SITE PREPARATION

Once you have selected a site using the site selection criterion you now have to get it ready for seeding. It is recommended that this begins the previous fall, or one year before actually seeding ginseng. This gives time to prepare a proper seed bed with less problems for the seeding equipment.

Critical Preparation Elements

ELIMINATION OF PREVIOUS PERENNIAL CROPS AND WEEDS

Generally a chemical like Roundup is used to kill what is presently on the site. The most common situation is that alfalfa / grass is there presently but sites may also contain quackgrass, Canada thistle, morning glory, and other perennial weeds. It will take time to eliminate these as well as the alfalfa / grass which are also perennial. A typical program would be to spray 4.7 – 11.5 L / ha (1.9 – 4.6 L / ac) of Roundup on the site depending on the weeds you need to control. Wait 7 to 10 days then plow or cultivate the site. In the spring cultivation would begin as well as watering to start annual weed growth. This would continue until fall, working deeper so that by bed formation time adequate soil is loose for the bed plow to work property. See weeds page 93 for more information on rates.

LOW ORGANIC MATTER (OM)

Sites that are low in OM (< 2%) may require additional attention to increase this. Crops such as fall rye, oats, etc. may be used or manure could be added to give an increase. This increases the friability (looseness) and water retention capability of the soil. A cover crop (green manure) should be left until adequate growth is achieved to give a good return to the soil, then plowed into the top soil. See cover crops, page 34 for details.

SOIL TESTING FOR CHEMISTRY, NUTRIENTS AND PESTS

It is imperative some of this testing be done by a qualified laboratory to determine what needs to be added before seeding takes place. After seeding, some things cannot be done. The following items need to be tested for or observed to ensure adequate amendments or preparation is done.

- Chemistry of soil (pH and conductivity) Page 40.
- Necessary nutrients available Page 39.
- Presence of Sodium and Amount (Na) Page 43.
- Presence of Pests in Soil (Page 90 to 94) e.g., wireworm, cutworms, and rodents. See also page 38 for more information on nematodes.

ROCK REMOVAL

The removal of large rocks down to an adequate depth will become obvious when cultivation begins. An unencumbered soil depth of at least 12" will be needed at harvest time to ensure equipment can work properly. If enough depth cannot be achieved with the digger, roots may be cut off in the process, reducing quality and damage to equipment could also happen. If proper attention is not given to this area it may be difficult to get someone to come and do custom digging.

DRAINAGE

This is a specialized and costly form of soil amendment and will require engineering and special equipment. Contact any agriculture extension office for advice and / or direction. This is a very uncommon correction for soils in the interior of British Columbia, that are suitable for growing ginseng.

Maintaining Soil Structure And Fertility

Soil structure is the most important soil characteristic that must be considered when managing soils, because it is structure which is most affected by management practices. In turn, soil structure is one of the most important factors in crop growth. Therefore, the main objective in soil management is to promote and maintain good soil structure which will be favourable to crop growth.

Most aspects of soil management are concerned with the structure or tilth of the soil within the cultivated or plow layer. Here, the upper 10 to 30 cm or more of the surface soil is subject to the influence of repeated tillage operations, cropping sequences and frequent additions of soil amendments. Below the plow layer, soil structure can be affected by traffic and tillage causing deep compaction. Soil compaction at the bottom of the plow layer, or deeper in the soil profile, can occur in the soils of the British Columbia Interior.

This compaction is the result of both natural soil processes and farming activities. Soil structure improvements below the plow layer can be achieved over a long period by the use of deep tillage, sub-soiling, drainage and the growth of deep-rooted perennial crops. If the compacted or degraded soil structure is just below the plow layer,

it is more readily reversed through the use of crop rotations, drainage and variation of tillage implement and tillage depth.

As a general rule, the plow layer in most soils has a granular structure, and it is this type of structure which provides the best tilth for seeding, germination and crop growth. Granular structure provides a balanced supply of air and water as well as a friable medium through which roots can penetrate. Over cultivation, particularly with power driven tillage implements, has degraded the surface soil structure in many soils in the region.

Massive, crusted or lumpy structure are adverse conditions which will reduce or even prevent plant growth by creating poor aeration and drainage. This structure will also physically restrict growth of roots or emergence of seedlings.

Perennial forage crops, annual cover cropping, additions of organic residues, such as manure or compost, and reduced tillage will help to reverse the soil structure degradation and return the soil to a granular structure.

THE FORMATION OF SOIL STRUCTURE

Aggregates and structural pores in the soil are formed by a number of means, including the growth of plant roots, activities of soil organisms, wetting and drying, freezing and thawing, and tillage.

PLANT ROOTS

The growth of plant roots is one of the most important agents in the formation of aggregates and pores. Growing roots expand and force individual soil particles closer together; they extract water from the soil, causing the mass to shrink and cracks to develop. Dead roots leave numerous pores and channels. The result of this process is the development of many aggregates and pores. The most favourable and stable soil structure is developed under a perennial (minimum three to four years) grass or grass-legume crop. Plant roots excrete simple sugars and resins that bind soil particles.

SOIL ORGANISMS AND ORGANIC MATTER

Soil aggregate stability is proportional to its organic matter content. As a general rule, when soil organic matter levels are high, there are more stable aggregates than in soils with low organic matter levels.

By their movement through the soil, the larger soil organisms, such as earthworms and soil insects, leave small channels and promote good soil structure. When soil organisms decompose organic matter, cementing agents such as sugars and gums are formed. These substances serve to bind soil particles together as aggregates, but in time these substances are themselves decomposed by other soil organisms. Therefore, in order to maintain a constant supply of cementing agents to promote soil structure, soils must have a continuous replenishing of organic matter; otherwise, the original structure will deteriorate.

In soils under cultivation for annual crops, the structure deteriorates faster than it can be built up by plant roots and organic matter. Note that the addition of manure also increases the formation of aggregates.

SOIL TEXTURE — CLAY

Clay particles are an important agent in soil aggregate formation. In sandy soils, a small percentage of clay may be the chief agent binding sand particles together. In soils which are dominantly clay, aggregates may tend to be larger than desirable for the preparation of a seedbed. In such soils, the addition of generous amounts of organic matter tends to promote smaller aggregates.

SOIL WATER — WETTING AND DRYING — FREEZING AND THAWING

In drained soils, alternate wetting and drying and freezing and thawing of the soil mass has a very important effect on structure. When soils freeze, water in the pores expands, forcing aggregates apart. Moist or dry soil aggregates break down into smaller particles when they are wetted, unless the wetting is very gradual. As wet aggregates dry out, they shrink and crack, breaking down into smaller aggregates. When soil aggregates are large, several centimetres in diameter, this process may be desirable. In soils with small or very weak aggregates, these processes may destroy most of the structure.

Tillage implements, operating in wet soils, can also rapidly destroy structure simply by mechanical forces acting upon soil aggregates. Even on a weakly structured dry soil, tillage can have a detrimental effect on the soil structure.

SOIL STRUCTURE, DEGRADATION AND PLANT GROWTH

The air and water relationships within the soil are markedly influenced by soil structure. Optimum plant growth depends upon an adequate, but not excessive, supply of water and air, as well as a loose, friable medium through which roots and shoots can penetrate. Such a favourable structure is usually found in the plow layer of most cultivated soils, where the common structure is described as granular or crumb-like. The plow layer is subject to many agents or forces which break down or build up soil structure. Some structural conditions, unfavourable to plant growth, commonly occur in soils. These are outlined in the following sections.

CRUSTING AND PUDDLING

By the action of water or mechanical forces, the granular or crumb structure in the plow layer may become completely broken down into a solid mass with no large pores. Such a soil is said to be puddled. When the puddled surface dries out, a hard crust forms. This crust may prevent seedlings from emerging, and tend to seal off the soil surface, preventing the infiltration of air and water.

SOIL COMPACTION

Soil compaction refers to the disruption and reduction of the large pores within the soil. The presence of excess soil moisture at the time of any field operation is the main factor leading to soil compaction. Once a soil is compacted, the bulk density and the strength of the soil are increased. For construction purposes, a compacted soil is ideal, but under normal crop production, a compacted soil can be a serious problem. Penetration into the soil by tillage implements and crop roots is restricted. The movement of air and water through the soil is hampered, causing the soil to remain wet and cool long into the growing season. Because compaction is such a serious threat, a closer look should be taken at ways to reduce or reverse its effects.

HOW TO RECOGNIZE A COMPACTED SOIL

Soil compaction occurs when a force compresses the larger soil pores and reduces the air volume of the soil. The continuity of the pores from the surface of the soil to deeper depths is disrupted, and thus, the transmission of water through the soil, and gases between the crop's roots and atmosphere is reduced.

Measurements of compaction damage to agricultural soils can be based on changes in density, strength or visual estimates of structure.

Bulk Density

The measurement of a soil's bulk density provides a relative value of soil compaction. The porosity of a soil can be related to the bulk density measurement, with further laboratory procedures.

Bulk density is expressed as weight per volume of soil (usually in terms of grams per cubic centimetre). Variation in bulk density can occur on a year to year basis, as freezing and thawing, wetting and drying cycles, and cultivation can alter the basic structure of a soil. See table 7 for average bulk densities of various soils.

TABLE 7. Examples of average mineral soil bulk densities

	(gms/cm^3)*
Well structured high organic loam soil	0.9
Silt loam	1.1
Medium top fine textured loam	1.3
Sand	1.5
Compacted soil or clay subsoil	1.3 – 1.6

** 1 gm/cm^3 = 62.43 pounds/cubic foot*

Penetrometer Method

Another method of measuring soil compaction is using a penetrometer. Penetrometers can give quick results in the field, and many measurements can be taken in a short time. However, the use of penetrometers and interpretation of the results requires considerable skill, especially if soils are in the initial stages of compaction. Penetrometers are useful in finding hard layers that will obviously obstruct root development or water flow through a soil.

Although using penetrometers is much easier and quicker in the field, the number of factors that come into play in interpreting their results makes them as difficult to use as the bulk density method. If proper sampling techniques are used, the bulk density method may give a more accurate result for any particular site in the field. Because both technical methods have limitations, the visual method may be the quickest and best alternative.

Visual Method

Often the best method of determining soil compaction is visual observation of both the soil and crops. Cloddy seedbeds, increased surface water ponding, loss of granular soil structure and reduced pore spaces through the soil are good visual indicators of compaction. Digging an observation hole in the field and observing rooting depths and patterns helps to determine if the crop is exploring the total soil volume or is restricted. Probing soil layers with a knife can indicate compacted zones and help determine where rooting or water flow has been curtailed.

Depressed crops, stunted or contorted root systems, a tendency to show yellow colouring, especially during or after large rainfalls (poor aeration), indicate compacted soils. Shifts in weed population are also good indicators. In addition, root rot diseases may increase with surface compaction.

EFFECT OF SOIL COMPACTION ON CROPS

A reduction in yield or yield potential is the most significant effect that soil compaction has on crops. The inability of roots to penetrate compacted soil layers will result in decreased yield. With less root penetration into the soil, root mass is reduced and a plant's ability to take up nutrients is reduced. As a result of surface soil layers having lower water storage capacities, plant roots remain closer to the surface and are, therefore, more susceptible to drought during periods of peak evapotranspiration. Compacted soils often have higher subsurface soil moisture contents because soil water is unable to drain away freely and air movement in the soil is restricted. This reduction in internal drainage generally leads to surface ponding which may drown the crop when evapotranspiration is low.

As a result of the reduction in the size and number of macropores in the soil and the subsequent reduction in aeration, microbial activity is reduced. Soil microbes play an important role in the breakdown of organic matter and fertilizer into usable plant nutrients, so soil fertility may be reduced. Poor quality, low fertility organic matter accumulates on the soil surface because soil microbes are not present to breakdown crop residues. Well decomposed organic matter (humus) levels in the upper soil layers will decline with a reduction in microbial activity. With this loss of humus, soil aggregate stability is reduced.

Mechanical pressure and manipulation from equipment and loss of aggregate stability lead to further degradation of the soil structure. Compacted soils also tend to warm more slowly, resulting in slower crop growth and higher moisture contents. Compacted soils remain cool and wet into the growing season resulting in conditions that favour the growth of soil borne pathogens such as Pythium or Rhizoctonia root rot. Plants under stress are also much more susceptible to root rots and other diseases.

If compacted layers are present in the soil, the risk of soil erosion is increased. The movement of water into and through the soil is reduced resulting in greater overland flow and subsequent surface erosion. Increased erosion will result in lower crop yields.

FACTORS INFLUENCING COMPACTION

The potential of any soil to compact is dependent upon its physical properties, water content and the nature of the force applied. The physical properties influencing compaction include the original bulk density and structure as well as the texture and organic matter content. In general, soils with fine textures (silt and clay), low organic matter contents, high porosities and weakly aggregated structures, are more susceptible to serious compaction. From a soil management stand point, all soils should be considered as capable of being compacted.

The two major management factors that influence the soil's ability to compact are the soil moisture content at the time of any field operation and the contact pressure exerted by the implement or vehicle involved in that operation.

THE CAUSES OF SOIL COMPACTION:

Natural

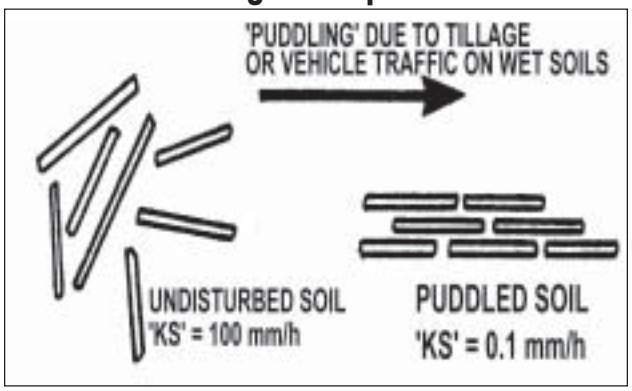
Compaction is the result of either natural soil formation processes and / or cultural practices. Natural compaction, resulting from soil formation processes, is found in many areas. This compaction is usually related to chemical transformations below the surface of the soil. It may also be related to the texture of the subsurface material and how it was deposited. Natural compaction may take the form of hardpans or cemented subsoils. Because some natural compaction continues as the soil formation processes continue, there is little or nothing that can be done to prevent its occurrence. Cemented layers or shallow natural hardpans may be disturbed by deep cultivation.

Other management practices, such as drainage, may reduce the effects of the hardpans or reverse the soil formation processes that lead to cemented layers.

Cultural Practices

Most soils in their undisturbed state have porous surface layers, but after years of cropping this porosity is often significantly reduced. This reduction in pore space and size is the result of several cultural practices performed either alone or together. Some cultural practices that cause reduction in porosity and compaction are untimely or excessive tillage, repeated tillage at the same depth, pulverizing of soil aggregates by tillage equipment and excessive or untimely access to field by farm vehicles. The process of deformation of randomly placed soil particles into a dense layered mass is known as puddling. See figure 9.

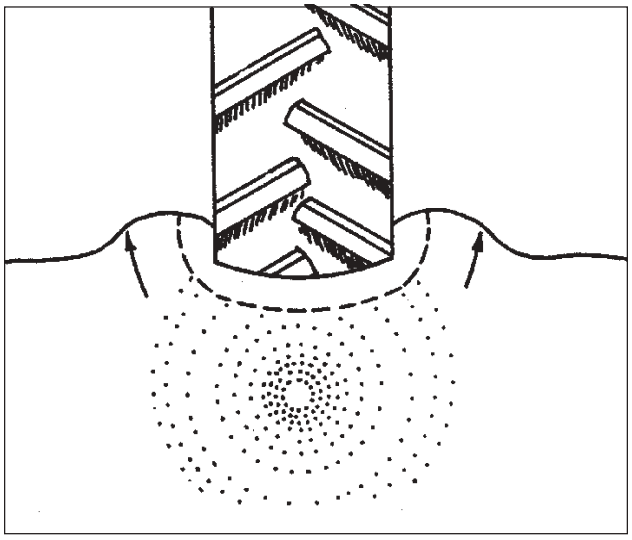
FIGURE 9. Puddling of soil particles



Traffic

Traffic from all heavy farm vehicles and equipment such as loaded sprayers, exert force on the soil. See figure 10. The degree of compaction caused by vehicle traffic is dependent on two main factors that can be controlled by the crop producer. The first is the contact pressure of the vehicle which is determined by the overall weight of the vehicle and the foot print of the vehicle tires or tracks. The greater the contact pressure and / or the more frequently the vehicle passes over a particular area in the field, the greater and deeper will be the resulting compaction. The second factor is the soil moisture content at the time the vehicle is in the field. The greatest amount of compaction occurs when the soil is wet. It has been estimated that up to 80% of the soil surface of a field can be exposed to wheel traffic at least once in any field season; this is particularly true in the case of fields used for forage production. Ginseng would be considerably less but some specific areas would receive more than normal.

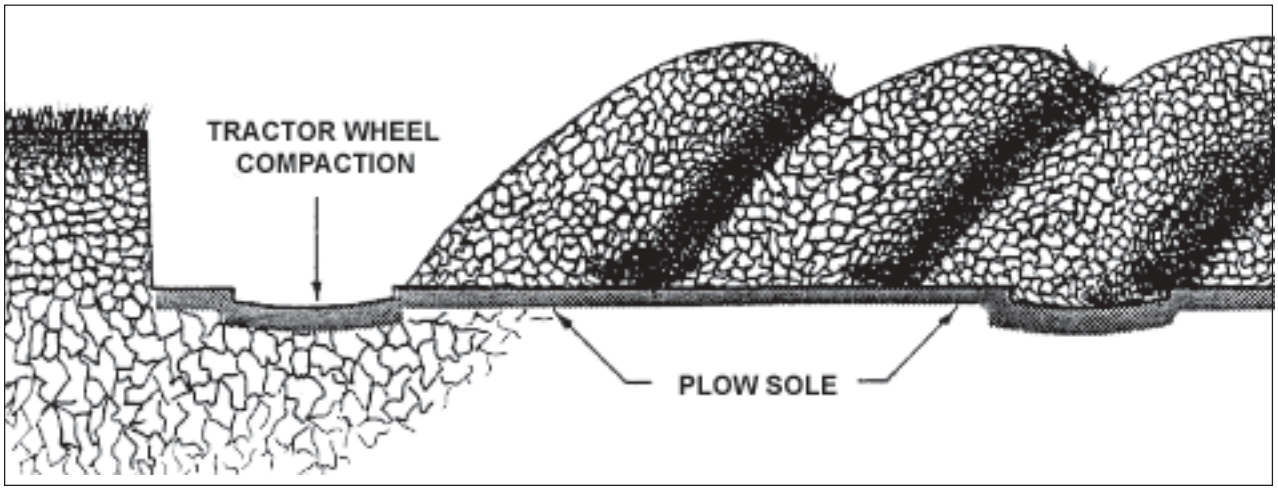
FIGURE 10. Effects of wheel traffic on soil (dotted/dashed lines indicate zones of compaction)



Tillage

Tillage breaks apart soil aggregates, permitting soil particles to move apart or be forced closer together. Exposure of the soil particles to air also causes more rapid decomposition of soil organic matter which is important for soil aggregate stability. In wet soils, tillage does not break apart soil particles, but rather smears the particles together to form clods. Tillage, depending on the implement used, also exerts downward pressure on the soil layers below the surface leading to deep compaction and the formation of "plow pans." Thin layer smearing by implements such as mouldboard plows or rotovators, plus the compaction on the bottom of the furrow slice resulting from the contact pressure or any slippage of the tractor wheel cause deep tillage related compaction. See figure 11.

FIGURE 11. Schematic diagram of the effect of tillage practices on soil



Other Cultural Practices

Other cultural practices that lead to compaction are soil surface exposure, organic matter depletion and the use of some crop nutrition and protection products. The exposure of soils due to lack of vegetative or trash cover allows raindrop impact to disperse soil particles leading to "puddling" of the soil, and ultimately, compaction. One use of tillage is to incorporate organic matter. However, it is also possible for the simple act of tillage to accelerate the breakdown of some types of organic matter in the soil which are required to bind soil particles together.

In reduced tillage and forage production systems, soil structure is improved by microbial decomposition of organic residues without the benefit of tillage. Because many of the binding agents that maintain a soil's structure are the result of the activity of living organisms, excessive applications of soil amendments and pest control products may be harmful to those organisms. This would lead to a decline in the breakdown of organic matter into products that bind soil aggregates and the end result would be an increased risk of soil compaction.

SOIL FERTILITY

Factors which contribute to soil fertility are the physical factors discussed elsewhere in the section, as well as chemical and biological factors. Plants require various amounts of essential nutrient elements which for the most part, must come from the soil. These include macronutrients such as: nitrogen, phosphorus, potassium, sulphur, calcium and magnesium and micronutrients such as: iron, manganese, zinc, copper, boron, molybdenum, cobalt and chlorine.

In cultivated soils, most of these nutrients are subject to removal by crops, to leaching or conversion to unavailable forms. Therefore, deficiencies occur sooner or later and nutrients must be added to the soil. Most Southern Interior soils are deficient in nitrogen and boron. Phosphorus, magnesium, copper, zinc and potassium may be deficient in some soils.

Practical Aspects of Soil Management

Good soil management begins with an evaluation of specific soil conditions and an understanding of potential problems before attempts are made to grow a crop. Land under natural vegetation, or cleared land under pasture may prove to be difficult to manage after it is cleared or cultivated. It may be inadequately drained, have shallow topsoil, impermeable subsoil, or it may be too steeply sloping to permit cultivation without excessive erosion.

Many potential problems can be identified with information in soil survey reports and maps. Farmers and other land owners are encouraged to obtain more detailed soil management information by contacting soil management specialists. Specific problems and recommendations for management can only be made on the basis of an examination of actual soil conditions. Therefore, recommendations made in this Production Guide should be considered as general guidelines only.

LAND CLEARING AND LEVELLING

Improper soil management practices during and following land clearing, levelling and re-contouring operations, can result in severe soil degradation either due to excessive compaction and / or erosion of the topsoil.

Land Clearing

Land clearing is any operation which includes the removal of excess undesirable vegetation or debris from a site, such as trees, shrubs, stumps, logs or rocks.

The practice of land clearing must be thought of in several phases in the Southern Interior region in order to reduce soil degradation. The site should be mapped to identify intermittent streams, surface water runoff channels and steep slopes such as ravines. Land at the edges of ravines, river banks or other steeply sloping areas subject to erosion, **should not be cleared**. If they are cleared, they should be seeded to a permanent vegetative cover. Intermittent streams or surface water runoff channels should also be left uncleared unless provision is made to keep water from entering them. If these areas are cleared and cultivated without some means of controlling runoff water, they will soon develop into gullies. By identifying water courses and severe slopes, a drainage plan can be prepared and installation take place prior to the fall of the year of clearing. This will reduce the risk of soil saturation and erosion in the first and subsequent winters following clearing.

Every attempt should be made to clear land only during the dry season in order to reduce water runoff and soil erosion. Trees could be removed in the fall and winter, but soil disturbance should be avoided. Once the trees are removed, stumps, rocks and under brush can be removed in the summer and the soil can be prepared with a breaking disc or plow. Discing is recommended for shallow soils, while a mouldboard plow may be more satisfactory in sod, or soils with a deep topsoil. Traffic on and tillage of wet soil should be avoided in order to reduce compaction.

Newly cleared land could be cover cropped with cereals, grasses and / or legumes in order to prevent surface soil degradation from erosion and help rebuild the soil structure.

Land Levelling

Land levelling is any operation which scrapes soil material from high points in the field and places that soil material in low points in order to render the field level (or on a constant grade). Land levelling may take two forms, the first being simply the scraping and dragging of soil around the field until the surface is level with no consideration given to topsoil variability and / or salvage. The second is the deliberate removal of the topsoil, then levelling of the subsoil to a constant grade and the subsequent replacement of the topsoil in a uniform layer over the entire field. This second method may be more appropriate in shallow organic soils with undulating subsoils or in areas where the subsoils are very coarse-textured or high in salts.

Some critical points to remember when preparing to level a field are as follows:

- what are the soil moisture conditions? Soil that is very wet or extremely dry is very susceptible to structure degradation. Wet soil smears while dry soil fractures. Very dry soil that is worked excessively becomes powder and structureless.
- is there adverse chemical or physical constituents in the soil that could be exposed by the levelling operation? Examples of that would be salt layers or compacted or stony subsoils. If this is the case, it may not be appropriate to remove the topsoil and level the subsoil.
- is there a need to crown the land or put a constant slope on the soil surface to aid in surface drying? Where soil texture, structure or management restrict drainage and underdrains are in place, crowning or shallow sloping of soils may be appropriate to relieve the risk of surface ponding.

TILLAGE — INTRODUCTION

Tillage is done for a number of reasons:

- to prepare a suitable seedbed;
- to bury or incorporate crop residues, fertilizers, lime or other soil amendments;
- to kill weeds; and,
- to form raised beds or irrigation furrows.

Tillage implements exert mechanical forces on the soil which alter soil structure and bring about changes in soil tilth. As a rule, for most soils, there is a limited range of soil moisture conditions when tillage methods are effective. That is, if soils are too wet or too dry, tillage may leave the soil in poor tilth.

In cultivated soils, the structure in the plow layer is weakened or destroyed by two main agents: the weather and machinery traffic. Bare soil left exposed to the weather, to rain and alternate wetting and drying ,will naturally become less porous and more compacted as structural aggregates break down and become more closely packed.

Machinery traffic breaks down and packs soil aggregates directly, and if the soil is wet, the resulting compaction can be very great. Excessive tillage, that is, more tillage than the minimum necessary for the purpose, can also contribute to poor structure in the plow layer.

The effects of tillage implements on the soil are quite variable, depending upon soil texture and structure, the moisture content, and the organic matter content.

Medium and fine-textured soils with a high clay content are most difficult to manage because they can be successfully tilled only when the moisture content is ideal. It is common to find such soils too wet one afternoon, workable the next morning, and too dry the next afternoon. In such soils, it is generally found that high levels of organic matter promote workability and tilth.

Many coarse and medium-textured soils are easy to till over a fairly wide range of moisture conditions, and maintaining suitable tilth is not difficult. Some sandy soils, with very low clay and organic matter content, will not form aggregates at all.

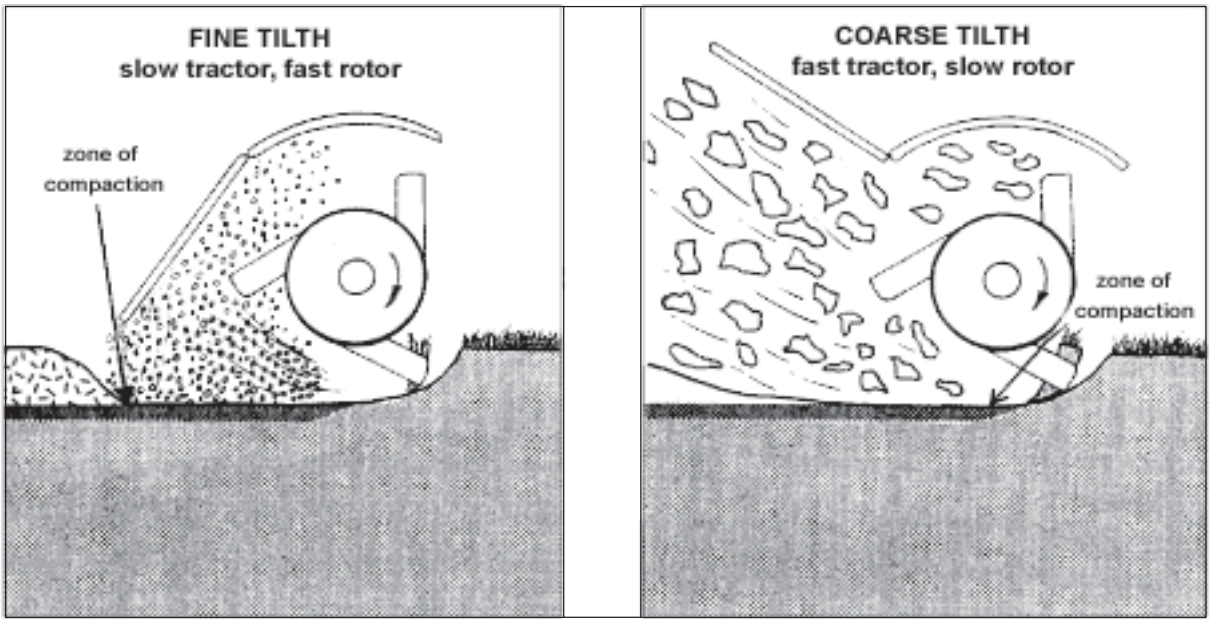
TILLAGE IMPLEMENTS

There are two main types of tillage implements: plows and discs, which lift and invert the soil; and cultivators and harrows, which lift and stir the soil without inverting it. Some of the more common implements and tillage practices, and their effects on the soil, are explained in the following sections. For more details on tillage implement operation and / or use, a suggested reference is *Fundamentals of Machine Operation — Tillage, by John Deere*

Rotary Cultivators (Rototiller, Rotovator)

The action of rotary cultivators results in a complete mixing and pulverizing of the plow layer. See figure 12.

FIGURE 12. Schematic drawing of the action of rotary cultivation



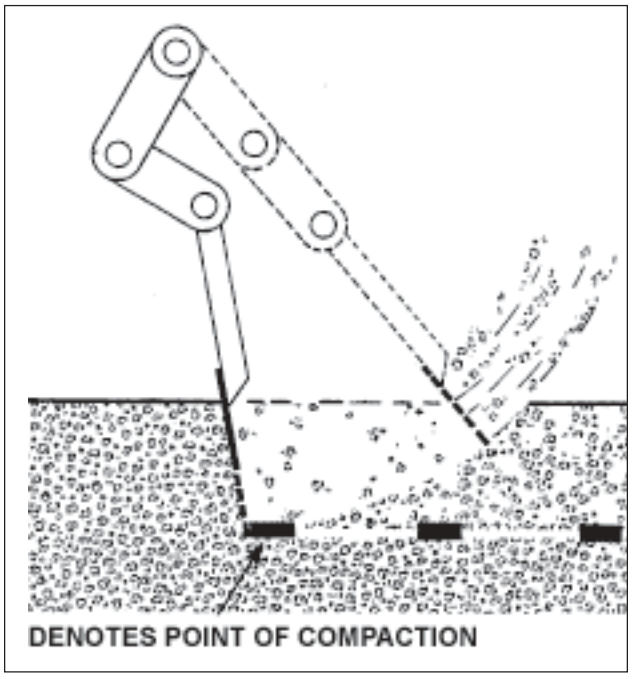
Because of this, the rotovator is popular as a means of breaking up and completely incorporating sod, crop residues, and soil amendments, while preparing a fine seedbed at the same time. However, the implement has some serious disadvantages. First, the plow layer tends to be too pulverized and repeated use over time is detrimental to stable soil structure. Second, the rotovator compacts the subsoil at the depth of penetration. Avoid slow tractor speeds which result in excessive pulverizing of the soil. Rotovating appears to achieve good practical results, but when used without deeper tillage to break up the tillage pan, the rototiller can do more harm than good.

Rotovators are most useful for breaking up old sod prior to plowing, or as a final tillage operation prior to seeding on sandy or organic soils. Deep rotovating is not recommended on medium and fine-textured soils because of the damaging effect the implement has on the structure of these soils. Following rototilling, soils must be rolled to make a firm seedbed as poor seed germination fields are the result of planting into fluffy, rototilled seedbeds. Rotary cultivators do not work very well in stony soils.

Spading or Digging Machines

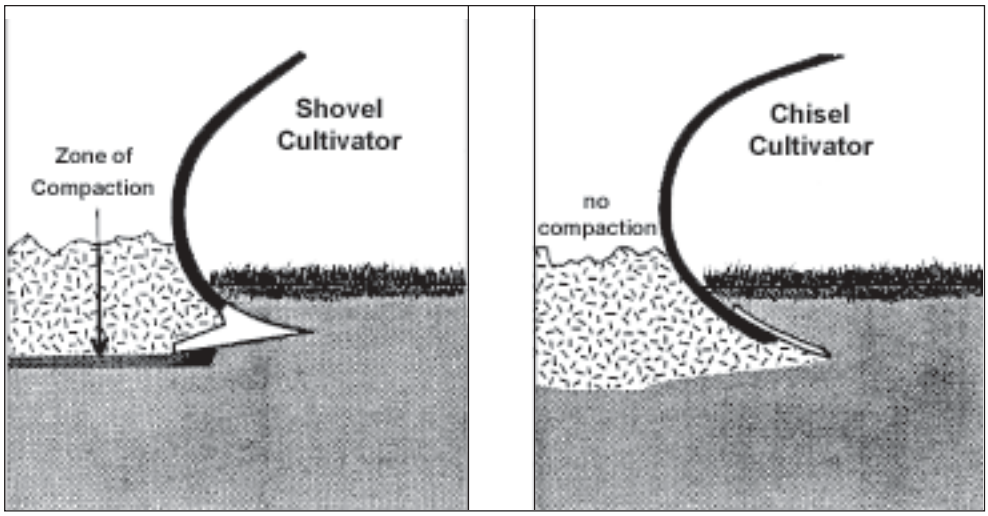
Used as a primary tillage implement, the spading machine operates on the same principle as a human powered shovel. In most cases, the implements are built with multiple bottoms or spades which are attached to a PTO (Power Take Off) driven cam shaft. An example of this type of implement is the "Tortella" which has six spades on a cam shaft that is driven by a PTO through a variable speed gear box. The spade is driven vertically into the soil and as it reaches its lowest vertical position, the cam then kicks the spade back. This action slices and breaks the soil as the implement moves forward. See figure 13. This digging action reduces the downward compaction forces that are often associated with tillage equipment such as plows. By varying the speed of rotation of the camshaft and speed of travel, the soil can be broken into a wide range of aggregate sizes. Rotary spades, as compared to other tillage implements, work reasonably well in stony soils.

FIGURE 13. Rotary



Cultivators

FIGURE 14. Schematic drawing comparing the effect of shovel and chisel cultivation on soil

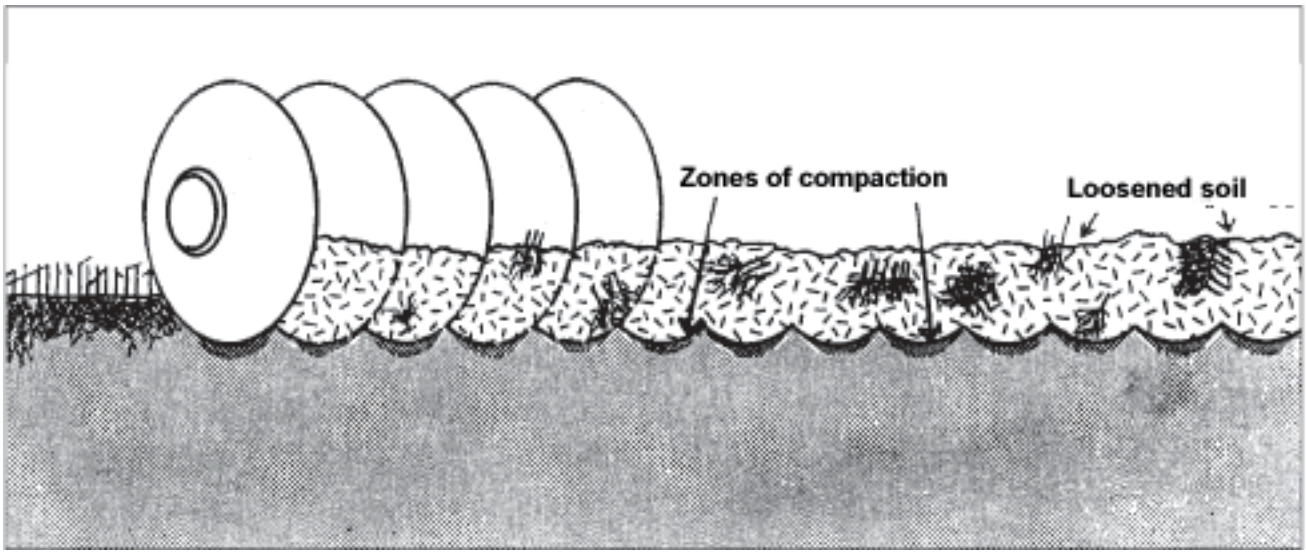


The action of most cultivators is to lift the soil upward and forward, loosening it and allowing it to fall back into place. See figure 14. Cultivators may be used for deep tillage or for shallow surface tillage to prepare a seedbed and to aerate the soil surface, to kill weeds or to incorporate soil amendments. The effects of the cultivator on soil structure are much less severe than the effects of plows and discs. However, too many cultivations with sweep shovels will pulverize the soil, and if repeated cultivations are done to the same depth, compaction and a tillage pan can develop. Chisel points do not bring about compaction. The use of a chisel plow is recommended for relief of shallow traffic of tillage compaction. Working depth should be just below the compacted layer.

Disc

Like the plow, the action of disc implements is one of lifting the soil mass and throwing it sideways, but without a complete inversion of the soil. See Figure 15. Discing is useful in smoothing a cloddy surface for preparation of a seedbed, or simply as a surface tillage operation to kill weeds or to incorporate soil amendments, fertilizers, lime and pesticides. Repeated shallow discing, to the same depth, may lead to a compaction zone or tillage pan at the depth of the cut, as well as pulverizing the surface. It is important to adjust the angle at which the disc moves against the soil; too small an angle will tend to pack rather than loosen the soil.

FIGURE 15. Schematic drawing of the action of disc implements



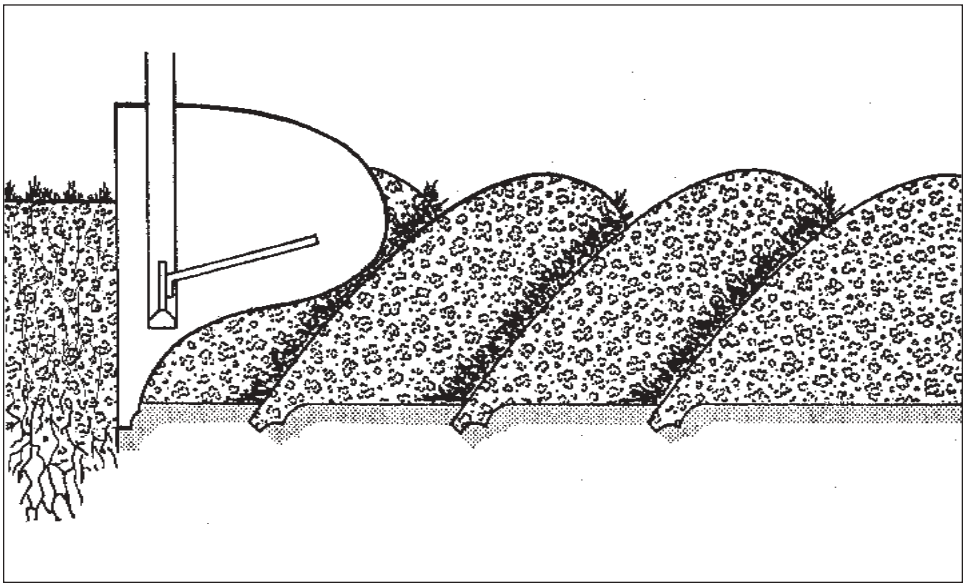
Plows

The mouldboard plow is designed to lift the soil mass and throw it sideways so that most of the original surface soil is inverted and buried under soil from the bottom of the plow layer. See figure 16. Plowing is an effective method of restoring good tilth to a soil in which the surface structure has broken down, while the soil below the surface has developed a granular structure through the action of plant roots. The plow is also quite useful for burying sod or a heavy growth of weeds or crop residues.

Plowing when soils are at the right moisture content is most important. If soils are too wet, the plow will turn over a solid mass of soil which has been compressed and compacted by shearing forces of the plow itself. In addition to this, the bottom of the furrow will also be compressed and the pores sealed off by the smearing action of the tractor wheel and the plow bottom. It is possible to hitch the plow so that the tractor wheel remains on the unplowed land instead of in the furrow. If soils are too dry, plowing may result in the formation of larger clods which will take longer to break down.

Repeated plowing to the same depth may form a compacted layer (a plow-sole or plow-pan) which can become a severe impediment to air and water movement and root penetration. To minimize the formation of a plow-pan, it is recommended that plowing depth be varied. An existing plow-pan may be broken up by deep tillage with a chisel plow or a subsoiler.

FIGURE 16. Schematic drawing of the effect of plowing on soil



Harrows

Harrows are either rigid or flexible tines which are simply dragged across the soil surface, stirring it and breaking down larger clods. Harrowing may be useful in preparing a seedbed, or to incorporate certain pesticides to a shallow depth, to break up straw and spread it more evenly over the field, or to scarify pastures and break up and spread manure on pastures. Repeated harrowing has the effect of pulverizing the surface and compacting the plow layer.

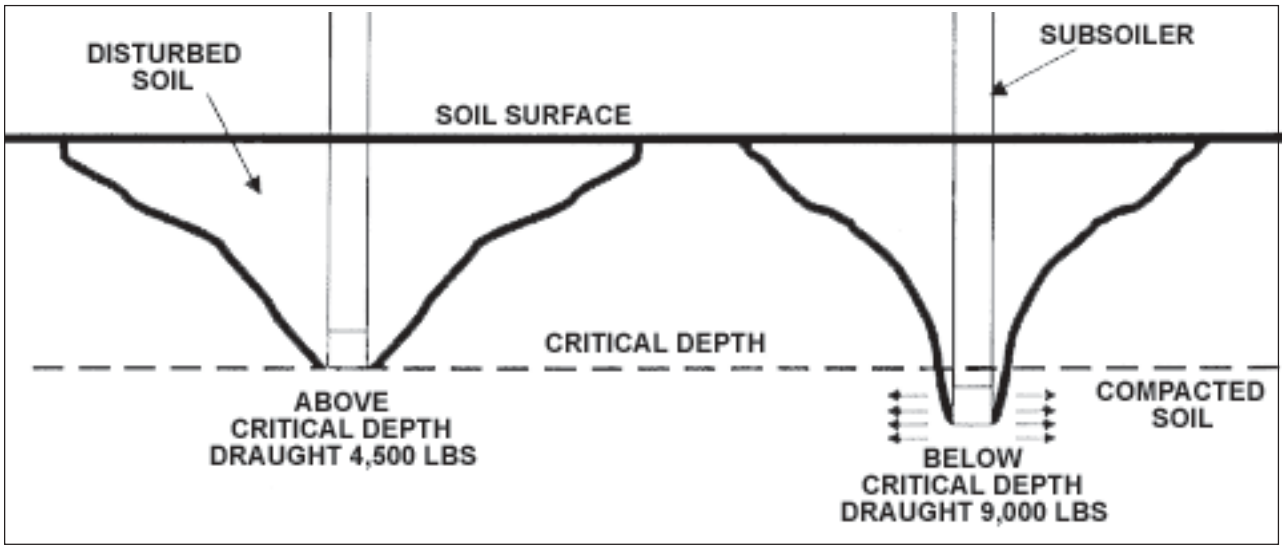
SOIL LOOSENING/SUBSOILING

Many factors influence soil structure, and soil loosening is only one of many practices used to improve soil structure. Soil loosening is no replacement for good management practices, including crop rotation and avoiding tillage when the soil is wet and easily compacted. Practices such as subsurface drainage and cover cropping, which adds organic matter and improves the soil structure, will tend to increase the effectiveness of subsoiling by stabilizing the aggregates formed.

CRITICAL WORKING DEPTH

Whenever subsoiling is to be used, the critical working depth of the soil and implement should be determined. Critical working depth is a function of soil texture, soil moisture content and the tractor / implement configuration. Many researchers have reported that subsoiling operations should be designed to work at a depth just below the compacted layer or near the desired rooting depth of the crop. However, the actual working depth should be less than the critical depth of the soil implement combination. The critical depth generally occurs at a depth corresponding to an aspect ratio (tine depth / tine thickness) in the order of 5 to 7, although, it becomes shallower as the soils become more plastic (i.e., wetter) or the surface confining layers become harder and drier. Tine spacing is usually equal to the working depth which gives a considerable overlap of soil disturbance in the upper soil layer and adequate disturbance in the lower layer. For subsoiling to be effective, the critical working depth should always be less than the critical depth. The critical depth is defined as the depth at which maximum soil disturbance occurs. If the working depth exceeds the critical depth, draught will increase, compaction on the bottom of the furrow will occur and the volume of disturbed soil will not be maximized. Also, flow fracture, rather than brittle fracture will occur. Figure 17 demonstrates soil disturbance and critical working depth.

FIGURE 17. Cross section showing soil disturbances caused by subsoilers just above and just below the critical depth



THE SIX CASES FOR SUBSOILING

Soil loosening has been found to be economically viable in most situations where it would increase yield. The key is to determine under what conditions soil loosening will increase yield. Before a decision can be made to undertake a soil loosening procedure, information on several soil properties is needed. Many soils can be grouped into the following six cases. Recommendations for soil loosening are made for each case.

Case 1 — Well Structured Soils

If the rooting pattern is well formed (i.e., the rooting is dense and reflects the preferred growing habits of the crop), the field does not require soil loosening. In this situation, the cost of subsoiling will not be warranted. The added traffic and mixing of soil, caused by soil loosening methods, will likely damage the soil structure and reduce yields. If the rooting pattern is restricted, additional observations will be needed to determine the cause.

Case 2 — Saline or Sodic Soils

Saline Soils

Excess salts greatly affect yield, soil properties and the response to soil loosening. Salinity may be the result of natural processes, such as residual salts from a marine soil origin or by salts added from groundwater. Cultivation practices, such as irrigating with saline water, over irrigation that causes subsoil leaching or applying excess fertilizer may also cause salinity problems. Often the presence of saline soils is demonstrated by good hydraulic conductivity in the surface soil, good tilth and the soil surface may appear white from salt crystals.

Whatever the case, electrical conductivity (E.C.) tests should be run on soil samples taken from at least three soil layers, the root zone (0 to 20 cm), the middle tier (20 to 50 cm) and the subsoil (50 to 100 cm). An E.C. can be performed inexpensively by any soils laboratory. If any soil layer is over two decisiemens per meter (dS/m), the soil is somewhat saline. In this case, soil loosening should be avoided and desalinization, using drainage, leaching and altered cropping strategies, should be utilized.

A Sodium Adsorption Ratio (SAR) may also be useful to determine if the soil has the potential to form a hardpan during leaching. SARs greater than 15 indicate a potential for hardpan formation.

Subsoiling, used by itself, may increase the salinity problem by bringing salts to the surface which will lower infiltration and make the soil harder to desalinize. The normal desalinization practice on these soils is to add soluble calcium to replace the sodium on the soil exchange sites, to improve the soil drainage and to irrigate with low-salt water to leach salts from the root zone. After drainage has been established, subsoiling may be required to help breakup a salt enriched (Bt) horizon. During the period of desalinization, lower yields may occur on the subsoiled areas.

Sodic Soils

Sodic soils are also referred to as alkali or solonetzic soils. They are often characterized by the presence of a sodium and clay enriched layer in the lower root zone. The surface topsoil layers may produce a reasonable crop yield in moist years or under irrigation, however, the hardpan and electrical conductivity (E.C.) of the subsoil restrict root development and air/water movement.

Subsoiling, to physically break this hardpan, has been very successful under dryland conditions. In some cases where the topsoil pH was low or the topsoil layer was shallow, lime or gypsum have been added to the surface prior to subsoiling. This either alters the pH, using lime or adds calcium to the soil to displace the sodium salts from the subsoil, but is an expensive process. pH adjustment should only be used for fine-textured lacustrine type soils. If very shallow topsoil layers exist or there is a hardpan layer, subsoiling should be avoided. Drainage may be required if sodic salts are a result of salty subsoil or salty ground water conditions.

Case 3 — Poorly Drained Soils

If salinity was not effecting the rooting pattern, the next possibility is poor drainage. Soil drainage is defined in terms of:

1) soil moisture in excess of field capacity, and
2) duration of the period during which excess water is present in the root zone.

Poorly drained soils are defined as having soil moisture in excess of field capacity remaining in all horizons for a large part of the year. Poor drainage conditions are typified by gleying which gives the soil a steel gray appearance. A practical way to assess drainage is to dig a small pit or well about 30 cm in diameter to a depth of 1 m. If the watertable observed in the well is within the normal root zone of the crop for over a week at a time during the growing season, the soil would probably benefit from improved drainage.

Case 4 — Plow Pans

If a layer of dense soil, just below the plow depth, restricts or stops root penetration, a pan or plow-pan exists. Normally, the pan will be 1 to 20 cm in thickness and will break into large, hard to crumble, clods. Below the pan, the soil will be more friable and will break into smaller crumb-like aggregates. Generally, larger pores will be visible throughout the soil profile, but not visible in the pan.

In the case of the plow pan, deep subsoiling, while possibly beneficial in the short term, is not the best approach. The pan is generally the result of improper conventional tillage. Under conventional tillage, plow pans disrupted by subsoiling will likely reform rapidly. The first and best approach to handling plow pans is to avoid the cause of the problem by adjusting tillage practices and field traffic and equipment ground pressure.

Case 5 — Soils With Compact Fine-Textured Subsoils

The glaciolacustrine and glaciofluvial soils may have compact subsoils or hardpans and could benefit from subsoiling. The following is a discussion of subsoiling in these and other similar soils.

In cases where the root restricting layer comprises all or a large portion of the soil profile, subsoiling may have a distinct beneficial effect. The soil texture of the restrictive layer plays an important role in determining the success of soil loosening. Fine-textured soils present a problem to soil loosening. When a subsoiling tine (or any implement) is pulled through the soil, two types of fractures may occur. The desired type of fracture is brittle fracture. In brittle fracture, the soil ruptures along planes of weakness, the aggregate size is decreased and large

pores are created along the fractures. After the passing of the implement, the soil resettles, but some of the large pores remain. The undesirable type of fracture is flow fracture. Flow fracture is analogous to a knife moving through butter. A large tubular void is created behind the tine and the soil around the void is compressed. The compressed soil has a larger, rather than smaller, aggregate size than the original soil. In the compressed area, the volume percentage of large pores is reduced rather than increased. In practice, both flow and brittle fracture may occur along the path of cultivation.

Flow fracture is increased by three major factors: the water content of the soil, the fineness of the soil texture and the overburden pressure. High water content lubricates soils, therefore, subsoiling should be done in early fall when soils are at their driest. Fine-textured soils are much more prone to flow fracture than coarse-textured soils. Since brittle fracture requires the soil to expand upward, more than flow fracture, the weight of the overlying soil increases the amount of flow fracture. Critical depth is a term used to specify the depth at which flow fracture will start to dominate. Critical depth is greatly dependent on soil texture and water content and the water content will often increase with depth.

Only shallow subsoiling is recommended for the fine-textured soils. The depth of subsoiling should be only 15 cm into the restrictive layer. Fine-textured soils are also more prone to recompaction, than coarse-textured soils. Subsoiling may be required every few years. As the soil structure and drainage improves after repeated treatments, the depth of subsoiling can be increased.

Case 6 — Soils With Compact Coarse-Textured Subsoils

Coarse-textured soils are not as prone to flow fracture and recompaction as fine-textured soils. The result of these factors is that it is often possible, and profitable, to deeply subsoil coarse-textured soils. Soils that are loam in texture or coarser, can normally be successfully subsoiled 75 to 90 cm, as long as the implement and its speed also influence fracture. The only dependable method to determine if the critical depth is being exceeded is to dig a trench across the path of the subsoiler and see if the soil is fractured to the depth of the tine. Subsoiling below the critical depth damages the soil structure and will normally have a negative economic effect. It is recommended that the subsoiler tines be 75 cm apart and angled up, so that all of the soil between the tines is fractured. Ideally, the soil surface between the tines should be raised up uniformly. Some re-compaction will take place, so subsoiling may be beneficial every five years or so. In the dry Interior, calcium cemented layers may be present in coarse-textured soils. Subsoiling may be beneficial in fracturing these cemented layers.

IMPLEMENTATION OF SOIL LOOSENING

The success of soil loosening depends on many factors, some of which are hard to quantify in advance. It is recommended that test plots be established before a soil loosening operation is carried out on a whole farm. One way of accomplishing this is to put subsoiling, where appropriate, into a normal crop rotation pattern. In this way, only a portion of the farm would be subsoiled each year. Problems, such as movement of salt into the root zone, would be detected and practices could be changed before the entire area is affected. Rotating subsoiling throughout a farm also aids in scheduling operations when the soil is as dry as possible.

SOIL AMENDMENTS

Soil amendments are substances added to the soil to improve fertility or structure. The use of several common amendments is discussed below:

Organic Matter

The value of organic matter added to the soil cannot be overstated. Organic material serves as a food supply for soil organisms which decompose it, releasing plant nutrients and promoting better soil structure. Most soils will benefit from the addition of organic matter; but loose, sandy soils will benefit more from the effects of organic matter on improving water-holding capacity and fertility, while fine-textured soils benefit from improved granular structure. Advantages of adding organic matter to peat and muck soils are not as easily recognized when compared to additions to mineral soils.

Among the many organic materials that may be used to some advantage are farm products such as crop residue, straw, manure and litter, compost and cover crops; industrial products such as vegetable processing wastes, peat, sawdust; and municipal wastes such as paper and domestic sewage sludge (biosolids). The main benefits of these are from the addition of organic matter itself, and secondarily, from addition of nutrient elements contained in the organic matter.

Straw

Straw can be a beneficial source of organic matter for soil. It is generally available in large particles which aid in aeration and porosity within the soil. However, when large quantities of straw are added directly to the soil, most available nitrogen in the soil may be used by soil bacteria in the decomposition of the material. This “tie up” of nitrogen can lead to nitrogen shortage in the crop and it is recommended that livestock manure or a soluble nitrogen fertilizer, such as Urea (46-0-0) or an Ammonium

Salt (34-0-0, 16-20-0 or 21-0-0) be added at the same time at a rate of 20 to 40 kg / ha actual nitrogen equivalent to approximately 1% N by weight of straw. Beneficial uses of straw include mulching for moisture retention and erosion control or to increase soil tilth. Straw may also be a source of weed seeds.

Manure

The use of livestock manure is covered by the Code of Agricultural Practice for Waste Management. This Code is part of the Agriculture Waste Control Regulation under the *Waste Management Act* and became law on April 9, 1992. The Code describes general practices for the use, storage and management of agricultural waste in an environmentally sound manner. The Code requires that agricultural waste, particularly manure, be stored in a storage facility prior to use. The storage must prevent escape of manure to the environment that would cause pollution. Manure can only be used as a fertilizer or soil conditioner.

Manure may be stored uncovered in the field for up to two weeks prior to use. Manure may be stored in the field up to nine months if it is stored in a temporary storage facility that prevents the escape of nutrients to the environment (i.e., securely tarped on a dry site). The field storage facility must be 30 meters from a water course or a water source used for domestic purposes.

Livestock manures are commonly used for fertilizers or soil conditioners. Manures supply plant food over a period of time, but on average, in the year of application each tonne of manure should supply approximately the amount shown in table 8, below. The table gives a general indication of the nutrient content of various types of livestock manure.

Note: *The moisture and nutrient content of manure varies as a result of storage method, litter content and age of manure.*

Table 8. Typical Nutrient Contents of Various Manures

		Nutrient Content * (kg/tonne) (X 2.0 = lb/ton)				
		% Moisture	Total N	Available N year 1 #	P_2O_5	K_2O
Beef	(solid)	68	4.2	2.1	4.8	8.2
Dairy	(solid)	77	3.9	1.9	3.4	9.0
	(liquid)	91	2.9	1.5	2.1	4.5
Swine	(covered pit)	93	6.3	5.0	3.3	3.9
	(uncovered pit)	98	3.5	3.3	1.5	1.7
Horse	(with shavings)	72	2.4	1.0	1.7	3.2
Spent Mushroom Compost		70	5.8	1.5	2.5	8.5
		Nutrient Content * (kg/m3) (X 1.7 = lb/yd3)				
Poultry	(broiler)	25	15.8	13.4	11.4	6.1
	(layer)	50	11.4	10.3	14.6	5.6

* Nutrient values for manure assume proper storage, handling, and application to minimize losses

Conversions:

1 tonne of liquid manure = approximately 1000 litres = 220 gallons

1 m^3 = 1.25 yd^3 = 28 bushels

1 tonne of solid manure = approximately 2 m^3 = 2.5 yd^3

\# Losses of nitrogen upon application of manure can range from a low of 20% if manure is incorporated within 24 hours to as much as 50% by volatilization if manure is left on the soil surface

Once the manure has been received and stored on your farm, the manure should be tested for its nutrient content. Nutrient content will not be adversely affected if the manure is kept covered by either a roof or tarp.

Recommended application rates of fertilizer nutrients (N, P_2O_5 and K_2O) should be adjusted downward depending on the amount and nutrient content of the manure used. If a manure test is unavailable, the table values can be used, but should be adjusted if the moisture content of your manure is different. In any one year or for any one crop, manure should only be used to supply up to 75% of the crop requirement for nitrogen. Only about 50% of the phosphorus in manure is readily available in the year it is applied unless the field has received repeated applications of manure. In cases of repeated manure use the phosphorus is assumed to be 100% available. All the potassium in manure is available in the year of application.

If manure is to be used as a soil conditioner it must be applied at the same rate as if it were to be used as a fertilizer. Using manure together with cover crops can improve soil structure. The decomposition of the manure in the presence of cover crop roots stimulates biological activity, and increases aeration, permeability and water holding capacity of the soil.

Cover Crops/Green Manure

Cover crops are grown for protection against soil erosion, for improvement of soil structure and soil fertility, and for suppression of pests. They are not generally grown for harvest or forage, but rather to fill gaps in either time or space when cash crops leave the soil bare.

Cover crops are also called green manure, living or dead mulches, plow down, companion, relay, double or catch crops depending on their specific use. Suggested cover crops include legumes, cereals, brassicas, grasses and mixtures.

It is important to know the soil degradation problem you are trying to solve before planting a cover crop. For example, cover crops will not prevent flooding, but if a field is drained they can help to improve the infiltration of rain water into the soil so it can get to the drains without ponding on the soil surface.

Some precautions that should be taken before using cover crops are:

- Certain cover crops can result in the build up of pests. For example a legume or brassica cover crop should not be grown in a field before a bean or cole crop because of the potential build-up of white-mold or club root.
- Some soil active herbicides (e.g., atrazine, metribuzin or trifluralin) applied to the cash crop may harm cover crops planted following the cash crop.

The following table 9 indicates the range of species, seeding rates and most appropriate planting date for some cover crops that are useful for agricultural producers.

TABLE 9. Cover crop or green manure species, seeding rates and seeding times

Species	Seeding Rate	Seeding Date
Spring cereals (barley, wheat or oats)	80 – 150 kg/ha	before mid-September
Winter cereals (*'Monopol' winter wheat or fall rye*)	80 – 150 kg/ha	after mid-August & before mid-October
Annual ryegrass ('Westerwolds')	20 – 40 kg/ha	late summer or fall
Brassicas:		
Winter rape ('Liratop')	10 – 15 kg/ha	after mid-August & before mid-October
Oilseed Radish	10 – 15 kg/ha	before mid-September
Mustard ('Cutlass')	30 – 70 kg/ha	before mid-September
Winter legumes (Austrian winter peas or hairy vetch)	30 – 70 kg/ha	late summer or fall
Faba beans	80 – 150 kg/ha	before mid-September
Perennial legume (Pacific double cut red clover)	10 – 15 kg/ha	early summer to mid-September

Note: Recommended variety is listed in brackets.

These seeding rates and dates generally apply to fall seeded cover crops. Some crops such as clovers, spring cereals, annual ryegrass and oil seed radish can be used as in-season cover crops. If seeding late in the seeding window use the highest seeding rate.

Spring cereals are usually winter killed leaving a protective mat on the soil. Spring cereals are recommended for muck soils and areas where early planting is desired. Winter cereals will usually grow slowly over the winter, producing the majority of their growth in the spring. Early seeding dates for winter cereals may reduce the risk of waterfowl grazing.

Spring Management of Cover Crops

Prior to plowing down living cover crops, mowing or spraying herbicides (e.g., glyphosate or paraquat) may be useful. If large amounts of plant material are to be plowed under, 100 kg/ha of ammonium nitrate (34-0-0) or manure (to meet cash crop requirement) can be applied to speed decomposition.

Cover crops should be disced to completely bury them rather than rotovated prior to plowing. Plowing is the best method of turning the residue under in fields that are going to be seeded early.

Woodwaste

"Woodwaste *(as defined by the Code of Agricultural Practice for Waste Management)* includes hog fuel, mill ends, wood chips, bark and sawdust, but does not include demolition waste, construction waste, tree stumps, branches, logs or log ends." Woodwaste, like straw, can be a beneficial source of organic matter and aid in the improvement of soil tilth. Wood-waste can also be the source of very toxic leachate. Generally, woodwaste leachate will not be generated in the arid conditions of the interior. However, if woodwaste is used in such a manner that it is subjected to leaching from rainfall or irrigation, a woodwaste leachate will be generated. The use of woodwaste is recommended for a plant mulch, soil conditioner, ground cover or livestock bedding. Only small amounts of product like sawdust would be suitable for amending soils before planting ginseng.

Peat Moss

Peat moss or other types of organic soil material provide a small quantity of plant nutrients, but their greatest benefit comes from improving the water-holding capacity of sandy soils and improving the tilth of fine-textured soils. Abundant, economical sources of peat moss for soil amendments are not readily available for field scale agriculture. However, in intensive horticulture markets, nursery and greenhouse, supplies are available. In place of using peat moss in field scale agriculture, products such as composted animal manures may be more readily available and also have the benefit of supplying some plant nutrients.

Compost

Compost is made from organic materials such as crop residues, clippings, leaves, small animal morts, animal manures or woodwastes. Soil organisms almost completely decompose the organic matter and the end product is a humus-like substance which is a valuable soil amendment. Composting organic waste is a method of converting raw organic materials into a more decomposed stable product from which plant nutrients are more readily available.

The main benefit of composting is that it allows the use of low nitrogen organic materials, such as straw or woodwaste, without reducing available soil nitrogen, which would occur if these materials were added directly to the soil. If adequate time is allowed for decomposition of crop residues or manures on the field prior to crop seeding, composting will not likely provide benefits in addition to those derived from direct incorporation of underdecomposed organic materials. Significant amounts of compost can improve soil structure, water-holding capacity and supply of plant nutrients.

INORGANIC MATTER

Chemical Fertilizers

Chemical fertilizers are commonly used to effectively overcome nutrient deficiencies in the soil.

Although fertilizers are valuable, and often essential crop production inputs, they are not a substitute for good soil management. Supplementary practices including crop rotation and additions of organic matter, are strongly recommended to ensure that good soil structure and organic matter levels are maintained. Some fertilizers applied to the soil surface (i.e., phosphorus fertilizers) and not incorporated, have much less effect on plant growth.

Many fertilizer materials will lower soil pH over time and excessive application rates can result in temporary salt injury or nutrient imbalances which interfere with normal crop growth. Use of chemical fertilizers, as with the additions of any nutrient source, should be in accordance to a soil and / or plant tissue testing program to ensure crop and soil health and to avoid adverse effects on the environment.

Lime and Liming

The addition of liming materials is effective in raising soil pH. Many orchard soils in the Okanagan and Similkameen Valleys are somewhat acidic due to the effects of nitrogen fertilizer applications and irrigation on soils with a low cation exchange capacity. These soils require periodic liming to maintain soil pH at levels high enough for good plant growth. In addition, lime provides calcium, which is an essential plant nutrient and which promotes granular structure in soils. Generally, soils with high clay / organic levels have a higher buffering capacity and require higher lime application rates to initially change the pH.

Common liming materials include ground limestone (calcium carbonate), ground dolomite (a type of limestone which contains both calcium and magnesium), hydrated lime (calcium hydroxide) and packinghouse or CA lime (calcium hydroxide, which has been exposed to carbon dioxide and has a chemistry equivalent to wet calcium carbonate). CA lime is often lumpy and should be pulverized prior to application. Hydrated lime is quite caustic and it raises soil pH quickly. Excessive applications of hydrated lime can adversely effect soil organic matter and plant growth by raising the pH very rapidly. Ginseng prefers a lower pH soil so it would be doubtful if liming would ever be an issue. If a soil test calls for it more information is available.

Sulphur and Acidification

Sulphur may be required as an essential plant nutrient, however, this section will refer to the use of sulphur as a soil acidifier.

In some areas of the interior, soil pH is above 8.0. It may be desirable to lower the pH to increase the availability of some plant nutrients. Lowering soil pH involves the same cultural practices and considerations as raising the pH with liming, except that different products are required. Adjusting a soil pH downward is more difficult and often more costly than moving a soil pH up. Care must be taken to ensure that the high pH >8.0 is not the result of an alkali (sodium) or saline condition which may require other soil management such as gypsum addition or drainage.

The principal agents used to lower soil pH are elemental sulphur, sulphuric acid, aluminium sulphate and iron sulphate (ferrous sulphate). Ammonium sulphate, ammonium phosphate and other ammonium containing fertilizers are also quite effective in reducing soil pH, though they are primarily sources of plant nutrients.

For large areas, elemental sulphur (or a mixture of it and bentonite to improve its stability and safety when handled in confined spaces) is probably the most economic product. However, elemental sulphur has to be oxidized by soil microorganisms. Sulphuric acid can of course also be used, but it is unpleasant to handle as well as very corrosive. Generally, elemental sulphur, when fully converted to sulphuric acid, will react with three-fold its applied weight of residual carbonate. As with limestone applications, limiting the maximum rate of applied sulphur at any one time (about two tonnes per hectare) will lower the pH gradually while preventing or minimizing the chance of salt buildup. The soil test laboratory will determine the total soil acid and sulphur requirement to attain a desired soil pH upon request. For more information, refer to the Soils Factsheet: “Acidifying Soils” at: http://www.agf.gov.bc.ca/resmgmt/publist/600series/638100-1.pdf

Fumigation of Ginseng Gardens

To fumigate or not, that is the question! Because ginseng is a high value crop, this question cannot be ignored. You need to by various means, determine if the expense will reap rewards. If certain factors are present there may not be other alternatives. It is also a process that you will likely not do yourself so planning ahead to have it done at the proper time is important.

WHY DO YOU FUMIGATE OR WHAT DOES FUMIGATION CONTROL?

NEMATODES — Nematodes are fairly easily killed by fumigation although proper timing, and placement of product is critical. (See Nematodes page 108 and testing for them later in this section, page 38.)

DISEASE ORGANISMS — These will not be controlled at lower rates of application for nematodes but most are controlled at higher rates. (See Disease section pages 94–100 and information later in this section.)

INSECT CONTROL — Any insects that are in the soil zone where fumigation is applied will be killed by most rates of a fumigant. (see Insect Section pages 89 to 93.)

WEED SEEDS — Results vary with control of weeds at any of the rates used for nematode control. Some seeds will be killed, some not controlled and some stimulated to grow by the chemicals.

THREE MAJOR FACTORS AFFECTING EFFECTIVENESS OF FUMIGATION:

PROPER LAND PREPARATION — *(see section below)* This includes many individual factors and cannot be accomplished quickly

TEMPERATURE OF SOIL — There are maximum and minimum levels to get optimum effect

DEPTH OF APPLICATION — This is important because of the process of building beds, where soil is brought up from a considerable depth to form a bed. If soil is not fumigated below this level, unfumigated soil will be brought up and spread over the bed surface, contamination the top fumigated portion.

GUIDELINES FOR FUMIGATION

(supplied by Buckman Laboratories of Canada Ltd.)

- Summerfallow or grow cover crops which suppress nematodes
- Take nematode samples to determine if a problem exists
- Subsoil the field so the proper depth of application can be achieved
- Remove any rocks and large stones
- Work land deeply to seedbed condition — no lumps
- Crop residue and straw must be rotted away
- Soil moisture should be at 50 – 80 percent soil capacity
- Do not fumigate if soil temperature at 3" depth is 90°F (or over 32°C).
- Fumigate 12 – 18" deep
- Seal immediately with a packer or apply 1/4" of water / day for three days
- Leave undisturbed for a week
- Do not reintroduce nematodes and disease by dragging untreated soil onto the treated area or pulling up untreated soils when building beds. (See Sprayer Cleaning (Exterior), page 86.)

RE-INFECTION OF GARDENS

Note: *A week after fumigation the process starts over again, although you control to some extent what happens with the reinfection of a garden. When soil is fumigated with chemicals, the number of soil microorganisms is greatly reduced for the first few days, then it rises and eventually exceeds that of untreated soil. The fumigating destroys a large part of the dense population of soil microbes, and the first organisms to return after treatment meet no severe competition. Thus, if plant pathogens are among the first to recolonize the soil, they develop rapidly and can cause severe disease losses. It is therefore important to the grower that every effort is made to prevent disease organisms from gaining entrance to the food.*

Pathogens can gain entrance to the soil by:

- Planting infested seeds or plants.
- Wind-blown or water-splashed pathogens.
- Irrigating with dirty water.
- Movement of infested soil.
- Using contaminated machinery, footwear, etc.

FUMIGATION PRODUCTS

Because fumigation is done before a crop is planted and all product residue has to be gone before the crop will grow, they are not registered specifically for a crop. You must however use a registered product (see table 10) and proper application methods. Generally fumigants are custom applied although there are a couple of products, Telone C-17 and Basamid that could be applied by yourself with proper equipment.

TABLE 10. Fumigation products available for soil fumigation

Product	Active Ingredient	Registrant	Pests Controlled	Rate (broadcast)	Comments
Telone II	1,3-dichloropropene	Dow Agro Sciences	nematodes	See label. See note below.	
Telone C-17	1,3-dichloropropene chloropicrin	Dow Agro Sciences	nematodes, soil-borne diseases	See label See note below.	Use higher rates for disease control.
Vapam	metam sodium	Syngenta Crop Protection Canada Inc.	nematodes, soil-borne diseases, weeds	550 – 900 L/ha See note below.	Lower rates adequately control nematodes. Apply by soil injection.
Busan 1020	metam sodium	Buckman Laboratories	nematodes, soil-borne diseases, weeds	700 – 935 L/ha See note below.	Lower rates adequately control nematodes. Apply by soil injection. Use higher rates for disease control.
Basimid	dazomet	BASF	nematodes, soil-borne diseases, weeds	325 – 500 kg/ha See note below.	Apply as a granular with a spreader and then incorporate immediately.

Note: Rate will vary according to application technique/equipment. Check with your dealer.
Source: Ontario Ministry of Agriculture, Food and Rural Affairs. 1995 Ginseng Pest Control Recommendations.

Nematode Diagnostic Services

There are laboratories in British Columbia doing diagnosis on soils for the presence and count of nematodes. See the list of laboratories in the Appendices.

SAMPLING FOR NEMATODE DETECTION

Plant parasitic nematodes can live in the soil as well as in plant tissue. To examine the extent of their existence in your field it is important to take a sample which will properly represent the area you want tested.

Most of the nematodes exist in the feeder root zone of the plants. The injury incurred by nematodes often manifests itself as a general decline in plant growth. The plants appear to be growing poorly and are easily damaged by any source of stress such as heat, moisture and disease. Nematodes tend to occur in a patchy distribution within a field. This necessitates a systematic method of sampling the field.

The sample should be taken with a soil probe or a trowel to a depth of 8 inches (20 cm) for most crops. If a trowel is used, a 1/2 in. vertical slice of soil should be taken. The field is walked in a zigzag pattern taking approximately 20 cores to represent an area of not more than five acres.

The sample should be thoroughly mixed in a pail and approximately one litre placed into a plastic bag. The bag should be closed with a twist tie and labelled. The label should include a sample number written at the base of the plastic bag or a tag attached to the twist tie **outside** of the sample.

A "Nematode Sample Information Sheet" should accompany each sample, recording all pertinent information for that sample.

Samples should **never** be left in the sun as they heat up very quickly which can kill the nematodes. Ideally, the samples should be kept at about 10°C, although this is difficult in a field condition. It is best to send the sample as soon as possible after it has been collected.

TAKING A ROOT SAMPLE

It is often helpful to include a root sample, like raspberries, since the majority of root lesion nematodes live in the roots. It is important to collect the fine feeder roots for a sample as this is where the majority of the nematodes will be found.

The roots should be collected from several areas and approximately 1/2 litre of them placed into a plastic bag with soil from the area where the roots were collected. The feeder roots dry out very quickly, therefore they must be covered well with moist soil.

WHEN TO SAMPLE

Samples should **not** be taken when the soil is too wet, dry or frozen. The best time to sample is in early September so as to allow enough time to process the sample and still have time to fumigate if necessary. The nematode population should be at a peak at this time of year, as well. However, samples for crops like ginseng, may be taken any time between March and November, to meet cropping requirements. See the list of Laboratories in the Appendix for one that tests for nematodes.