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Original Research Article

Productivity of Sweet Maize on Spikes under Previous Crops and Cropping Systems in the Coastal Tablelands of Sergipe Brazilian Northeast

ABSTRACT

The level of productivity in the agroecosystems of the Coastal Tablelands can be affected by the management system adopted in the soil, altering its physical, chemical and biological properties, thus compromising the productivity of the harvested crops. This study evaluated the effect of no-tillage systems (no-tillage, minimum tillage and conventional tillage) and previous crops: Peanuts (*Arachis hypogea*), ~~Crotalaria~~ (*Crotalaria juncea*), Beans (*Phaseolus vulgares*) and Guandu (*Cajanus cajan*)) Under the yield of sweet maize (*Zea mays* L.) in a Ultissol (Argissolo Vermelho Amarelo), aiming to measure the productivity of the agroecosystem studied in the Coastal Tablelands sergipano. The no-tillage system provided better levels of yield of sweet maize, as well as a higher number of plants per hectare, a higher number of spikes per hectare and a higher ratio of plants with spike and total plants. Among the previous crops, sun hemp provided higher productivity of sweet maize in conventional and minimum cultivation systems, while the culture of bean as the previous crop of bean in the no-tillage system, after eight years leading of experiment.

Keywords: Agroecosystems, Agricultural productivity, No-tillage, Minimum tillage, Conventional tillage.

INTRODUCTION

The need to produce food to satisfy population demands, in addition to being concerned with the productivity of agroecosystems, has been aimed at higher levels of environmental sustainability aiming at its maintenance. The way in which this activity is conducted, ie the agricultural practices adopted, affects the environment in which it is inserted at different levels, which can cause direct negative impacts on the soil, for example.

Soil degradation is one of the most serious environmental problems faced by today's society, since soil is often neglected as an integral part of the environment, and essential to the existence of life. It should be noted that the use of soil for agricultural purposes promotes chemical, physical and microbiological changes in its profile, and these should be monitored and evaluated so that preventive or corrective actions can be implemented [1].

The adoption of soil management techniques and crop that guarantee the greater sustainability of agroecosystems has been highlighted, since as pointed out by [2], the importance of soil in the agricultural system is not only a means of maximizing production, but rather of optimizing the use of this resource and sustaining productivity over a long period of time. In this way, its conservation or improvement is vital for sustaining productive activity.

The no-tillage system has been used as a management method to raise or maintain high levels of sustainable soil use. This management interferes in the physical, chemical and microbiological properties of the soil, through its low mobilization, high organic matter input and reduced speed of mineralization and minimization of the soil erosion due to the presence of the vegetal cover, creating an adequate environment for the process of restructuring of the soil indispensable to the sustainability and productivity of the exploited systems. In this way, the productive potential of the soil is ensured over time.

One of the factors essential to the introduction and maintenance of sustainable soil management is the presence of dead vegetation cover to protect it. In this case, the use of plant species in rotation, succession, antecession or consortium with the commercial crops, must present good phytomass production and adaptation to local conditions. These plants will benefit the commercial culture and the

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environment, as they control soil erosion, contribute to increase the availability of nutrients to commercial plants, and intervene in the physical, chemical and biological properties of the soil [3].

In Brazil, with the expansion of the market for maize for consumption in natura and for the canned, frozen, dehydrated or baby maize industry [4] has provided greater interest in research on the subject. The difference between maize and common is in the sugar and starch content of the endosperm, due to recessive genes. While maize has around 3% sugar and 60 and 70% starch, maize has 9 to 14% sugar and 30 to 35% starch [5].

The maize crop has been strongly disseminated in the state of Sergipe, presenting [6] relevance from the food, economic and social perspective.

In the state of Sergipe, the coastal tablelands and the Coastal zone comprise an area of approximately 7,126 km^2, of the total 21,910 km², representing about 32% of the area of the state of Sergipe. The importance of the coastal tablelands is related to the significant population that lives on it, occupying about 45% of the Northeast region, as well as the use of the soil for the cultivation of several annual and perennial crops, and animal husbandry, which in turn generate employment and income [7].

Thus, in the agroecosystems of the Sergipe coastal tablelands, where maize is also planted, it is necessary to develop and apply conservation techniques of soil management, so that the physical, chemical and biological properties maintain the same in a level of resilience [8] In the present study, it was found that the water content of the soil was higher than that of the soil. In this way, the present work has the objective of evaluating the influence of cropping systems associated to previous crops on maize productivity in green maize cobs of agroecosystems in the Sergipano coastal tablelands in its eighth year of conduction.

MATERIAL AND METHODS

The study area was conducted since 2001 in long-term experiment with ~~fifteen~~ years located in the central portion, physiographic region coast, at the experimental station of the agronomy department at the federal university of sergipe, municipality of são cristovão, state of sergipe, geographic coordinates 37°12'00" ~~w~~, 11°01'00" ~~s~~, with an altitude of 22 m above level of the sea. According to the köppen classification, the region's climate type as humid tropical with a dry season in summer, with an average annual temperature of 22 ° ~~c~~ and average annual rainfall of 1200 mm, concentrated in the months from april to september.

The soil is classified as argissolo vermelho-amarelo dystrophic tb, a moderate, sandy texture / clay frank, subperenepholia rain forest, gently rolling relief [9]. At the beginning of the experiment, the soil presented the following chemical and physical characteristics in the 0-10 cm layer: p~~h~~ (~~h_2o~~): 5.2; organic matter (om): 7.0 g kg^{-1}; p: 2.4 mg kg^{-1} and ~~k~~: 11.2 cmolc kg^{-1} [9]. The horizons present in the soil profile at the experiment site are: a (0 - 27 cm) and bt (28 - 77 cm), respectively with sandy texture (sand - 82.1%, silt - 12.5% and clay (sand - 15.4%, silt - 24.7% and clay - 59.9%) [10].

The experimental design was a randomized block in a 3x4 factorial design, resulting from the adoption of three soil tillage systems: conventional tillage (ct), minimum tillage (mt) and no-tillage (nt); and four crops predecessor to maize were evaluated: beans (~~p~~haseolus vulgaris ~~l.~~), peanuts (~~a~~rachis hypogeae ~~l.~~), guandu (~~c~~ajanus cajan (~~l.~~) Millsp.) ~~A~~nd ~~crotalaria~~ (~~c~~rotalarea juncea). Twelve experimental plots with an area of 60 m² (6 m x 10 m) were implanted, with three replications, totaling 36 experimental plots and space between the plots to allow the maneuver of agricultural machines and implements

Annually, before the implantation of the predecessor crops between the months of january to march and the sweet maize 90 days later, the soil preparation was performed according to the management systems adopted.

The ct was adopted the sequence: harrowing (grading of mixed discs), plowing (disc plowing) and re-harrowing. In mt, 1 or 2 harrows were used with open disc leveling, depending on the incidence of invasive plants. The nt was applied the non-tillage of the soil, and for the control of invasive we used broad-spectrum action herbicide (glyphosate) at the dosage associated with manual weeding, when necessary.

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After the flowering of the predecessor crops, the biomass generated was cut and fed into each plot. In the fertilization of the previous crops, urea, triple superphosphate and potassium chloride were used, corresponding to 60, 80 and 70 kg ha-1, respectively of n, p and k, n being applied 50% at sowing and 50% at 30 days after germination of the seedlings.

Then, sweet maize (do-005 dow agroscience) was planted with a manual seeder, spacing 0.9 m between rows and 0.2 m between pits. The nutrients applied at the these values were obtained based on the soil analysis and recommendations established for the maize crop, according to [11]. Liming for soil acidity correction and calcium and magnesium supply is carried out according to the chemical analysis of the soil, following the technical recommendations for the maize crop in the state of sergipe [11].

The parameters of evaluation of maize yield were: number of spikes, number of productive plants, weight of green spikes and relation between number of plants with spikes and total number of plants; being these parameters measured for each systems of preparation of the soil and culture antecedent to the maize.

All data were submitted to analysis of variance and the means were compared by the tukey test at the 5% probability level in the sisvar software [8].

Time of maize sowing consisted of nitrogen in the form of urea (45% of n), phosphorus in the form of triple superphosphate (42% of p_2o_5) and potassium in the form of potassium chloride (58% of k_2o), corresponding to 120, 90 and 110 kg ha-1, respectively n, p and k, with n applied 50% at sowing and 50% at 30 days after seedling germination

RESULTS AND DISCUSSION

In relation maize productivity (Table 1), it was observed that there was a significant statistical difference at the 5% probability level between the cropping systems, as well as between the previous maize crop.

Table 1. Maize productivity in commercial spikes of green maize with straw, under different cropping systems and associated with previous crops

Culture in succession	Productivity (kg ha^{-1})		
	CT	MT	NT
Peanuts	2.353,00 d*	6.920,00 b	9.554,00 b
Beans	4.286,00 c	6.174,00 d	9.674,00 a
Crotalária	5.103,00 a	7.263,00 a	9.004,00 c
Guandu	4.808,00 b	6.473,00 c	8.438,00 d

*Means followed by the same letter do not differ from each other (Tukey test at 5% probability)

From the data presented in Table 1, it can be observed that the NT system, after eight years, can yield higher yield (kg ha^{-1}) in average terms of commercial spikes of green maize compared to the other cultivated systems studied (over 1/3 higher than the MT and 2.22 times larger than the CT), under the edaphoclimatic conditions of the Sergipano Coastal Board. This superiority is attributed to the benefits inherent to such cultivation practice, for example: because the soil is not mobilized, the conservation of water in the soil profile for a longer period of time and quantity, probably due to the better biological activity observed field, resulting in better soil structuring; lower rate of change of soil temperature; higher fertility of the layer explored by the roots, due to the slower mineralization rate of the previous crops and less occurrence of losses of the layer due to water and wind erosion; greater maintenance of aggregate stability, improving soil structure; and lower subsurface compaction [12],

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due to the presence of the biological pores of the previous crops, mainly the pigeon pea and the crotalaria.

The NT system underwent a great technological evolution, faced with the requirements to ensure productions equivalent to or superior to those of conventional methods of soil preparation. These include the use of soil cover plants (green manures), adapted to local soil and climatic conditions, with nutrient fixation and / or recycling capacity, giving greater protection to the soil and greater productivity of the agronomic crop [13].

Thus, in addition to the management system adopted, the choice of the use of soil cover crops - previous crops also affects the productivity of agronomic crops. According to [14], the use of cover crops is an alternative to increase the sustainability of agricultural systems, and can restore considerable nutrients to crops, since these plants absorb nutrients from the subsurface layers of the soil and later release them into the soil. surface layer by the decomposition of its residues.

Thus, hedging plants established with a suitable cropping system is a strategy for improving soil quality in agroecosystems and reducing the harmful effects of monoculture. Based on the data in Table 1, it can be observed that all previous crop species, both commercial crops (peanuts and beans) and soil cover crops (pigeon pea and crotalaria) caused statistically significant differences in yield values of maize cobs in each of the cropping systems studied.

In average terms, commercial crops promoted higher maize productivity compared to soil cover crops, when conventional (50% higher) and minimum (5% higher) cultivation systems were adopted. On the other hand, when the PD system was adopted, commercial crops (peanuts and beans), which when used prior to maize, provided higher yields (10% higher) of maize. Probably this result is due to the fact that the PD conservation system offers better soil conditions for the potential expression of the commercial crops that leave more significant benefits, and potentially more useful for the subsequent maize crop (Table 1).

In this sense one of the main challenges for the implementation of conservationist systems in the Coastal Tablelands Sergipano is the definition of species of plants of cover of the ground adapted to the local edaphoclimatic conditions. These plants must at the same time have as outstanding characteristics, rapidity of establishment and phytomass production; ease of management [15]; aggressive and abundant root system with high biomass production contributing to reduce the effects of soil compaction a common problem in CT crops [3] possibility of commercial use; and potential of not hosting pests and diseases that attack the crop of agronomic interest, as well as support to soils with medium to low fertility, as is the average condition of the horizons A of the Argissolos coming from the barreiras sediments present in the coastal tablelands.

The advantage of the use of cover crops of the Fabaceae family, such as those used in this study, is linked to their biomass accumulation potential and their ability to supply nitrogen to the successor crop [16]. [17] report that crops in precession to maize with low nitrogen availability compromise the development and yield of grains, due to the high carbon to nitrogen ratio (C/N), immobilizing a good part of the nitrogen present in the soil. This observation should also be taken into account for maize cultivation, aiming at an acceptable productivity, translating into nitrogen fertilizer economy by the rapid decomposition and utilization by the residual N maize available to the soil by the biological fixation.

In this sense, the forage of legume crops to maize within a system of conservationist cultivation like the NT favors the increase of the productivity, due to the improvement of the physical properties of the soil due to the effect of its root system and biomass; and improvement of its chemical behavior, due to the higher nitrogen input to the soil, since the crop is very demanding about this nutrient, translating into higher productivity, as obtained in the present experiment (Table 1).

Thus, it is observed that crotalaria when grown in succession to maize provided higher maize productivity in relation to commercial crops such as beans and peanuts in the cropping system in which there is soil revolving (CT and MT), characterizing itself as a plant of important coverage for the agroecosystems of the Sergipe coastal tablelands, that adopt these systems of soil management [18] in a work carried out under Latossolo Vermelho Distroferrico, cultivated in NT, involving crop rotation systems with seven different cover crops, identified that crop rotation positively influences the productivity of maize grown under NT when cultivated after sunbathing and vetch.

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At the end of the eighth year of conduction, the NT system associated with the bean predecessor crop provided better maize yield, the peanut crop associated with the MT system occupied the second position in terms of the production of green maize in spikes (Table 1). Beans are among the plant species most associated with maize planting (in precession, succession and consortium), because they provide a positive economic income, thus being economically viable for income generation and with this, making it easier to acquire the technological package of maize.

In a study conducted under Latossolo Vermelho distroférrico, [19] found that there is interaction between soil management and crop rotation under maize productivity, when adopted NT, considering two complete cycles of crop rotation (maize / common bean / maize / common bean). The authors observed relatively higher yields of maize and beans in relation to the other associations, which leads to higher gross income per hectare, corroborating with the results found in this study.

Differing from the results found in an experiment conducted by [20], conducted in Latossolo Vermelho distroférrico in the experimental farm of Embrapa in Santo Antônio de Goiás-Go, aiming to determine how much soil preparation systems and crop rotations (bean), affect the yield of maize, soybean and wheat grains, it was verified that there was no effect of crop rotation on maize yield.

However, the antecedent culture of guandu did not provide high levels of maize production regardless of the management system adopted (Table 1). However, it stands out for its phytomass production, its cultivation on the Sergipe coastal tablelands being culturally very important for the exploitation of agroecosystems mainly in crops for family agriculture, reinforcing the potential of this crop in this agricultural region.

Therefore, maize cultivation, in succession to leguminous plants in conservationist systems such as NT and MT, can provide improvement in soil quality, translating into higher productivity, increasing the profitability and sustainability level of agricultural activity. Thus, the relative high yield of maize reached in this study by the NT (9.2 t~~on~~ ha^{-1}), followed by the MT (6.7 t~~on~~ ha^{-1}), is justified, although limitations exist in the Sergipe coastal tablelands as presence of a cohesive layer of pedogenetic character and irregular rainfall distribution (spatial and temporal variability), where 70% of the precipitation is concentrated in a continuous period of 5 to 6 months.

Linked to plant residues of cover crops, the cultural remains left by maize on the soil surface can be of great importance to the conservation of soil moisture, improving the microbiological activity of the soil, especially in the tropical regions. These residues also decrease soil losses due to erosion, since maize straw has a slower decomposition than legumes due to high C/N ratio, contributing to the reduction of decomposition rate and slower release of nutrients in the soil [21], with physical protection of soil, both radiation and raindrops.

The intense oxidation rate of organic matter, conditioned by high humidity and temperature for a good part of the year, typical conditions in the Sergipe coastal tablelands, provide the most transient "umbrella" effect of plant residues and the positive effects of organic matter on the soil by the rapid decomposition of the deposited phytomass, releasing nutrients that can be harvested by maize. Thus, the legume consortium as covers plants and antecedents (low C/N ratio), with the residues of maize (high C/N ratio), condition of the present experiment, can reconcile soil protection and fertilization, as well as the greater perenniality of these conditions [22]. In this way, the agroecosystem is established at an adequate level of resilience, thus promoting higher levels of sustainability without compromising the productive potential of the agronomic crops.

This improved balance of the agroecosystem in the NT has provided a lower incidence of spontaneous plants, pests and diseases, while the CT system, where there was intense soil rotation, besides providing lower maize productivity, showed a higher incidence of pests and spontaneous plants, probably due to the more stressful conditions for the maize crop [23] in a study under the influence of the bean culture on the dynamics of spontaneous plants during the cycle of cultivation of organic maize under NT and CT systems, under Argissolo Vermelho Amarelo, verified different effects of the bean straw and other antecedent crops under the quantity and variability of the population of spontaneous plants, as well as in the control of these plants. This is probably due to the selective character of the allelopathic effects of the residues of the previous cultures on the invasive ones, providing positive effects for the subsequent maize crop, reducing its population and consequent competition with the maize plants, as observed in the present study.

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It is worth noting that maize productivity is determined among other factors by the number of plants, number of spikes per plant, accumulation of green mass in the spikes measured by weight (kg) and the relation between.

Number of plants with spikes and the total number of plants. This last parameter shows that although some crops may present a greater number of plants, which translates into greater phytomass production, this higher quantity will not always indicate a higher yield of spikes or grains.

Thus, when evaluating the potential of maize plants to produce commercial spikes of green maize at average ha per hectare under different cropping systems and after the succession of the four previous crops studied (Table 2) indicates that there were sensible numerical differences NT in relation to the other cultivation systems studied (5% between NT and MT and 4% between NT and CT). This was a result of the number of plants per hectare and number of plants with commercial spikes, showing that the NT provides better conditions for the development of the plants, resulting in a better stand, as these plants were able to express higher production of commercial spikes, translated by their statistically significant differences between their superior means for NT.

Table 2. Number of maize plants, spikes per hectare and percentage of plants with commercial spikes in the different cropping systems.

Cultivation system	Number plant~~as~~ ha-1	Number spikes ha-1	Number plant~~a~~s with spikes /Total plants (%)
CT	28683 c*	24632 c	85
MT	42559 b	35679 b	84
NT	44382 a	39679 a	89

*Means followed by the same letter do not differ from each other (Tukey test at 5% probability).

In this way, it was observed that the NT system presented, in addition to a larger number of plants, a higher number of commercial spikes, in relation to the other cultivation systems (CT and MT), and in the CT resulted in the lower quantitative of both plants like spikes per hectare. These results are in agreement with the results obtained in the third year of cultivation of the experiment, a situation of behavior that has been repeated, confirming that NT for providing conditions for better maize development, translates into higher productivity and efficiency of the plants in this variable.

The data observed in this study are also in agreement with the results found by [24], who affirm that NT provides larger plant populations and number of spikes per hectare when compared to the other cultivation systems. It is also worth noting that the NT increased production of 5,030.00 kg ha^{-1} of maize in relation to the CT and 2,460.00 kg ha^{-1} in relation to the MT, corresponding to an increase of 54.86 and 26.83% respectively, in relation to ND.

The average productivity achieved in this study, even for conservation systems, is considered low in relation to the national average (12 t~~on~~ ha^{-1}), according to [25]. When comparing the data obtained in the study with the results obtained by [5], in Latossolo Vermelho Eutrofico in Uberlândia-MG, when evaluating the yield of spikes with straw and yield of eight hybrids of common and green maize as a function of harvest intervals with average productivity of 20,15 ton ha^{-1} (26 days after flowering), confirm that the data in this study are below a potential level. It is worth mentioning that the markedly coastal soil conditions are of low fertility and drainage difficult in the period of intense rains (due to the presence of the textural B horizon) and in small summer, making water retention difficult (due to texture horizon A sandy), translating into low productivity.

Similar results were also found by [26], that also, studying green maize hybrids, obtained average yield of spikes with straw of 12 t~~on~~ ha-1; and by [27], which also evaluated thirty six maize cultivars in Ijaci-MG, obtaining on average a yield of 13.03 ton ha-1 of green maize cobs. It is understood that this difference is due to the local edaphoclimatic characteristics (of the Sergipe coastal tablelands), which as emphasized by [28],, are responsible for 60% of the maize production, associated with the genetic characteristics of the hybrids studied, responsible for 40% of the productivity achieved.

In this way, the NT system, in addition to contributing to soil conservation, can guarantee a real possibility of profitability for farmers, with long-term cultivation, increasing maize productivity both for

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phytomass (for soil cover maintenance or production (Tables 1 and 2), without raising the cost of production, evidencing the efficiency of this management system under the soil and climate conditions of the Sergipe coastal tablelands. It should be noted that crop productivity and consequently its financiais profitability is one of the main determining factors for susceptibility in the adoption of new technologies.

CONCLUSIONS

Conservation management systems: NT followed by MTprovide higher yields of maize when compared to conventional cultivation, when associated with the presence of predecessor crops. From the predecessor crops studied for maize cultivation, crotalaria cultivation provides higher yields of maize in commercial spikes of green maize, under the systems of minimum cultivation and conventional cultivation. The NT system, the bean's predecessor crop, provides a bigger stand, maize productivity and efficiency per plant of the production of commercial spikes of green maize, markedly when compared to MT and mainly CT.

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