QUACKGRASS (*ELYTRIGIA REPENS*) CONTROL METHODS IN ORGANIC AGRICULTURE

By Jean Duval

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Figure 1 – Quackgrass (Drawing : Rae Chambers, Penn State College of Agricultural Sciences)

Introduction

YES! It is possible to control quackgrass in organic farming operations. However, it is still very difficult to completely eliminate quackgrass, especially in field crops, where soil cultivation is generally less intensive, and where cropping areas are generally larger than in horticultural operations. The non-chemical control of quackgrass is first and foremost a matter of PERSEVERANCE, although weather conditions also play a role in the success or failure of the type of control undertaken.

In 1990, economic losses attributable to quackgrass were an estimated $17/ha for conventional grain and oilseed crops in Eastern Canada.[6] The economic impact of quackgrass on organic crops is undoubtedly even greater, given that the weed is more difficult to control without herbicides and because of the higher value of certified organic crops.

When glyphosate ("Roundup") was introduced to agriculture, it was mistakenly believed that the quackgrass problem had been permanently solved. However, it is becoming increasingly evident that glyphosate does not eradicate quackgrass! This bulletin may therefore be of interest not only to organic or transitional producers, but also to producers seeking alternatives to the chemical control of quackgrass.

With all weed control strategies, it is important to have a sound knowledge of the plant concerned and its biology. In addition to control methods, it is also necessary to adopt preventive measures to ensure that quackgrass is not reintroduced into plots where it has been eradicated.

This technical bulletin also discusses possible uses of quackgrass because, after all, there is no such thing as a useless plant!

This bulletin does not claim to provide infallible solutions for fighting quackgrass. Each farm is unique and the suggested techniques have to be tailored to each farm's circumstances in order to be successful.

Welcome to the fascinating world of one of the most notorious, if not *the* most notorious, weeds!

Biology

Quackgrass (*Elytrigia repens,* formerly known as *Agropyron repens*, and also known as couchgrass) originated in Europe and was introduced to North America by settlers in the 17th century. It is found in nearly all agricultural communities.

Description

Quackgrass is a perennial weed of the *Graminaceae* family, which is reproduced through rhizomes and seeds. Its rhizomes are whitish or yellowish underground stems between 1.5 mm and 4 mm in diameter with hard pointed tips. They are rich in carbohydrates and serve as food reserves for the plant. While each bud on the nodes of a rhizome can produce a new stem or new rhizome, most buds remain dormant.

Quackgrass can be identified without having to dig up to expose its rhizomes. In fact, at the base of the stems of the leaves, there are auricles resembling tiny hooks or claws hugging the stem (Figure 1). However, to confirm that the plant is quackgrass, it can be dug up and checked to see if it grew from a rhizome.

The leaves have other characteristics. The first leaves are almost always hairy, whereas later leaves may or may not be hairy. New leaves are furled when they poke up from the ground. They are between 10 cm and 20 cm long and between 2 mm to 2.5 mm wide. There is often also a fluted area near the tips of the leaves.

Adult quackgrass can grow as high as 40 cm to 150 cm, and forms a spike between 5 cm and 25 cm in length. The seeds are an average of 1.25 cm in length.

Quackgrass can often be mistaken for smooth brome (*Bromus inermis*), but brome rhizomes are shorter and darker in colour. The “W” on the brome leaf is clearly visible in the middle of the leaf. The seeds of both species are very similar in appearance.

Propagation

Propagation methods in quackgrass populations vary considerably. Some produce a greater number of rhizomes, while others produce more seeds. In a cropland context, an abundance of nitrogen and light tends to encourage propagation via rhizomes, whereas in a grassland context, particularly in natural meadows, seed propagation is more common.[15] However, the main propagation method for quackgrass is still rhizomes.

Rhizome propagation

Quackgrass forms tillers as its rhizomes spread out in all directions. Under optimum conditions, rhizomes can spread 1.5 metres from the original site in a single season, with the numbers of buds on the rhizomes multiplying 30 to 60 times.[12] Rhizomes can produce up to 3 tonnes/ha of dry matter annually!

The behaviour of rhizomes during soil cultivation has been studied extensively. A rhizome section just a few centimetres in length can be enough to produce a new quackgrass plant. However, it is incorrect to believe that all rhizome nodes will produce stems or new rhizomes. About 90% of the buds on rhizomes will remain dormant until they are activated through soil cultivation. Even when a segment of rhizome is cut off, only one of the nodes of the segment will produce a stem. The other buds become inactive as soon as one successfully produces a stem.[4]

The deeper a rhizome segment is buried, the less able it is to produce stems that will reach the surface.[16] However, the longer the rhizome segment, the stronger the stem produced will be, and the more likely that the quackgrass will be able to grow to the surface from a greater depth. If the soil is not cultivated, for example, in a grassland area, the rhizomes will only develop near the soil surface, often at a depth of less than 10 cm. (Figure 9).

Unlike other perennials, rhizome production in quackgrass is not related to flowering. A plant can produce rhizomes as early as the three-leaf stage, and if the temperature is between 2°C and 30°C, it can produce rhizomes once the spring thaw begins and until the ground freezes in November. However, very few if any new rhizomes are produced when the light intensity begins to taper off in October. Instead, the plants will store food reserves in the existing rhizomes. Since quackgrass is a cool-season grass, its growth also slows during the dry, warm summer weather.

If there is a lot of nitrogen present, quackgrass tends to produce above-ground stems rather than develop its rhizomes or produce new rhizomes. However, if there is a lot of competition for light, for example, in a densely sown grain field, quackgrass will develop its rhizomes[2] instead. In Quebec, rhizomes last for two years (one winter and two growing seasons).

Seed propagation

Seed propagation is less common than rhizome propagation, but it should not be overlooked. It has often been reported that very few quackgrass seeds are viable, but this is false. In fact, the seeds have to be exposed to temperature variations in order to germinate. A quackgrass plant produces about 25 seeds on its main stem. Tiller stems are less likely to have spikes.

Seeds can germinate even if they have not been harvested at full maturity, which is often only in August. They survive for up to four years in the ground. All viable seeds at a depth of 5 cm (2 inches) germinate, but at a depth of 20 cm (4 inches), they almost all die.[17] In a manure pile, quackgrass seeds do not lose their ability to germinate, unless the pile heats up to a high enough temperature.

Once quackgrass has been brought under control in a field, it is extremely important to watch out for seed propagation.

Life Cycle

Starting with a rhizome section a few centimetres in length buried in the ground in the fall, the possible life cycle of the plant in Southern Quebec could be as follows.

1. The rhizome produces a stem from one of its buds. If it is late fall, the stem may only appear in the spring when conditions become more favourable, ie, as soon as the ground thaws.

2. In May, when this first stem has three or four leaves, new stems (tillers) are produced from the nodes located close to the surface. In the meantime, rhizomes are produced from the other nodes. If the plant was produced from a seed, the production of rhizomes only begins at the six-to-eight-leaf stage.

3. In early June, some stems start to spike. The spikes reach full maturity in August.

4. Throughout the summer, other rhizomes develop as branches from existing rhizomes. Other stems emerge from these rhizomes.

5. Starting in the late summer, the tips of the rhizomes will point upwards and become above-ground stems.

6. The oldest stems die before the onset of winter. Only the youngest stems survive.

7. In the following spring, stems can appear in several places: overwintered stems; rhizome tips; rhizome nodes; and upper parts of the crowns of stems that died the previous fall.

Ecology

Quackgrass prefers soils with a neutral or basic pH, but grows well even in acidic soil. It prefers heavy soils, but also invades light soils. It is therefore a highly adaptable plant that cannot be associated with any specific soil condition.

Allelopathy

All quackgrass components, whether living or decomposing, are known to contain compounds that are harmful to other plants. Although these so-called allelopathic compounds often have been found to have significant effects in laboratory situations, their allelopathic effects in field situations have not been as pronounced. However, seed germination can be affected when quackgrass rhizomes decompose.

Uses

Despite its official status as a weed, quackgrass is a plant that can also be very useful.

Erosion control

In agriculture and rural engineering applications, quackgrass can be used to stabilize sand dunes, buffer strips or any other area subject to erosion. However, it is better to use other less invasive grasses, such as smooth brome.

Forage

Quackgrass provides excellent forage and pasture for animals. Its nutritive value is similar to that of timothy (*Phleum pratense*[1]). However, the digestibility of quackgrass decreases rapidly. Ideally, it should be harvested before heading. Quackgrass can also be harvested as silage, with the added benefit that late mowing will alter the viability of the seeds. Sheep more than cattle like the taste of quackgrass.

One disadvantage of using quackgrass as a forage plant is that most of its biomass is below the soil surface and cannot be harvested. This is even more true of quackgrass growing in natural meadows. A quackgrass-filled hay field can be reinvigorated by passing a light disc harrow over it a few times in the spring. This should stimulate the growth of new shoots.

Phytotherapy

Quackgrass, which is rich in silica, potassium and other minerals, has always been used as a natural medicine. The rhizomes contain an active ingredient called triticine, as well as a sugar called mannitol. These are given as decoctions or infusions used as diuretics as well as used to treat urinary problems, rheumatism, gout and cystitis.

Dogs, cats and wild animals eat the leaves to facilitate digestion or induce vomiting when they are sick. A few kilograms of quackgrass rhizomes mixed in with the daily feed of a horse will give the horse a shiny coat.

Other Uses

During the food shortages of the First World War, bread made from quackgrass was popular in southern Germany. The seeds as well as the rhizomes were used to produce a nutritious flour to replace wheat and other grains. Dried rhizomes can also be used to make brushes. As well, quackgrass roots contain a substance that is fatal to slugs.[8]

Preventive Measures

Several preventive measures can be taken to control quackgrass and its propagation via rhizomes or seeds.

Preventing rhizome propagation

***Clean equipment*:** Agricultural implements should be cleaned when they come back from a field containing quackgrass and before going to a field where there is little or no infestation. Quackgrass rhizomes can stick to ploughs, harrow and cultivator teeth, and tractor tires. (Figure 2)

Figure 2 – Rhizomes caught on a vibrashank cultivator tooth. Rhizomes stuck to implements can spread quackgrass.

Isolate infested areas: If only one section of the field is infested with quackgrass, it is better to till it separately, if possible, to avoid spreading the problem. Similar precautions should be taken when cultivating between rows.

Spread manure with caution: The spreading of manure can spread quackgrass, especially if the manure comes from a pile on the ground with quackgrass growing nearby. A neglected pile of compost can also be a source of quackgrass. A good practice from both an environmental standpoint, ie, preventing loss of nutrients, and from the standpoint of preventing quackgrass infestation, is to plant rye all around the pile to be protected and to cover windrows of compost in the field with a geotextile fabric. Quackgrass can also be spread if the soil excavated during the digging of ditches or irrigation ponds is spread on fields. (Figure 3)

Figure 3 – Quackgrass was spread in this field when the earth removed during the digging of an irrigation pond was spread to fill up a low spot.

Do not allow hay fields to deteriorate: Quackgrass often takes hold if perennial forage legumes have not survived the winter well. Rather than keep such areas as grassland, it is better to plant annual forage plants on them instead. Ideally, fields should not be left as grassland for longer than three years.

Preventing seed propagation

Use clean seed grain and grass seed: Quackgrass seeds contaminate oats more easily than other seed grains because of the similarity of the seeds. They are even more difficult to tell apart from smooth brome seeds. Seeds to be used for seeding should be well screened.

Avoid losses during harvesting: The introduction of the combine-harvester in the 1950s contributed to the seed propagation of quackgrass. It is worthwhile for farmers who carry out a good post-harvest screening to keep as many weed seeds as possible inside the harvester. Straw can also be contaminated. Strawberry growers should be vigilant when buying straw.

***Avoid late haying*:** If animals consume hay containing viable quackgrass seeds, the seeds will end up being spread on fields during manure spreading. There is chance that all first-cut hay harvested after early July in southern Quebec may contain viable quackgrass seeds.

***Cut uneaten grass in pasture fields*:** Quackgrass often produces spikes in large pasture fields. It is better to mow any uneaten grass prior to the heading stage or, better still, to intensively manage the pastureland.

Providing competition for quackgrass

***Correct problem areas*:** Soil conditions that are unfavourable to crops in some areas often give quackgrass a chance to take root. It is better to correct wet zones conditions and other factors that could result in uneven growth and development because these measures make the crops better able to compete against quackgrass.

Plant ground-cover plants: Although ground-cover plants cannot control quackgrass by themselves, intercropping with ground-cover plants slows down the growth of quackgrass and prevents its rapid spread during the crop-ripening stage and after harvesting (Figure 4). Dwarf red clover can be planted as ground cover at a rate of 5 kg/ha in the case of grain crops, and a mixture of ryegrass and medium red clover can be sown at a seeding rate of 10 kg/ha in the case of corn.

***Increase the seeding rate*:** As an emergency measure for a plot containing abundant quackgrass, it is better to densely sow seed grain and forage plant seed. To demonstrate the soundness of this practice, an experiment conducted in the Lac St Jean Region over several years found that barley yield in a heavily infested field,[14] compared with barley yield in a control plot free of quackgrass, fell by 41% when the seeding rate was 50 kg/ha, but dropped by 19% when the seeding rate was 200 kg/ha.

Figure 4 – Clover ground cover in a plot of sweet corn. Intercropping with ground-cover plants curbs the growth of quackgrass after harvesting.

Seed field edges: Quackgrass will often begin its infestation from the edges of the field, where it has not been destroyed. Other perennial grasses such as orchard grass (*Dactylis glomerata*) and brome (*Bromus inermis*)[13] that can effectively compete with quackgrass can be sown all around the field, particularly after resloping or digging of a ditch.

Tolerance of quackgrass

The sensitivity of crops to quackgrass varies from one species to another, as well as according to the density of the quackgrass, the season and the time of the year.

Assessment of infestation level

It is difficult to quickly and objectively assess the degree of quackgrass infestation in a field. Because the "population" spreads continuously throughout the season, a low infestation level at the start of the season may become a high infestation level by the end of the season. Therefore, the presence of quackgrass quickly becomes intolerable.

Several detection methods have been suggested, but none of them is ideal. It takes a lot of time to count the number of rhizomes or rhizome buds in a given area. It is faster to count the number of shoots, but the result also changes quickly over time.

For practical purposes we have determined three levels of quackgrass infestation (Figure 5), as follows.

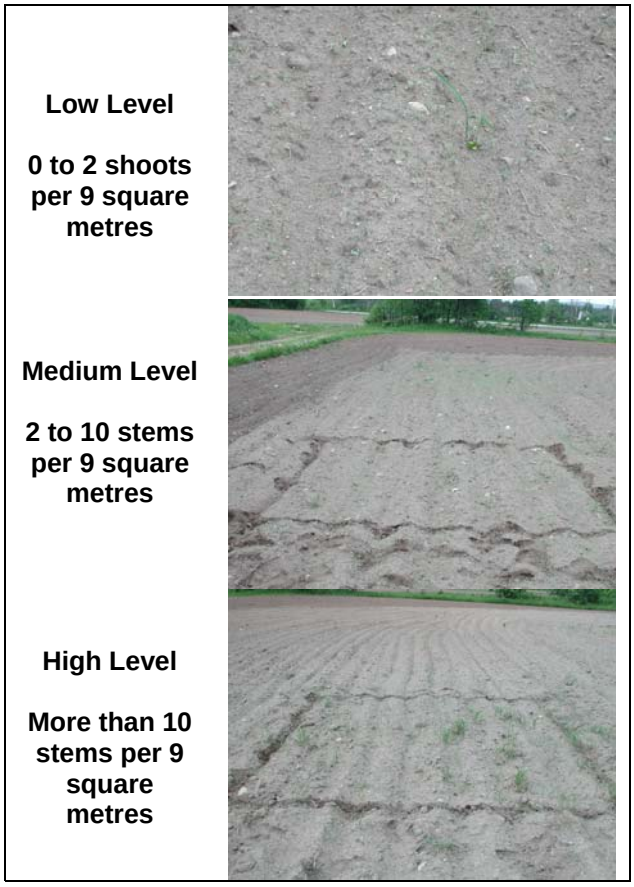

Figure 5 – Quackgrass infestation levels

Ideally, the assessment should be carried out in the early summer, while keeping in mind that a low level at that stage can become a high level if nothing is done to control the quackgrass.

Sensitive crops

Many common crops, such as oats, barley, corn, clover and alfalfa, do not tolerate the presence of quackgrass very well. So that yield is not affected,[18] corn should not be exposed to quackgrass during the first six weeks of its growth. The effect of quackgrass on grain crops is a reduction in the number of spikes rather than in the size of the seeds or length of the spikes. Flax is very sensitive to quackgrass. Vegetables generally have a low tolerance for quackgrass, and beets are the least tolerant.

Tolerant and competitive crops

At low to medium infestation levels, the yields of some crops are less affected by quackgrass than others. This is the case with winter grains (winter wheat and especially winter rye, but not spelt wheat), buckwheat and potatoes.

Because winter crops develop in cool temperatures in the fall and early spring, as does quackgrass, the two compete directly with one another (Figure 6). It is better to sow winter grain at high densities (up to 200 kg/ha) to obtain maximum benefit from this competition. It is also necessary to properly prepare the soil and to ensure that the grain survives the winter in good condition.

Figure 6 – Winter wheat seedlings after a short fallow period. Winter crops compete well with quackgrass.

Because buckwheat germinates and grows very quickly, it blocks light from other species, including quackgrass (Figure 7). However, its competitive effect is short-lived. As soon as flowers form, the light can filter through to the ground and allow quackgrass to grow. In the fight against quackgrass, buckwheat is therefore particularly suitable as a green manure crop within a series of crops rather than as a crop to be harvested.

Buckwheat should be planted in the spring as soon as there is no longer any risk of frost. Seedlings should not be planted after mid-August in southern Quebec because they risk being killed by early fall frosts before they have had a chance to grow very much.

Figure 7 – Buckwheat in the early flowering stage. Buckwheat grows very quickly and usually prevents quackgrass from growing for six weeks.

In the case of potatoes (Figure 8), frequent tillage (hilling) kills quackgrass, as well as turning of the soil during harvest. However, rhizomes can penetrate the tubers and reduce their market value.

In a plot containing quackgrass, priority should be given to market garden plants that provide a lot of shade (*Cucurbitaceae*) or plants that can be easily weeded (sweet corn, tomatoes and cole crops).

Figure 8 – Potato crops require a lot of tillage, which is usually detrimental to quackgrass. In this case, very little quackgrass was found after the potato harvest.

In cases of medium to high infestations, crops of competitive plants are not enough to control quackgrass.

Principles of Rhizome Destruction: Depletion and Desiccation

There are two major approaches to killing quackgrass rhizomes using mechanical methods: depletion and desiccation. Depletion involves cutting up the rhizomes and repeating the operation when the quackgrass starts to grow again so that the food reserves of the rhizomes are depleted. Desiccation involves bringing the rhizomes up to the surface, where they are exposed to the open air and dry out, weather permitting.

Priority should be given to desiccation because it involves less repetition of the operations. It only produces good results in hot, dry weather, but under these conditions, the rhizomes can die in just a few days. It is more difficult to make this approach work with clay soils because clumps of earth sometimes prevent the rhizomes from completely drying out. Contact between a single portion of the rhizome or stem and enough moisture will enable the plant to survive.

The depletion method is more effective in cool, wet weather than desiccation, but it requires more repetition of the operations. Because rhizomes become depleted more quickly in fertile soil, it is worthwhile to fertilize the soil before a fallow. In fact, nitrogen promotes the growth of shoots, usually at the expense of rhizome reserves and rhizome production.

In practice, desiccation can be combined with depletion if the weather permits. However, if the rhizomes are finely cut up initially, it will be more difficult later to bring them up to the surface to dry out. Conversely, if the rhizomes are brought up to the surface at the start to dry out, but the weather does not stay dry, it is still possible to deplete them through continued tillage.

Regardless of which approach is used, the important thing is to persevere. Otherwise the problem can only get worse because once quackgrass is disturbed, it comes back with renewed vigour.

Frost does as good a job of killing rhizomes as drying. However, in practice, it is difficult to expose all of the rhizomes to frost by bringing them up to the surface, unless special quackgrass harrows are used (see *Use of Specialized Equipment* further on).

WILL QUACKGRASS BE DIFFICULT TO ERADICATE IN YOUR FIELDS?

- The heavier and more poorly drained the soil is, the more difficult it will be to control quackgrass.
- The less intensively tilled the soil is, the more persistent the quackgrass will be.
- Large quantities of stones will also hamper the mechanical eradication of quackgrass.

Control Methods for Field Crops

Short fallow

The SHORT FALLOW technique is the best way to control quackgrass in field crops or in operations with both livestock and field crops. The method involves repeated tilling of the soil over a three to six-week period.

GRASSLAND IS BEST SUITED TO SHORT FALLOW METHOD. After a field has been left as grassland for several years, the quackgrass rhizomes are concentrated in a layer of soil 7 cm to 10 cm below the surface (Figure 9). The best time for a short fallow is in July and August, which is usually the driest period of the year. It is important to begin the short fallow as soon as possible, ie, after the first cut of hay or after the second cut of hay, if taken off early.

Figure 9 – In a grassland field, rhizomes are concentrated in the upper 10-cm layer of soil.

A field can be left in short fallow after a winter grain crop is harvested in late July or early August. Depending on the region, a short fallow is also possible after a spring cereal, such as barley, is harvested, but the chances of success diminish as September approaches. In fact, rainy weather and cooler nights increase the resistance of quackgrass to soil cultivation, and opportunities to till the soil become less frequent.

A short fallow is not recommended in the spring because the soil is usually wetter at that time of year than in the summer. Sometimes in southern Quebec, if the spring weather has been very dry, a short fallow is possible on well drained soil before soybeans or silage corn are sown.

As part of crop rotation, a field crop producer who also raises ruminants should plan a short fallow, preferably one that involves early destruction of a grassland area, or, as a last resort, after a small-seed grain crop has been harvested. One less hay cut should therefore be planned for the grassland area to be ploughed up, which in some cases, may make it necessary to increase hay acreage on the farm.

A field crop producer who does not raise ruminants and does not have pastureland should ensure that his or her crop rotation allows for a short fallow period AT LEAST ONCE EVERY THREE YEARS. The producer should therefore not grow corn or soybeans in the same fields for more than two consecutive years as long as quackgrass continues to be a problem in those fields.

Because fallowing can be very energy-intensive, it is best to do it during the driest period possible in order to reduce the number of times tilling is carried out to kill rhizomes.

The following provide additional information on the three stages of a short fallow.

Stage 1: Stubble ploughing

Stubble ploughing is a primary tillage operation in which the cohesion of the soil and plant roots are coarsely broken up. The implements used in stubble ploughing vary, depending on the firmness of the soil and quantity of roots to be turned over.

In the case of a grassland with thick root networks, stubble ploughing can be done using several types of implements: heavy discs, chisel ploughs, combination disc and chisel ploughs, C-type cultivators, modified ploughs (without mouldboards), etc. PLOUGHING WITH A CONVENTIONAL PLOUGH IS STRONGLY DISCOURAGED (See *Ploughing* further on). The use of a rototiller is another possibility (see *Horticultural Control Methods*).

The implement to use will depend on the soil type, and above all, on what is available in the area. Do not hesitate to rent implements, even a tractor, if necessary, to carry out the stubble ploughing correctly. The following table can be used as a guide in choosing appropriate equipment. The objective is to produce relatively small clods of earth and have uniform coverage over the entire soil surface.

In the case of grain straw or relatively young grassland on light soil, where there is usually low cohesion, stubble ploughing can be carried out directly using a secondary tillage implement, such as a C-type cultivator equipped with sweeps measuring at least 10 cm in width, or even a vibrashank cultivator (S-shaped teeth). The sweeps have to be wide enough in this case to prevent the rhizomes from slipping through the teeth of the implement.

Table 1 – Stubble ploughing implements based on soil conditions

Implement		Conditions	Comments
Combined disc/teeth implements (eg, soilsaver, DMI,, etc)		Good for most conditions.	Rollers, if installed, should be removed.
Heavy discs (eg, offset discs)		Ideal in rocky soil or in dry clay soils.	The angle adjustment of both series of discs is important. Avoid making clods that are too large because it will make subsequent tillage more difficult.
Chisel plough with wide teeth (or subsoil cultivator) or modified plough without mouldboard		To be avoided in heavy soil because it leaves the soil very rough for subsequent tilling.	Chisels with the least amount of spacing (< 30 cm) between the shares are preferable. There are ploughshares specifically designed to pull out rhizomes.
C-type cultivators with 15-20 cm spacing and wide sweeps		Appropriate, especially in light soil.	Teeth should claw into the soil properly.

IT IS UNNECESSARY TO STUBBLE-PLOUGH AT A DEPTH GREATER THAN THAT OF MOST RHIZOMES. If you are ploughing old grassland or pastureland, a depth of 7.5 cm to 10 cm (3 to 4 inches) can be enough to reach nearly all of the rhizomes. If you are ploughing grain stubble that was ploughed the year before, the stubble ploughing should be done at a greater depth.

Note: It is important to mow and gather hay or to have the pasture closely grazed before stubble ploughing. In all cases, it is advisable to dig down in several spots to see how deep the LIVING AND ACTIVE rhizomes are and to adjust the depth of the stubble ploughing accordingly.

Ideally, the area is gone over with stubble ploughing equipment twice. In the first operation, the stubble ploughing is done half way down to the depth of the rhizomes, and in the second operation, it is done to the depth of the rhizomes.

Stage 2: Repeated harrowing

After the stubble ploughing, several passes with a harrow will be necessary. The number and frequency of passes will depend on the implement available, infestation level and the weather. A flex-tine harrow or a high-clearance vibrashank cultivator, if available, can be used to bring the rhizomes up to the surface (desiccation approach). Alternatively, a disc harrow can be used to finely cut the rhizomes (depletion approach). The disc harrow will produce finer earth than the vibrashank cultivator, which can be a disadvantage in fragile soils or soils that tend to form a crust. The disc harrow may also bury some rhizomes. Ideally, harrowing should be done during hot, dry weather to promote drying of the rhizomes.

It used to be recommended that harrowing be done systematically every week or even as soon as the quackgrass started sending up shoots. Such intensive tilling is only recommended if the rhizomes can be dried out. If the intention is to deplete the rhizomes, it is better to wait for the quackgrass to grow to a certain point. However, it is important NOT TO ALLOW THE QUACKGRASS LEAVES TO GROW LONGER THAN 12.5 CM (5 IN) OR HAVE MORE THAN 3 OR 4 LEAVES PER STEM; otherwise it will begin to grow vigorously and extend its rhizomes, or even produce new rhizomes.

When rhizomes become very dense, and if the stubble ploughing has not produced fairly small clods, it is sometimes necessary to remove the rhizomes from the surface of the field. To carry out this operation, a vibrashank cultivator can be used or implements with closely positioned teeth, such as a chain harrow or pasture harrow, spike tooth harrow or even a finger weeder. Ideally, the selected implement will be attached to the three-point hitch of the tractor, rather than drawn, so that the implement can be raised in order to drop piles of rhizomes at various spots in the field or on

the edges of the field. Otherwise, you will have to patiently clean off the teeth several times. A mechanical hay rake can also be used, which will form windrows and make gathering easier later on.

Stage 3: Sowing a green manure crop

The sowing of a green manure crop or winter grain after a short fallow is recommended in order to recover the nutrients released by the fallow, prevent regrowth of quackgrass, reduce erosion and rebuild soil structure. The more finely the rhizomes are cut, the less they can compete with the green manure crop.[9]

Table 2 shows the seeding rates and times for green manure crops after fallow periods. The main disadvantage of green manure crops sown in August is that dry weather often delays the emergence of seedlings, and if the emergence is uneven, competition with the quackgrass will be uneven as well.

Some farmers sow green manure crops using a broadcast seeder rather than a seed drill, and then pass over again with the harrow to bury the seed and stir up the quackgrass one last time. In the case of winter grain, it may be worthwhile to go over the field with a roller before or after seeding to obtain a more even emergence of seedlings, although some producers prefer to leave the soil irregular to increase chances of survival over the winter.

If a green manure crop or winter grain cannot be sown because it is too late in the season or because the fallow was insufficient, the field can continue to lay fallow based on the same principle throughout the fall, ie, the quackgrass should not be allowed to grow stems with more than three leaves. It would then be a good idea to finish the tilling with a plough, which is the next topic to be covered.

Table 2 – Sowing rates and times for main green manure species and crops used after short fallows

Species	Seedling Rate	Seeding Time*
White mustard	10-15 kg/ha	Mid to late August
Oilseed radish or forage radish	10-12 kg/ha	Mid to late August
Winter rye or wheat	110-200 kg/ha	Late August to late September
Spring oats	110-150 kg/ha	Mid-August to mid-September

* For Southern Quebec

SECRETS OF SUCCESS

START AT THE SURFACE – To eradicate quackgrass in a grassland area, till close to the surface as much as possible before going down deeper to the limit of the rhizome layer.

ACT AT THE RIGHT STAGE OF QUACKGRASS DEVELOPMENT – Once the fallow period begins, do not allow the quackgrass leaves to grow longer than 12.5 cm (5 in) or to be more numerous than three or four leaves per stem; otherwise, the quackgrass plants will start developing their rhizomes again. In cool weather, it is better to take action at the two-leaf stage in case it becomes impossible to till the field at a later time. In dry weather, the field can be worked as often as once every three days in order to quickly dry out the rhizomes.

PERSEVERE – Tillage implements have to be used on the field three or four times, and sometimes five, six or more times, before quackgrass is eradicated.

Moldboard Ploughing

Moldboard ploughing is fairly effective in quackgrass control, but is not enough on its own. The type of ploughing carried out and the time when ploughing is done play a key role.

If standard ploughing is done to a depth of 20 cm (8 in) using a plough with mouldboards spaced 40 cm (16 in) apart, many of the rhizomes will be buried under a deeper layer of earth where they will deplete themselves trying to push new shoots up to the surface. Up to 75% of the rhizome buds may be eradicated this way.

Although moldboard ploughing is a good way to finish off a fallow, it is NOT ADVISED AT THE START OF A FALLOW. In fact, rhizomes at an intermediate depth (10–15 cm or 4–6 in) will be difficult to kill in subsequent harrowing operations using a disc harrow or vibrashank cultivator. The abundance of fine earth created by the ploughing operation can also allow quackgrass rhizomes to escape the later soil tilling operations. If standard ploughing is done at the start of the short fallow, there is a greater chance of quackgrass reappearing the next year.

If other primary tillage implements are not available, try to plough to as shallow a depth as possible in the case of grasslands (preferably 10 cm), which requires well sharpened plough points and a well-adjusted plough. The result will be a flat or layered type of ploughing. Harrowing should then be done, preferably with a disc harrow because a vibrashank cultivator tends to pick up large chunks of ploughed earth, which can be very frustrating for the tractor driver.

Figure 10 – The skim coulter on a plough helps to bury quackgrass rhizomes and stems in the bottom of the furrow more effectively.

If it is too late in the season for a short fallow, then **fall ploughing** is a solution of last resort that will limit the extent to which quackgrass competes with the crop at the start of the next season. A plough is for this purpose better than any other implement that does not turn over the soil (eg, chisel ploughs and heavy-duty discs). To obtain maximum benefit from this method, cut or mow the quackgrass several times during the fall and do the ploughing as late as possible. Having skim coulters on the plough will help bury the quackgrass stems properly so that they will not quickly resume growing in the spring or even continue growing during the fall (Figure 10). However, remember that enough time will have to be allowed in the near future in the same plot to do a short fallow operation on the area because the problem will simply be postponed, not eliminated.

One of the techniques used by our ancestors to control quackgrass on land used as grassland or pastureland for a few years was to **plough thin surface strips** and flip them over. The ploughing was done at a depth as shallow as 5 cm (2 in) using a specially designed plough equipped with a very long mouldboard. The ploughed "strips" were turned over face down on the surface of the ground. The earth was then repeatedly "scraped" with a flex-tine harrow with C-shaped shanks, which disrupted rhizomes on the surface. This method is not very practical nowadays because modern ploughs are not made for such shallow ploughing, and flex-tine harrows have given way to implements such vibrashank cultivators.

Deep ploughing has sometimes been recommended for quackgrass control. In practice, it involves ploughing to a depth of 30 cm in order to turn over a layer of soil that is 20 cm thick. Such an operation requires not only a very wide plough (over 50 cm or 20 in), but also a very powerful tractor for heavy soil. Although fairly effective, this method is not recommended from an organic farming standpoint promoting respect for the living soil. The reason is that deep ploughing buries the most living layer of the soil and brings earth of poor quality to the surface. It is also very energy-intensive.

Spring ploughing quickly depletes the reserves of quackgrass rhizomes.[11] This can be enough to give the crop a head start, particularly if the quackgrass started growing before the ploughing was done, preferably in early May. However, if no tilling is done afterwards, the quackgrass will come back in full force in the fall. Spring ploughing is therefore only an emergency measure and not recommended for heavy soils, where it will produce a coarse seedbed unfavourable to crops.

According to the theory of biodynamics, ploughing should be done in a **descending moon pattern** to prevent quackgrass regrowth. Ploughing in an ascending moon pattern would have the opposite effect.

When a field is ploughed, the central furrow may be poorly turned over. This is often where quackgrass will first reappear, even if the fallowing was properly done. To avoid this problem, make sure, when returning to the starting point, that the first strip of the central back furrow (which supports the first furrow) is uprooted.

Horticultural Control Methods

Horticultural producers may consider the same methods as those described above for field crops. For example, a vegetable grower may plan a short fallow after early harvesting of a vegetable crop. However, because horticultural crops are grown on smaller surface areas with higher crop values per hectare than field crops, other quackgrass control methods that are more intensive or costly than they would be for field crops can be considered.

Long fallow with successive green manure crops

If a producer can afford not to grow a crop on a plot of land for an entire season, a long fallow with consecutive sowings of green manure crops offers a greater guarantee of success against quackgrass than a short fallow does.

This method is particularly recommended before establishing perennial crops, such as fruit, berries and asparagus, which are crops where quackgrass control becomes very difficult later on. Ideally, a long fallow should last two consecutive years, if there is a high concentration of quackgrass in the plot concerned.

For a long fallow, tilling or stubble-ploughing, preferably not moldboard ploughing, begins in the spring. Stubble ploughing implements, described above, should be used if the land is idle land or grassland, or a lighter implement can be used, if an annual crop is to be turned over. The field should be harrowed several times when the quackgrass starts growing again, and the plants should never be allowed to grow more than three leaves per stem.

Afterwards, buckwheat (or other green manure crop) should be sown at a rate of about 50 kg/ha in early to mid-June, when there is no longer any risk of frost. When about 40% of the buckwheat has flowered and its seeds are beginning to form, it is better to destroy it because it easily turns into a weed in an organic farming operation. At this stage, quackgrass is still visible in the buckwheat. Destroy the buckwheat by going over it with a disc harrow, allow it to dry, then go over it again with a disc harrow a few days later.

You can then sow buckwheat again or continue harrowing once a week until early September, then plant winter rye to be destroyed in the spring or spring grain, which will be killed by the winter.

There are several variations of the long fallow method with consecutive green manure crops. Some farmers sow up to three consecutive buckwheat crops. Others prefer two consecutive, dense sowings of spring rye. Still others prefer grasses such as sorghum or Sudan grass hybrids or Japanese millet. For the latter grasses, there is only one sowing, but it is possible to take off one or more cuts of these crops and even harvest them as forage. These are hot-weather grasses, which resume growth very quickly in hot, dry summer weather if they are cut 15 cm above the ground, thus leaving quackgrass little opportunity to start growing again. You should also plan on possibly retilling the soil before the end of the summer in order to complete the fallow properly.

In more northern regions, millet or sorghum can be replaced by annual ryegrass, which is sown at a rate of 15 to 25 kg/ha, or even orchard grass. Ryegrass and quackgrass can be cut repeatedly during the season. If the soil is fertile and sufficiently moist, ryegrass will tolerate repeated mowing, whereas quackgrass will gradually wither. Once again, as with a short fallow, it is better to rework the soil before the end of the summer to ensure adequate quackgrass destruction.

The **long fallow with no crop** technique used to be recommended to control quackgrass. The soil has to be tilled frequently during the season. Although very effective, the technique is no longer recommended. In addition to not producing a crop, a field worked in this way is exposed to wind and water erosion throughout the season, and the technique is potentially very polluting. In fact, tilling the soil triggers the release of a large amount of nitrogen generated from organic matter oxydation. This nitrogen can then be lost through leaching or other causes because there are no plants to collect it.

Rototilling

The rototiller (Figure 11), a common implement in horticultural operations, is the ideal tool for killing quackgrass using the depletion method. The rototiller has to till the earth at a depth of about 10 to 15 cm (4 to 6 in), preferably in hot, dry weather. During this first tilling, the tractor speed should be slow but the rototiller blades should be spinning at high power to ensure that the rhizomes are properly cut off. Once the quackgrass is well dried out and before new growth reaches a height of 12.5 cm, go over the area again with the rototiller at the same depth or down to a depth of 20 cm, if necessary. Rototill the area several times, if need be, before sowing a competitive green manure crop.

Studies conducted on very infested sites in England[4] have shown that two passes with a rototiller, with an interval of about 21 days, may be enough to control quackgrass in dry soils, but that up to four passes may be required for wetter soils. In dry conditions, the rear cover of the rototiller should be kept in a raised position so that rhizome pieces are brought to the surface to dry out. Otherwise, it is better to leave the cover in a lowered position to ensure that the soil is well pulverized.

Figure 11 – A tractor rototiller is the ideal tool for the rhizome depletion method.

Other Methods

Use of specialized equipment

In his excellent 1923[10] bulletin on quackgrass control, Kephart mentions that implements had already been specially invented to control quackgrass. More recently, quackgrass harrows have been developed in Germany and Denmark. The Danish model, called a CMN couchgrass killer, consists of a series of 48-cm sweeps, which are used for stubble ploughing, followed by a series of knives that slowly rotate in the opposite direction of the movement of the tractor, which makes it possible to leave on surface quackgrass rhizomes or the roots of other perennials that have been brought up to the surface after the implement has passed over. Dry weather or frost will then kill the rhizomes. To obtain more information about this implement, visit the Internet site: www.cmn.dk/kvik_killeruk.htm.

The German model, developed by Walter Kress (Figure 12), operates according to the same principle, but does not have a cover, and the rotor only turns when the tractor moves forward, which certainly makes it less effective than the Danish implement.

Some producers use potato diggers to obtain the same soil culling effect with quackgrass rhizomes deposited on the surface. Lastly, there is the rod weeder, a device that is better known in Western Canada, which also culls the soil and places rhizomes on the surface of the ground where they can dry out properly.

Figure 12 – The Walter Kress quackgrass harrow, which combines stubble ploughing with culling (photo: Denis La France).

Mulching

On small surface areas, an **opaque plastic mulch** prevents the growth of quackgrass, but in order to completely destroy the rhizomes, the mulch must be left in place for a full season (at least six months) or even two seasons. The mulch has to extend beyond the area to be cleaned by a full metre.

Organic mulches (straw, ramial chipwood, etc) do not eradicate quackgrass unless they are spread over the area very thickly (30 cm) or more of the material is applied as soon as the quackgrass appears. Quackgrass rhizomes sometimes colonize thick organic mulch when the materials settle.

Woven groundcovers (woven polypropylene sheets) are appropriate for perennial crops such as vines (Figure 13) and highbush blueberries, but are inappropriate for plants that grow new stems every year, such as asparagus and raspberry bushes. Unlike ordinary plastic mulch, they allow water and air to pass through. Sheets should be installed preferably before the crop is planted and after the ground has been properly fallowed.

Quackgrass does not like heat. **Solarization** can therefore be a good small-scale way to eliminate a quackgrass patch. Cover the infested area with a transparent plastic sheet for six weeks during the hottest part of the summer. Be sure to seal the edges of the plastic sheet thoroughly. Afterwards, rototill the area and plant winter grain or a green manure crop.

Other mulching materials may be considered in certain circumstances. Large cardboard boxes are sometimes used around the bases of trees in small orchards.

Figure 13 – Woven grouncovers in hardy vines. Grouncover sheets made of woven polypropylene are ideal for protecting vines or highbush blueberries from quackgrass infestations along the rows.

Burning

The burning of quackgrass stems is not a highly recommended strategy. A single burn carried out in May stimulates the production of quackgrass stems. However, REPEATED burning in the spring (from May to early June) can significantly weaken the quackgrass. Quackgrass is highly sensitive to burning just before it flowers.

Burning quackgrass seeds and rhizomes and spreading the ashes afterwards in the area to be protected is a technique used in biodynamics to make the quackgrass less vigorous or even to eradicate it. Depending on the site, this method can only have significant results after a few years. The homeopathic approach of this technique should be even more effective. The procedures to follow are outlined below:[7]

- Obtain some dried rhizomes and quackgrass seeds. It is often easy to obtain large quantities of quackgrass seeds in places where clover seeds are screened.
- Burn the seeds and rhizomes together in a wood stove (preferably using beech wood) or coal stove. It is easier to burn the seeds to ash by injecting some air during combustion.
- Grind the ashes of the seeds and rhizomes together in a mortar for an hour (dynamization).

- Mix 1 part ash with 9 parts water. Stir for three minutes. The result is known as D1 Mixture.
- Take 1 part of D1 Mixture and mix with 9 parts water. Stir for three minutes. The result is D2 Mixture.
- Repeat the same operation until you obtain a D8 Mixture, which corresponds to the eighth dilution. A portion of the water can be discarded each time, rather than using all of the liquid produced, which would require large, awkward containers.
- The "Quackgrass D8 Mixture" should then be sprayed on the field at a rate of 15 to 40 litres/hectare three consecutive times, preferably when the moon is in Sagittarius, according to the Biodynamic Calendar.

Mowing and pasturing

As with burning, repeated mowing will reduce the rhizome reserves, but mowing by itself rarely eradicates quackgrass. Its advantage is that it prevents seed production. Mowing carried out between the middle and end of June is highly effective at depleting quackgrass.[3] Mowing can be good front-line strategy for putting fields that have lain idle back into production, but mowing has to be followed by a period of fallow.

Intensive pasturing (and even overgrazing) in the spring or fall when the quackgrass is actively growing, can also weaken quackgrass before mechanical control operations are carried out. It is widely known that pasturing not only promotes the development of rhizomes closer to the surface, but also slows quackgrass infestation and causes the production of finer rhizomes than those produced in cultivated fields. One or two years of pasturing will therefore facilitate mechanical eradication if it is also carried out at the surface. Sheep, which tend to nibble down to ground level, are the best to weaken quackgrass.

In the case of small surface areas with light soil, pigs can do a very good job of cleaning out any quackgrass rhizomes if they are left long enough to root through the entire area (Figure 14). Older documentation[10] recommends a density of 15 pigs per hectare for one month. It is important to provide them with water and shade. Interestingly enough, quackgrass seeds lose their viability once they pass through a pig's digestive system. This method is not advised in areas with heavy soil, where pigs can damage the soil structure during a rainy season.

Lastly, young geese can also be used to control quackgrass on strawberry farms because they repeatedly eat the leaves.

Figure 14 – A plot cleared of quackgrass rhizomes because pigs have rooted through the pasture. Notice that there is still quackgrass growing on the other side of the electric fence used to confine the pigs.

Pulling and weeding

To finish the job of quackgrass eradication in horticultural operations, it may be necessary to destroy quackgrass patches by hand if mechanical or other methods have not been effective. Rhizomes can be pulled out and the above ground parts repeatedly cut up with a hoe.

The weeding of row crops such as corn can help slow the growth of quackgrass early in the season. Priority should be given to cultivators fitted with wide rather than narrow sweeps that will thoroughly eradicate the quackgrass stems. If weeding is not preceded or followed by other control measures, it will simply cause the quackgrass to spread even more in a plot.

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