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UNDERSTANDING CEREAL CROPS I
WHEAT, OATS, BARLEY, AND RYE

By
Roy M. Stephen & Betsey Eisendrath

Technical Reviewers
Dr. Glen M. Wood
Dr. Dennis Sharma
David Ray

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VITA
1600 Wilson Boulevard, Suite 500
Arlington, Virginia 22209 USA
Tel: 703/276-1800 . Fax: 703/243-1865
Internet: pr-info@vita.org

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PREFACE

This paper is one of a series published by Volunteers in Technical Assistance to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose technologies that are suitable to their situations. They are not intended to provide construction or implementation details. People are urged to contact VITA or a similar organization for further information and technical assistance if they find that a particular technology seems to meet their needs.

The papers in the series were written, reviewed, and illustrated almost entirely by VITA Volunteer technical experts on a purely voluntary basis. Some 500 volunteers were involved in the production of the first 100 titles issued, contributing approximately 5,000 hours of their time. VITA staff included Suzanne Brooks handling typesetting and layout, and Margaret Crouch as editor and project manager.

VITA Volunteer Roy Stephen is a professor of agronomy at Lake Land College in Mattoon, Illinois. Betsy Eisendrath is a technical writer and editor who frequently helps VITA on projects such as this. Dr. Glen Wood is an agronomist and professor of plant

and soil science at the University of Vermont. VITA Volunteer agronomist Dr. Dennis Sharma is a technical adviser to both the private sector and government institutions through his company. International Agricultural Consulting Services. David Ray has many years of farming experience, with emphasis on rice, wheat and soybeans. Mr. Stephen was assisted by Lisa Nichols. Mike Medernach, and Sharon Spray, students at Lake Land College.

VITA is a private, nonprofit organization that supports people working on technical problems in developing countries. VITA offers information and assistance aimed at helping individuals and groups to select and implement technologies appropriate to their situations. VITA maintains an international Inquiry Service, a specialized documentation center, and a computerized roster of volunteer technical consultants; manages long-term field projects; and publishes a variety of technical manuals and papers.

UNDERSTANDING CEREAL CROPS I
Wheat, Oats, Barley and Rye

by VITA Volunteers Roy M. Stephen and Betsy Eisendrath

I. INTRODUCTION

Cereal crops, or grains, include a wide variety of plants that are members of the grass family (Gramineae) grown for their hard seeds or kernels, which are used primarily for food. Grains are rich in carbohydrates and contain substantial amounts of protein, as well as some fat and vitamins. They are the staple food for

most of the world's population. Over 70 percent of the world's harvested area is planted to grains, for an output of a billion and a half tons a year.

All grains consist of the same three basic parts: (1) the endosperm or starchy interior of the seed, the food source for the developing seedling; (2) the germ or embryo; and (3) various covering layers.

Most grains can be grown under a variety of weather and soil conditions, and most are cultivated in a number of different regions. However (speaking very generally), oats and rye are most often grown in cool climates with less fertile soils, and wheat and barley in mild climates with better soils. Maize is preferred in warm temperate and subtropical areas. In moist tropical areas, rice is predominant; in drier tropical areas, sorghum and millets. These eight are the most widely cultivated grains. Less common grains, having limited production, include wild rice and Job's tears. There are also several plants, like flax, buckwheat, and amaranths, that are often mistakenly referred to as grains, but are not members of the grass family.

This paper focuses on production and use of wheat, oats, rye, and barley. "Understanding Cereal Crops II" covers maize, sorghum, rice, and millet.

It is not known exactly how long ago people began to eat wild grains, but 75,000-year-old implements have been found that may have been used for milling them. Grains were among the first

plants to be domesticated. This discovery lies at the source of recorded history, for it was the cultivation of grains that made it possible for human beings to end their constant wanderings in search of food. With the cultivation of grains, they could settle together in communities. By 3000 B.C. they were growing all the major grains we raise today.

Many of today's varieties of these grains, however, are improved varieties that have been developed at places like the International Rice Research Institute (IRRI) in the Philippines and the International Maize and Wheat Improvement Center (CIMMYT, from its name in Spanish) in Mexico. Researchers at centers like these work to develop strains that will produce higher yields, lodge(*) less, tiller more, resist diseases and pests, and have an improved nutritional value.

In combination with improved agricultural techniques, these hybrids have produced dramatic increases in yields. But there are limitations. To achieve the full yields of which they are capable, they often require irrigation and increased inputs of fertilizers, as well as of pesticides and herbicides in some cases.
These create further pressures on already strained water and fuel resources, as well as a need for larger capital investment.
Moreover, a new variety of grain seldom remains under cultivation for more than three to five years before new strains of diseases and pests develop to which the variety is susceptible.

ADVANTAGES AND DISADVANTAGES OF GRAIN CROPS

Grain crops have the following advantages:

1. There is a grain crop, and often more than one, suited to almost any climate or soil.

2. They give farmers the highest yield per unit of land of any crop.

3. They can be grown using manual labor, but are well-suited to mechanized farming, which makes them significantly less labor-intensive and less expensive to produce.

4. They are easy to handle and compact to transport and store.

5. Under good storage conditions, they can be kept for a long time.

6. They are rich in starch and calories. and provide significant amounts of protein, as well as some fat and vitamins.

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(*)Lodge: the tendency of the grain stem to fall over under the weight of the seed head. Tiller: capable of producing more than one shoot from the root of the plant.

The disadvantages of grain crops include the following:

1. They are more vulnerable to damage from pests and diseases than legumes.

2. They must be dried thoroughly before storing, and cannot be stored in a humid place.

3. Their protein does not supply all essential amino acids. It must be supplemented with protein from other sources.

MAJOR USES OF GRAINS

Grains as Food

Grains supply over 65 percent of the calories that people consume worldwide. In parts of the world where most of the grain crop is used as human food, they supply an even higher proportion--80 percent in the Far East and Southeast Asia, and over 70 percent in Africa and the Middle East.

People consume grains in a variety of forms: whole, in porridges and soups, dried, and ground into flour that is used to make flat and leavened breads, noodle products, and cakes and cookies. People eat syrups and oils extracted from grains, and drink beer and other beverages brewed from them.

The outer hull of most grains is indigestible and must be removed before the grain can be eaten. Often the grain is milled further to remove the germ and the inner layers of the endosperm's covering. This improves the keeping qualities of the grain and

makes it more uniform in appearance, but results in major losses in its nutritional value.

Grains as Feed

When grain is used as animal feed, it is consumed in the form of seeds themselves, and as pasturage, hay, and silage. Worldwide, animals consume about the same amount of the grain crop as people do, but if current trends continue the animals will soon be consuming the greater proportion.

Feeding grain to animals being raised for meat is an inefficient use of the crop. It takes, for example, 4 kilograms of grain to produce 1 kilogram of pork, and between 7 and 8 kilograms of grain to produce 1 kilogram of beef.

Nonfood Uses of Grains

The nonfood uses of grains are much less important than the food uses. Hulls are used as fuel and mulch, and straw is used as a packing, thatching, and bedding material. Grains are used industrially in the manufacture of soaps, solvents, alcohols, plastics, and paper.

II. MAJOR GRAIN CROPS

This section summarizes the cultivation requirements and primary uses of four major grains--wheat, oats, barley, and rye. More detailed information for specific grains on specific sites may be

obtained from local agricultural extension services, ministries, and research stations.

WHEAT

More hectares of land worldwide are devoted to wheat than any other crop. Wheat has been cultivated since before recorded history. It probably originated in western Asia; it was being grown along the Nile by 5000 B.C., in China by 3000 B.C., and was imported in Greek and Roman times. Today the chief producing countries are the Soviet Union, United States, China, India, France, and Canada.

There are thousands of varieties of wheat. Three important types are common or bread wheat (Triticum vulgare or T. aestivum), club wheat (Triticum compactum), and durum wheat (Triticum durum).

Wheat may be classified as hard or soft. Hard wheats, generally grown in the more arid wheat-producing regions, have higher protein content than soft wheats. Most of this protein is in the form of gluten. Hard wheat produces what are called strong flours. Strong flours have granular texture, with small, hard grains of starch and a high proportion of gluten. They can absorb large quantities of water, and are particularly suited to bread-making. Durum is a kind of hard wheat used mainly to make noodle products. Soft wheats (further subdivided into red and white wheats) usually grow where rainfall is plentiful. Flour made from soft wheat has larger, softer grains than flour from hard wheat. It contains a lower proportion of gluten and can

absorb relatively little water. This limits its suitability for bread-making. Is is often called pastry flour, and is used mainly for making cakes and cookies. Most of the wheat produced in Australia and Western Europe is soft wheat; elsewhere, hard wheat is predominant.

The main wheat-producing regions of the world lie in the temperate zones. Wheat is adaptable to a wide range of growing conditions, but is best suited to cool climates with moderate rainfall. Cool weather is especially important during the tillering and early growth stages. In tropical countries, wheat is usually grown at high altitudes, but it can be grown in lower, warmer areas if the humidity is low.

Wheat needs 25 to 100 centimeters of rainfall a year in the cooler climates where it is most common; in hot areas, it requires 50 to 175 centimeters. It can be grown under irrigation where the rainfall is insufficient. Prolonged drought without irrigation reduces yields. Relatively dry areas produce wheat of higher quality than humid or irrigated areas do, but yields in dry areas are substantially smaller. Rusts and other diseases that attack wheat flourish in hot, humid areas.

Wheat can be grown on a wide range of soils, but does best on well-drained, fertile soils of medium to heavy texture. Silt and clay loams usually give the best yields, but wheat also does very well on fine sandy loams and clay soils. Very heavy or very sandy soils should be avoided.

Production

Bread wheats can be divided into two groups, winter wheats and spring wheats, depending on how they are cultivated. Winter wheats are planted in the fall for harvest the following summer. They cannot be cultivated where winters are too severe, but where they can survive winter, they produce a larger yield than spring wheats. Winter wheats are grown in most of the world's major wheat-producing ares. Spring wheats are grown where the winters are too severe for winter wheats; they also do better than winter wheats in warm climates. Spring wheats are usually sown in March in the northern hemisphere, for harvest in the autumn. They have a shorter growing season than do winter wheats, but require at least 90 days, so they should be planted as early as the soil can be worked.

Wheat may be grown alone or mixed or in rotation, often with a leguminous crop. Methods of cultivation vary according to the type of wheat and to climate and soil conditions. The ground is thoroughly cultivated, either by hand or by machine. The seedbed should be well-pulverized but compact. If beds for irrigation are to be used, they are made just before sowing, fertilizer is often broadcast, and a presowing irrigation is performed.

**The rate of seeding varies between 22 and 135 kilograms per hectare (the larger amounts are used where moisture is plentiful.
Seed may be broadcast by hand, but this can result in fairly poor germination, wasted seed, and an irregular plant stand. Drill seeding in rows can alleviate these problems and produce higher**

yields. The seed is usually deposited in a moist seedbed and covered with 2.5-7.5 centimeters of packed soil, deeper only when the climate is very dry.

Wheat takes up most nutrients from the soil before it blooms, but continues to take up nitrogen until the grain is ripe. It usually responds to fertilizers. Applications of nitrogen range from 34 to 135 kilograms per hectare. Heavier amounts are applied in regions where there is more moisture in the soil. Too much fertilizer can reduce yields by causing plants to lodge and by delaying maturity so the crop becomes more subject to damage from rusts. Semidwarf wheats can take up larger amounts of nitrogen without lodging, enabling them to produce larger yields. Phosphorus is usually applied at 34 to 56 kilograms per hectare, especially in humid regions; potassium, at 23 to 56 kilograms per hectare. Manure and compost may be used, and green manuring is sometimes practiced.

Spring wheats can mature in as little as three months, more quickly than winter wheats, which usually grow five to six months in the tropics, and often longer elsewhere. Wheat is usually harvested with a sickle, or mechanically with a combine, when the grain is completely ripe and the straw is brittle and golden. The moisture content of the grain must be 13 percent or less. If it is higher, the grain needs to be dried before it can be safely stored.

The average yield for wheat worldwide is about 1,600 kilograms per hectare, but the range is enormous, and far higher yields

have been obtained with hybrid cultivars on intensively managed lands.

As long as it is kept clean, cool, dry (no more than 12-13 percent moisture), and free from insects, wheat can be stored almost indefinitely. For this reason, wheat is often stockpiled for distribution during famines.

Diseases and Pests

Wheat is subject to many diseases and insect pests. Wheats resistant to some diseases and pests have been developed, but no wheat variety is resistant to all.

Black stem rust (Puccinia graminis) is one of the worst and most common diseases. Its spores are carried on barberry plants and on the wind. Much of the infection can be avoided by early sowing. Wheat is also susceptible to several smuts; crop rotation and clean seed are used against them. The poisonous fungus ergot sometimes attacks wheat, but is less common in wheat than in rye.

The most common insect pests include grasshoppers, which are sometimes sprayed from airplanes, and Hessian fly (Mayetiola destructor), which can be limited by timing the planting of the wheat to avoid the main brood of insects. The wheat stem sawfly (Cephus cinctus) is another insect enemy of wheat.

Uses

Wheat seeds are ground into flour for human consumption. Wheat is an important ingredient in many breads, biscuits, cookies, cakes, dumplings, noodles, breakfast foods, and beer. Immature wheat makes good forage for livestock, and by-products of milling are widely used as animal feed. There are also nonfood uses. Wheat straw is used as a mulch, and as a weaving and stuffing material. In industry, wheat is an ingredient in emulsifiers, adhesives, and polishes.

Wheats vary in their protein content, but hard wheats average 13-16 percent, and soft wheats 8-10 percent. The protein is deficient in lysine, one of the essential amino acids. The wheat germ and bran are high in niacin, thiamine, riboflavin, and vitamin K, as well as phosphorus and iron. However, the more refined the flour is, the more of these nutrients are lost. A highly refined flour may contain about one ninth of the niacin. a fifth of the thiamine, and a quarter of the riboflavin that the original, wholegrain flour contained. Some flours are enriched to restore some of the lost nutrients.

Triticale

Considerable research effort has gone into developing tritacale, a hybrid of wheat and rye. It is somewhat higher in protein content than wheat, and can be grown in places where wheat does not do well. However, its yields have been undependable, and its protein is low in gluten. These and other drawbacks have not been totally overcome and triticale is still not very widely grown.

OATS

About 50 million tons of oats are grown worldwide each year. Avena sativa is the most common species. (Oats are relative latecomers to the domesticated cereals, since they were probably not raised until around 2500 B.C., with cultivation be-ginning in North Africa, the Near East, and the temperate parts of Russia. Oats are widely grown in temperate zones, especially in North America, the Soviet-Union, and northern Europe. Outside these areas, there is considerable production in China, Argentina, Australia, and Algeria. Oats are fairly new to tropical areas, and not very important there. In such areas, they are grown mainly at high altitudes during the cool season.

While oats are generally tolerant of a wider range of climate, soils, and agricultural techniques than are most other cereals, winter types of oats are actually less hardy than rye, wheat, or barley. Oats are best suited to cool, moist climates, but can also be grown under irrigation. Hot dry weather causes developing oat grains to wither or fill poorly. Heat damage can be limited to some extent by selecting early varieties, particularly of red oats (Avena byzantina), or better yet some of the heat-resistant hybrids that have been developed. Oats can do well on a variety of soils. They grow best on rich, friable loams, especially silt and clay loams, that are well drained. Oats are often grown in rotation. In cooler regions, maize is the crop that most often precedes oats.

Production

Oat culture is fairly simple. First the land is usually plowed and harrowed, sometimes more than once. Then the seed is sown broadcast or drilled in rows. Most often, it is sown broadcast when the crop is for fodder, and drilled in rows 23 to 30 centimeters apart when it is for grain. The seed rate averages 90 kilograms per hectare, less when the oats are broadcast in dry regions or are a companion crop for legumes.

Like wheat, oats can be divided into winter and spring types, depending on when they are planted. In the northern hemisphere, oats are usually sown sometime between October and December, but almost any month of the year oats are being sown somewhere in the world. When they are a spring crop, they are planted as soon as the weather is warm enough for the land to be worked. Planting must be done before the average temperature reaches 10[degrees]C.

The fertilizer requirements for oats are similar to those for wheat. Nitrogen is the most important element, but applications of more than 34 to 67 kilograms per hectare are likely to cause lodging. Often, for a grain crop, this is avoided by applying the manure or chemical fertilizer to the crop preceding the oats in the rotation. Nitrogen may be applied directly to the fodder crop at the rate of 38 to 45 kilograms per hectare. Stiffstrawed cultivars that can accept heavy fertilization without lodging have been developed. Oats also respond well to phosphorus, and often to potassium, in humid areas.

Oats are not usually intercultivated. If they are being grown under irrigation, they receive three or four irrigations. If they are being grown for fodder, they are usually cut between one and three times, and then the plants are allowed to set seed.

Oats planted in the spring are usually ready for harvest in about three months. Winter crops take longer to mature: if the oats are sown in October, the grain will ripen in April. Premature harvesting lowers yields of both grain and straw, but harvesting too late increases losses of grain through shattering. Oats usually yield 10.75 to 21.5 quintals per acre of grain.

Diseases and Pests

The main diseases that attack oats are smut and rust. Smut is prevented by seed treatment. There is no remedy for rust, but hybrids resistant to the disease have been developed. Another disease that damages oats is Septoria, which is most likely to develop during rainy or humid weather; chemicals are used to combat it. The greatest insect threats come from the spring grain aphids, the chinch bug, and the armyworm.

Uses

Oats are used mainly as animal feed. The young leaves are very nutritious and high in protein. They can be pastured or cut for hay before maturity. The grain can be fed by itself or as part of mixtures. The straw is used as an emergency feed and as animal bedding. Oats are often fed whole to horses and sheep; for cattle

they are usually ground or chopped.

Human beings consume oats mostly in the form of oatmeal made from rolled oats. Their protein does not make oats suitable for breadmaking, but they can be used in cookies and cakes. The oat grain is quite high in fat and protein. Its usual protein content is 12-13 percent, but Avena sterilis with a protein content as high as 30 percent has been bred experimentally. Oats are a very good source of vitamin B1. They contain an appreciable amount of vitamin E and the same amount of riboflavin as other grains, but much less niacin than wheat.

Oats are put to a number of uses in industry, one of the most important of which is for the manufacture of furfural, a widely used solvent made from oat hulls.

Nitrate Poisoning

Certain soil and climate conditions may cause growing oat plants to contain high enough levels of nitrates to be poisonous to livestock. Ample applications of phosphate may help prevent this. The symptoms of nitrate poisoning include rapid breathing and a blueing of the mucous membranes; death occurs from asphyxiation. The remedy is an early intravenous injection of methylene blue, at a dose of 4 milligrams of methylene blue per pound of body weight in a 4 percent solution with distilled water.

BARLEY

There are a number of species of barley, the most common of which is Hordeum vulgare. (Barley was one of the earliest cereals to be domesticated, probably originally in the Near East. It was in use as a food for people and animals in China around 2800 B.C. and in Stone Age Europe). Barley was the most important grain for breadmaking in Europe until around the 16th century, when it was gradually replaced by wheat and rye. Today, the Soviet Union is by far the biggest producer, followed by France, Canada, and the United Kingdom. Important producers outside Europe and North America include Turkey, India, Morocco, and Korea.

Barley does best in temperate regions where the climate is cool, but it can adapt better than any other cereal to extremes of climate, as well as to salinity, drought, and summer frost. It is cultivated farther north than any other cereal, to the edges of the Arctic, and at altitudes of 4,572 meters in the Himalayas. Winter types, however, are less cold hardy than rye and wheat. It does best when the growing season is 90 days or more but can reach maturity in as little as two to three months. It is superior to other grains in its ability to withstand dry heat; it does very well on the desert margins where rainfall is very limited, as in North Africa, where it is the most important grain.

Barley is most often grown on light soils, but it does best on well-drained, even-textured loams of fair fertility. Barley needs a more porous soil than wheat does, and can tolerate alkalinity better. It is unsuited to acid soils with a pH below 6; these cause aluminum toxicity, which retards root growth. (This toxicity

can be corrected with calcium applications.)

Barley can be grown unirrigated in areas where there is between 38 and 51 centimeters of rainfall. Where the climate is drier, irrigation is needed.

Yields for barley range between 1,120 and 2,240 kilograms per hectare depending upon variety, soil, and climate.

Production

Like wheat and oats, barley can be divided into spring and winter types. Spring barleys can be planted farther north than any other grain. In warmer climates, barley is usually sown in fall or winter. In the northern hemisphere, the best time for planting is usually between the middle of October and the middle of November.

Barley is most commonly planted in rotations; it is also often a companion crop with grasses and small-seeded clovers. The seedbed should be well prepared, though cultivation for barley is usually less thorough than for wheat. Nevertheless, the best yields of barley come from soil that is well tilled and completely free of weeds. Three or four plowings with a wooden plow or one plowing with an improved iron plow, followed by a harrowing, should be adequate. Unlike wheat, barley needs a seedbed that is slightly loose.

The seed may be broadcast, or drilled in rows 15 to 23 centimeters apart. It should be sown about 4 centimeters deep in

humid areas, and deeper where the soil is drier. The usual seeding rate ranges from 54 to 135 kilograms per hectare, with the smaller quantities in drier regions.

Intercultivation is not normally practiced with barley unless the soil is very weedy. If this is the case, then it is useful to hand-weed and hoe once. An irrigated crop needs two or three irrigations; generally speaking, barley needs less water than wheat does.

Barley usually responds well to an application of 28 to 56 kilograms of nitrogen per hectare, the larger quantities going on moist soils. An excess of nitrogen can cause lodging and lower the malting quality of the grain. On some soils, the barley crop is not fertilized directly, but draws on nutrients in the manure, compost, or commercial fertilizer that was applied to the preceding crop in the rotation.

Barley is usually harvested when fully ripe, that is, when a dent made in the kernel with a thumbnail stays visible for some time. The crop can be harvested by hand or by machine. Harvesting in the early morning can sometimes help reduce losses from shattering. Barley is often dried in windrows to reduce the moisture of the grain, which should be 14 percent, or preferably 12 percent, for safe storage. It should be stored under moistureproof conditions.

Diseases and Pests

Barley is subject to many of the same diseases and pests that attack wheat. These include rusts, stripe, scab, and rot. It is susceptible to the parasitic fungi of the Helminthosporium species and to several smuts. Barley seeds can be chemically treated against scab, smut, or stripe, but the most effective approach is to grow disease-resistant varieties.

A number of approaches are used to limit infestation of barley by insects. Wireworm infestation can be reduced by using a crop rotation that includes species not subject to attack (such as clover, soybeans, flax, or buckwheat). Time of planting can play a role in controlling Hessian flies, which live no more than 10 days, and aphids. Chinch bugs can be trapped as they migrate, and induced with lures to lay their eggs where they can be destroyed. Chemical treatment can also be used.

Uses

The main uses of barley are to make malt and to feed animals. The most important use of barley for human consumption is for malt, used primarily in brewing beer, but also in the manufacture of breakfast food and confections. Malt is prepared by soaking and germinating barley. Since only unbroken grains will germinate, care in the threshing and handling of barley is particularly important. High protein content is not desirable in a barley grown for malt. Otherwise, barley in human food is eaten primarily in the form of pearl barley, which is barley that has been dehulled and mechanically polished in the same way that oats sometimes are. Barley is a staple food grain in parts of Asia and

North Africa, where it is eaten as a porridge or flatbread. Because of its low gluten content, barley flour cannot produce a porous bread.

Because of its hull, barley contains 5 percent less digestible material than maize does, and its feeding value for animals is considered to be 95 percent that of maize; compared to maize, barley contains about the same percentage of carbohydrates, a little more protein, and a little less fat. Barley is considered particularly well suited to fattening cattle and hogs. It is usually ground or rolled before being fed to any animal except sheep. Its straw is of a soft type that can be used as a bulk roughage feed or as animal bedding.

RYE

Rye (Secale cereale) was probably first grown in the eastern Mediterranean area or in western Asia. It was the last of the cereal crops to come under cultivation, and even now is the least important economically. The principal rye-growing areas are the Soviet Union, eastern and central Europe, the United States, Turkey, and Canada. Production is declining because of consumer preference for wheat, and because of wheat's higher yields.

Rye is grown primarily for grain, but sometimes for pasturage and hay, and as a cover crop. It is an annual, but it sometimes tends to maintain itself as a perennial by sprouting from its stubble. It is grown primarily in temperate and cool nonhumid regions. The ability of spring rye to withstand cold is greater

than that of any other grain except barley, which may equal it. It can be grown as far north as the Arctic Circle, and at altitudes of up to 4,270 meters. It is also grown in warmer areas, but production there is much less than where it is colder.

Rye grows quite dependably on poor soils, and can produce yields on soils considered too poor for wheat. It responds well to fertile land and good care, but usually the better soils are reserved for other crops, and the poorer, sandier soils are used to plant rye. Rye benefits from fertilizers, especially nitrogen; up to 134 kilograms per hectare can be applied. Too much nitrogen will promote lodging in rye grown for grain, but a spring top-dressing of nitrogen may be used where the rye is being grown for pasturage.

Production

Rye is grown in much the same way as other small grains. Like wheat, it can be grown as a winter crop or a spring crop; winter rye is most common. Winter rye is sown at about the same time that winter wheat is sown, but the timing is not as important with rye, because it is more resistant to cold than wheat is. Winter rye can be sown almost any time during the late summer or early fall for harvest the following summer; early seeding produces the most fall pasture. Spring rye should be planted as early as possible. Rye can be grown continuously or in rotation. Rye for pasture or green manure is often grown in mixtures with winter legumes.

The land may be disked or plowed. Rye is sown broadcast or drilled. Sometimes it is drilled directly into small-grain stubble, without preparing the soil; this is satisfactory if the land is fairly free from weeds. Rye is seeded at between 63 and 125 kilograms per hectare. The lower rates are commonly used when the rye is being grown for grain, the higher rates when it is to be pastured or used to suppress weeds.

Rye ripens the earliest of the small grains; it is usually ready about a week before winter wheat. It has the tallest and strongest straw of the small grains, which makes harvesting difficult. The average yield worldwide is 1,560 kilograms per hectare.

Diseases and Pests

Rye suffers less from most diseases than any of the other grain crops. Its only serious enemy is the parasitic fungus ergot (Claviceps purpurea). The fungus penetrates the developing kernel and produces a large purplish mass that contains several highly poisonous substances.

Uses

Rye is the richest in carbohydrates of all the cereal crops, and contains less fat than wheat. Its vitamin B1 content is a little lower than that of barley and wheat, and much lower than that of oats. Rye flour can be used for bread-making, but pro-duces a compact, heavy loaf compared to a loaf made from wheat flour. For

this reason, rye flour is usually mixed with wheat flour for bread-making. Rye is also used to make alcoholic beverages.

The most important use of rye is for animal feed. Its leaves are high in vitamin A. It is grazed and fed as hay. Since rye grains are sticky to chew and not very palatable, they are usually ground and fed to animals in mixture with other grains. Rye seldom makes up more than a third of the mixture.

Rye is often used as a cover crop to prevent soil erosion, and as a smother crop to limit weeds. It is sometimes plowed under be fore flowering, for use as green manure. Its straw, which is tough for animal feed, is used as a packing material, and to make thatching and matting.

III. QUESTIONS TO ASK BEFORE PLANTING A GRAIN CROP

The overview presented above is intended to give the reader a sense of the requirements of the various grain crops. Before attempting to raise any grain in an area where it is not presently grown there are a number of preliminary questions that should be answered. Further guidance should be obtained from local agricultural specialists.

Some of the questions to be considered are:

1. Is the climate suitable for this crop?

2. Are the type of soil and its pH and salinity characteristics

known, and are they suitable for this crop?

3. Are fertilizers available to meet the crop's nitrogen, phosphate, and potassium needs?

4. Can the crop's moisture needs be met through naturally available water? If not, is enough water available for irrigation? Does the cost of irrigation compare favorably with the benefits the crop will yield? Is the necessary equipment available? Is the terrain suitable?

5. Have sources of supply been found for seeds, fertilizers, pesticides, herbicides, equipment, and anything else that may be needed for growing this crop?

6. Is enough capital available to purchase the necessary equipment and supplies?

7. Is the farmer able to invest the time and effort needed to grow the crop successfully?

8. Has the information been gathered about the varieties and hybrids that are available? Has a choice been made about the variety to be planted?

9. What kind of erosion control, if any, will be necessary if this crop is planted? Are the resources for carrying it out available?

10. If part of the harvest is to be kept for later use, are storage facilities available that can keep the grain cool, dry, and safe from pests?

11. Is there a market for the grain products?

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