TROPICAL FORAGES IN INTEGRATED SYSTEMS: STRAW FOR NO-TILLAGE

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ABSTRACT
In recent years, crop-livestock integration (ICL) has gained prominence as a promising strategy to increase sustainability in agricultural and livestock production. This system, widely adopted in the Brazilian Cerrado, enables the rational use of inputs and land, favoring both grain production and cattle raising in the same area. The advantages of ICL include the recovery of degraded areas, the maintenance of soil fertility levels, and the reduction of the need for chemical inputs, such as herbicides and pesticides. The adoption of the no-tillage system (NTS) combined with the intercropping of crops, especially forage and grains, allows the formation of a protective layer on the soil that minimizes erosion and improves water retention. In addition, the benefits of crop rotation and succession contribute to nutrient cycling and biological control of pests and diseases, crucial elements for the long-term economic viability of ICL. The implementation of this approach faces challenges, especially regarding regional adaptation and variation of forage species. Even so, studies indicate that the integrated system has substantial advantages in the environmental resilience and productive stability of agricultural properties.

Keywords: Crop-livestock integration. Sustainability. Soil recovery. No-tillage system. Culture consortium.

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INTRODUCTION

In recent years, the intercropping between tropical forages and other crops, known as the crop-livestock integration system, has been increasingly adopted by rural producers in the Cerrado, mainly due to studies demonstrating the feasibility of the intercropping between a given crop and the various forage species in simultaneous sowing.

Such a system consists of the exploration of the same area for the purpose of grain production and livestock exploration for the production of meat, milk, or others, with the potential to increase production and reduce the risks of pasture degradation, thus improving the chemical, physical and biological characteristics of the soil, in addition to the productive potential of grains, forages and silages. Currently, this technique stands out as being part of the sustainable and competitive technologies to leverage Brazilian agribusiness (ALMEIDA et al., 2012).

The use of integrated systems is a way to partially or totally compensate for the lack of forage during the dry season, with the cultivation of forages sown in succession to summer crops (MACHADO; ASSIS, 2010).

The intercropping and/or succession system provides increased forage availability and silage production in the dry season, with sufficient quality for nutritional maintenance of the herds, promoting weight gain and straw production for no-tillage, in addition, its main advantage is the recovery of degraded pastures at a lower cost (BARDUCCI et al., 2009).

In the integrated crop-livestock system (ICL), soybeans also play a fundamental role, because in addition to being an economically relevant crop, they contribute to the sustainability and recovery of the soil. In intercropping with forages, soybeans improve fertility, favor nutrient cycling and reduce pest cycles. This integrated cultivation also helps to form a layer of straw, which protects the soil and maintains moisture, essential for no-tillage. Thus, soybeans strengthen agricultural yields and promote synergy between crops and livestock, consolidating themselves as a key element in sustainable systems (VENGEN et al., 2020).

DEVELOPMENT

CONSERVATION SYSTEM

Agriculture, especially after the 1950s, opted for a technological model that makes intensive use of mechanization, highly effective fertilization and pesticides. This model ended up increasing crop production, but causing numerous environmental problems, with an emphasis on soil degradation by erosion, loss of organic matter and consequent compaction, due to the inappropriate use of agricultural practices (KAMIYAMA et al., 2011).

Studies related to the efficiency of soil management conservation systems in relation to the control of nutrient losses show that the amount of nutrients that are lost is lower when the system is used, compared to conventional ones. This decrease with the use of conservation systems can be attributed to the effects linked to the increase in soil cover with plant residues, and to the decrease in water and soil losses (GUADAGNIN et al., 2005).

The use of conservation management techniques, such as the no-tillage system (NTS), has as a priority to conserve the characteristics of both the soil and the environment, without dispensing with the achievement of high productivity of the crop of economic interest (CARVALHO et al., 2004).

SDP, which is currently the most widely used conservation management in the country, has not been fully executed, but it still has benefits, especially in erosion control in regions with high rainfall (DENARDIN et al., 2008).

No-till system (NTS)

Population growth, especially in underdeveloped countries, coupled with increased demand for food, has led to major changes in agriculture. Such changes can be explained by the use of innovative technologies that sought greater production, leading to an expansion in agricultural frontiers, with the inclusion of new areas for planting, however, simultaneously with this expansion, there was an increase in environmental degradation. To solve this problem, NTS was introduced in several agricultural areas in Brazil, and this system has been consolidated over time among farmers and researchers as a conservationist technique that adapts to different regions and technological levels from large to small producers (TORRES, 2003).

NT is a conservation cultivation technique in which planting is carried out without the stages of conventional tillage and harrowing, keeping the soil always covered by developing plants and plant residues (CRUZ et al., 2008).

The use of NTS was already adopted for a long time in other countries such as the United States and also in Europe, however, the introduction of this system in Brazil occurred at the end of the 1960s, which began in small areas as a form of academic studies on soil conservation management (MOTTER; ALMEIDA, 2015). The pioneer farmer in the adoption of no-tillage was Herbert Bartz, in 1972, in the State of Paraná. In the regions of the Cerrado biome, NTS was consolidated in the 1990s with the arrival of immigrants from the southern region of Brazil with extensive experience, as well as due to the adaptation of soybeans in these areas (VILAS BOAS et al., 2007).

In the search for management systems that reduce soil loss and benefit the use of water, NTS has been qualified for showing, especially in the most superficial layer, greater structural stability, which, associated with the conservation of crop residues in the most superficial layers of the soil, has provided greater protection against the impacts caused by rain. contributing to better infiltration and reduction of water loss through surface runoff (CARVALHO et al., 2004).

One of the basic premises of NTS is the adoption of crop rotation, preferably alternating commercial crops, such as soybeans, corn, rice, beans and sorghum, with green manures such as sunn hemp, velvet bean, pigeon pea and grasses such as millet and brachiarias, providing efficient soil covering, in addition to high nutrient cycling and increased productivity of crops in succession (SILVA et al., 2006).

Crop residues should cover at least 80% of the soil surface, or maintain 6 t $^{ha-1}$ of dry matter for soil cover. This is one of the most important requirements for the success of no-tillage, as it affects practically all the modifications that the system promotes, and the most variable between different regions, since the options for farms and soil cover depend on climatic conditions, as well as the availability of information regarding alternative species and sowing times in each location (CRUZ et al., 2008).

In the Brazilian Cerrado, the climate is characterized by a dry winter, with shortening of the photoperiod, which makes it difficult to establish plants at this time of year. Thus, the establishment of a soil cover with plants sown for this purpose, in March and April, has been the greatest challenge for the system in the region (ALVARENGA et al., 2001).

The use of forage species such as those of the genus *Brachiaria* for the formation of straw has aroused the interest of farmers and researchers (APDC, 2001). These forages have great potential in maintaining straw on the soil due to their high C/N ratio, which delays its decomposition and increases the possibility of use in warmer regions.

Timossi et al. (2007), evaluating forage species for straw formation for the adoption of the no-tillage system, found that the vegetation cover provided by brachiaria (*B. decumbens* and *B. brizantha*) ensured accumulation of dry plant mass, above 11 t $^{ha-1}$, at the time of chemical management.

Crop-Livestock Integration

Agriculture and livestock in Brazil kept their productive activities carried out separately, that is, they did not occur simultaneously, with almost no synchronism. This practice, over the years, contributed to accelerate the degradation process of both pasture and crop areas, as there was no replacement in the soil of the nutrients extracted by pastures used in livestock and crops and the replacement was only partial, with fertilization carried out at sowing (ALMEIDA et al., 2012).

A very efficient alternative, which proposes maintenance of productivity and recovery and/or indirect renewal of pastures is the crop-livestock integration, where the insertion of crops is not occasional, but a constant part of a grain production system and animal production, which will interact and complement each other in aspects related to management, fertility, soil physics and biology, raising the income of producers and introducing social progress to the countryside. The system allows for a more rational use of inputs, soil, machinery and the property's labor, in addition to increasing food production, diversifying the producer's income alternatives (MARCEDO, 2009; MARTHA JR. et al., 2011).

The crop-livestock integration system consists of the implementation of different types of production systems, whether for grain, fibers, meat, milk, among others, in the same place, in a plantation that is intercropped, sequential or rotational (MACEDO, 2009). On a property, the use of the land alternates, in time and space, between crops and livestock. And it is in the high potential for synergism between the components of pasture and crop, that the benefits of ICL are found (VILELA, 2008).

Also according to Macedo (2009), positive points are found in the literature with the use of this system, with biological improvements, such as breaking the cycle of pests and diseases and increasing the biological activity of the soil. Regarding the physical and chemical properties of the soil, it has an improvement in fertility, through nutrient cycling and efficiency in the use of fertilizers, due to the different needs of rotation crops. The modifications in relation to the physical properties have been in the increase of the stability of the aggregates, reduction of the apparent density, compaction and increase of the water infiltration rate.

In a study carried out by Ikeda et al. (2007), at Embrapa Cerrados, they observed significant reductions in weed seed banks in crop-pasture rotation, when compared to the continuous tillage system, especially when no-tillage was adopted. The reduction in the use of agrochemicals, in relation to breaking the cycles of pests, diseases and weeds, is another beneficial factor to the environment of systems such as crop-livestock integration.

Crop-livestock integration is a system that has been increasingly adopted on properties over the years, fully or occasionally, in many countries. As it is a more complex system, it generates impacts on the soil, environment, economic performance and the entire management of the property. These impacts can be both positive and negative, which will depend on the situation, and need to be well understood (MACEDO, 2009; VILELA et al., 2011).

According to Franzluebbers (2007), the most varied systems, such as crop-livestock integration, are fundamental to replace and preserve organic matter (OM) and provide well-structured soils that will favor a higher rate of rainwater infiltration and the penetration of roots into the soil, which will increase the volume of soil explored by the root system of plants and, consequently, the greater efficiency of the use of water and nutrients.

CROPS IN SUCCESSION IN THE OFF-SEASON PERIOD

The entire sustainability of an agrosystem can be measured by the action of several aspects related to the natural phenomena of the region and the management that can occur due to anthropogenic modifications. Several approaches have been used in recent years to reduce the harmful effects of the entire agricultural system on the environment. Techniques such as NTS, use of soil cover and crop succession are fundamental (JUNIOR et al., 2009).

Crop rotation and/or succession proves to be one of its main advantages to improve or maintain soil fertility, thus contributing to the reduction in the appearance of pests and diseases in the crop. Having a greater diversification of crops within a property can lead to a reduction in the risks of failure in agricultural activity, thus contributing to a maintenance and improvement in crop productivity (FIDELIS et al., 2003).

Another benefit of crop succession that is of paramount importance is nutrient cycling, as varied crops require different fertilization, that is, leading to different types of residues that will remain in the soil after cultivation (FRANCHINI et al., 2011).

With the conservation practices and care of the plant residues present in the soil, whether or not the incorporation occurs, these factors are beneficial to the microbial action, reducing the negative effects on agricultural soils, leading to favorable effects on the crop that is implanted (MOREIRA; SIQUEIRA, 2002).

INTERCROPPING BETWEEN SOYBEAN AND FORAGE, OR SOYBEAN IN SUCCESSION

The intercropping between grain crops and forage crops in the crop-livestock integration system is used to anticipate the establishment of pastures, favoring a better soil cover for no-tillage, reflecting positively on their properties, since the high volume of roots in depth and production of organic matter increases nutrient recycling (VILELA et al., 2011; GUEDES et al., 2010; SOUZA et al., 2011).

One of the most used intercropping in integration systems is that of corn with tropical forages, which can be carried out in the most different methods. Sowing can be carried out simultaneously, that is, at the same time as corn sowing, or in a lagged way, at the time of corn cover fertilization. The spacing of corn can be normal, reaching up to 0.90 m between rows, or reduced, with a spacing of 0.45 m. The variation between the mechanism of forage implantation is also great, ranging from the mixture of forage to fertilizer to adapted seeders, with forage seed boxes (BROCH; CECCON, 2007).

On the other hand, the intercropping of grass with soybeans, although it can be carried out, is operationally complicated and, in certain situations, can harm the productivity of grains or the forage itself (VILELA et al., 2011).

Brazil is the largest exporter of soybeans, having exported 66.6 million tons between January and August 2022, which demonstrates the economic importance that the grain has for the country (CONAB, 2022), and losses in productivity impact the Brazilian economy.

In a study carried out in Dourados-MS, with single soybeans intercropped with different forage species, it was found that the cultivation modalities did not differ in terms of grain yield, and it was possible to observe numerical differences, but not significant (MACHADO et al., 2017).

In another study carried out by Machado et al. (2009), with the intercropping of soybean with different forages, no statistically significant difference was observed, but the authors report a decrease of 16% in the yield of soybean intercropped with Massai grass. Due to the high costs in soybean production, even small decreases (8%) can compromise the entire economic sustainability of the producer.

Soybeans sown after pasture have been showing good results. Vilela (2008) in an experiment at Embrapa Cerrados, noted a benefit of pasture on soybean grain yield. Soybean sown after a three-year cycle of U *. brizantha* cultivar Marandu pasture showed a higher yield of 17% than that found in the continuous tillage system. It is worth noting that this higher grain productivity was found in the area that received the lowest amounts of fertilizers, about 45% less, during the 17 years of cultivation.

According to Vilela (2011), the greater efficiency in the use of soil nutrients by grain crops in the ICL system, when compared to single cultivation, leads to greater fertilizer savings and a consequent decrease in production expenses. However, such benefits are not easily achieved in a short time.

Santos (2017), cultivating soybean in straw of single Paiaguás grass and Paiaguás grass with pigeon pea, subjected to N doses, verified a reduction in soybean yield with the increase of the N applied. Both the application of N doses and the vegetation cover composed of pigeon pea left residual N in the soil, provided a harmful environment for nodulation and may possibly be harmful to the main productive indexes.

FINAL CONSIDERATIONS

The crop-livestock integration system is established as a viable and sustainable alternative for producers who seek to maximize the productivity of their agricultural properties, reducing environmental impacts. In addition to providing greater resilience to the agricultural system, ICL contributes to the more efficient use of natural resources, allowing for improved soil and crop management. Although the challenges of regional adaptation and choice of ideal species for intercropping persist, the continuity of research and the dissemination of knowledge on the subject can consolidate this system as a standard practice in Brazil. The adoption of NTS and the use of vegetation covers, combined with crop rotation and succession practices, represent the main foundations of ICL, ensuring not only soil conservation, but also the improvement of property profitability.

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