds (grass weeds are not so serious) are:

- plant weed free seed
- fall tillage
- minimum waterdepth of 15 cm (6 inches)
- fallow, but flood first so seeds will germinate

There are no herbicides registered for weed control in wild rice in Manitoba.

Table 4
Weed Description

| Name | Description |
|---|---|
| Common waterplantain *(Alisma triviale)* | • Emersed, erect, aquatic perennial<br>• Reproduces by seed and root stocks<br>• Up to 1.2 m (4 feet) tall with elliptical leaf blades up to 25 cm (10 inches) long and 15 cm (6 inches) wide<br>• Leaves grow on long petioles<br>• Inflorescence pyramid shaped and branched<br>• Seeds are round, reddish brown<br>• Remain viable in soil for many years |
| Cattail *(Typha latifolia)* | • Perennials that reproduced by rootstocks and minute airborne seeds that germinate readily in mud and shallow, clear water<br>• Extensive rhizome system<br>• Erect with long narrow leaves<br>• Flowers in long, dense cylindrical spike terminating the stem<br>• Plants are 1.2 to 2.5 m (4 to 8 feet) tall<br>• Seeds remain viable in soil for more than five years |
| Burreed *(Sparaganium spp.)* | • Perennial, reproduces by seeds and spreads by rhizomes<br>• Plants 0.9 to 1.2 m (3 to 4 feet) tall<br>• Erect with sparingly branched leafy stem<br>• Leaves narrow and upright<br>• Inflorescence forked with seed heads burr-like before seeds fall away<br>• Seeds pyramidal in shape |
| Common arrowhead *(Sagittaria spp.)* | • Perennial, reproduces by seed, underground rhizomes and tubers<br>• Rooted aquatic with arrow-shaped leaves<br>• Lower leaves basal, with petioles as long as water is deep<br>• Plants 0.3 to 0.6 m (1 to 2 feet) tall<br>• Flowers are white and seeds clustered into a spherical head, seeds flat |

Table 5
Effect of Waterplantain Plant Density On Yield of Wild Rice

| Waterplantain Density | Plants m² | per ft² | Panicles/ plant | Seeds/ panicle | Weight/ 100 seeds g | Weight/ 100 seeds oz. | Grain Weight[1] kg | Grain Weight[1] lb. |
|---|---|---|---|---|---|---|---|---|
| Control | 37 | 3.4 | 2.0 | 54.2 | 2.1 | 0.075 | 1391 | 1241 |
| Waterplantain developed from seeds | | | | | | | | |
| 5 seedlings | 37 | 3.4 | 1.8 | 57.1 | 1.9 | 0.068 | 1240 | 1106 |
| 10 seedlings | 35 | 3.3 | 2.0 | 60.1 | 2.0 | 0.071 | 1323 | 1180 |
| 20 seedlings | 38 | 3.5 | 2.0 | 68.3 | 1.9 | 0.067 | 1549 | 1382 |
| Waterplantain developed from rootstocks | | | | | | | | |
| 1 rootstock | 37 | 3.5 | 1.2 | 48.6 | 2.0 | 0.070 | 741 | 661 |
| 2 rootstocks | 31 | 2.9 | 1.2 | 35.4 | 1.8 | 0.064 | 580 | 517 |
| 4 rootstocks | 25 | 2.4 | 0.8 | 24.2 | 1.7 | 0.059 | 163 | 145 |

1 grain weight is reported as harvested weight (wet) kg/ha or lb/acre
Source: University of Minnesota

*Algae*

Algae can significantly reduce the plant population in areas of paddies by forming a mat on the water surface before the wild rice emerges from the water. Copper sulphate at 17 kg/ha (15 lb/acre) will help control algae.

*Other Weeds*

Weeds other than the ones mentioned in Table 4 which have been found in wild rice paddies, but are not usually economically significant are:

- water starwort *(Callitriche heterophylla)*
- small pondweed *(Potomageton pusillus)*
- water parsnip *(Sium suave)*
- nodding beggarsticks *(Bidens cernua)*
- marsh grass *(Rorippa palustris var. glabrata)*
- barnyard grass *(Echinochloa spp.)*
- spikerush *(Eleocharis spp.)*
- duckweed *(Lemna minor)*
- chara *(Chara spp.)*
- naiad *(Najas flexilis)*
- American sloughgrass *(Beckmannia syzigachne)*
- reed-meadow grass *(Glyceria grandis)*

## Other Pests

*Carp*

This carnivorous fish, causes considerable damage by dislodging wild rice as it thrashes and stirs up the muddy sediment in the water.

*Crayfish*

Flood waters carry crayfish into paddles where they forage on the seedling plants. They survive and reproduce in burrows in the moist sediment between periods of paddy flooding. One species, *Orconectes virilis,* has caused stand reduction.

*Blackbirds*

Blackbirds which use ditch banks as nesting sites are a major problem. When the first kernels are in the milk stage, they start feeding on the crop. The glumes are squeezed forcing the soft kernel out through the split in the glumes. Start control measures at the first appearance of the blackbirds.

Various methods have been tried to reduce the damage caused by migrating flocks of both blackbirds and resident birds. Bangers, scarecrows, hawk kites and speaker systems which loudly broadcast the blackbird distress call as well as helium balloons have been used to move the birds from the stands.

Another technique used is sowing oats around the outside of the paddy to attract the birds away from the rice. Chemical toxicants, Av-Alarm records and continual flight over the area are other control measures. Methiocarb, a bird repellant which causes illness, and induces aversion in blackbirds must be placed on the hull of individual wild rice grains to be effective. No method has been completely effective in keeping blackbirds away from crops.

Wild rice is a resting, foraging, nesting and brood rearing site for migratory and resident water birds. At least four species of ducks, mallards, blue-wing-teal, green-wing teal and pintail, use paddies during the nesting season. Wild rice paddies are prime duck producing areas. Waterfowl damage is rarely of economic significance.

Animals such as the racoon, mink and skunk forage paddy dykes and ditches for food. Both deer and moose have been observed in fields, causing occasional damage but seldom are they economically important. Muskrats and beavers use the areas in the summer. Beavers can assist or be a nuisance by building dams. Muskrats create problems by boring holes in dykes. Generally, wild rice paddies have positive value for animals.

## Harvesting

*Drainage*

Gradually drain paddies in August when the grain is beginning to fill. Drying takes about two weeks and varies with the soil type. If drainage is late, excessively wet fields will cause machine support problems. Besides increasing the soil strength for machine support, drainage speeds plant maturity.

Peat soils must be completely drained, although harvest on clay soils with water standing on the field is possible.

Table 6

Grain Characteristics and Yield of Wild Rice Harvested in 1975[1]

| Harvest date | Dark kernels % | Grain moisture % | Grain Weight at harvest kg/ha | lb/acre | Processed Grain recovery % green weight |
|---|---|---|---|---|---|
| K2 Variety | | | | | |
| August 27 | 9 | 42 | 938 | 837 | 12 |
| September 2 | 16 | 42 | 1415 | 1262 | 33 |
| September 8 | 32 | 37 | 1939 | 1730 | 37 |
| September 12 | 36 | 33 | 1649 | 1471 | 44 |
| September 16 | 40 | 33 | 1667 | 1487 | 44 |
| September 22 | 62 | 39 | 1275 | 1137 | 47 |

1 University of Minnesota

If precipitation persists through the field drying and harvest period, the soils will remain extremely soft. Some growers construct intermediate ditches within the paddy to facilitate water draw-off. These ditches are an addition to the regular perimeter ditches and a spacing of 90 m (300 feet) is useful. This allows each segment of land to be within 45 m (150 feet) of a drainage ditch.

Soil conditions at harvest on peat soils range from firm enough to support a rubber tired combine, to very soft where the most extensive track system has difficulty negotiating. Under soft conditions, an individual walking in the field can sink 30 cm (1 foot). Some track systems can negotiate this very soft soil condition.

Wild rice plants ready for harvest range in neight from 1 to 2 m (3 to 7 feet), with the majority of heads above 1 m (3 feet) unless the crop is lodged. Maximum yield of processed grain occurs when 35 to 40 percent of the kernels are dark rather than green in colour. The percentage of processed grain recovery will be 35 to 40 percent (Table 6). Harvest takes place with grain moisture condition at a high level. Waiting for drier conditions promotes preharvest shatter. Even with shatter resistant wild rice, the kernels on individual panicles ripen unevenly and some seed shattering occurs before all the kernels are ripe. In addition the grain in the initial panicle is usually lost before the grain in the panicle of the tillers is ready for harvest.

Uneven ripening and shatter susceptibility results in harvesting before all the kernels are mature. This results in a processed yield potential of about 42 percent if harvested by a combine or 50 to 55 percent if harvested by picker.

**Harvest Methods**

The first harvesters floated on the water and the paddies were harvested five to seven times at two or three day intervals. With this system from 112 to 224 kg/ha (100 to 200 lb/acre) of green rice are harvested. For individuals who harvest natural stands, using an airboat is an inexpensive way to initiate paddy production. The floating harvester is particularly useful for harvesting shattering types of wild rice.

Shattering wild rice in a paddy has been harvested by a specially constructed multiple pass harvester with finger-like troughs mounted on a special chassis. Troughs are pointed and spaced to permit wild rice stalks to pass between the troughs and slither through as the machine moves forward.

A reel mounted over the troughs increases the agitation of the rice heads and detaches the rice kernels. Most of the mature kernels fall into the troughs. As the multiple pass harvest machine moves forward, the stalks bend and pass beneath the chassis. The remaining kernels in the wild rice head are left to mature for the next pass of the harvester.

Normally, a paddy is harvested five to seven times in a season at two day intervals. On each succeeding pass, the machine drives on the same path so the least number of plants are destroyed. Unloading takes place by tilting the troughs rearward. A more mature and uniform lot of grain is produced by the multiple pass harvester than one which harvests all the grain at once.

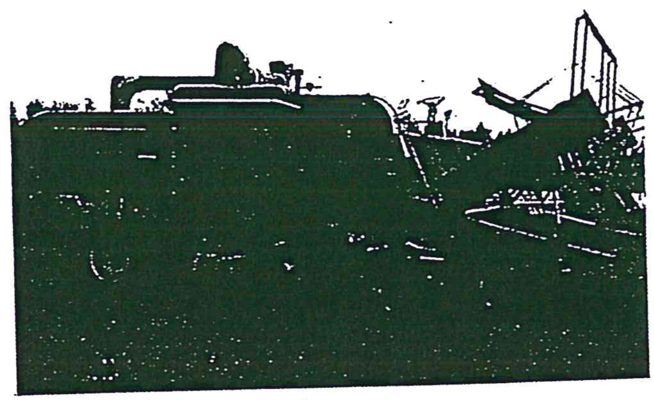


*Photo 5 — Combine harvesting.*

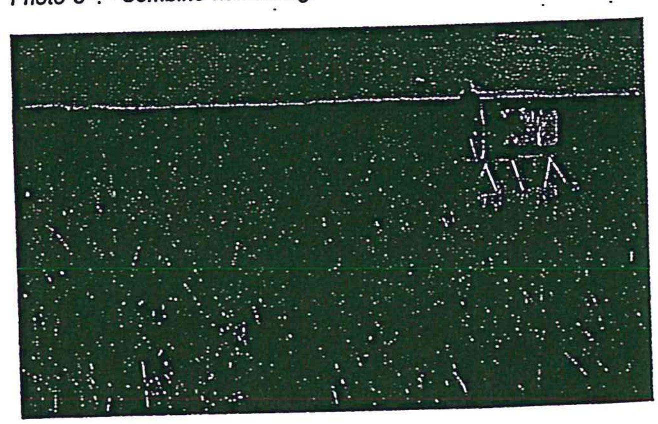


*Photo 6 — Airboat harvesting.*

*Direct Harvest*

Direct harvest by cutting the wild rice with a combine is a common procedure for shatter resistant

varieties. By 1977 almost 95 percent of domesticated wild rice in Minnesota was harvested by combine. Experiments have shown that the combine collects from 75 to 90 percent of the kernels on the stalks at harvest, with the remainder being lost through gathering, threshing and separation losses.

Preharvest losses have ranged from near zero to well over 100 percent of net yield. High winds, early frost, and hail are particularly detrimental to the loosely attached wild rice kernels.

*Straight Combining*

Heavy, high-capacity machines are needed to straight combine wild rice because of its bulky foliage. At the same time, ground conditions are often extremely soft. Wild rice grows in clumps and produces almost no sod for support. Peat soil is often raw, having lost fiber strength after repeated tilling.

Growers are making modifications to meet the challenge of the wild rice crop. The quickest and easiest improvement was bolting oak pads 7.6 cm x 12.7 cm x 102 cm (3 x 5 x 40 inches) to half-track and by dualing the guide wheels. This doubles the combine supporting surface and reduces the ground loading by half. This places the soil pressure in the range of a man's footprint.

For particularly difficult situations, machines have been converted to a full track configuration. Since the market for full-track machines is very limited, growers often do the conversion. The guide wheels must be removed and the rear of the combine mounted on a "walking beam," supported at each end by the track frames which are lengthened to as much as 4.2 m (14 feet). Conversion to full track is a major undertaking, including not only the building of the track frame and walking beam, but also a steering mechanism.

Many growers find it economical to operate both a half-track and full-track combine. Half track machines are used to open paddies and to combine the firmer areas, while the full-track machines are used when the half-tracks cannot continue to operate on soft ground.

For long stalks, the conventional rice draper extension is used. This permits the long wild rice stalks to lie down before being advanced by the cross auger. A larger diameter reel, 2.1 or 2.4 m (7 or 8 feet) is needed for long stalks. Extended bats on the reel and crop-divide points prevent the wrapping of straw on rotating members.A pick-up type reel is necessary to reduce shattering losses. Adjust the reel tines so that they point downward, or somewhat rearward to provide lifting action. This also avoids a "press down" action on the crop. This adjustment is depicted as a positive pitch of the pick-up teeth.

Wild rice requires a slower reel speed than does white rice. Keep the combine travel speed between 2.6 and 3.7 km/h (1.6 and 2.3 miles/hour) and a reel peripheral speed sufficient to control the crop and press it slightly rearward.

Maintain the reel peripheral speed in the range of 1.25 to 1.75 times the combine travel speed. The draper extension assists in moving the plant material to cross auger chamber helping to provide uniform feeding of the combine threshing system. A reduction in stem loss from the combine header front also results. A large pointed harpoon-like divide point is effective.

Combines with spike-toothed or rasp-bar cylinders are used to thresh wild rice. Comparative evaluations show little or no advantage of one type over the other.

The threshing loss is considered quite low because of the ease with which the kernels are dislodged from the heads. Separation losses have ranged from 10 to 25 percent of net yield, with most of the loss being over the walkers. The condition and amount of the straw cause overloading of the walkers.

Height of cut is determined by balancing two opposing factors. These are a height which minimizes the amount of bulk entering the machine and one which saves the majority of grain. Uncut losses at the header may well reduce discharge losses in the straw. Operators are advised to evaluate these factors under their own particular conditions.

The tailings return is provided on combines for recycling of material that needs rethreshing or which was not adequately separated at the sieves. The tailings return permits another opportunity for separating material not adequately separated in the first pass over the sieves. Rethreshing is not required as any material not threshed in the first pass is attached to straw and passes out the discharge over the walkers with the straw. Adjust the sieves and the air to permit only a small amount of tailings return material.

Air setting adjustment is critical to separating the rice on the sieves. Too much air causes the light but marketable kernels to be blown out the rear of the machine, while too little air permits too much of the light chaffy material to accumulate with the clean grain. Air passages may become plugged with light chaffy material so check them often.

The distribution of material on the walkers and sieves is determined by stopping a normally operating combine very quickly. Stop the engine but keep the machine engaged and apply the brakes. When the machine is stopped abruptly in this way it is called the "quick-kill" procedure. Inspecting the material on the sieves and walkers will reveal how uniformly it is distributed. Pockets of dense material collection are undesirable and indicate non-uniform air or material distribution.

Once examined, disengage the header and machine drives, start the engine and then the threshing portion. After the threshing portion is started, re-engage the header.

Because of the high moisture content of the grain entering the grain tank, severe problems are encountered in the unloading operation. Kernels may become interlocked, causing a bridging in the grain tank. Many growers have removed obstructions in the grain tank to reduce bridging. Additional manual assistance to dislodge bridging is often necessary.

## Post Harvest Handling

Harvested grain is loaded into a truck as soon as possible and taken to a processing plant. Moisture content of the freshly harvested wild rice will be over 30 percent and improper storage may result in the severe quality loss due to heating. If the grain cannot be delivered to the processor immediately keep it cool by immersing it in water or by spreading it on the ground and turning daily.

To spread the harvest period over the longest possible time and make the best use of harvest equipment, some growers choose different varieties for different paddies. Wild rice from lake regions, or other native stands, matures earlier than the cultivated varieties and there is a difference of maturity date between varieties.

As wild rice varieties become further domesticated, and shatter resistance developed, the grain will be more mature at harvest making handling easier.

## After Harvest Paddy Maintenance

**Tillage** — Tillage assists in the control of weed growth, especially cattails. Discing is faster and cheaper than rototilling, although rototilling is better. Some growers will disc the field lightly to chop and partially turn under the straw and then rototill to finish preparation of a fine seedbed. If a floating picker is used for harvest, there will be less time after paddy drainage to till the field before winter. However, rototilling is recommended when time permits. Extra flotation, provided by large rubber tires attached to the rear of a rototiller may be needed for tillage in soft peat soils. Tillage also tends to reduce the degree of excessive plant population the following spring and thus reduces the amount of thinning required.

Producers often burn plant residue to reduce the presence of disease on wild rice debris. Seeding of areas where the stand was thin should be carried out as part of the fall preparation. Similarly, additions of fertilizer should also be considered.

If drainage was incomplete or harvest operations have left the land uneven, land planing should be undertaken. Where flotation is a problem, peat soils may benefit from rolling.

Finally, paddies should be flooded before winter.

Fields can be rotated with dryland crops, if the paddy area is properly drained to avoid saturated soils during the growing season. Wild rice is a grass so choose an alternate crop which will not introduce undesirable diseases. Avoid grasses and barley in particular, as they are susceptible to brown spot. Canola or rapeseed is a suitable alternate crop not in the grass family. Other crops for consideration include buckwheat, wheat, mustard and flax.

**Ditches and Dykes** — After the paddies are drained check ditches and dykes to assure that they function properly. Clean out any materials blocking water flow so that complete drainage is achieved. Assure that dykes do not leak, are free of weeds and provide paddy access.

**Changing Varieties** — Wild rice seeds survive a number of years in the soil so changing paddies to a new variety is difficult. The best way is to leave the paddy out of wild rice production for two or three years. Do not till the selected paddy in the fall. Many of the seeds which fell from the plants before and during harvest will be on top of the sediment. Leave them to dry out and lose viability. Flood the fields the following spring to allow viable seeds to germinate. After four to six weeks, drain the field then till it to eliminate volunteer wild rice plants. A short season crop could be planted after tillage. A high percentage of the wild rice seed of the old variety will be eliminated after two years of this procedure. However, if the plant population in the second year is heavy, a third year of the elimination program may be warranted.

The new variety should then be sown using the regular procedures and rates.

**Deep Plowing** — Some growers have been successful in switching a paddy to a new variety in one year by deep plowing. Plow the field 50 to 60 cm (20 to 24 inches) deep in the fall to bury most of the seed deep enough so the seedlings cannot emerge. Deep plowing is very costly and is only used if the subsoil is not too close to the surface. It is difficult to establish wild rice in infertile, clay subsoil.

## Equipment Requirements, Maintenance and Storage

General:
- Tractor
- Truck
- Rotovator and Disc
- Fertilizer spreader
- Seeder
- Roller — if problems with floating peat
- Pumps — 30 cm (12 inch) pumps delivering 18,200 litres per minute (4,000 gallons/minute) will serve 4-12 hectare (10-30 acre) paddies.

Specific:
- Airboat — fitted with cutting bar for thinning, and a header if used for harvesting in flooded paddy
- Combine — with alterations for wild rice
- Harvester-picker — instead of airboat or combine

Optional:
- Airplane — for crop spraying or seeding
- Backhoe, bulldozer, land plane — for dyke construction and shaping, instillation of culverts and paddy forming.

Regular maintenance of equipment permits the operator to observe and correct problems as they develop. This helps reduce cost of repair and reduces the risk of equipment failure in high use periods of the season. Particular care should be taken to assure that regular lubrication and fluid level checks are carried out as specified in the owners manual for each machine.

Storage of equipment under protective cover will avoid deterioration caused by weathering. If under-

cover space is not available, provide partial cover for weather sensitive parts such as motors and tires. Clean equipment of soil and debris, drain all compartments that hold liquids subject to freezing and lubricate moving parts in preparation for off-season storage.

**Cost Consideration (Base — 1980)**

*Development Costs*

There is no charge for the surveying costs and advice given by PFRA. In 1980, construction costs were $27/hour for a scraper and tractor. Large bulldozers or dragline equipment cost more. One 4 ha (10 acre) paddy took 260 hours to construct, with a total cost of construction $7020, or $1755/ha ($702/acre).

A larger paddy will not cost much less. The particular paddy constructed in 1980 is on land where the clearing cost was nil as it was previously cropped. A minimum cost for paddy development is $2000/ha ($800/acre).

*Capital Investment*

In 1981, Manitoba land values ranged from $1485 to $185/hectare ($600 to $75/acre). Higher prices are found in the central and southwest while the interlake and areas east of the Red River suitable for cattle raising have lower prices.

Airboat for thinning and harvest $3500 to $8000.

Tractor $45,000.

Rotovators from $1751 to $6500 depending on size.

Combines range from $65,000 to $100,000.

*Paddy Equipment*

Metal culverts 30 cm (1 foot) diameter $19/m ($6.00 per foot). If the culverts are double the diameter, the cost is $36.00/m ($11.00 per foot). A crisafulli 30 cm (10 inch) pump with capacity of 11,350 litres/minute (2500 gallons/minute), costs $5,310 (brokerage paid) F.O.B. Glendive, Montana (south of Regina). Industrial tubing for flexible connections costs $1155 for 15 m (50 feet). A 20 cm (8 inch) pump with a capacity of 7,570 litres/minute (1,660 gallons/minute), costs $4,525 and $895 for industrial tubing and clamp. Crisafulli pumps are driven by a power take-off on a tractor, and need about 76 cm (30 inches) of water depth to operate efficiently.

A floating pump with capacity of 2,650 litres/minute (580 gallons/minute), costs $1095 and in the package is a 4.5 kW (6 HP) engine and 122 m (400 feet) of hose. A self contained unit, 25.4 cm (10 inches) pump and engine, capable of delivering 15,000 litres/minute (3300 gallons/minute) costs $14,000.

*Operating Costs*

An efficient operating unit is between 100 and 125 ha (250 to 300 acres). Larger areas require multiple units of equipment. Expansion from the efficient operating unit size should be a doubling or tripling in size to remain efficient.

Operating costs were estimated for two 100 hectare (250 acre) wild rice farms in 1980. Operating costs include oil and gas, machinery repairs, paddy maintenance, transportation and labour. Costs for the two units were $18,750 and $50,000. They vary depending on the equipment used, spraying and fertilizing necessary and management practices.

*Seeding Costs*

Seeding is not an annual cost. If a paddy is kept in production for three years and fallowed for one, seeding takes place every fourth year. When paddies need seeding, the cost is $150 to $185/hectare ($60 to $76/acre).

*Fallowing Costs*

If a paddy is fallowed every fourth year, the cost of taking the area out of production for one year, and the costs of caring for the fallowed area, must be spread over the three productive years. If an alternate crop is seeded in the fallow year, returns will contribute to costs of production.

*Production Costs*

Two levels of production costs illustrate a low and high level of investment and management costs (Tables 7 and 8). Calculations are based on 100 hectare (250 acre) unit size. Capital and land investment is considered as requiring adequate return to the grower on the basis of interest rates. Return on investment calculation must consider all investment and not just operating costs.

Table 7

Annual Production Costs of Wild Rice Using Low Levels of Investment and Management Costs

| Item | Dollars /ha | Dollars /acre |
|---|---|---|
| Land investment — $18750 at 15% | 28.13 | 11.25 |
| Equipment | | |
| tractor $45000 | 67.50 | 27.00 |
| rotovator $ 1751 | 2.63 | 1.05 |
| combine $65000 | 97.50 | 39.00 |
| airboat $ 3000 | 4.50 | 1.80 |
| Development costs $200,000 | 300.00 | 120.00 |
| Operating costs | 187.50 | 75.00 |
| Seeding cost | 50.00 | 20.00 |
| TOTAL | 736.76 | 295.10 |

Table 8

Production Costs of Wild Rice Using High Levels of Investment and Management Costs

| Item | Dollars /ha | Dollars /acre |
|---|---|---|
| Land investment — $150,000 at 15% | 225.00 | 90.00 |
| Equipment | | |
| tractor $ 60,000 | 90.00 | 36.00 |
| rotovator $ 6,500 | 9.75 | 3.90 |
| combine $100,000 | 150.00 | 60.00 |
| airboat $ 7,000 | 10.50 | 4.20 |
| Development costs $300,000 | 450.00 | 180.00 |
| Operating costs | 500.00 | 200.00 |
| Seeding cost | 61.67 | 26.33 |
| TOTAL | 1,496.92 | 599.42 |

Table 9
Dollar Returns/ha

| Price Received $/kg | Yield (kg/ha) 112 | 168 | 224 | 280 | 336 | 392 | 448 | 1120 |
|---|---|---|---|---|---|---|---|---|
| 1.10 | 123 | 185 | 246 | 308 | 370 | 431 | 493 | 1232 |
| 2.20 | 271 | 370 | 493 | 678 | 739 | 862 | 986 | 2464 |
| 3.31 | 371 | 556 | 741 | 927 | 1112 | 1298 | 1483 | 3707 |
| 4.41 | 494 | 741 | 988 | 1235 | 1482 | 1729 | 1976 | 4939 |

Table 10
Dollar Returns/acre

| Price Received $/lb. | Yield (lb/acre) 100 | 150 | 200 | 250 | 300 | 350 | 400 | 1000 |
|---|---|---|---|---|---|---|---|---|
| 0.50 | 50 | 75 | 100 | 125 | 150 | 175 | 200 | 500 |
| 1.00 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 1000 |
| 1.50 | 150 | 225 | 300 | 375 | 450 | 525 | 600 | 1500 |
| 2.00 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | 2000 |

### Examples of Return Potential

The price received by producers in 1979 and 1980 dropped from $4.63 to $1.32/kg ($2.10 to $0.60/lb) of green, unprocessed wild rice. Returns for eight different yields and four different prices received are shown in Tables 9 and 10 respectively.

To recover total production costs at the low levels of investment used in Table 9, and at a price of $1.10/kg ($0.50/lb), the yield must be 671 kg/ha, (590 lb/acre). For recovery of all costs at a price of $4.41/kg ($2/lb) the yield must be 167 kg/ha (147 lb/acre). The higher production costs are just about double the lower and so twice the yield would be needed to break even.

If only operating costs and seed costs are considered, these are 35 percent of the total costs and 35 percent of the calculated yield is necessary for recovery.

*Average Returns*

Considering the Minnesota average of 336 kg/ha (300 lb/acre) in a year when the price was $4.41 per kg ($2/lb), the return is $1481/hectare ($600/acre). Total costs were $1497/ha, ($599/acre) at the high level and $737/ha ($295/acre) at the low level of investment. When the price was $1.10 per kg ($0.50 per lb), the return would work out to $370/ha ($150/acre), between the low and high level estimates of operating and seeding costs.

Paddies were taken out of production in Minnesota in the mid-seventies when prices fell below $1.55/kg ($0.70/lb) to the grower. Cost estimates presented are an illustration of returns at various prices and show why paddy prouction decreased at low prices.

# PRODUCTION IN NATURAL STANDS

## Major Problems

### Fluctuating Water Levels

The greatest single hazard to natural wild rice stands is fluctuating water levels. In 1977, a low water year in the Lake of the Woods area, some 5500 hectares (13,560 acres) of lakes produced wild rice for harvesting. Yet in the high water year of 1978, producing areas were estimated at 130 hectares (320 acres).

Increasing water levels at the floating leaf stage cause wild rice plants to be uprooted. An increase in water level of 30 cm (1 foot) from the preceding year almost eliminated the wild rice crop. If water rises more rapidly than 15 cm (6 inches) in several hours, plant damage will result. Water levels below 15 cm (6 inches) will allow weeds to invade the stand.

### Diseases, Insects, Weeds and Weather

Ergot is a fungus disease. Often local situations encourage ergot infestation and affect a particular stand in one year. The wild rice worm is the main insect causing damage to native stands of wild rice. All the insects, diseases, weeds and other pests mentioned in the paddy section have been found in natural stands.

Wild rice is not aggressive. If water levels are over 45 cm (1.5 feet) there is little emergent weed competition.

High winds, rainstorms, hail and temperatures above 30ºC are detrimental to wild rice in native stands. High or low temperatures during pollination will cause pollen damage and poor pollination. Rain prevents pollen from being carried on the wind.

### Yields

Yields fluctuate from year to year, but are made more consistent through water management and reseeding. The production is low when compared to well managed and fully mechanized paddy production.

### Harvesting

Improvements in the amount of seed harvested often relate directly to the harvesting equipment being used, the timeliness of the harvest operations and the efficiency of the equipment operator. These factors affect the seed loss from shattering as well as the recovery percentage at the processor.

## Management Practices Contributing to Productivity

### Seeding

Some success has been achieved by seeding natural bodies of water. Where stands are thin or spotty, spot seeding may be warranted. Where these areas are small, use of mechanical spreaders mounted on boats is a practical procedure. Where areas are large, aircraft are a practical and effective alternative.

### Water Control

In some instances it is advantageous to construct dams or modify water body outlets to reduce water level fluctuations. This assists in maintaining a constant area of production and yield can increase. However, modification of this nature must receive the approval of agencies administering the land and water rights of the area affected.

### Harvesting Techniques

Some wild rice is harvested by the traditional technique using canoes and rice sticks. However, more and more of the crop from natural areas is harvested mechanically. One device is a bumper head attached to a canoe, boat or pontoons. The head is pushed through the rice stand by a motor driven air or water screw. As the machine passes through the stand of rice, ripe grain falls from the heads and is caught in trays. The speed of travel is critical. If it is too fast, unfilled grain is dislodged and plants are damaged. If speed is properly controlled several passes, at intervals of two or more days, are made to harvest the crop.

Yields from the native stand harvest have increased with advanced harvesting techniques. Estimated yields according to method of harvest are:

| | |
|---|---|
| hand picking | 10 percent of the crop |
| boat harvester | 30 percent of the crop |
| pontoon harvester | 50 percent of the crop |
| ESTIMATED CROP | 1700 to 2250 kg/hg (1500 to 2000 lb/acre) |

# HANDLING AND PROCESSING

## Initial Handling of Harvested Green Wild Rice

The earliest wild rice processing procedures used by the Indians consisted of spreading the wild rice out in the sun and air for curing. The dried crop was placed in a bowl over an open fire and stirred continuously until parched.

Modern processing plants have incorporated traditional procedures for fermenting, curing, parching and hulling. The separation of immature kernels, cleaning, grading and packaging have been added (Figure 6).

### Storage

The moisture content of freshly harvested wild rice is over 30 percent. Improper storage will cause severe loss of quality due to heating. If the grain cannot be delivered to the processor immediately on harvesting, keep it cool by immersing it in water or by spreading it on the ground and turning daily.

Wild rice harvested in lakes and rivers is transported to the processor by truck or airplane. In remote areas, float planes land and pick up bags of green wild rice. Pickers keep the bags in water until sufficient quantity is obtained to warrant pick up.

Paddy producers load the combined grain into trucks for immediate transport to a processing plant.

## Processing

### Separation of Immature Kernels

Wild rice which has been combine harvested contains kernels at different stages of maturity. The very immature kernels are mainly hull and are very light and are of no value compared to the fully mature, well filled kernels. A separator which removes a high percentage of immature kernels from the combined wild rice has been developed by the University of Minnesota. (Figure 7 and Table 11).

The gravity separator divides the kernels into three fractions, light, medium and heavy. By weight, the green wild rice separates into about 51 percent heavy, 38 percent medium and 11 percent light on average.

**Figure 6 — Handling and Processing of Combined Harvested Wild Rice.**

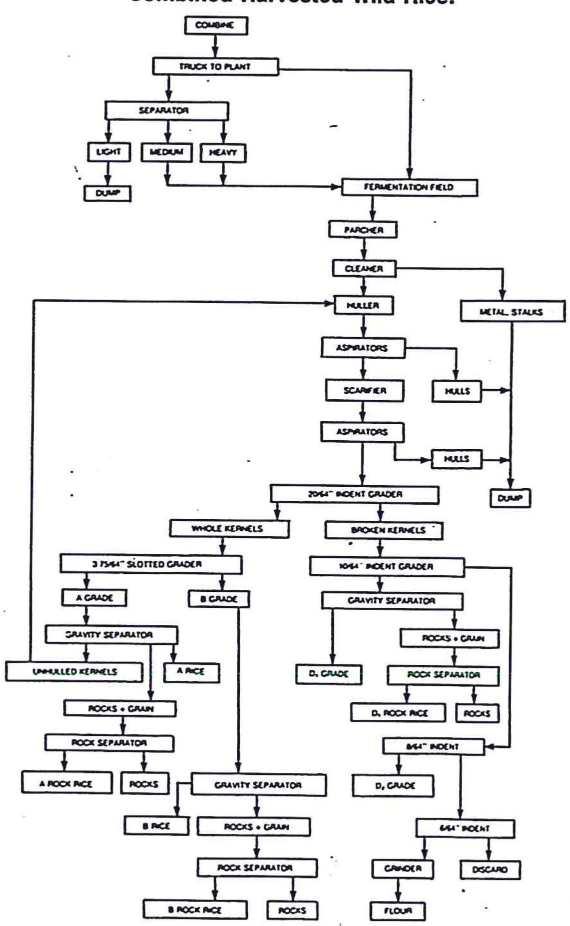


Figure 7 – Modified Air Stream Separator.

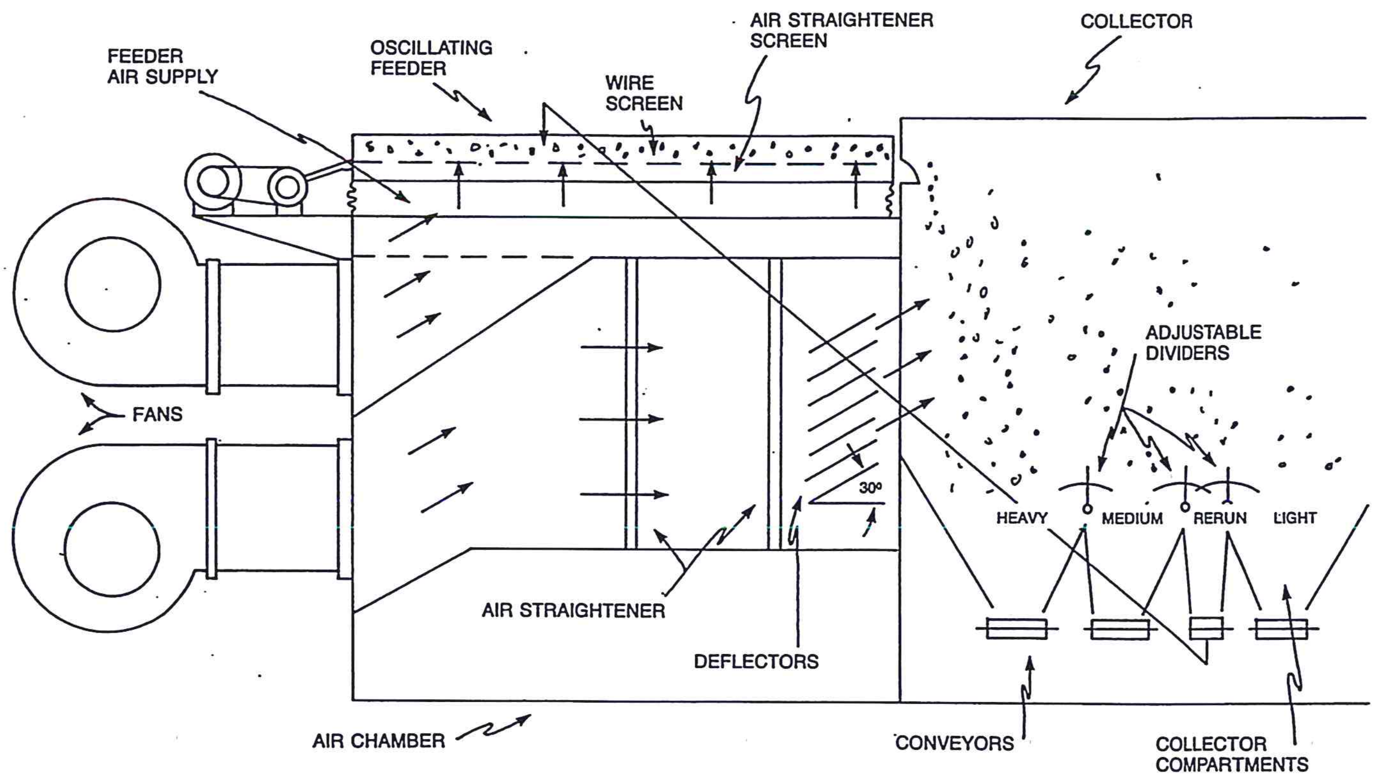



Table 11
1977 Prototype Separator

A. Feeder
1. 810 mm (32") wide by 1830 mm (72") long
2. Screen, 12 mesh, 19 ga (0.89 to 1.04 mm) wire
3. Air straighteners, perforated sheet metal 6.4 mm (¼") round openings, 35% open area
4. Speed of oscillation, 900 cycles/min., adjustable
5. 8 mm (5/16") front to back movement

B. Fans
1. Double width, double inlet, backward curved blade 50 cm (20") wheel diameter
2. Air delivery to collector, approximately 17,000 m³/h (10,000 CFM)
3. Air delivery to feeder, approximately 13,600 m³/h (8,000 CFM)
4. Collector fan is equipped with a variable speed drive

C. Air Chamber
1. 910 mm (36") wide x 1880 mm (74") long
2. Straighteners, perforated sheet metal 6.4 mm (¼") and 4.8 mm (3/16") round openings, 35% open area
3. Height of air passage at straighteners, 760 mm (30")
4. Deflectors 410 mm (16") wide galvanized iron set at 30º to the horizontal

D. Collector
1. 910 mm (36") width x 2100 mm (83") long
2. Dividers, galvanized iron, adjustable

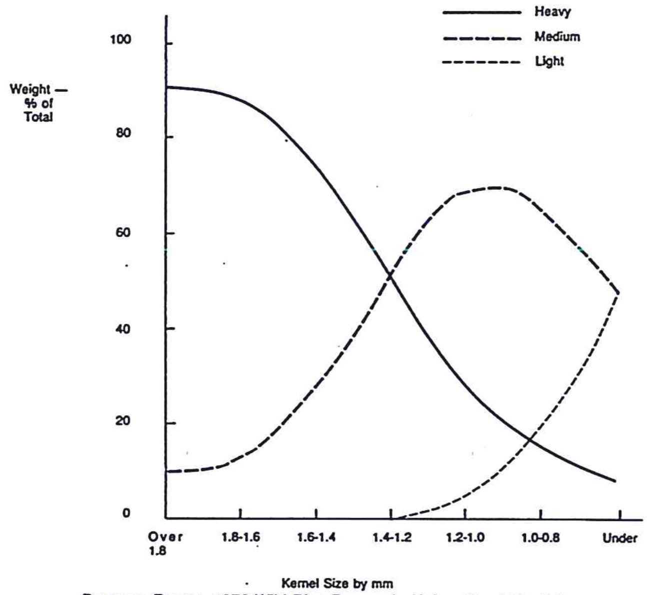
E. Conveyors
1. Collector cross conveyors, 300 mm (12") wide, cotton belt
2. Forage feeder wagon to separator 410 mm (16") wide cotton belt
3. Collector cross conveyors to wagons 300 mm (12") wide cotton belt

F. Approximate overall dimensions of the separator, 1220 mm (48") wide, 4900 mm (16') long, 2600 mm (102") high excluding conveyor

G. Capacity, about 2722 kg/h (6000 lb/hour)

After processing the heavy fraction contains about 47 percent of the original green weight, the medium fraction about 24 percent and the light fraction has 2 percent of the original green weight. Of the final processed wild rice, about 71 percent originates in the heavy fraction and 28 percent in the medium fraction. Due to the small recovery of the light fraction, it is usually discarded (Figure 8).

**Figure 8 — Percent Distribution of the Total Weight of Kernels of a Particular Size Within the Three Maturity Fractions of Wild Rice.**




Progress Report, 1976 Wild Rice Research, University of Manitoba

The separator design includes an optional rerun feature, which allows borderline material between medium and light collection compartments to be rerun through the machine for resorting. Without the rerun about 23 percent of the combined wild rice volume is sorted into the light fraction and with the rerun in operation about 32 percent was sorted into the light fraction. The capacity of a processing plant's volume is limited and reducing the volume handled by 25 to 30 percent increases the seasonal capacity of the plant. Some processors parch the heavy, mature fraction directly without fermentation.

If a plant has a separator, the wild rice is run through it before it is placed in windrows for fermentation. If there is no separator, the crop is unloaded directly into the windrows in the fermentation area.

## Fermentation or Curing

The windrows, in which the wild rice is placed when delivered to the processing plant, may be 1.2 to 1.8 m wide (4 to 6 feet) and about 30 to 60 cm (1 to 2 feet) deep. Periodically they are agitated and water is added to prevent the grain in the windrow from drying below 30 percent moisture. Excessive temperature build-up is also prevented.

Some processors have developed mechanical devices to turn and add water to the windrows once or twice daily during normal weather conditions. The ideal fermentation period is four to seven days. However, some wild rice may be fermenting for three weeks because harvesting capacity is greater than processing capacity.

Wild rice quality depends on proper fermentation or curing. The flavour profile is determined by fermenting and parching conditions. The bland, cereal-like, grain and starchy taste of the unfermented wild rice is replaced by a tea-like, hay-like, mouldy, marshy, earthy, swampy, fishy, toasted, scorched, burnt, medicinal or bitter flavour.

Fermentation is a complex chemical and biological process involving respiration, heat and moisture transfer and a large number of microorganisms. It is necessary for the kernels to gain colour and flavour development and hulls to degrade.

Dry matter losses and a yield reduction of finished wild rice occurs during curing. Over 20 percent of usable wild rice can be lost in 10 days due to respiration and the microbial action.

During fermentation, the wild rice kernels change from greenish tints to the browns characteristic of mature kernels. Hull degradation which results in a more efficient operation of the hulling device takes place during curing.

## Parching

Once fermentation is complete, parching removes the moisture. The moisture content of wild rice as it comes from the fermentation field is 40 to 45 percent (wet basis). It is dried to a moisture content of about seven percent in the parcher (Figure 9).

A parcher consists of a rotating drum approximately 1.2 m (4 feet) in diameter and 1.8 to 2.4 m (6 to 8 feet) long, supported on rollers at the front and rear. Rotation is continuous during the parching operation. Vanes set at an angle to the axis of the cylinder are provided at the forward end of the drum, to aid in retaining the wild rice during the parching. It also assists in moving grain out of the drum when the direction of drum rotation is reversed for emptying.

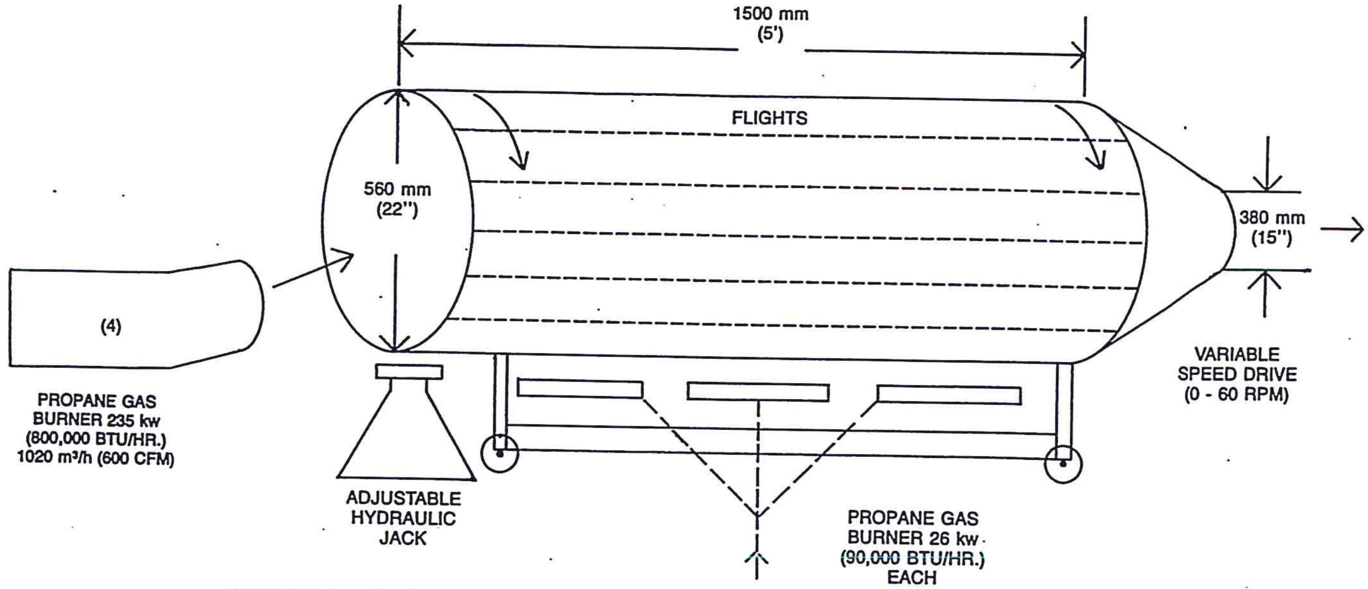
Heat is transferred through the drum's surface from propane, gas or wood burners below the drum to the wild rice. The drum rotates and the wild rice tumbles and slides in contact with the inner surface. Some parchers are equipped with small bars, which extend longitudinally through the parcher drum. This gives additional mixing or agitation to the tumbling wild rice. After the grain is dried, the rear of the drum is raised slightly and the direction of rotation is reversed so that the parched grain is discharged.

The wild rice is parched for about two hours at a temperature of 135ºC to obtain the desired, slightly toasted flavour. A high degree of starch gelatinization in the kernels takes place during parching.

Continuous parchers have been designed which permit a steady flow of wild rice through the equipment. This system is less labour intense and once it is well developed will likely replace the majority of the batch type systems.

High kernel strength, with a minimum of stress cracks will minimize broken kernels. Conditions that

**Figure 9 — An Experimental Parcher.**




Note: A shroud was placed around the drum with a 50 mm (2") air gap for combustion gas and insulation.

cause severe moisture gradients in the kernel increase the kernel fragility. Kernels which are hulled cold are less fragile than those hulled immediately after parching. Good kernels are hard, flinty and translucent once dried.

Drying too rapidly causes an air space along the major axis of the kernel, producing a hollow center. This also causes a scorched or burnt flavour. To reduce white centers, dry above 65°C and have an initial moisture over 30 percent.

The parching process involves steaming, which gelatinizes the starch. It also assures drying for good keeping quality, and toasting if the temperature is above 100°C. Drying below 80°C leaves the finished grain with an earthy or green tea flavour. A scorched or burnt flavour results when drying takes place at a temperature over 200°C. A high degree of starch gelatinization takes place at 105°C, but none occurs at 50°C. The gelatinization temperatures is 62° to 65°C.

Investigations on the use of a solid heat transfer medium for parching, such as sand, have been carried out at the University of Manitoba. The sand temperature entering was 157°C and leaving was 85°C.

Parchers in use can dry from 100 to 180 kg/h (250 to 400 lb/hour).

### Hulling

After parching, the wild rice may be passed over a cleaning screen to remove the stalk fragments or other debris. A permanent magnet is often placed in the path of the wild rice entering the cleaner to remove pieces of ferrous metal. From the cleaner, the grain is conveyed to the huller. During the parching process, shrinkage of the kernels occurs. This lossens the hull from the kernel and permits hull removal.

The barrell huller, an enclosed drum into which a batch of wild rice is placed removes the hulls with internally rotating flails.

The double roller huller is another type. Kernels fall between two closely spaced rubber covered rollers, which impart a rubbing action because of the difference in speed and rotation. An aspirator removes the hulls and the chaff. Hulled wild rice smaller than 7 mm long and 1 mm in diameter (0.3 inches long and 0.04 inches wide) are separated as brokens.

The hot wild rice is cooled before dehulling and the lower the moisture content, the higher the yield of hulled wild rice. At seven percent moisture there is less than one percent of the kernels unhulled, while at 21 percent moisture two to four percent of the kernels are unhulled.

### Scarification

Scarification is the removal of a portion of the outer layer of the wild rice kernel. Most processors use a scarifier made of a closed cylinder type container having a shaft extending longitudinally through the drum and carrying several rubber paddles. Scarification is controlled by the inclination of the longitudinal axis of the scarifier and the aggressiveness of the rubber paddles. This aggressiveness depends on the speed and clearance.

Scarification reduces cooking time, an important factor when wild rice is mixed with white rice for sale.

## Cleaning, Grading & Packing

After parching and hulling the grain proceeds through a series of cleaning, separating and sizing devices (Figure 6). The object of this is to remove stalks, hulls, stones and other debris, and to size the kernels according to the demands of the market outlets. In this latter sizing operation, broken kernels are separated from whole kernels. Often the broken kernels are used to produce wild rice flower.

Once cleaned and graded, the wild rice is packed into containers of various sizes. These range from about 500 g to 50 kg.

# MARKETING

## Market Structure and Use

The marketing system of wild rice consists of harvesters or growers, buyers, processors, wholesalers and retailers. Harvesters of wild rice from natural stands frequently sell the freshly harvested green wild rice to buyers. They may be buying on their own or on a commission basis for a stage further up the market chain, particularly a processor or wholesaler. In some cases the harvester or grower processes his own wild rice or has it custom processed and returned for sale to wholesale or retail outlets. From the above it is evident that the market is not fully formalized but rather is one where actions of those involved vary widely.

The industrial market uses 75 percent of each year's production with 15 to 20 percent for restaurants and other food services. Only about 10 percent finds its way into the retail and specialty market. Industrial food manufacturers do not own any wild rice production facilities or paddies, but purchase on the free market, with heavy reliance on suppliers. Advance sales contracts have been used to assure price and quantity, and remove speculation.

Both green and finished wild rice move across the U.S./Canada border. Recently the formation of an International Wild Rice Association encourages the joint development of increased consumption of the product. In addition, individual agencies make direct contact with potential market outlets and engage in private promotional activity.

## Supply and Historical Production Levels

Before 1970 the majority of wild rice was produced from natural stands. Volume harvested fluctuated widely and a reliable source of supply was not available. Production levels from natural stands in Manitoba are listed in Table 12.

Since 1970, paddy production has increased, and is now the major stabilizing sector of wild rice production. North American wild rice production is about 2.7 million kg, (6 million lb), with paddy production assuring over 1.8 million kg, (4 million lb) of the total. Stock piling does occur to even out the supply.

Wild rice from paddies in Minnesota is listed in Table 13.

Table 12
Wild Rice Production in Manitoba 1949-1980
(harvested green weight)

| Year | Weight Tonne | Weight 1000 lb | Year | Weight Tonne | Weight 1000 lb |
|---|---|---|---|---|---|
| 1949 | 152 | 335 | 1967 | 269 | 593 |
| 1950 | 60 | 132 | 1968 | 91 | 200 |
| 1951 | 62 | 136 | 1969 | 73 | 161 |
| 1952 | 51 | 113 | 1970 | 68 | 149 |
| 1953 | 13 | 29 | 1971 | 227 | 500 |
| 1954 | 22 | 49 | 1972 | 273 | 601 |
| 1955 | 27 | 61 | 1973 | 284 | 627 |
| 1956 | 222 | 488 | 1974 | 62 | 137 |
| 1957 | 40 | 89 | 1975 | 65 | 142 |
| 1958 | 121 | 267 | 1976 | 159 | 351 |
| 1959 | 2 | 5 | 1977 | 524 | 1154 |
| 1960 | 121 | 268 | 1978 | 205 | 453 |
| 1961 | 147 | 325 | 1979 | 272 | 600 |
| 1962 | 48 | 105 | 1980 | 635 | 1400 |
| 1963 | 64 | 141 | 1981 | 205 | 453 |
| 1964 | 106 | 233 | 1982 | 188 | 415 |
| 1965 | 11 | 24 | 1983 | 152 | 336 |
| 1966 | 55 | 121 | | | |

Table 13
Wild Rice Production From Cultivated Fields In Minnesota

| Year | Area[1] | Production[2] | Year | Area[1] | Production[2] |
|---|---|---|---|---|---|
| 1970 | 2 ( 5) | 413 ( 910) | 1976 | 5 (12) | 1701 (3750) |
| 1971 | 4 ( 9) | 689 (1520) | 1977 | 4 (10) | 1361 (3000) |
| 1972 | 7 (17) | 1696 (3740) | 1978 | 5 (12) | 1905 (4200) |
| 1973 | 7 (18) | 1361 (3000) | 1979 | 6 (15) | 2087 (4600) |
| 1974 | 5 (12) | 1225 (2700) | 1980 | 6 (15) | 1950 (4300) |
| 1975 | 5 (12) | 1452 (3200) | | | |

1 Area in thousands of hectares (acres)
2 Production in tonnes ('000 pounds)

## Demand

Advertising and general market promotion has introduced wild rice to a greater percentage of the population. Increased interest by many groups and individuals has produced a wide range of use. Consumption has increased in the past decade and has been assisted by the development of recipes.

Efforts continue to create an increased awareness of the product by a greater percentage of the population and utilization is expected to increase steadily. A drop in the price of the finished product would result in a significant increase in consumption. However, for this to occur, major agronomic improvements would have to take place to reduce the production cost per unit.

## Nutrition

The protein content of wild rice is relatively high for a cereal, and it contains more lysine and methionine than most cereals (Tables 14 and 15). Wild rice is a good source of the B vitamins, and it contains common minerals in amounts comparable to those in oats, wheat and corn. Unprocessed wild rice compares favourably with cultivated brown rice and wheat. The amino acid composition of processed wild rice is similar to unprocessed, which is one indication of lack of damage to the nutritional quality through processing. Wild rice is nutritionally capable of supplying the nutrients generally obtained from other cereal crops at the present time and can diversify the consumer's diet.

Table 14

The Composition of Wild Rice, Cultivated Brown Rice and Wheat

| Nutrient | Wild Rice[1] | Cultivated | Wheat |
|---|---|---|---|
| Protein % | 13.8 (12.8-14.8) | 8.1 | 14.3 |
| Ash % | 1.7 (1.4-1.9) | 1.4 | 2.0 |
| Fiber % | 1.2 (1.0-1.7) | 1.0 | 2.9 |
| Ether Extract % | 0.5 (0.3-1.0) | 2.1 | 1.9 |
| Phosphorus % | .28 | .22 | .41 |
| Potassium % | .30 | .22 | .58 |
| Magnesium % | .11 | .12 | .18 |
| Iron ppm | 17 | 10-17 | 60 |
| Manganes ppm | 14 | 30-39 | 55 |
| Zinc ppm | 5 | 24 | |
| Copper ppm | 13 | 4-7 | 8 |
| Nitrogen Free % Extract | 82.4 | 87.4 | 78.9 |

1 Number in brackets is range of values
Source: B.M. Watts 1980

Table 15

Amino Acid Composition Of Processed and Unprocessed Wild Rice, Two Varieties Of Unprocessed Cultivated Rice and Wheat[1]

| Amino | Wild Rice | | Cultivated Rice | | Wheat |
|---|---|---|---|---|---|
| | Green | Processed | Brays | Lebonnet | |
| Lysine | 5.23 | 4.05 | 3.78 | 4.28 | 2.79 |
| Histidine | 2.75 | 2.66 | 2.53 | 2.64 | 2.38 |
| Ammonia | 2.37 | 2.41 | 2.39 | 2.29 | 3.98 |
| Arginine | 8.18 | 7.31 | 8.85 | 8.77 | 4.67 |
| Aspartic | 10.40 | 10.26 | 9.61 | 9.81 | 5.40 |
| Threonine | 3.64 | 3.60 | 3.68 | 3.79 | 2.90 |
| Serine | 5.46 | 5.23 | 5.16 | 5.01 | 4.76 |
| Glutamic | 18.70 | 18.24 | 19.35 | 18.34 | 35.39 |
| Proline | 4.11 | 4.12 | 4.96 | 4.63 | 11.75 |
| Glycine | 4.84 | 4.76 | 4.96 | 5.16 | 4.33 |
| Alanine | 5.83 | 5.82 | 5.80 | 5.94 | 3.57 |
| Cystine | 2.78 | nd | 3.92 | 3.60 | 3.28 |
| Valine | 5.76 | 5.70 | 5.82 | 5.85 | 4.44 |
| Methionine | 2.79 | 3.01 | 2.19 | 2.06 | 1.42 |
| Isoleucine | 4.36 | 4.26 | 4.01 | 4.06 | 3.63 |
| Leucine | 7.39 | 7.33 | 8.32 | 8.30 | 7.19 |
| Tyrosine | 3.75 | 3.50 | 4.47 | 4.34 | 2.86 |
| Phenylalanine | 5.11 | 5.01 | 5.01 | 4.88 | 5.28 |
| Tryptophan | 1.80 | 1.64 | 1.78 | 1.72 | 1.57 |

1 Amino acid composition expressed as grams amino acid per 100 g protein
nd — not done
Source: B.M. Watts 1980

Table 16
Export of Wild Rice From Manitoba in 1979[1]

| Country | Amount kg | Amount cwt | Value $ | Price per Unit $/kg | Price per Unit $/lb |
|---|---|---|---|---|---|
| France | 408 | 9 | 7,014 | 17.17 | 7.79 |
| W. Germany | 181 | 4 | 3,216 | 17.72 | 8.04 |
| Sweden | 1,543 | 34 | 16,774 | 10.87 | 4.93 |
| Switzerland | 2,450 | 54 | 32,789 | 13.38 | 6.07 |
| U.S. | 201,534 | 4,443 | 2,088,350 | 10.36 | 4.70 |
| Total | 206,116 | 4,544 | 2,148,143 | 10.43 | 4.73 |

Table 17
Export of Wild Rice From Manitoba in 1980[1]

| Country | Amount kg | Amount cwt | Value $ | Price per Unit $/kg | Price per Unit $/lb |
|---|---|---|---|---|---|
| France | 544 | 12 | 9,195 | 16.90 | 7.66 |
| W. Germany | 590 | 13 | 7,358 | 12.47 | 5.66 |
| Switzerland | 2,858 | 63 | 43,797 | 15.32 | 6.95 |
| U.S. | 370,047 | 8,158 | 1,231,831 | 3.33 | 1.51 |
| Total | 374,039 | 8,246 | 1,292,181 | 3.45 | 1.57 |

1 Statistics Canada, Domestic Exports, No. 06175

### Exports

Exports of wild rice from Manitoba in 1979 and 1980 were over one million dollars (Table 16 and 17). Exports to the United States were 97.8% of total exports in 1979 and 98.9% of total exports in 1980, but on a unit price basis, other destinations provided better market areas This reflects the shipment of green wild rice to the United States for processing, while only processed wild rice is sent to other countries.

## AGRO-MAN

The $18.5 million Subsidiary Agreement on Value Added Crops Production, called Agro-Man, is cost-shared by the federal government through Agriculture Canada and by the Manitoba government through the Departments of Agriculture and Natural Resources. This investment is shared 60 percent by the federal government and 40 percent by Manitoba.

### Agro-Man Objectives

- to accelerate the production of value-added crops — those crops which are processed or have the potential for processing in Manitoba and
- to improve the efficiency of livestock production and the conversion of forage crops through livestock into red meats.

To meet these goals, Agro-Man proposes various programs to strengthen agricultural production and contribute to new opportunities for employment in the farm service and processing sectors.

### Agro-Man Programs

The Agro-Man Agreement, launched April 1, 1979, runs for 5 years. It contains a wide range of demonstration projects and on-farm trials covering four major program areas:

- Value-Added Crops Investigation and Evaluation
- Special Crops Products
- Livestock Products
- Related Productivity Measures (Land Resources Productivity Measures)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