CONILON
Coffee

3rd Edition
Updated and expanded




The Coffea canephora produced in Brazil

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Soil Preparation, Management and Conservation in Conilon Coffee Crops

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1 INTRODUCTION

Coffea arabica and *Coffea canephora* are cultivated in Espírito Santo, the latter being responsible for about 72% of coffee production in the State of Espírito Santo (CONAB, 2015) and known as conilon coffee. In the State, it is cultivated in places of low altitude and hot weather and, lately, also has been produced in areas of up to 700 meters of altitude. However, most of the production is concentrated in the municipalities located in the northern region, above the Doce River. In these locations, the crops are predominantly distributed in two geo - environmental units: on the Coastal Tableland soils formed by tertiary sediments of the Barreiras Group and Crystalline land occupied by Precambrian Crystalline rocks, classified mostly as gneiss acids, rich in silica, with predominance of the minerals quartz, alkali feldspar and biotite mica (EMBRAPA, 1978). In the Tertiary, the terrain varies from plane to smooth wavy and rugged in Crystalline. Climatic data from these environments indicate irregularities in rain levels, usually with annual water *deficit*, soils with low natural fertility, low water storage capacity and erosion, where high temperatures and constant winds, especially at certain times of the year, cause high evapotranspiration, damaging the plants and reducing productivity.

The practices carried out before the implantation of a coffee crop have a special meaning, which can result in success or failure of the activity. In this context, soil is one of the most important factors of production, and must be managed in a way that preserves all its physical, chemical and biological characteristics, in order to guarantee its economic exploitation for many generations. This resource represents an important asset not only for coffee cultivation, but also for oactivities developed by mankind, under the sustainability point of view.

Several authors have shown concern with soil preservation reporting that any practice that applies to the soil should be based on a prior knowledge of this natural resource, understood as a fundamental and exhaustible factor of production of agriculture and, as a result, it needs to be managed in a way that preserves and/or improves its characteristics and potentialities (BERTONI; LOMBARDI NETO, 1985; DADALTO; LANI; PREZOTTI, 1985; CHAVES, 2002; PROCHNOW et al., 2005).

Properly managing the soil means preserving its productive capacity. In order to know it

with greater detail, it is necessary to carry out the pedological survey, subjecting it to physical, chemical and biological analyzes, besides the evaluations of humidity retention, along the profile, to work as a base for the irrigation projects, an essential item for guaranteeing harvesting or reducing the risks of conilon coffee production in the main producing regions of the State. The most common and essential is the chemical analysis, which reveals the current soil fertility condition. The others are also important and reveal whether the roots will find a favorable environment or not for their perfect development. The soil survey data will also be important in determining whether subsoiler will be required to reduce physical impediments that may hamper root penetration of conilon coffee tree.

With the chemical analyzes results of the soil layers along the profile, it is possible to detect if there is any chemical impediment hindering the roots penetration.

2 CHOICE OF AREAS

The choice of areas for the conilon coffee planting should be made after careful analysis considering three main aspects: climate, soil and cultivation.

In the macroclimate aspect, it is necessary to observe the zoning for conilon coffee in each region and to take into account the appropriate ranges of temperature, rain and water guarantee. In addition, it is necessary to observe the conditions of top-climate seeking the location of the crops according to the exposure face of the land and its position in relation to the slope. Dadalto and Barbosa (1995) stratify and describe the areas of agricultural aptitude, as preferential, with restriction and inapt for the conilon coffee cultivation. In chapter 3 Agroclimatic Zoning for the Conilon Coffee Culture in the State of Espírito Santo, of this same edition, presents a new stratification for culture.

In general, the recommended areas for conilon coffee cultivation should have the following characteristics:

a) Be mechanically preferable, since the mechanical practices, from planting to harvesting, usually reduce, considerably, the cost of coffee production, as well as facilitating the activity exploitation on a larger scale, enabling semi-mechanical and mechanical harvesting. In mountain regions, it is necessary to adopt areas with a more favorable topography, with a maximum of 45% slope.

b) Being covered of grasses, like the brachiaria or capoeira and it should not have forest due to the ecological issue and the difficulty with deforestation and the removal of invading vegetation, which increases the costs.

c) Do not having problems with soil pests (nematodes, cochineal etc.) that attack the coffee tree.

d) Ease access, favoring the transport of inputs for the crop and of the coffee harvested for the drying and processing facilities.

e) Being close to a source of water that can be used for crop irrigation. In this way, the climatic risks that can affect productivity are reduced, as well as less labor dependence, since

most of the fertilizers could be applied via fertigation.

The soil depth, along with the texture and structure, influences the storage capacity of water and nutrients. The coffee tree needs at least 1.5 m of soil depth, in good texture and structure, so that it can maintain an adequate root system. This depth is most important in dry climate regions, where coffee should not be planted in soils with little depth unless irrigation is adopted. Most of the active (thin) roots of the coffee tree is concentrated in the first layer of the soil, up to 30 cm deep.

The soil, through its physical, chemical and biological characteristics, must provide suitable support to the coffee tree, directly influencing the volume and depth of the roots, conditioning better development and production of the aerial part of the plant, since the plant has access to higher amounts of water and nutrients (MATIELLO et al., 2010).

When choosing the areas, soil physical conditions, which are difficult to alter, should be observed with priority, while chemical and biological improvements can be obtained more easily through liming, fertilization and correct soil management.

3 AREA PREPARATION FOR PLANTING

The preparation of the area for coffee planting comprises a series of operations aiming at giving more suitable conditions to receive the plants. The necessary practices are: the land cleaning, the coffee crop location, the soil preparation and correction and the preparation of the planting grooves or pits.

3.1 LAND CLEANING

For areas with a topography ranging from flat to undulating, for those with sparse vegetation, native pastures, and others previously cultivated with annual cropping, the usual is the use of a tractor with a plow or a disc harrow, in which the largest and most powerful equipment (greater than 65 hp), four-weel drive (4 x 4) and plows of three or more discs are more efficient and indicated (MATIELLO et al., 2010).

The disc harrows, popularly known by farmers as “grade Rome”, feature discs of great diameter and weight that penetrate deeper into the soil. They are widely used to replace plowing because they have a high operational efficiency and can work on land with great weed infestation. For better results, two disc levels are usually required in the same area. In order to reduce the “spraying” of the soil surface, it is recommended that the soil be prepared slightly moist.

For areas covered with capoeira or forest, a rare condition since these areas constitute legal nature preserve and necessarily require release of the environmental organs where the mechanization is foreseen, cleaning and bush removal with a track-type tractor and tractor blade is indicated.

In mountainous areas or small planting areas, cleaning is usually done using hand tools,

such as sickle and axes, or, in the case of pastures, cleaning before or after the opening of the planting grooves can be done with the use of post-emergence herbicides. In case of sparse vegetation or native pasture, the cleaning can be only in the line where the grooves will be done, being the temporarily covered by the vegetation, which will be gradually eliminated. It is also possible to use plow with animal traction, which would favor the incorporation of the limestone randomly distributed. However, this type of preparation has not been widely used due to the slowness of the work (MATIELLO et al., 2010).

In the specific case of planting in an old coffee plantation area, eradication should be carried out with a tractor equipped with a blade or with a back bush hog, attached to the three points, to remove the coffee trees with the roots. It is recomended to wait at least 15 days until the leaves dry and fall, when it is possible to pass a heavy plough or shearer on the plants to cut off the thin branches. Then, the thick wood is enclose, and can be used in the dryer. It is necessary to examine the roots of the coffee trees to verify the presence of pests in the root system, and, if it is confirmed, it is necessary to wait one year to perform the new planting.

In the preparation of areas that present soils with good structure and in which it is not necessary to practice liming, only the opening of planting grooves or pits has been carried out, similar to the direct planting. In the total area, if necessary, it is possible use the shearer only once or the post-emergence herbicide application. When there is no revolving of all the soil in the area, there is greater humidity retention, greater soil particles aggregation and greater deposition of mulch near the planting groove or pit favoring the survival of the seedlings planted.

Flat areas with more clayey soils and with previous successive crops may present a density problem. In such cases, a special preparation should be made to mitigate these problems with deeper plowing, preferably with mouldboard ploughs or using total area subsoiling.

The preparation should be done with the soil a little moist to favor penetration and plough cutting, besides allowing the fragmentation of the larger clods. Excessively moist or dry soils are harmful.

In order to complement the preparation, especially if the planting is done right after the plowing, it should be used the harrowing to break the clods and hit the ground and may also assist in the control of remaining weed or that appear after the plowing.

3.2 MARKING AND OPENING OF CARRIERS

The coffee crops spot includes the location of the carriers (in level and slopes), the basic auxiliary levels and the planting lines marking of the coffee crop, as well as cords, terraces, retention boxes and other practices indicated for the erosion control.

The coffee planting in wavy or sloping areas is done in a level to facilitate the erosion control. In almost flat areas and in large plantations in which the priority is the mechanization, the coffee plantations marking aims primarily at the machinery transit. In this case, even with some unevenness, it is preferable to trace long planting lines, which will reduce maneuvers.

In warmer or drier regions under plateau conditions, it is also advisable to locate the lines in

the direction of the sun movement (east-west), avoiding the afternoon sun effect on the coffee trees side, which can lead to scalding of leaves, drought of branches and loss of production (MATIELLO et al., 2010).

In areas with central pivot irrigation, when the planting is done in a mechanical row, the marking has been indicated with planting in circular lines for water and labor saving, and also to facilitate semi-mechanical or mechanical harvesting.

The carriers location and their construction can be done before or after the soil preparation. In mountainous areas where the mechanical process is unfeasible, carriers must be marked and open before grooving or pitting, facilitating erosion control, transit in the area, and transportation of inputs and materials required to prepare grooves or pits.

In areas where the mechanical process is feasible, the previous marking of the basic levels and the carriages assists in the soil conservation since the plowing and other operations of soil preparation happen to be made in level.

The location must be carried out as follows: every 20 or 30 m towards the slope, the basic levels are marked, which are numbered from the top of the terrain. About the even ones, the carriers in levels will be opened, and the odd ones will work to mark the lines of coffee. In this way, level carriers will be spaced from 40 to 60 m, maintaining a width of 6 to 7 m, with a small slope (5%) to the interior. In addition, dry boxes should be built, beside the ravine and, along the carriers, allowing greater retention of water. In larger and flatter areas, carriers should be in a distance ranging 100 and 120 m apart.

In the perpendicular or slightly oblique to level carriers direction, the slopes must be opened by connecting two of them at a distance of 70 to 100 m and alternating to prevent the floods water from running continuously, which increases its volume and speed causing more erosion. Slopes should also be 6 to 7 m wide.

In areas with a slope of over 25%, sloping carriers must be constructed in a very oblique direction to facilitate climbs with less declivity, always taking advantage of spines, depressions and other terrain facilities. In these areas, level carriers should have their ends extended to facilitate the vehicles return. In necessary cases, some parts of the carriers do not need to be exactly in level. In uneven areas, with high inclination, no level carriers are used, but clibing roads in zigzag. In this case, it is important to keep these roads vegetated and open retention boxes to receive the water excess diverted from them.

The way of doing and the equipment indicated for the opening of the carriers or paths in the middle of the crops depend on the area topography. For flat or slightly wavy areas, it is not necessary to use any type of equipment, leaving only the free space (6 to 7 m wide) where the level or sloping carriers match, as the tractor and the machinery will normally travel there. With a slight slope, only for the level carriers, it is possible to pass the black blade of the tractor or the patrol leaving a small ravine at the upper part. The smaller is the ravine in the carrier, the easier it will be for the tractor to enter in crops lines that "die" there.

For wavy or sloping areas, the opening of the carriers is indispensable, being performed with the use of track-type tractor with blade, since, on the contrary, it would not be possible to transit with machines and vehicles due to the land inclination. Level carriers should have a

slight slope to their base (near the ravine) to facilitate water retention.

3.3 SOIL PREPARATION

The preparation should be done with the ground a little moist to favor the penetration and plough cutting and to allow the spalling of the clods. Too much humidity or excessively dry soil is harmful. Deep plowing facilitates grooving work.

Flat areas with more clayey soils and previous successive crops may have some problem of density. In such cases, a special preparation should be made to mitigate these problems, with deeper plowing, preferably with a plough or using total area subsoiling (ripping) with a higher power machine.

In order to complement the preparation, especially if the planting is done right after the plowing, ground leveling with a harrow should be used, with the purpose of breaking the clods and hitting the ground and may also assist in the control of weeds that remain or appear after the plowing.

A widely used equipment is the subsoiler. It does not make a mixture of soil and fertilizer as well as the implement called mechanical hole digger, but it has the advantage of additionally subsoiling the ground and enlarges the planting hole itself, that changes its shape from **V** to **U**. It should preferably be used with tractors above 65 hp. Another little used implement, is the chain trencher, in which a fertilizer deposit can be coupled. Their income is small, but the work is well done.

In case of planting with planter, the groove preparation must be done with special equipment, rotary type, because the soil must be well loose and pulverized to facilitate the excavator bucket work. This equipment can have an upper tank combining the opening, simultaneous application of the fertilizers and refilling the grooves in a single operation, leaving a small groove to facilitate planting.

For mountainous areas, mixing the fertilizers with loose soil (removed from the hole) is done out of the holes using hoes. This mixture is then pulled with the hoe into the holes and the surface should be curved, slightly higher than the mouth of the hole, for this loose soil will lodge immediately.

The mixing and filling of the grooves or holes should preferably be done one month before the coffee planting, so that the rains in the period are enough to the occurrence of corrective and fertilizer reaction in the soil in order to improve the seedlings initial nutrition that tends to facilitate its survival.

3.4 MARKING AND OPENING OF GROOVES OR HOLES

a) Marking and opening

In areas where the mechanical process is feasible, the spacing between plant lines is marked by a wooden (or bamboo) rod attached to the front of the tractor, with the size corresponding to two distances (eg: 6 m for spacing 3 m), whose middle matches the center of the tractor.

At the both ends of the rod a small rope with a weight is attached. Thus, the tractor driver will match this end within the groove already open, always maintaining a fixed distance when opening another groove, which is parallel to the previous one. The groove should be made with moist soil. The first groove should be open over the basic level, while the others are parallel to it, up and down. The grooves are open through a heavy furrower, coupled to the three points of the tractor, set to deepen about 50 cm. It has two lateral "wings" adjustable to the width of the groove, which should be **V**- shaped, about 20 cm wide at the bottom and 60-80 cm at the surface.

In harder or poorly prepared soils, you have the option to pass the furrower twice, being the first time for marking the place by slightly deepening the groove and, in the second moment, to the desired depth. It is also possible to put a weight on the furrower facilitating its stability and the deepening of the implement in the soil.

Although it is possible to groove with the less potent and narrow gauge coffee tractors, the work is much better and yields better when done with more powerful tractors.

In mountainous areas or in small plantations, the lines are also marked parallel to the basic level, with a bamboo rod or rope with the line spacing, with two operators: the first walking on the previous line and the second marking the next line. The lines or holes are marked with small bamboo stakes.

b) Preparation of grooves or holes

In areas where the mechanical process is unfeasible, the holes are opened individually, with the aid of hoes or drill. In the mechanical preparation, the planting should be done in grooves, opened with the furrower (Figure 1), 50 cm deep and carried out towards the level of the ground. The groove is intended to facilitate or even replace the planting hole operation. The distance between one groove and another must match the line spacing desired by the producer. In these grooves, limestone, phosphate fertilizer, the fertilizer which is a micronutrients source and the organic fertilizers are distributed, when available (Figure 2). With a three-point hitch subsoiler (Figure 3) pulled by a tractor, over the open and fertilized groove, it is performed the subsoiling and widening of the groove area and at the same time the mixing of the fertilizer in the soil and the closing of the groove. The soil an fertilizers mix and furrow closure can also be done with a zone till (Figures 4 and 5).

Another option is the drill (Figures 6 and 7), which is a kind of drill attached to the three points of the tractor and activated by the porwer that makes it turn. Using the tractor hydraulic system, the operator raises and lowers the drill at the same time that the power makes it turn removing the dirt from the hole. Using a "4100 tractor", up to 1,000 pits per day (8 hours) can be made, depending on the soil conditions and the operator's ability. When using the drill, it should be noted if there is any mirroring on the sides of the holes. Mirroring of the holes side also depends on the humidity and soil type or even on how the tractor's hydraulic system and the drill are activated by the operator. To reduce this mirroring, rod pieces of about 10 to 12 cm are welded in the drill, in order to scarify the sides. Even with all these precautions, the producer should inspect the holes and check if the mirroring happened in any of them. If so,

use an spading machine to remove the mirroring. Whether or not the drillis used will depend on tests done at several points in the area and whether it really is more economical to use this hole preparation system.

Figure 1. Furrower with variable depth and width, used in the crops implantation in flat relief soil.

Figure 3. Three-point hitch subsoiler for breaking the compact soil layers and fertilizers mixing.

Figure 2. Fertilizers distribution in the furrow.

Figure 4. Outside of zone till.

Figure 5. Internal detail of zone till.

Figure 6. BDrill - soil drill of 18" diameter used in the opening of furrows.

Figure 7. Detail of the furrow opened by drill.

In areas with manual tillage, the operator opens individual holes with the hoe in the approximate dimensions of 40 x 40 x 40 cm. If you can deepen another 40 cm in the middle of the hole, with the help of a post hole digger getting 20 cm in diameter, the results will be better. For lighter or loose soils, holes should be opened with wider hoes, and for denser spacing between plants, continuous furrows can be opened with the use of a hoe. After opening, the furrows or holes will receive the fertilizers and correctives indicated according to the needs observed in the soil analysis. For this, the fertilizers and the corrective are mixed, when necessary, with the soil removed. It is worth mentioning that the phosphate fertilizer and the corrective fertilizer must be mixed to the soil separately; first the corrective and then the phosphate fertilizer. After mixing, the soil is returned into the furrow or hole.

In the mechanical areas, two equipments are used. The first is called a zone till, an equipment coupled to the three points of the tractor and activated by the power take-off. It consists of a central axis and two side wings. The axis is made in the form of a screw, which, rotating, activated by the power take-off, mixes the soil and the fertilizers that are in the center and at the sides of the open furrow. The two side wings, more open at the front and closed behind, do the filling work of the furrow, grouping or concentrating the soil plus the fertilizer revolved, closing the furrow. The second, more used, consists of the subsoiler itself, working with three rods, at the same time effecting the subsoiling, mixing and filling of the furrow. The subsoiler is coupled to the tractor (three points), to which a subsoiler rod must be adjusted in the center to deepen in the middle of the open furrow, and the two sides must be 30 to 40 cm apart from

each other and each side of the central.

c) Furrowing with hand tools

The opening of the furrows on the soil surface is done manually with the aid of hoes and diggers. It begins by marking the furrows according to what was planned. They should have dimensions of 40 x 40 x 40 cm. The soil surface must be separated from that of the deeper layers and mixed with the fertilizers according to the recommendation obtained through the previously performed soil fertility analysis (FERRÃO et al., 2007). Currently, the use of this form of furrowing for planting is very restricted to some more specific conditions, especially for small producers that lead the crops in a family economy system and for the implantation or renovation of areas with few plants.

d) Semi-mechanical furrowing

It is a system that has been prioritized in smaller properties, replacing that exclusively manual. A small hole is usually opened with the aid of a hoe, marking the location of the furrows where the recommended chemical fertilizers are deposited. For the opening of the holes, motorized, gasoline-powered equipment, coupled with drills or drills equipped with side devices that penetrate the ground, are used to revolve it and prevent lateral mirroring of the holes. Generally, the drills have dimensions of about 35 cm in diameter and 50 cm in depth. In this way, by making two lateral perforations, it is possible to totalize approximately 70 cm wide and 50 cm deep. This form of planting hole preparation reduces the cost of the process when compared to the manual furrowing, in addition to providing better soil homogenization (Figure 8).

e) Mechanical furrowing

The furrower is an equipment with a central base, with a longer length to reach a greater depth, and optionally with two shorter side flaps, normally used when the coffee is cultivated in consortium with papaya facilitating the lateral revolving operation and the terracing.

In order to compare the development of conilon coffee seedlings planted in 40 x 40 x 40 cm holles, manually open with hoes, and in mechanically open furrows, Lani, Benassi and Bravim (2005) observed a productivity increase of up to 20% when plants originated from seed were planted in furrow. For the plants originated from clonal seedlings, the increase in productivity was up to 12% for furrow planting, in relation to planting in holes.

The use of subsoilers for opening furrows

Figure 8. Gasoline solo drill, 63 cylinders, 7500 RPM and 3.5 HP, for hole opening.

has been a suitable option for conilon coffee plantations in places where this practice is possible. Among the advantages of using subsoilers, they can be mentioned: it does not revolve the soil layers; increases its porosity and structure by breaking the more compacted layers of the surface to depths between 60 and 70 cm. There is also the possibility of using subsoilers adapted with distributors of fertilizers, which are already used for fertilizing the lines (Figure 9).

Figure 9. Subsoilers of 1 rod for subsoiling at depths of 80 to 90 cm, with fertilizer applicator in depth.

It has also been done the opening of furrows using the backhoe, mainly in areas with sloping topography. The marking of the planting lines is done in level curves with the aid of devices marking the points with wooden stakes. The marking of the lines is done using limestone fillets to facilitate the visualization of the furrows by the the backhoe operator.

The backhoes with adapted furrower in its mechanical arm are equipment developed for sloping regions aiming the opening of furrows in level. The machine operates by moving in the direction of the terrain slope (going up and down). In general, the furrows have a good depth and width ranging from 60 to 70 cm and from 50 to 60 cm, respectively. Because it is a relatively recent practice, there is still a need for refinement and adaptation. (Figure 10).

Figure 10. Furrows pening in sloping areas using the backhoe. Marking lines using limestone.

4 SOIL CONSERVATION

4.1 IMPORTANCE

Traditional coffee plantations were planted in recently cleared areas and exploited the natural fertility of soils, without the use of rational cultivation practices, among them erosion control.

The forest gave rise to coffee plantations, most of the time planted

down the hill easing the floods, which gradually led to the most fertile layer of soil. The loss caused by erosion, aggravated by the lack of nutrients replacement, through fertilization, accelerated the process of crops depletion, which after 10, 15 years, at most, were abandoned.

The renewal of coffee plantations, promoted after the 1970s, was carried out in low fertility lands, either because they were poorly exploited in the past or because they are naturally poor in nutrients. Thus, current coffee plantations are located on these lands, requiring the producer to invest in correctives and fertilizers, which makes erosion control even more important, since it reduces soil loss and increases the use of these inputs.

In crops grown in steep areas, without the use of conservation practices, soil erosion loss is high. In this sense, Dadalto, Lani and Prezotti (1995) observed an average loss of 40 t ha^{-1} $year^{-1}$ in an arabica coffee crop cultivated in a Distrophic Red Yellow Latosol, with a slope of 45%. In conilon coffee trees also conducted on Red-Yellow Latosol, in the northern region, with 18% slope, the average loss was 10 t ha^{-1} $year^{-1}$.

Erosion in the State is even more serious, since the soils, for the most part, are dystrophic, basically having the superficial layer as a source of nutrients for the plants.

These facts explain, to a large extent, the low productivities obtained in some properties. In addition, erosion has a number of indirect negative consequences, such as pollution of watercourses, silting and destruction of roads.

In order to reduce the erosion process and improve soil properties, conservation practices should be used based on two basic principles: increasing vegetation cover and ground roughness (obstacles against floods).

Conservation practices that meet these principles and have economic viability should be used in coffee plantations, highlighting the correct location of the plantations, those in contour lines and densities, the management of native vegetation and the carriers planning.

4.2 PLANTING LOCATION

Coffee plantations should be located according to the land use capacity and should be formed and exploited only on lands suitable for cultivation. They should preferably be implanted in soils with good physical properties, such as high effective depth, well drained and with high retention and availability of water. It is recommended the planting preferably in areas with slopes of up to 30% and 45% for soils with low and high tolerance to erosion, respectively (DADALTO; LANI; PREZOTTI, 1995). Most of the Red-Yellow Latosols that concentrate in the central and southern regions of the State can be considered to be tolerant to erosion, due to their good aggregate stability and good permeability. On the other hand, the soils of the central-west and northwest regions usually have low erosion tolerance because they have low aggregation and/or low permeability, especially in the subsurface horizon ("B" horizon). In all situations described, erosion control practices should be used, which will be reported below.

4.3 CONTOUR PLOWING

It consists of arranging the coffee rows and performing all cultivation operations across the land slope. It is recommended that the plants between the rows be offset so that they constitute an obstacle to the flood free run, reducing the speed and soil dragging capacity. According to Bertoni and Lombardi Neto (1985), contour plowing reduces soil loss by up to 50% and water loss by up to 30% when compared to "down hill" plowing.

Contour plowing, if not associated with other conservation practices, is not sufficient to reduce erosion to tolerable levels, especially in rugged terrain, in areas where heavy rains occur or on highly erodible soils.

The practice of terracing, used to fight the erosion caused by rainwater drainage and to facilitate the entry of machinery into coffee plantations, may be an alternative to enable coffee cultivation in mountain areas (SILVA, 2015). Very used in regions of greater slope, the terracing consists of the construction of terraces, in the shape of stairs, and presents a structure composed of a dam, that can be used also in the regions of greater slope of the State of Espírito Santo, as much for arabica coffee as for conilon coffee (Figure 11).

4.4 DENSE PLANTING

The increase in the number of plants per area, especially in the planting line, reduces soil, water and nutrient losses by erosion, as well as improving soil characteristics due to the increase in vegetative cover, the formation of more efficient barriers against the flood and production of organic matter.

Figure 11. Terraces to facilitate soil management and conservation.

Photo: Peabirus.

The dense planting in rugged relief is efficient in the erosion control, especially after the coffee tree formation period (DADALTO; LANI; PREZOTTI, 1995). These authors observed an average soil loss of 40 t ha^{-1} $year^{-1}$ in the first three years of arabica coffee cultivation. However, after this period, there was no further soil loss, due to the increase in its coverage and to the coffee line itself, which began to work as a torn.

Prochnow et al. (2005) report that the coffee crop was efficient in controlling soil losses, decreasing them by 78% in the first five years and 99% in the fifth year onwards, regardless of the spacings studied, and that the reduction of spacing between lines and coffee rows was important for the control of water erosion. The spacing of 3.0 x 1.0 m was the most efficient in the reduction of water erosion in the coffee crop, although the annual losses of land and water for the coffee tree were 4 t ha^{-1} and 18 mm respectively, and for the first five years, the average

value of the ground loss ratio in the coffee tree was 269.6 kg ha^{-1} and 1.7 kg ha^{-1} for the fifth year onwards.

Guarçoni M. (2011) evaluated the fertilization in conilon coffee efficiency and found that, in areas where the crops were dense, there was an increase in the nutrient concentration in the soil and in the subsoil.

4.5 CARRIER PLANNING

Carriers have the main purpose of facilitating access to crops to carry out the various activities, from planting to harvesting. However, when well constructed, they can be a conservationist practice. The these carriers maintenance through methods that dissipate the stormwater runoff, such as the use of vegetation along the slopes edges, are important factors.

In addition to well-planned carriers, rainwater collection boxes called dry boxes, which are also called "dry holes", or simply "holes" (PELISSARI; PERINI; MIRANDA, 1997), should be constructed. For its construction, holes are manually dug or with the help of a backhoe, along the road, to accumulate the rainwater that runs in that area. The holes are made on the side of the road, inside the pasture or between the coffee lines distanced from each other in about 30 to 50 m. They must be calculated in such a way that they will slow down the water and store it in the ground.

The dry boxes shall be measured in relation to the width of the road and the slope of the area. The more inclined the area, the closer the holes should be to each other. After the first rains have occurred and the holes have been made, all the soil accumulated inside them must be removed, being reviewed once a year. They can be made to the desired length, without a defined shape, provided they offer safety to hold all the water. For example, on a road 4 m wide and about 18 to 20% slope, always observing the rate of water infiltration into the soil of the area, dry boxes should be constructed every 30 m distance, which can store from 10 to 12 m^3 of water, including the entire edge (Figure 12).

Figure 12. Dry box constructed in the internal area of the crop to reduce the superficial flow and capture rainwater.

Other ways to reduce soil and nutrient losses in conilon coffee plantations are:

a)mantaining the native vegetation (capoeira, forest) in the headwaters;

b)using suitable spacings according to the clones that compose the cultivar;

c)to keep in the middle of the streets, between the rows of plants, all the stems and shoots taken after the crop implantation, at the

time of pruning.

4.6 NATIVE VEGETATION MANAGEMENT

Proper management of native plants in coffee plantations is aimed at minimizing the erosion process, improving soil characteristics, especially physical-water, and increasing productivity. This technique sucsess depends on the knowledge of the native herbs in terms of competition, seeking to eliminate the most harmful ones to the coffee tree.

The most recommended management system is the use of retention stripes with native herbaceous vegetation between rows the coffee tree rows. Dadalto, Lani and Prezotti (1995) report that, in a management system where predominance of molasses grass (*Melinis minutiflora*), soil losses were reduced by 95%, and coffee yield increased by 20% in rugged terrains.

The vegetation strips, perpendicular to the slope of the terrain, may consist of grasses or legumes that are economically viable, providing the producer with extra income and soil conservation. Other types that can be used are the natural vegetation that grow spontaneously on the ground. The strips should be arranged on contour lines and located on the lines without the cultivations. These strips are effective in reducing soil and water loss, and the more the number of strips increases, the benefits are potentiated (LANI et al., 1996).

In an experiment carried out in the Espírito Santo highlands, there was a reduction in soil loss as the number of molasses grass strips increased (ROCHA; PREZOTTI; DADALTO, 2000). According to the authors, this practice, besides contributing to the reduction of the erosive process, also favored the maintenance of soil humidity for longer periods, in such a way that it did not compromise the yield of arabica coffee production in the weed system every two and three streets (Figure 13).

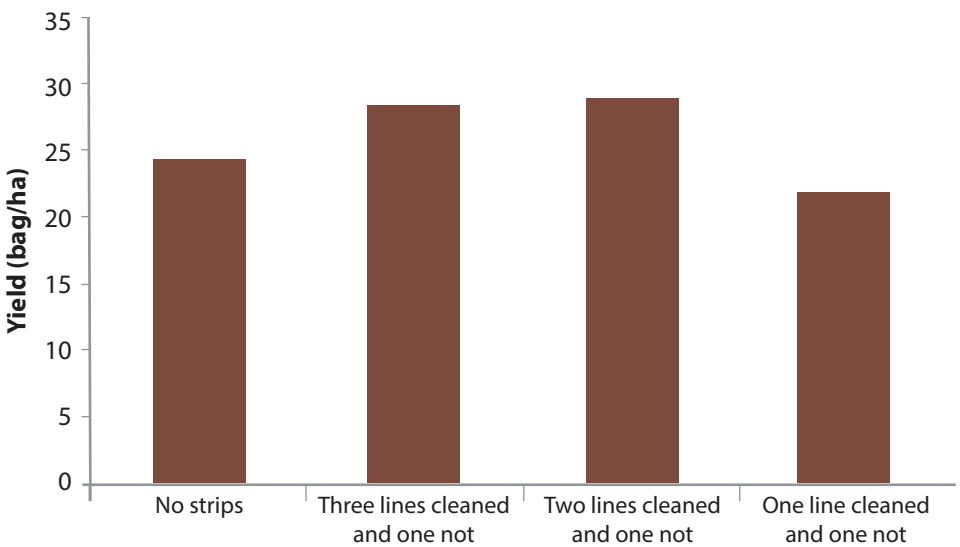

Figure 13. Yield in bag./ha of arabica coffee, in a conservation system with weeding in the planting line up to 0.5 m wide from the projection of the crown.

Source: Rocha, Prezotti and Dadalto (2000).

Lani et al. (1996) evaluated the losses of soil, water and chemical composition of the sediments collected in Red-Yellow Latosol soil in an experiment with four treatments, being them: I - all grass weeding (without strips); II - one strip every three streets of coffee trees (1: 3); III - one strip every two streets of coffee trees (1: 2); IV - one strip to each street of coffee trees (1: 1). Soil and water losses were collected after rainfall of 70.8 mm and 49.6 mm, with a duration of 1.5 and 2.0 hours, happened on days 15 and 16/03/1995, respectively. The authors concluded that, when comparing the treatment without strips to the others, the reduction in soil loss for treatment (III) was 30%; treatment (II) of 45%; and treatment (IV) of 77%. In relation to the water factor, this reduction was 8% for the treatment (III); 20% for treatment (II); and 55% for treatment (IV). It was also suggested that natural vegetation, despite competition with the coffee tree during the period of crop formation, and especially in nutrient-poor and water *deficit areas*, could be an ally (if well managed) of the losses of soil, water and nutrients, as well as reducing costs with weeding and fertilizers replacement (Figure 14).

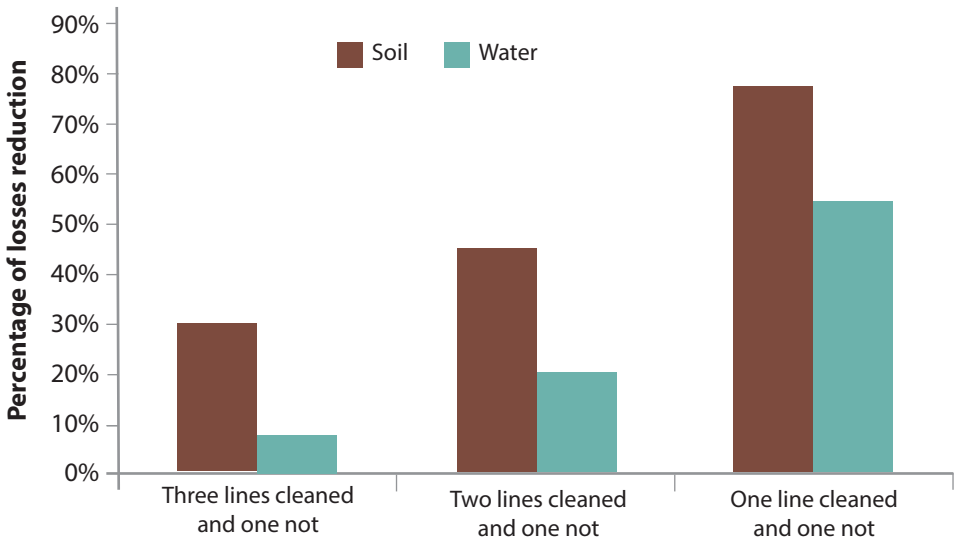

Figure 14. Soil and water losses reduction due to vegetation strips after rainfall of 70.8 mm and 49.6 mm, lasting 1.5 and 2.0 hours, on 15 and 16 March 1995, respectively.

Source: Adapted from Lani et al. (1996).

The vegetation strips may consist of grasses or legumes that present economic viability, providing the producer with extra income. Other types of vegetation that can be used are the natural vegetation that grow spontaneously on the ground. The strips should be arranged in contour lines and located between the lines of coffee plants.

The management of the vegetation should be done through weeds, from the coffee line up to about 50 cm wide from the projection of the crown, mainly during the crop formation phase. Further, the removal of crops residues should be carried out whenever necessary, so that there is no flowering or exaggerated growth of spontaneous native vegetation. The maximum moist stripe spacing, according to Dadalto, Lani and Prezotti (1995), depends on slope and soil type (Table 1).

Table 1. Maximum spacing between strips due to slope and soil tolerance to erosion, during the crop formation and production phase

Soil Type	Declivity %	Maximum spacing between strips (m)	
		Formation[1]	Production
High tolerance to erosion[2]	0 - 30	9	18
	30 - 45	6	12
	> 45	3	6
Low tolerance to erosion[3]	0 - 30	6	12
	> 30	3	6

Source: Dadalto, Lani and Prezotti (1995).

[1] Formation phase - up to the third year.

[2] Soils with high tolerance to erosion - soils with physical characteristics that disfavor the erosion, with high depth, clay texture, good infiltration of water and good stability of aggregates. Examples of this type of soil are the Red-Yellow Latosols of the inlands high lands, which correspond to about 35% of the State.

[3] Soils with low erosion tolerance - have physical characteristics that favor erosion, such as low water infiltration, especially in the subsurface horizon ("B" horizon), and/or low aggregate stability. The soils of the high dry climate region can be cited as examples.

Another form of conservationist management of native plants is through the use of post-emergent herbicides, which provide the formation of *mulching* cover, which minimizes the erosion effects, maintains soil humidity for a longer period and increases the content of organic matter in the soil.

In order to evaluate the width of the brachiaria grass stripes in the arabica coffee lines, Souza et al. (2006) observed that the minimum width of the control strip to be used was equal to or greater than 100 cm on each side of the line (weed area), in order to keep coffee plants free from brachiaria grass interference. The brachiaria roots penetrate deeper into the soil than those of other plants. Once the brachiaria has been established in the area, desiccation with the use of herbicide is done, and the roots die in the soil profile, which facilitates the deepening of the coffee tree root system at greater depths, also allowing better water infiltration, which reduces erosion and perpetuates streams and rivers.

4.7 DIRECT PLANTING

The presence of residues on the soil reduces the impact of the rain drops and, as a result, reduces the water erosion process, maintains soil physical properties and improves water infiltration rates (PANACHUKI et al., 2011).

5 MEASURES OF EROSION CONTROL MEASURES

The measures of erosion control in coffee plantations can be adopted in two situations: a) in the planning and installation of the crop; and b) during the conduction of the coffee plantation.

In planning, it is necessary to consider the soil conservation of the coffee plantation more widely, within the micro-basin in the property, inserting the crop in an integrated project of use and conservation of the soil, not forgetting the water conservation and the possibility of contamination of headwaters.

In the implantation of the crop, it is important to choose the area and the planting system, the marking and the proper alignment. Areas that are very steep, with a slope of over 45%, should be avoided, as well as facilitating erosion, hamper all harvesting and treatment. Even so, preference should be given in these areas to the denser system, which closes the ground faster.

During the conduction of the coffee crop, the annual plan of practices in each crop should consider the protection of the soil in all the treatments.

The practices indicated for erosion control are of two types: vegetative and mechanical, which must be used in combination, for greater efficiency and economy.

5.1 VEGETATIVE PRACTICES

They are the simplest and cheapest, of which the following can be used:

a) Weed management with brushing, reduction and alternation of weeds - some weeds are replaced by brushing during the rainy season, which thus keeps the bush low, covering and protecting the soil, without much competition with the coffee. If necessary, weeding is done only on the line (mechanical or chemical path), keeping the road clear. Another option is to use weed every other street, alternating the season, always keeping one street covered and working as a protection (bush barrier) for the clean one. As required, you can weed 50% of the streets or more, thus getting a dirty or scouring every two or four clean streets.

Elimionating the operatyions of soiol movement improves physical quality (FIDALSKI et al., 2009) and greater stability of aggregates, keeping the soil more structured and thus enhancing its water retention capacity (PANACHUKI et al., 2011). In addition, the removal of the plants that appear between the lines of coffee (native) leads to a formation of straw on the surface. According to Panachuki et al. (2011), the presence of residues on the soil reduces the impact of the rain drops and, as a result, reduces the water erosion process, maintains soil physical properties and improves water infiltration rates.

b) Post-emergence herbicides - used on the bush, in addition to avoiding soil revolving, promote the formation of a layer (blanket or cover) of dead bush, which acts to control erosion by reducing the impact of raindrops directly on the soil, by the barrier formed against the stormwater ronoff and by the improvement in the infiltration of water through the canaliculi left by the root rotting of the herbs.

c) Permanent vegetation lines - are indicated for mountainous areas, mainly in the phase of formation of the coffee, as auxiliaries or substitutes of the cords or ditches, whose opening and maintenance are expensive. The lines are planted in level, every four or six streets of coffee

(according to the slope), with nearby plants forming loines or living barriers. Lemon balm, sugar cane and banana can be used. The latter has its trunks, when cut the bunches, enclose against the slope, in the upper part of the clumps, increasing its effect. Lemon balm and cane must be cut in the dry season, thus reducing competition with coffee during that period, also enabling the utilization of by-products of these plants. At the beginning of the rains, again resprout. The lines can be conducted singly or in combination, staying just above the cords or ditches, adding effects and, mainly, holding the ground that would accelerate the clogging of the furrows.

d) Carrier vegetation - the maintenance of weeds in the carriers, duly scoured, aleways when ecessary, reduces the carrying of loose soil and water, reducing erosion and releaving the periodic maintenance work of these roads in the crop.

(e) Retention strips and bush management - the occurrence of intense and short-term rainfall (torrential rainfall) contributes to soil loss through stormwater runoffs, especially on rough terrain, culminating in soil erosion and degradation (SANTOS; GRIEBELER; OLIVEIRA, 2010), and thus favoring the reduction of the productive capacity of the soil and its fertility (ROCHA; PREZOTTI; DADALTO, 2000). According to Santos, Griebeler and Oliveira (2010), the soil particles drag by the water erosion causes surface runoff, reducing the infiltration capacity and redistribution of water in the soil profile. The adoption of conservation practices on steep terrain, such as retention strips, allows minimizing the impacts caused by torrential rains, which are intensified in uncovered soils.

The vegetation strips in the direction perpendicular to the land slope can be constituted of grasses or legumes that present economic viability, providing soil conservation, besides extra income to the producer. Other types of vegetation that can be used are the natural vegetation that grow spontaneously on the ground. The strips should be arranged on contour lines and located on the lines without the cultivations. These strips are effective in reducing soil and water loss, and the more the number of strips increases, the benefits are potentiated (LANI et al., 1996).

a) Cultures association - the planting of annual crops promotes the cover of the soil, functioning as a bush. The cultures that best occupy the area, such as beans and peanuts, are ideal in this regard, and preference should be given, especially in mountainous areas, to their direct planting after post-emergence herbicides, avoiding preparatory harrowing to planting, which predispose to erosion. Perennial or semi-perennial crops, associated with coffee, such as fruit trees, rubber trees or grevilleas, also reduce the rainfall impact, which, together with falling leaves, helps to protect the soil. The cultivation of brachiaria in the middle of the coffee plantation, a practice recommended by some technicians, might improve soil protection against erosion.

5.2 MECHANICAL PRACTICES

With this type of practice, the objective is to create some form of mechanical barrier in the crop to hold the water and soil from the stormwater runoff, which, in general, requires greater investments in its installation and maintenance.

The main mechanical practices used in coffee plantations are:

a) Contour farming: differently from what happened in the past, besides arranging the plants in order to form barriers against the stormwater runoffs, is the basis for the application of other erosion control practices, whether vegetative or mechanical, which are also carried out in levels diverting the waters direction. In fact, the coffee lines are not, each one, exactly in level, since parallel are drawn to a basic level, but always perpendicular to the slope. In circular plantations, made to facilitate irrigation, or in those aligned according to the insolation, not obeying the level, flatter areas and complementary protective measures should be used in the early years (wide base terraces and vegetation cover).

b) Coffee plantation marking: Proper distribution of plots, level carriers, slopes, cords, drainage channels and retention boxes is basic for erosion control. The level carriers should stay every 40-70 m and have slight slope (5%) inward to better retain the water. In areas with a slope greater than 30% or where the soil has a lower infiltration capacity, these carriers must be traced with a slope of approximately 2%, diverting excess water to the drainage channels. The slopes should be slightly offset to avoid the continuous course of stormwater runoff formed therein.

In the case of coffee plantations, due to the natural difficulty of transiting within the crop and the need to move more inputs and crop by area, the carriers should be closer and, between one slope and another, one or two narrow ways to facilitate the entry or exit of crop products.

c) Living fences and ditches: these are terraces with a narrow base, level or with a slight drop every 10 or 15 m, variable distance with slope, having a total width (channel + chameleon) of 1 to 3 m. In areas with a slope greater than 30%, it is common to replace the channels with ditches, narrower (approximately 30 cm) and deeper (40-50 cm), septate, open with hoe. In these areas, the living fences should be leveled at 1% to 2%, pouring the excess water to drainage channels or to areas adjacent to the coffee plantation such as pastures or forests where this water is properly retained. In areas where the mechanical process is feasible, the living fences are no longer used due to the fact that they hinder the passage and the use of tractors.

d) Drainage channels: complement the action of carriers and uneven living fences. Those should be protected by vegetation barriers, such as banana tree, napier grass and so on. Deep glens or terrain depressions can be used to drain the excess water.

e) Retention boxes: they also complement the action of living fences and can be used to receive the excess water from the latter and also collect the water that would drain through the pending carriers, a very useful measure in the mountainous areas and that facilitates the conservation of the roads (carriers) within the crop. The boxes are usually built with backhoe loaders, approximately 2 x 2 x 2 m, in a suitable number, calculated to meet the excess water produced in the area and with no other destination (drains in a neighboring pasture or forest area). The number and size of the boxes varies according to declivity, rainfall, soil type and crop layout, which should be located at critical points near the intersection of carriers. Where necessary, after the rainy season, the boxes should be cleaned and unclogged with the soil removal. It is advisable to leave one of the box walls less inclinated, because some animals, wild or domestic, that might fall inside the boxes, will be able to get out there naturally.

f) Level furrowing: it is a temporary practice, carried out in the first two years of the crop to assist when the area is still very open (with new coffee and not much bush), that consists of the passage of furrowers or, in the slope areas, of mouldboard plough (drawn by working animals such as oxen and donkeys)opening furrows in the middle of the streets, in all of them or every two or three streets, as needed, to improve the retention of the runoffs. When they have water flowing all the way down, in the stretches that are not level, problems can be avoided by obstructing the furrow at some points. In mountainous areas, the furrows retain not only the water/soil complex, but also fertilizers and the debris produced in the crop (dry buches, foliage), improving water infiltration and nutrient utilization. In such cases, especially when in already hard and degraded soils, the furrows, made with donkey plow, should be opened closer and at the top of the line of young coffee trees, being displaced as the diameter of the coffee tree increases.

g) Subsoiling/scarification: can be used mainly in areas of compacted soil (on the surface or subsurface) to improve water infiltration and thus reduce erosion. It is indicated for this purpose, also before planting, in the fields in formation and in the pendant carriers to reduce stormwater runoffs. It is also a useful practice in circular plantings, especially in the first two years of the crop to improve the infiltration of the water from the irrigation itself. In this case, a subsoiler marks two risks bordering the coffee trees line, which quickly infiltrate the water and the fertilizers, applied through this equipment, avoiding drainage and losses.

5.3 COMBINATION OF ESSENTIAL PROCESSES AND PRACTICES

In the conilon coffee plantation, it is possible to adopt several alternatives of soil management and conservation, but for each case, it is necessary to select and apply the most appropriate, more economical and of better efficiency, being common, therefore, to associate several of them in the same area, varying according to the stage and the system of cultivation in the coffee plantation.

Some of these practices, however, are essential, as is the case of contour farming and the use of row in the line, which already gives base and favors the other practices.

The priority of using certain practices, is also closely related to the type of topography and consequent management, with and without mechanization.

For mountain areas or areas where the mechanical process is unfeasible, dense planting technique, the use of brushing and/or post-emergence herbicides are priorities and, in the first years, vegetation rows, furrows and ditches, as well as auxiliary intercropping. It is also necessary to vegetate the carriers and make retention boxes for better conservation of the roads.

For areas where the mechanical process is feasible, the priorities are the planting in a row, the carriers in level, the the bush removal during the rainy period, complemented by post-emergence herbicides. In the early years, assist with furrows in the middle of the streets.

6 EQUIPMENT USED

Specific equipment is used to control erosion in coffee plantations only for mechanical practices, which involve the formation of barriers, canals and other impediments, to reduce stormwater runoff.

Thus, they are employed in mechanical practices:

(a) The mechanically driven tractor furrower or small animal plow to validate the crop, forming small furrows in level, very useful in the first two years of the coffee crop, when the soil, still loose and with little coverage (of bush and coffee plants), is more subject to erosion.

b) Bulldozer or a tractor with a dozer blade (front or rear) to open level carriers, with inward drop, to aid in the retention of rainwater.

c) Plowing with oxen to open living fances. In mountainous areas, the living fances are replaced by narrow, deep, septate, ditches manually opened with hoes. In flatter areas and in circular plantations, under pivots, terraces of wider base, also open with plows, are used.

d) The backhoe or hoes (in smaller areas) are used in the opening of retention boxes, used to absorb excess water from living fences, carriers or pendants.

e) The subsoiler is indicated to improve the water infiltration in the soil and, thus, to retain the water of the runoffs. It is used in coffee plantations, in areas where soils have compacted layers.

7 SUBSOLING

Subsoiling is an eventual operation in coffee plantations, carried out only when necessary, consisting of the use of equipment (subsoiler or scarifier) to eliminate problems of thick layers of soil, which make it difficult to penetrate water, reduce soil aeration and development of the coffee plants root system.

7.1 SOIL DENSIFICATION

The soil densification can occur in two ways:

a) On the surface, or closely adjacent, dense layers may occur, resulting in the continued passage of tractors and agricultural implements.

b) In the subsurface, with layers usually 40-60 cm deep and formed according to the soil nature, by infiltration and gradual deposition of clay along the profile. Improper soil handling with harrows or other implements that pulverize it tends to give rise to the same problem. Densification is favored in areas with flat relief (plated) and in soils with higher clay or silt content, especially when poorly structured.

7.2 DENSIFICATION EVALUATION

The evaluation of the presence of very hardened (dense) layers of soil with high density can

be done in several ways:

a) In trenches, holes are opened in the area, with depth to where it is desired to evaluate. Normally, they are opened in the projection under the coffee tree or where the wheels of the tractor pass. There, with the aid of a knife, it is verified, from the top to the bottom, in the soil profile, if there are more compacted and hardened areas, where the knife does not penetrate well. Also, it should be observed, in the trench, how the penetration and the presence of roots (coffee and bush) are in the various layers of the profile.

b) Opening holes with the auger in the desired zone of the terrain, it is possible to evaluate the presence of hardened layers, due to the difficulty of penetrating the equipment, as well as to analyze the consistency of the soil removed from the auger in that part of the ground. It is also possible to observe the presence of roots in the various depths.

c) By determination of soil density or specific mass in the laboratory.

d) By observing the root system of the coffee tree, its shape, in the trenches or during the planting of old coffee trees, in the area under analysis, in case of problems, the thick roots developed only laterally that form a chicken foot. Thus, the plant stump can remain vertical even after being plucked.

e) With the penetrometer - it is a device with a rod that penetrates the ground whenever pushed by the weight in it. The rod is graduated and allows to evaluate the soil hardness, in the several layers, through the number of beats (of the weight) necessary for the rod to penetrate determined distance. Thus, with the aid of a graph, constructed according to the collected data, the presence of density is verified. After subsoiling, the entire extent of the layer, from the surface up to about 50 to 60 cm, became less hard and more favorable to the coffee root system.

f) Profile layers - soils with increasing clay content reaching high density levels before 1 m can not be classified as problems of a particular layer and therefore do not result in major improvements through subsoiling. So they should not be used for coffee.

7.3 DENSIFICATION AND SUBSOILING

Subsoiling should be carried out to improve the soil physical conditions by bursting the dense layers in order to facilitate the development of coffee roots and to normalize water penetration and aeration in problematic layers.

In the presence of dense layers, the main roots grow laterally, like a chicken's foot. Some roots that can overcome the layer, when thinner, develop themselves downer again. In the areas without the presence of dense layers, the root system deepens normally, with the regular distribution of roots in the profile.

The presence of these dense layers decreases the useful depth of the soil, and coffee trees suffer, in the rainy season, from excess water, which does not flow through the problematic layer, as in drought, because they have a restricted and superficial root system. With excess water, the roots of the coffee trees rot. Whenever problems of densification occur and the subsoiling reduces them, there is improvement of productivity in the crop.

Another situation in which subsoiling or scarification has been useful is in improving water infiltration, either in sloping carriers or in the field, avoiding erosion and also improving the infiltration of water from the irrigation itself.

7.4 METHODOLOGY FOR SUBSOILING

The subsoiling is made with an equipment coupled in the three points of the tractor, being composed of a superior structure of steel bars, where they are fastened of one to three "forks" or subsoiler stems, that penetrate the ground. The equipment may or may not have wheels for depth adjustment. It usually works deepening up to 50-70 cm. The equipment with three "forks" are used in the subsoiling (and closing) of the furrow when preparing for planting. In adult crops, when necessary, due to problems of superficial densification, the subsoiler is used with a rod on each side, making the marks in the prejection of the downer side of the coffe tree. When the distance between the lines of coffee is greater, only one rod is used passing from one side of the line at a time.

The furrowing equipment may eventually work on the subsoiling, for which it is necessary to remove the two lateral "wings".

In coffee plantations where the density is more superficial, caused by the successive passage of the tractors with machinery, the regulated subsoiler can be used to deepen less (20-30 cm), to break the crust of the ground or, then, to use a scarifier.

For adult coffee plantations, with less space for the passage of machinery, narrow coffee tractors are used. Thus, suitable, lighter subsoilers must be operated.

In coffee cultivation, the most appropriate is the subsoiling in the projection under the coffe tree and one side of the line at a time, as the root breaking on both sides at once may harm the plant, especially if it takes a while to rain.

There are no research papers that show the best frequency of subsoiling practice, but in practice it should not be done annually as some producers do. It is possible to perform the operation on one side in one year, on the other side the following year, and then, as necessary, repeat it every two to four years.

The ideal time for subsoiling is after the harvest period and the closest to the rainy season (September-October). For the service to be well done, that is, for the "fork" to break the soil in blocks, it must be dry or slightly moist. With a really moist soil, the "fork" makes a smooth rip on the ground, without breaking it properly.

Whenever there is a need to apply inputs that go down in depth in the soil, such as limestone, calcium (Ca), magnesium (Mg) and phosphorus (P) and subsoiling is used, it is recommended to apply these inputs soon after subsoiling, so that part of them can deepen the soil better through the opening made by the subsoiler.

When used as an aid in water infiltration and erosion control, subsoiling should be done with a "fork" in the middle of the fields, alternately or not, depending on the severity of the problem. It can also be made on the carriers, especially on the slopes and along the lines of young coffee trees.

8 PREVENTION OF DENSIFICATION PROBLEMS

Most of the soils called Coastal Tablelands (formed from the Barreiras Group) predominantly Acrisol, which are naturally poor in nutrients, are flat and poorly permeable and have densification that hamper the penetration of roots and water. These soils are not suitable to receive intensive mechanization and are more appropriate for perennial crops (LANI et al., 2008). Thus, it is advisable to maintain the vegetation cover minimizing soil degradation problems (SALES, 2012).

There are some auxiliary measures, preventive, in the crop planting or in its management that avoid or reduce, in the subject areas, the problems with soil densification, in the coffee plantations, and the main ones are the following:

a) Choice of area - one should choose, for coffee planting, areas without problems of densification avoiding, in these areas, plateaus, excessively flat. Sloping lands, with more than 5% declivity, favor the percolation and lateral runoff of excess water. Also avoid areas of very clayey and poorly structured soil.

b) Deep plowing - a deeper plowing in the preparation, before planting, can reduce densification problems.

c) Subsoiling in the furrow - subsoiling, with three stems, on the open planting furow, reduces the problem enough, since the primary root system ("top") can already go down in the opening left. In case of manual preparation, make large and deep holes.

d) Little soil inversion - adopting this procedure during the treatments, using as little as possible the disintegrating implements, such as grid, rotary, etc.

e) Reduction of the use of mechanical implements - avoiding many tractor passes along the year. A good option for this is the use of herbicides and also the application of pesticides via soil. Avoid some treatment, such as mechanical weeding, with moist soil.

f) Use of organic material whenever possible to improve soil physical conditions.

g) Crop densification - the coffee trees together have a better root/aerial part balance (=production), and in this system the losses due to hardened layers are less sensed. In addition, further formation of organic waste occurs and the passage of machinery is not necessary.

h) Weed management - should be done with post-emergent herbicides to form canaliculi along the soil profile after the death of the herbs roots.

9 LIVING CLIMATE ADVERSITIES

The potentiation of the use of adapted and drought-tolerant species, rainwater collection and the management of the vegetation cover are technologies that counteract the idea of fighting drought, showing that droughts are periodic natural phenomena that should not be fought, but with which it is possible to live (BARROS, 2014). Living with adverse weather conditions is a challenge to implement practices suitable to the agricultural environments.

a) Planting of drought tolerant cultivars

Cultivating food using less water and land, keeping creole/local seeds that prioritize resistance to periods of water *deficit* and maintain biodiversity, has been a challenge for thousands of farming families living in regions where climate change is becoming increasingly perceptible. The social technologies to save and rescue seeds, water and food for families and domestic animals have been disseminated as preventive measures by the Semiarid Articulation programs and other organizations that operate in the region where periodic droughts occur (KOBIAMA et al., 2006; AGROBIODIVERSIDADE, 2015).

Resende (1998) refers to irrigation as a practice of reducing the drought problem and exemplifies the practices of coexistence with the use of biological methods, such as the use of species and varieties that are more resistant to drought. The author points out that the small farmer tends to use these coexistence practices more often.

In the case of conilon coffee cultivars, there is probably no single characteristic that confers drought tolerance. The combination of factors, such as soil water extraction efficiency, deep root system and leaf area may favor the selection of genetic material more adapted to the water *deficit* (FERRÃO et al., 2007; RONCHI; DAMATTA, 2007).

10 CROP MANAGEMENT

10.1 WEED CONTROL

The management of coffee plantations can be defined as the way of combining and executing culture practices in coffee crops. It involves the way and the time to do, that is, how, when and where carrying out the treatments or culture practices.

The management comprises ten culture practices, divided into two types: the routine ones, usually made by all producers, and the occasional ones carried out at different levels and times, among the producers.

The routine practices used in the management of coffee plantations are: weed control and harvestin/preparation. The practices considered occasional are: fertilization/liming, pest/disease control, erosion control, irrigation, subsoiling and crop combination. Many of these "occasional" practices, that is, in quotation marks, are currently mandatory practices, such as fertilization, essential in poor soils.

A group of practices is considered a priority because of its greater influence on productivity and production costs, as well as on the quality of the product. This group highlights fertilization/liming, pest/disease control, irrigation, pruning and harvesting/preparation.

10.2 WEED AND THEIR CONTROL

The weed is grown in the middle of coffee plantations, taking advantage of the free areas available in the coffee crops, especially in the young ones, in pruning and in the open fields.

However, the population of weed is reduced as the closure or densification of crops occurs.

The weed is formed by herbaceous plants, called herbs or weeds, or plants invading the economic culture, which, in this case, is the coffee plantation.

The weed represents, on the one hand, competition in water, light and nutrients with coffee trees. On the other hand, it brings benefits in soil protection and nutrient recycling. Thus, the weed must be managed and controlled to reduce the damages caused by taking advantage, however, of the benefits that the herbs offer to the soil and to the environment. Therefore, within the current concept, the term weed control should be understood as the management of invasive plants.

The habit of fast growing weed and the aggressiveness of their root system disadvantage the coffee in competition with the weed.

10.3 BENEFITS OF INVASIVE PLANTS (WEED)

The weed brings benefits by improving the physical, chemical and biological conditions of the soil.

The herbs take the advantage and recycle nutrient waste, reverted to the soil by the decomposition of the formed organic material, which facilitates the use of nutrients by the coffee trees.

The deep, well-distributed root system of some herbs can absorb nutrients from deeper layers of soil by making them in available on the surface.

The weeds cover the soil, increasing protection against erosion and excess temperature. There is greater infiltration of water in the soil by the canaliculi left by the herbs rotten roots (with a greater capillarity of the soil happening).

Weeds can be used as windbreaks, especially in the post-planting and in the young coffee crop, through the weed maintenance in a central strip of the crop street. The herbs roots exude organic acids of low molecular weight (citric, oxalic, malic, butyric, acetic), acids responsible for the availability of nutrients in more accessible forms (to themselves and coffee trees), especially for P and zinc (Zn).

In the dense coffee plantations, from the third and fourth years, the weeds are very small, the same happens in wooded crops.

10.4 CONTROL TIMES

When using the conventional planting system with plowing and harrowing and the weed control is done by the mechanical method, the weeds provoke the movement of the most superficial layer of the soil in periods normally of greater rainfall, favoring the erosive process. Therefore, it is recommended to reduce the use of weeds, which should be done only in the strps near the plant line, with management of the central strip between the lines, especially when using larger spacings, or that weeds are controlled by the use of herbicides.

The control should be done to eliminate the weed at a time when the most invasive ones

compete with the coffee tree, which matches with the development and the seed hardening of the fruits. In Espírito Santo, this occurs in the period between November and April, mainly from December to February. From April on, with the scarcity of rains and temperature decrease, the weed is reduced. The maintenance of the clean area during this period is essential to facilitate harvesting.

11 RECOVERING COFFE PLANTATION IS A NEED

Coffee plantations in Brazil have improved a lot in the last three decades, after the renovation promoted in the coffee plantations, with the incorporation of new technologies, with more productive varieties, new planting systems and more appropriate treatments, with greater professionalism of coffee growers. However, problems persist in graet part of the areas, caused by the plants aging, by the closure of crops and by mistreatments, aggravated by pest and disease problems and by climate abnormalities leading to plant and soil wear (MATIELLO, 2015).

In this way, the coffee grower, whenever possible, advised by an experienced technician, must annually carry out an analysis of his crops to verify the need for recovery of the problematic plots in order to achieve a more productive set in his coffee plantations. One must keep in mind that those bad, unproductive crops will jeopardize the profit of the others.

The analysis of the plots, in order to verify their condition and the necessity or not of recovery, is examined by three groups of factors to recover - the soil, the plants and the environment.

On the soil - the assessment should be based on the chemical analysis and, eventually, on the physical impediments check. The results obtained will indicate the use of suitable correctives to form the base for the development of the coffee trees and for a better functioning of the nutrition afterwards. In this aspect, the most common has been the supply of limestone or other corrective material of good reactivity for the short term required, also promoting the balance in the bases Ca, Mg and potassium (K). In some cases, the subsoiling may also be required.

In plants - the history of the area's productivity is very important, also considering the variety, the coffee trees age, the spacing/alignment, the faults and the appropriate location. The pest/disease aspects of the root system and the vegetative structure of the plants, the presence of excess rods, the absence of lateral branches and the malformation or narrowing of the crown should also be analyzed. In the plants recovery, corrective pruning, control of sanitary problems in the roots and, eventually, replanting/repopulation are indicated.

In the environment - the water balance must be analyzed to verify the condition of water availability for the plants, evaluating, if there are serious problems of water stress, the possibility of irrigation implantation, whenever possible, and should opt for more economical supplementary irrigation. In the condition of high temperatures, one must plant more adapted varieties, besides of using irrigation and, in the last case, afforestation.

The joint evaluation of factors - soil, plants and the environment - is essential for the definition of three types of crops: good ones, in which only the normal treatments should be

dispensed with; recoverable, where special recovery practices need to be carried out and; those in which the recovery does not compensate and should therefore be eliminated and replaced by new crops.

12 FINAL CONSIDERATIONS

There are several actions that can be used together for environmental preservation. It is important to raise awareness among all producers, especially those linked to small communities located in hydrographic micro-basins. Soil preparation, management and conservation practices carried out in an integrated manner give greater sustainability to coffee cultivation. Soil is a natural, nonrenewable, essential resource that needs to be exploited rationally in order to preserve its productive capacity and still be recovered if degraded by inappropriate use and management.

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