# Sustainable practices: alternatives for a complex problem

CEFET 2
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# Abstract

Household wastes constitute ubiquitous sources of pollution and their leachates are serious threats to the quality of surface and ground waters. Domestic wastes are commonly composed of 50% biodegradable organic matter that could be decomposed and used in the form of a bio-fertilizer (humus). Red wiggler earth worms (*Eisenia fetida*) are widely used in that transformation process. Despite its obvious benefits, domestic vermicomposting is not well-known in Brazil. The present project produced a low-cost vermicomposter and encouraged community members to embrace that technology. A website was developed to guide users. Humus samples were distributed free of charge in the local communities. Chemical characterizations of humus revealed good C/N rations and the ready availability of nutrients such as zinc, phosphorous, calcium, boron, sulfur, chromium, nickel, manganese, and magnesium. Those biofertilizers have been used in school gardens with poor soils to promote the development of 14 bean varieties belonging to four species. The beans seeds were inoculated with diazotrophic bacteria prior to planting to improve the nitrogen content of the soil. Those two sustainable practices for crop cultivation were promoted among students and are expected to contribute to organic and family farming situations where bio-fertilizers can be produced with locally available raw materials.


**Key-words: Bio-fertilizers, community, dizotrophic, soil nutrients, vermicomposter**

# 1. Introduction

Household wastes constitute ubiquitous sources of pollution and, as landfills are becoming overloaded, leachates pose serious threats to both surface and ground waters [1, 2]. Selective collection is a viable initiative for proper disposal; but it does not deal with the reuse of the biodegradable organic matter that usually composes 50% all domestic waste. This organic matter could be recycled and used in the form of bio-fertilizers. Red wigglers earth worms (*Eisenia fetida*) are widely used in this process [3]. Despite the benefits, domestic vermicomposting is not widely employed in Brazil. The prices of domestic vermicomposter can vary from R$170-290, preventing their use among low-incomes families. Domestic vermicomposting could contribute to reduce organic matter in garbage and improve quality of low nutrient soils in form of biofertilizers.

Besides the increase of garbage production, humanity has been facing other challenges. Our fast population growth requires higher amounts of food, and agricultural yields have correspondingly been rising. Agricultural crops are grown using especially inorganic fertilizers which can be readily leached and carried away by rain water, contaminating both surface and ground waters, and they also reduce and suppress populations of soil microorganisms [4]. Organic fertilizers represent sustainable alternatives for crop production, especially in organic and family farming situations where bio-fertilizers can be produced locally with available raw materials. The properties of the fertilizers produced from household wastes have not been well characterized and its use can be considered a viable alternative.

The city of Varginha, located in the state of Minas Gerais, has a population of approximately 124,000 inhabitants. Its economy was previously based exclusively on agricultural and livestock activities, however due to the industrial growth the lifestyle of the community has changed with the increasing generation of garbage. In spite of this, livestock activities and crops of coffee, corn, soybeans, beans and wheat still occupy a considerable area and generate employment. This activities cause alteration in the natural environment with significant negative impacts on the Cerrado biome. This biome is characterized by soils with limitations in essential nutrients and low water holding capacity. Historical records revealed that the area where the school unit Centro Federal de Educação Tecnológica de Minas Gerais (CEFET-MG), located in Varginha city was built in a land used for pasture for more than 30 years. The soil in the area is slightly acidic and has low levels of organic matter [5]. The school gardens were planted in 2014 and so far, some plant species have not yet bloomed and show deficiency in their development.

Previous studies [5], showed very low nitrogen content in the soil of CEFET Varginha. Nitrogen is the nutrient with the highest demand by crops, and 40-60 % of the N absorbed by crops comes from nitrogen fertilization with synthetic fertilizers, a practice that accounts for 20 % of the production cost [6]. Nitrogen availability depends on the content of the directly available N represented by inorganic N forms as well as organic and mineralizable forms during its cycle [7, 8]. Approximately 98 % of total soil N occurs in organic forms, and a significant portion of N is not readily available to plants [9]. It is well known the legume family (beans, peas, etc.) has symbiotic relationship with "nitrogen fixing" bacteria (*Rhizobium and Bradyrhizobium*). On the plants roots are nodules that house the rhizobia colonies which turn nitrogen in the air ($N_2$) to a form plants can use.

Therefore the objective of the project was to use sustainable techniques to recover this degraded Cerrado soil of CEFET Varginha gardens. Low-cost vermicomposter was built and the organic wastes from the school restaurant; specially fruits peels and vegetables were used as raw materials to produce organic fertilizers that were applied in school gardens to increase organic matter and allow the growth of experimental beans crops. To avoid the use of nitrogen inorganic fertilizes, diazotrophic bacteria was inoculated in bean seeds prior to planting. Small plantations of 14 varieties of beans, belonging to four species (*Cajanus cajan, Phaseolus vulgaris, Vigna unguiculata e Vigna angularis*) were planted in the school gardens. Among species, nine varieties belong to specie of common bean *P. vulgaris* (brown, black, white, ball, butter, red; purple, small purplish, "rape" and queen beans); two verities of *V. unguiculata* (cowpea and small cowpea), one variety of *C. cajan* (guandu), and *V. angularis* (adzuki).

Besides that, the work intended to spread the technique of homemade biofertilazers production using low-cost vermicomposter among the population, aiming to reduce inappropriate organic matter disposal. For that, low-cost vermicomposters were created in an innovative design to encourage users. A website was developed to guide the community to use it. A distinctive label for humus packing was developed, and bio-fertilizer was applied in the school gardens and distributed free of charge to citizens in the community. Physic-chemical properties (moisture, pH, electrical conductivity, water holding capacity, organic matter content, ashes, and macro- and the micronutrient contents) of the organic biofertilizers produced from organic wastes of school restaurant were determined.

# 2. Methods

Soil quality analyzes were performed by Laboratory of Soil Analyses (Universidade Federal de Lavras, Minas Gerais state, Brazil) prior the study. Analysis showed low organic matter concentration in soil, therefore we decided to: a) produce organic fertilizers using organic wastes from the school restaurant in a vermicomposting system. Low cost vermicomposter were made to allow this production and b) plant 14 varieties of beans, which seeds were inoculated with diazotrophic bacteria (nitrogen fixers) prior to planting.

## 2.1. Homemade vermicomposter with innovative design

Low cost vermicomposter were made using discharged butter bucket collected in local bakeries. Each system was composed of two buckets. The lid of one bucket was bounded using epoxy glue to the bottom of other one. A screw driver was used to make 25 holes (5 mm diameter), simultaneous on the bottom of the top bucket and the lid of bottom one (Fig. 1). A tap was coupled to one side of the bottom bucket to collect leachete during decomposition process.

The bucket was painted with a tint produced with low organic matter soil, water and paper glue (2:2:1). The procedure to prepare earth tint is described in [10]. After painting the buckets, can be decorated with dried leaves and seeds of watermelon and pumpkin (Fig.1).

## 2.2. Production of biofertilizers

Methodology of vermicomposting is described in [11].


Butter buckets donated from local; 2-The buckets were stacked and drilled with a 2mm drill to produce 25 holes of 5 mm. 3- A circumference of. 5cm was made in the lower level bucket and a faucet was installed; 4-5- For the decoration, a mixture of glue, water and earth was used, forming a biodegradable ink;

## 2.3. Physical and chemical characteristics of humus

Three batches of humus were characterized. For each lot of humus (organic compost) analyses were performed in triplicate in independent experiments and averages were shown. Macro and micronutrients analysis were performed in a composed sample by mixing in the same proportion samples of the three different batches.

## 2.3.2. pH and electrical conductivity

A spoon was used to weigh out about 10 g of organic compost into the 100 ml Becker, distilled water; 50ml was added to sample (1:5 diluted). Container was shaken for about 2-3 minutes and then it was allowed the soil to settle for 2 minutes. Measurements was performed with pHmeter and conductive meter and data recorded.

## 2.3.1. Moisture

Prior to packing, vermicomposting humus was allowed to dry under room temperature until moisture achieves 45%. Results were obtained after 10g of humus sample were weighted inside porcelain crucibles and were dried to constant mass in oven at 65 $^{o}$C. Moisture content was determined subtracting initial weight from the final one; that corresponds to the water evaporated during drying.

## 2.3.3. Water holding capacity

A 15-cm cores was used to add a mixture of 1:1 of vermicomposting humus and the soil collected from school gardens. A double layer of a square of cheese cloth was put on the bottom of the core with a rubber band. The core with the cheese cloth was weighted prior to and after the addition of mixture and results recorded. The core was set in a pan full of water until it was almost immersed; left it in the pan to soak up water for 24 hours until it was completely saturated. After this period, the core was removed from the pan, and the excess water drained until it stopped dripping. The set was weighted. The top of the core was covered with saran wrap to prevent evaporation and let it to drain for 24-48 hours. Carefully the cheesecloth was removed, weighted and replaced with a square of aluminum foil; core was put in the drying oven for 24 hours at 105$^{o}$ C. Core was removed from the oven and covered top with saran wrap to prevent it from sucking moisture from the atmosphere, and the dry core was weighted. The amount of water retained in the soil at saturation and holding capacity after 48 hours was determined. Water holding capacity in soil mixed with biofertilizers was compared to soil without biofertilazers.

### 2.3.4. Organic matter content and ashes (minerals)

Each sample was placed in a 100-ml beaker and dried at 105 °C in a drying oven for 24 hours to remove moisture. The porcelain crucibles were numbered and weighed, and weighted out a 10.00 gram sample (immediately upon removing each beaker from the drying oven), and the sample was placed into a labeled porcelain crucible. Samples were heated at 600 °C until constant mass. This process is referred to as "ignition". The difference between the mass of each sample before the ignition heating and the mass after this heating was calculated. This difference is approximate to the organic matter content. Organic matter content was expressed in percentage of the mass. Soil organic matter (SOM) is one of the best indicators of soil quality. Ashes represent minerals and were expressed as the percentage of residue remaining after ignition.

### 2.3.5. Macro- and the micronutrient contents

The macro and nutrients were determined by laboratories of Instituto de Agronomia de Campinas (IAC), São Paulo, Brazil. This laboratory uses standard and certified methods to determine the concentration of the following chemicals in organic compost samples: total nitrogen (Kjeldahl Method), P, K, Ca, Mg, S, B, Cu, Fe, Mn, Zn, Na, Cd, Cr, Pb e Ni (EPA3051/6010c), organic C (Dicromatometry method).

## 2.4. Beans and diazothrophic bacteria and crops plantation

Students from the second year of computer science course bought in local markets (Minas Gerais state, Brazil) 14 varieties of beans. This class was also responsible for crops plantation and watering. Beans species and types were identified by specific bibliography [12,13] and assistance technicians of Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA). An agreement was signed between the CEFET-MG and Embrapa Agrobiologia (Seropedia, Rio de Janeiro, Brazil) and Foundation for Support to Scientific and Technological Research of the Federal Rural University of Rio de Janeiro - FAPUR to pass 1 dose of 50 g each of the following inoculants BR322, BR3262, BR2003. The diazothrophic bacteria used to inoculate each bean variety is shown on Table 1. The inoculants of symbiotic bacteria are experimental and are intended for application in a scientific research project. For inoculation of the beans seeds before planting, the methodology used is described in [14].

Crops experimental design is shown on Fig 2. At least two rows with 10 plants of each variety were seeded. In one of the rows seeds were inoculated with peat innoculum of nitrogen fixing bacteria and the other row (control) seed where planted without innoculum. Experimental area has hard and compacted soil, so for that reason seeds were planted in holes of 5-10 cm depth, soil was mixed to organic biofertilizers obtained by vermicomposting method. Planted seed was irrigated with tap water three times a week and after one month irrigation was done once a week to minimize consume of water. Mulch was used to avoid water evaporation [15].

**Table 1: Different varieties of Brazil purchase in Minas Gerais Markets (Brazil) and correspondent innoculum used**

| Nº | Bean Variety | Species | Peat innoculum (Diazotrophic bacteria) |
|---|---|---|---|
| 1 | Black | *Phaseolus vulgaris* | *Rhizobium tropici*<br>BR 322 (Embrapa) |
| 2 | Brown | *P. vulgaris* | BR 322 (Embrapa) |
| 3 | Purple | *P. vulgaris* | BR 322 (Embrapa) |
| 4 | Purpleish | *P. vulgaris* | BR 322 (Embrapa) |
| 5 | Queen | *P. vulgaris* | BR 322 (Embrapa) |
| 6 | White | *P. vulgaris* | BR 322 (Embrapa) |
| 7 | Ball | *P. vulgaris* | BR 322 (Embrapa) |
| 8 | Red | *P. vulgaris* | BR 322 (Embrapa) |
| 9 | "Rape" | *P. vulgaris* | |
| 10 | Butter | *P. vulgaris* | BR 322 (Embrapa) |
| 11 | Cowpea | *Vigna unguiculata* | *Bradyrhizobium pachyrhizi*<br>BR 3262 (Embrapa) |
| 12 | Small Cowpea | *V. unguiculata* | BR 3262 (Embrapa) |
| 13 | Adzuki | *V. angularis* | BR 3262 (Embrapa) |
| 14 | Guandu | *Cajanus cajan* | *Rhizobium sp.*<br>BR 2003 (Embrapa) |

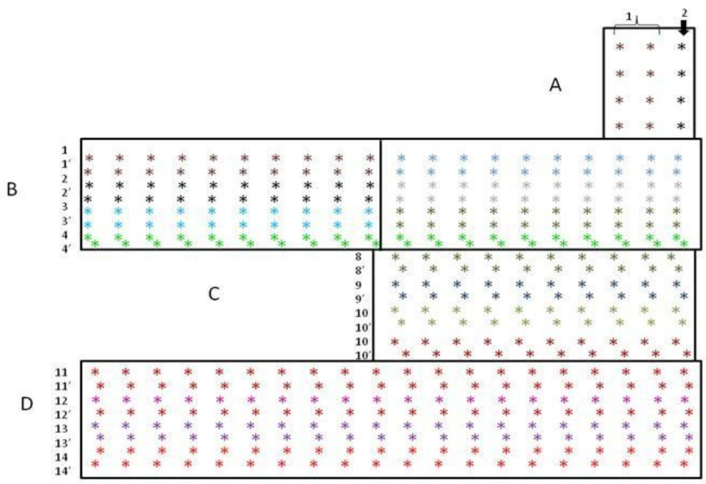



Figure 2: Experimental desing: Crops areas of beans varieties. Plot A (5x2m), Plots B e D (4x17m), Plots C (4x7m). Space between plants 70 cm. Row with (') correspond the ones that seeds were inoculated with peat diazotrophic bacteria, rows without (') seeds were plant without innoculum (control lanes). Beans varieties -1: Guandu (*Cajanus cajan)*, 2: Brown (*Phaseolus vulgaris*), 3: Black (*P. vulgaris*), 4: Cowpea (*Vigna unguiculata*), 5: Adzuki (*V. angularis*), 6: White (*P. vulgaris*), 7: Ball ((*P. vulgaris*), 8: Small cowpea *(V. unguiculata*), 9: Butter (*P. vulgaris*), 10: Queen (*P. vulgaris*), "Rape" (*P. vulgaris*), 12: Purple (*P. vulgaris*), 13: Purple (*P. vulgaris*), Purplish (*P. vulgaris*), 14: Red (*P. vulgaris*).

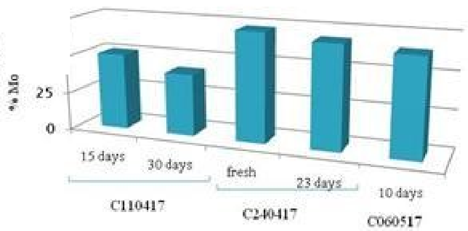
# 3. Results and discussion

## 3.1. Low-cost vermicomposter, vermicomposting and humus characteristics

Different size and decorative low-cost vermicomposter were made (Fig. 3). A website was developed to spread the vermicomposting technology among the citizens. The informative website (http://minhocariobaixocusto.hol.es/) has procedures to make vermicomposter and vermicomposting process. *Eisenia fetida* red wriggler earth worm was given free of charge to citizens who started to adopt this technique in their houses.

Figure 3: Low-cost vermicomposter to produce biofertilazers using household organic wastes.

At the end of the vermicomposting process when leachate stopped dripping in the bottom buckets, the worms were separated from organic compost; and it was left to dry until mo[illegible] reach around 45%. The period of drying was det[illegible]d after moisture analyses in three organic compost lots (Fig. 4A). The period of drying at room temperature that organic compost achieved the desirable moisture was about 30 days. This period can vary during the year's seasons depending on weather conditions. Most of the investigated humus lots from different batches had more than 50% of organic matter, just the lot C060517 organic matter content was below 50% and ashes were almost at the same percentage. It is probably due to a fast mineralization process in this sample.



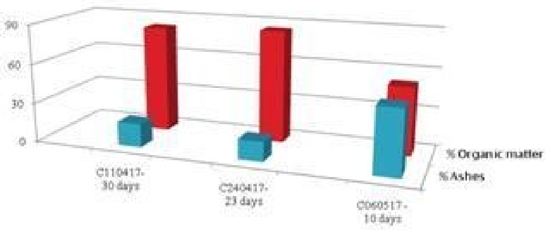
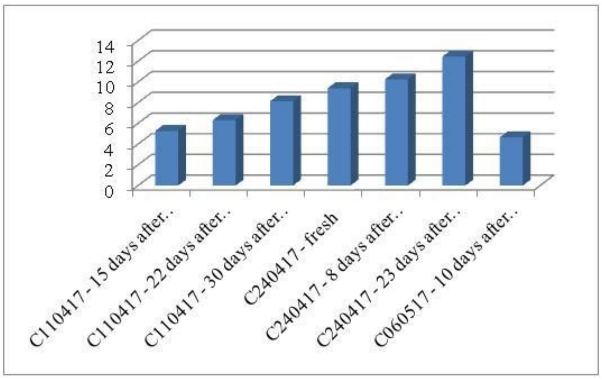




Figure 4: Moisture percentage (A), organic matter and ashes (B) were determined in biofertilizers form vermicomposting after different period of drying at room temperature.

When vermicompost organic matter shows pH over 6 and electric conductivity less 4 ms/m, it indicates the end of maturation process [16]. Despite in all samples the pH average was above 8 (Fig. 5A), indicating good quality of humus, electrical conductivity (Fig. 5B) in all sample were above 4 ms/m. It is important to mention that electrical conductivity increases during drying indication mineralization of organic compost. Therefore the end of maturation process was determined mainly by pH and observation of lack of food wastes.



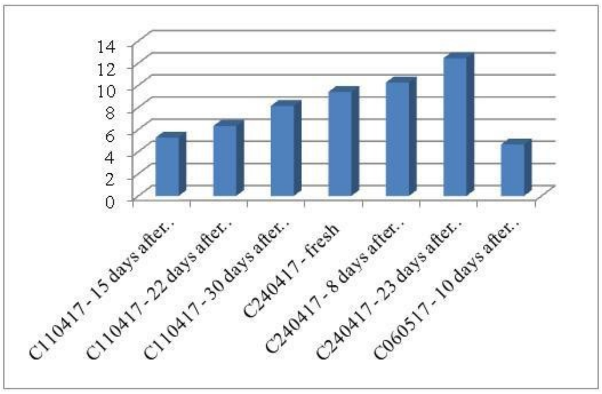




Figure 5: pH (A), electrical conductivity (B) were determined in organic biofertilizers from vermicomposting after different period of drying at room temperature

Analyses of water holding capacity (Fig. 6) showed the addition of vermicomposting organic matter to the soil of the school gardens increasing the absorption and retention of water, therefore it cannot only higher the availability of water for plants but also reduce costs of irrigation. In clay soil as the one found in CEFET Varginha gardens (Table 2), retention of water and its proper drain is a very important factor to allow plants development and growth.

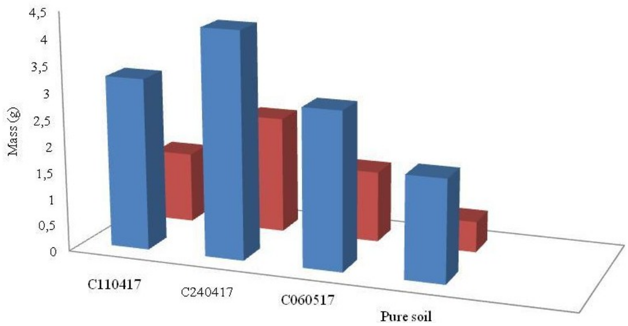



Figure 6: Water holding capacity investigated in three lots. Vermicompost organic matter was mixed (1:1) to school soil earth. Blue bars indicate de amount of water absorbed by each set after 24h soaked and red bars indicate the amount of water kept inside soil particles (no drained water).

Analyzes of vermicompost biofertilizer revealed that there are many essential nutrients for plant growth in the compost. The production cost of the fertilizer consists basically on human resources to maintain the system and minimum electric energy to make the holes in the low-cost vermicomposter, as most of the material used in the process is trash. It is observed in Table 2 that vermicompost biofertilizer can supply soil deficiency not only in organic matter content but also in minerals. The vermicompost therefore can be an alternative to reduce organic matter in domestic garbage as well as produce high quality fertilizer to recover the soil of degraded areas and for gardening. However the high concentration of phosphorus in compost can be harmful for environment causing eutrophication.

**Table 2. Profile of chemical elements present in CEFET Varginha garden soils and vermicompost biofertilizer produced from raw organic waste from school restaurant.**

| Parameter | Sample | |
|---|---|---|
| | Garden soil | Vermicompost biofertilizer |
| pH ($H_2O$) | 5.8 | 8.3 |
| P ($mg/dm^3$) | 0.5 | 3,400 |
| $Ca^{2+}$ ($cmol_c/dm^3$) | 0.75 | 89.8 |
| $Mg^{2+}$ ($mg/dm^3$) | 0.13 | 3400 |
| Organic matter (dag/kg) | 0.49 | 52.6 |
| Zn ($mg/dm^3$) | 0.7 | 5,282 |
| Fe ($mg/dm^3$) | 34.3 | 10,483 |
| Mn ($mg/dm^3$) | 16 | 426 |
| Cu ($mg/dm^3$) | 3.24 | 12.2 |
| B ($mg/dm^3$) | 0.04 | 28.6 |
| S ($mg/dm^3$) | 15.61 | 2,600 |
| C/N ratio | | 14.5 |
| Sand (dag/kg) | 43 | --- |
| Silte (dag/kg) | 9 | --- |
| Clay (dag/kg) | 48 | --- |

## 3.2. Beans varieties and crops

According to FAO (Food and Agriculture Organization), humanity has used more than 10,000 species of plants throughout its history to meet their food needs. However, world food production depends on a very small number of species, with about 15 species providing 80% of all energy needed by humans. Beans are one of species of this list. Many of these species has extreme importance to local communities and exploiting this potential is crucial to achieving food security.

In any case, considering that the importance of biodiversity in food and nutrition goes back to the very history of civilization and that the use of this biodiversity is in human nature itself, which has materialized through the domestication of plants and animals throughout the ages. The world depends, definitely, on a very small number of species for their food. It is an uncontested situation where the aggregation of global data (production and consumption) - clearly shows the existence of enormous fragility in providing the calories necessary for the survival of the human being.

Genetic resources represent, on the one hand, the most important raw material for breeders and, on the other hand, the great contribution of farmers to global sustainability. If properly used, these resources will never be exhausted and there will also be no incompatibility between conservation and use. Considering, however, population growth and the continuing challenges faced in food production, more and more breeders will be forced to use all available genetic resources. In addition to the ongoing challenge of improving existing cultures, research work, especially those focused on agricultural research, must go further with the development of new cultures, sustainable and environmental friendly agriculture practices to guarantee survival.

Brazil is very important site of grains biodiversity used for human nutrition. In the present work it was noticed by simple purchasing beans in local market. The students were able to work with different 14 beans varieties (Fig.7).

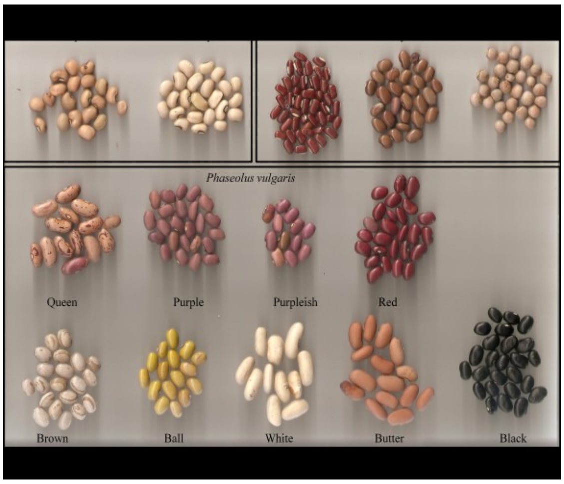



Figure 7: Different beans varieties used in the present work.

Extremely compacted, hard, dry soil with low nutrients and infiltration capacity was a challenge to plant the seeds. Another important factor considered was the costs of soil correction to make it ideal for planting. Concepts of pollution, environmental degradation and eutrophication and drought period were considered to choose the best alternative to overcome these limitations due to the possibility of failure in the development of the plants. Therefore soil supplementation with organic matter by addition of vermicompost biofertilizer, diazothrophic bacteria and mulch were the best low cost alternatives in agriculture practices to cope with the challenge. The planting of the varieties of beans started on May 22nd and ended on the 29th, 2017. After planting seeds in a mixture of natural earth and organic biofertilizers, crops were irrigated and covered with dry grass from the schoolyard. Literature indicates [15] the mulch maintains the soil with a temperature gradient of approximately 3.5 $^{o}$C lower than the uncovered treatment and the humidity remains 2.0% higher than the uncovered soil therefore its practices saved water from school. Pictures of this process step are shown in Fig. 8.

Figure 8: A: Compact and hard soil of CEFET-MG Varginha gardens, B: Irrigation of crops and mulch, C: Bean seeds inoculated with peat nitrogen fixing bacteria prior planting, D: general overview of bean crops.

In less than two weeks seeds started to germinate. It is important to mention the objective of the work was the enrichment of the soil and the understanding of the genetic ecology and not the productivity of grains. Seeds of *Vigna* varieties (cowpea, small cowpea) were not able to growth without inoculation with diazothrophic bacteria. The other varieties were able to grow in the degraded Cerrado soil however plants produced by seeds without nitrogen fixing bacteria have not produced fruits. After the development of the plants, students were resistant to rip out the plants to verify the nodulation of the symbiotic bacteria in the roots of the legumes. The original idea was to cut the plants stalks leaving the roots in the soil so that the effect of green manuring could have an effect in the long turn, just one or two plants of each variety would be ripped out to verify nodulation. The part that would be cut would be left on the surface of the soil for the natural decomposition and enrichment of the soil with dead organic matter. Despite the planned strategy, as raining season was coming, the plants remained in the soil still fulfilling their role as green manure. The plants covering the soil would also have an important role in reducing the impact of rainwater, favoring dripping of water on the soil and enhancing absorption and percolation of rainwater and would still act to avoid erosion processes. However at least two plants of each variety were ripped out to verify nodulation, pictures of some plants roots is shown (Fig. 9). Fruits and seeds of plants were collected and are kept in the laboratory; some of them are shown in Fig. 9.

Unlike of annual crops of species P. vulgares, V. unguiculata and V. angularis; Guandu beans formed a perennial culture can protect soil from erosion. It also can contribute with an organic matter input due the accumulation of leaves that fall in soil and will undergo decomposition process. Fig. 10 shows Guandu trees developing in area of very hard and compacted soil and the amount of leaves piled up.

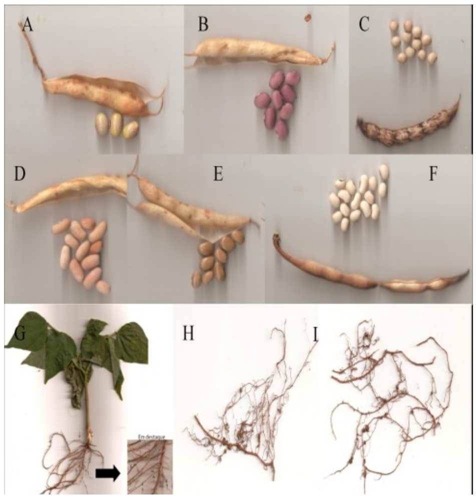


Figure 9: Seeds, fruits and nodulated roots. A: Ball bean, B: purple bean, guandu bean, butter bean, rape bean, small cowpea bean. Nodulated roots of brown bean (G), adzuki (F), small cowpea (G).

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Figure 10: Perennial crops of Guandu beans with leaves piled up, an important apport of organic matter in degrade soil.

# 4. Conclusion

The crops were developed from May to August 2017. During the school holidays (July) the irrigation was overtaken by the gardeners. The current status of this project is completed; however some students decided to plant Adzuki bean to study in statistical experimental design its nodulation with *Bradyrhizobium pachyrhizi* BR 3262 because its results are not described in literature and can contribute to application of sustainable practices for food production in near future. A web site was developed by students with the purpose to spread information obtained in the present work. The access of the website is in the address: http://projetofeijaomeioambiente.esy.es/. At the end of the project students are able to spread in community sustainable techniques of soil management, reuse of organic residues and plant productivity. It was possible to understand the importance of genetic heritage and its preservation. Improvement of the school soil quality must be achieved through green manuring. The challenge of improving existing crops needs to go beyond; not only in the development of new crops, but also their reconciliation with sustainability and the preservation of environmental resources.


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