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«REGENERATING SOILS WITH RAMIAL CHIPPED WOOD»

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REGENERATING SOILS WITH RAMIAL CHIPPED WOOD

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Every one involved in agriculture sooner or later comes to the same conclusion: we must make soil. Chemical fertilizers, pesticides and ploughing destroy the fertility of the soil; organic farming maintains its fertility but cannot replace lost soil. The most fertile agricultural regions were once hardwood forests, especially oak forest. We now know why and how to hasten nature's work.

HOW IT STARTED

The ramial chipped wood (RCW) story began in the mid-seventies when Mr Edgar Guay, former Land and Forest Deputy Minister in Quebec began searching for new products that could be derived from the huge piles of branches wasted after logging operations. The first field experiments with deciduous tree trimings were made during the summer of 1978. A research team nucleus was formed with Mr Lionel Lachance and Mr Alban Lapointe joining Mr Guay. In 1982, M. Gilles Lemieux, a now retired professor from the Faculty of Forestry at Laval University, joined the team to provide answers on the mechanisms involved.

The name and description of «ramial wood» was given in 1986 (Lemieux) under the French name of «bois raméal». Since the method put forward by Guay, Lachance & Lapointe (1981) was based on chipping, this «new material» was then called *«Bois Raméal Fragmenté* or BRF» in French, *«Ramial Chipped Wood* or RCW» in English (1992), *«Fragmentiertes Zweigholz* or FZH» in German (1992), *«Aparas de Ramos Fragmentados* or ARF» (1993) in Portugese *«Ramoscelli Frammentati* or RF» in Italian (1993) *«Madera Rameal Fragmentada* or MRF» in Spanish (1994): "Ramial wood" refers to twigs having less than 7 cm in diameter. They contain soluble or little-polymerized lignin, the base for soil aggregates and highly reactive humus. These small-size branches are not used as firewood, even in the poorest tropical countries.

Although fungi are most important for humus formation and cycling, the humic system performs best when fungi are associated with the fungivore soil mesofauna. This process, linked to virus, algae and protozoa, makes nutrients available when needed by plants.

In organic agriculture it is generaly believed that a soil treated for years with massive doses of chemical fertilizers and pesticides can be restored in three years with compost and a return to traditional practices. This belief does not take into account that the diversity of the molecules and the complexity of the soil ecosystem of the world's agricultural land has been claimed from the forest.

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THE PRODUCTION OF A STABLE HUMUS

There are humic subtances that have a short life (compost and manure) and others that have a long life (more than 1000 years). These substances play an important role in the balance of the soil. The Asian steppes, the South-American pampas and the North-American prairies, being covered with herbaceous plants, have a short-life humus. The soil claimed from hardwood forest has a long-life humus.

In soils farmed intensively with synthetic fertilizers exclusively, a modified bacterial and mostly fungal biology ends up consuming the long-life humus of forest origin. By using farm manure or compost in which the only source of lignin is straw, we cannot hope that humus having a long life will form massively and stabilize the soil on a long term. This type of organic amendment brings the soil to a condition similar to the North-American prairie soils which derived its lignin from Graminaceae over thousands of years and which have not long resisted to intensive farming. These soils are now subject to massive erosion. Only the addition of ramial chipped wood can be viewed as a mean to return the soil to its former forest origin condition and restitute, in three years, a long-life humus content.

HUMIFICATION RATHER THAN MINERALIZATION

Misunderstanding of the natural forest ecosystems, especially the forest soil, is so deep that all silvicultural practices use agriculture as a model and research has been directed mostly to managed agricultural systems. In agriculture, as well as forestry, the entire focus has been placed on mineralization, with little work done on, or interest shown for, humification which regulates mineralization and fertility. The lignin of Angiosperms is central to humification and biological controls of fertility. It has a deep impact on most mesic soils through the multilevel life they bear.

HOW A FOREST ECOSYSTEM WORKS

A close look at a forest ecosystem shows a fast transformation of plant tissues into nutrients by soil microorganisms. Nutrients are bound to the organo-mineral complex and are made available as needed for plant growth. In temperate forests, under a deciduous tree canopy, this organo-mineral humic complex is stable within an internal biological cycle. It becomes fragile under tropical conditions. It has several roles and therefore must be closely examined.

The basic mechanisms lie in the role played by «white rots» which use enzymatic systems to produce both fulvic and humic acids from lignin, the base for aggregate formation (Leisola & Garcia 1989). The best results are achieved with deciduous trees due the chemical structure of their lignin. Evergreens perform poorly, due to the transformation of their lignin by «brown rots» which produce polyphenols and aliphatic compounds (Swift [1991], Larochelle [1993]).

RESULTS OF WORLD-WIDE EXPERIMENTS

Twenty years of experiments with RCW in both forestry and agriculture in Québec, Africa, Europe and the Carribeans have provided:

- Better soil conservation due to the water retention capacity of humus content (up to 20 times its weight) and the capacity of water accumulation and management by soil organisms;
- An increase in pH from 0.4 to 1.2 or, under tropical conditions, in alkaline soils, a decrease in the range of 2.0.;
- A yield increase up to 1000% for tomatoes in Sénégal, and 300% on strawberries in Québec;
- A 400% increase in dry matter for corn in both Côte d'Ivoire (Africa) and the Dominican Republic (Carribeans);
- A noticeable increase in frost and drought resistance;
- More developed and highly-mycorrhized root systems;
- Fewer and less diversified weeds;
- A decrease or complete elimination of pests (under tropical conditions, a complete control of root nematodes, the worst and most costly pest in vegetable garden growing);
- Enhanced flavor in fruit production;
- Higher dry matter, phosphorus, potassium and magnesium content in potato tubers;
- A soil turning from pale to deep brown in the same season;
- Selective natural germination of tree seeds;
- A thick moder turning into a soft mull under a sugar maple canopy.

SPECIES OF TREES TO USE

Some species are quickly digested (in few months) by the soil, others take a few years even if they seem to have vanished. Coniferous trees, in cold and temperate climates, generate a blockage mechanism of soil pedogenesis. Their lignin, once into the soil, evolves in producing a great amount of polyphenolic inhibitors. This type of lignin is also found in many tropical tree species but high soil temperatures break the inhibitor effect to some extent. In cold and temperate climates, ramial wood from coniferous species must be avoided or restricted to 20% of the overall content. Coniferous trees are characterized by an asymetrical lignin (guaiacyl).

Coniferous trees store nutrients in the trunk and eliminate competition by making the soil unsuitable to competitors. Deciduous trees store some nutrients in the soil and enhance diversity. This strategy allows deciduous trees to replace coniferous wherever climate conditions permit. Deciduous forests are much more stable and long-lasting, whereas coniferous forests follow cataclysm cycles. When all the nutrients are blocked, coniferous trees send olfactory messages to pests that come and destroy the stand, then fire takes over and cleans all, and nutrients are freed.

Species to be used can be quickly determined on an ecological basis. Trees that grow in association with the most superior plants are to be favoured. Rich stands of red oak, sugar maple, beech, yellow birch, linden and ash give much better results than poor-quality stands such as red maple or trembling aspen. A mixture of species is suitable and will give an amendment with positive effects in the short as well as in the long term.

PARTS OF THE TREE TO USE

The C/N ratio for ramial wood ranges from 30/1 to 170/1 while for stemwood the C/N ratio ranges from 400/1 to 750/1. Branches under 7 cm in diameter, without their leaves, are the best choice for shredding. In the North-American species, essential plant nutrients (N, P, K, Ca, Mg) increase when branch diameter decreases. These concentrations reach a minimum in branches over 7 cm in diameter, so branches having less than 7 cm in diameter contain 75% fertilizing nutrients. The bigger the branches the less digestible they become. If sawdust, issued from tree trunks, is mixed with the soil, nitrogen will starve unless the sawdust is composted with farm manure. The trunk of the tree supports the branches which are the real biological center for wood production. The trunk is «dead» and does not allow lignin to be used by enzymes from microflora and fauna to integrate into the soil. For the forest, the «dead» trunk is «garbage», attacked from the outside, and transformed in CO^2 with very little benefit to the soil.

For a first treatment, the ramial wood should be without green leaves because green leaves contain chemical elements easily accessible to bacteria. These bacteria can prevail over «white rot» (Basidiomycetes). When leaves are dead, these chemical elements, tied to brown pigments, will be released through the soil mesofauna activity in perfect harmony with the «white rot» activity. It must be noted that persons following these rules have obtained good results.

TOOLS

Chipping or crushing ramial wood is nessaryto permit massive entry of soil microorganisms without facing the bark barrier. Moreover, chipping increases the surface of the material which accelerates soil digestion. In tropical countries, big pieces, grossly chipped with a machete, will be rapidly digested by the soil.

For a good chipping the cut must be made at an angle of 57° and the rotation of the blade 12000 RPM for one knife, 6000 RPM for two knives and so on. It is better to shred the branches lengthwise than cut them perpendicularly. A second-hand forage harvester could do a good job on farms. A chipping or crushing apparatus can be custom-made or chipping devices collectively-owned. Many types of chipping devices can be found on the market, some can be activated by a farm tractor.

Mechanized chipping is costly in both labor and money. Fifteen hours are needed to produce enough RCW for one hectare requiring 150^3 meters. This quantity is needed to enhance the quality of the soil and the crops for the following five years under temperate conditions. A RCW soil amendment should be perceived as an investment redeemed over a period of 10 to 15 years.

METHODS

The basic methods called «Sylvagraire» for agriculture and «Sylvasol» for forestry are better known. They give the best low-cost results. RCW must not be composted nor ploughed under but spread in a thin layer, a thickness of one inch being the optimum. The upgrading mechanisms best perform when RCW is mixed with the first 5 cm of the topsoil. The fundamental mechanism relies on massive entry of soil microorganisms into the twigs. Therefore chipping or crushing them is essential.

STORAGE

If it is not spread immediatly after chipping, RCW can be windrowed. If the pile is too high or too dense, it can induce anaerobic conditions which are very harmful after a few weeks.

After three months of storage, RCW is seen more as compost and can make an excellent organic amendment but its chemical constituents and its impact on the biology of the sol is different from freshly-made RCW.

WHEN TO USE RCW

Under cold and temperate conditions, the autumn period sems to be the best time to use RCW. Added to the soil, this material, rich in carbon and poor in nitrogen, may favor nitrogen immobilization by the microorgnisms during the first few months. When using RCW, this type of effects can be seen during two months, after which trophic chains are active and the amount of available nutrients is increasing with time.

Soils treated with RCW in the spring can show sign of nitrogen hunger during the growing season but this will not be harmful to the production and will not cause necrosis to the foliage. THIS WILL NEVER HAPPEN AGAIN IF RCW IS TO BE APPLIED ON THE FOLLOWING YEARS. If RCW is used as a mulch instead of being disked in, there is no nitrogen hunger but the integration to cultivated soil will be much slower. The autumn period favors the spreading of Basidiomycetes. They remain active at temperatures below freezing whereas bacteria die and massively encyst during the cold season.

FOREST LITTER ADDITION

Studies have proven that Basidiomycetes are often absent from cultivated soil and trophic chains are reduced to a minimum. The several organisms (fungi and symbiotic bacteria, microarthropods, insects...), found in forest soils and essential to the RCW transformation, are not found in cultivated fields. They must be reintroduced with the first application otherwise RCW may not behave correctly (towards a coaly colour). Migration of some of these organisms in the soil is sometimes very slow (a few centimeters per year) and a natural recolonization might take considerable time. To reintroduce forest soil fungi requires an addition of 10-20 grams of the forest litter per square meter. This litter can be taken from an old deciduous climax forest stand or something close to it, at a depth of 5 cm beneath the dead leaves. The dark brown leafmould should be harvested just prior to the spreading in order to avoid drying.

QUANTITY TO USE

RCW must not be composted nor ploughed under but spread in a layer not thicker than 1 $^{5}/_{8}$ inch, at the rate of 150 to 200 m^3/ha. The upgrading mechanisms perform best when RCW is mixed with the first 5 cm of the topsoil. This treatment is good for three years in temperate conditions and it has to be repeated by adding from 10 to 20 m^3 on the fourth year and years after.

INCORPORATION TO THE SOIL

In cultivated fields, it is very important to disk RCW in the first 5 cm of topsoil. The reasons for this surface incorportion are of a physical and a biological order. In the forest, RCW integration requires the interrelationship of many organisms. When conditions are not convenient (which is rare in the forest where a microclimate exists under the canopy), the organisms will migrate deep in the forest litter to be protected. In cultivated fields, these migrations do not to happen because these organisms are vulnerable to dry spells. This explains why spreading RCW in the forest does not require mixing with the topsoil.

To favor the multiplication of Basidiomycetes, wood humidity must vary from 30% to 120%, the optimum being between 60% and 100%. Basidiomycetes are aerobic fungi located in the first 5 cm of soil and in close contact with RCW in a moist environment.

RCW vs COMPOST

RCW is a pedogenetic amendment able to optimize or generate a true soil. This technique must not be mistaken with composting where basic material comes from diverse organic sources.

The compost is used to feed the life of the soil and bring nutrients to the plants, while RCW can rebuild and maintain the soil structure, long-term fertility and soil stability. The composting process results in the loss of organic materials, but the enzymatic combustion favors the destruction of polyphenols and pathogenic organisms. With RCW technology, the organic material goes directly into the soil structure and reach the trophic chains without any loss.

Mixed with the soil RCW is sufficient because all the necessary elements are in it. In soils treated with RCW there is no deficiencies. As stated above, the C / N ratio of RCW varies from 50 / 1 to 170 / 1 for twigs less than 7 cm in diameter. The farmer should not worry about the C / N ratio once biological action works.

NO PLOUGHING

By ploughing and disking the soil, the life cycles are destructured and, consequently, the soil improvements with organic amendment are less than expected.

In a field treated with RCW ploughing should be delayed for three years in order to prevent deep burrying and provide aerobic conditions favourable to RCW evolution and Basidiomycetes enzymatic activities.

The RCW material will remain the same after years under anaerobic conditions in deep soil. One benefit of ploughing is to allow water savings by breaking pore continuity whereas a soil treated with RCW will retain enough moisture to prevent dryness. Ploughing, by increasing the roughness of the soil, could limit washing and erosion; but RCW, as a humic amendment and a bioactivator, will improve the soil structure and regulate activity through polyphenolic chemistry. This structural stability is the most efficient tool for regenerating soils.

RCW AND WORM POPULATIONS

RCW treatments will favor the increase of earthworm populations. In Quebec, up to two tons of earthworms per hectare can be found in a natural sugar maple stand. These worms work without harming the root systems.

RCW AS MULCH

RCW can be used as mulch or, better, on the soil surface. In this way, RCW is slow to evolve and does not play the same role. It serves as a mechanical barrier to drying and as a shield against UV rays which are lethal for the life beneath. It is an ecological niche for forest insects and other biotas while preventing weed sprouting and agressivity. It is possible that the long-term effect will be similar to that of surface disking. Certain farmers prefer the mulching method because it does not interfere with the life of the soil.

THE MOST CONVENIENT SOILS

Soils constantly wet and cold should be avoided. The anaerobic conditions do not allow RCW to be involved into a fertile pedogenetic process. The sandy-silt soils containing a sufficient amount of clay will benefit best with RCW application. In such soils, the pedogenetic process is active and efficient. The clay particles favor exchange complexe and the stocking of nutrients.

RECOMMENDED FARMING PRACTICES

For an agronomist, the RCW technology is a very useful farming practice. A good way to proceed with very low productive soil is to disk in the RCW material in the fall and, the following spring , sow a cereal-hay mixture, i.e. a legume (white clover or alfalfa) that can trap nitrogen. The first crop is cereal and the following two years hay crop is harvested. Later potatoe crops can be grown easily.

CONCLUSIONS

Branches and brushes were always seen without value for centuries and as trash in the modern forest economy that has developed during the last century. A first assessment of small branch production shows a mere 100 million tons per annum for Québec alone and probably billions of tons throughout the world. Small-diameter branches can be transformed into a «soil food». Feeding soil microfauna and microflora is more likely to bring mid- and long-term benefits to both agricultural and forest ecosystems in redeeming costs and increasing benefits. RCWs represent the only large-scale upgrading technology. It involves a large number of shrub and tree species resulting in variable responses, all positive with regard to enhancement of the humic system. RCWs bring the benefits of the forest soil to the agricultural soil at the lowest possible cost [Lemieux, 1993].

Agricultural land was «extracted» from the forest. The forest can now help degraded soils by keeping them alive and microbiologically diversified. Ramial chipped wood is a good tool available to all societies, even the poorest, to reverse soil degradation and desertification. As we are now aware of the major role of RCWs upon the formation of a highly reactive humus system, our attitude toward the forest will have to change. Instead of depleting our natural forests as we now do to grow commodity trees, we must grow «forest ecosystems» and treat them like perennial gardens. From an enemy, the forest must become a friend. From a resource to be exploited for immediate profit, it must become the source of infinite wealth.

RCWs must be carefully looked at in both the southern and the northern hemispheres. More than 75% of nutrients are stored in twigs. Twigs are the center of life, stemwood being the result of the whole crown activity. Twigs, once chipped and brought in close contact with the soil, momentarily replace the rootlets that are constantly transformed into short-lived aggregates by the soil microorganisms. These aggregates are the managers of soil nutrients and energy for the ecosystem's own sake. They enable biological actors to play their vital role, from virus to mammals, using available energy and nutrients. It is of prime importance to understand and visualize the whole picture and the role played by each actor in this wonderful evolution of nature's work from which we now benefit after so many millions of years.

Time has come for large-scale worldwide organizations to deal with planetary problems. RCWs are the key to understanding the biological basics of our terrestrial ecosystems. There is no doubt concerning the value of RCWs and their positive impact in pedogenesis, which is a universal process. This universal biological material will have a direct effect in the short term as well as in the long term on soil, crops, economy and on both human and animal societies. It will be seen as one of the most important biotechnological contributions of this century [Lemieux (1993)].

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