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# SOIL TILLAGE TO PRODUCE CASSAVA ROOTS WITH LESS PHYSICAL LIMITATIONS IN PASTURE SUCCESSION

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**ABSTRACT -** Traditional cassava cultivation involves mechanical manipulation of the soil with one plowing and two harrowings, a practice that may generate problems such as soil erosion, compaction and nutrient loss. These issues may be even bigger in sandy soils. The objective of this study was to evaluate the cassava roots components and the soil physical attributes in planting rows and between planting rows in tillage systems substituting the conventional tillage before the Mombasa grass pasture (*Panicum maximum*), in Northwestern Paraná, Brazil. Soil tillage treatments in 2014 were carried out as follows: conventional (disc harrow, moldboard plow and disking), minimum (disc harrow and chisel plow - clod breaking) and zero tillage. In 2015, soil samples were collected in layers 0.0-0.1, 0.1-0.2 and 0.2-0.4 m deep**,** between, and within cassava planting rows, for soil bulk density and macroporosity determinations. Number of plants, number of tuberous roots per plant, fresh and dry mass of cassava tuberous roots were evaluated as well. The soil physical attributes within the planting rows negatively affected the production of cassava tuberous roots in zero tillage in succession to the Mombasa grass pasture. The minimum and conventional tillage systems did not present soil physical limitations to the cassava yield components in succession to Mombasa grass pasture. Minimum tillage may be an alternative to conventional tillage without compromising soil physical attributes and cassava root yield in the Mombasa pastureland reform areas, in northwestern Paraná.
**Keywords:** *Manihot esculenta* Crantz, soil compaction, soil bulk density, soil management.

**RESUMO -** O sistema tradicional de cultivo de mandioca envolve o preparo do solo mecanizado através de uma aração e duas gradagens, que podem ocasionar problemas de erosão, compactação e perdas de nutrientes do solo, acentuado em áreas arenosas. O presente trabalho teve o objetivo de avaliar os atributos físicos do solo nas entrelinhas e linhas de plantio e os componentes de produção de raízes tuberosas de mandioca em sistemas de preparo do solo, para a substituição do preparo convencional em sucessão a pastagem de capim-Mombaça (*Panicum maximum*) no Noroeste do Paraná. O delineamento experimental utilizado foi o de blocos casualizados com três tratamentos de preparos do solo e cinco repetições. Os tratamentos de preparo do solo, realizados em 2014, foram: convencional (grade aradora, arado de aiveca e grade niveladora), mínimo (grade aradora e escarificador-destorroador) e plantio direto. Em 2015 foram coletadas amostras de solo nas camadas de 0,0-0,1, 0,1-0,2 e 0,2-0,4 m das entrelinhas e linhas de plantio de mandioca para determinações de densidade e macroporosidade do solo e avaliou-se o estande de plantas e número, massa fresca e seca de raízes tuberosas de mandioca. Os atributos físicos do solo entre as linhas no plantio direto, influenciaram negativamente a produção de raízes tuberosas de mandioca em sucessão ao capim Mombaça. Os sistemas de cultivos mínimo e convencional em sucessão ao capim Mombaça não proporcionaram limitações físicas de solo nos componentes de produção da mandioca. O cultivo mínimo pode ser uma alternativa ao sistema convencional, sem comprometer os atributos físicos do solo e o rendimento da mandioca, em áreas de reforma de pastagens com capim Mombaça no Noroeste do Paraná.
**Palavras-chave:** *Manihot esculenta* Crantz, compactação do solo, densidade do solo, manejo do solo.

## INTRODUCTION

Empirical attempts by farmers to reduce the intensity of soil tillage in grassland reform areas, presenting a sandy surface layer (EMBRAPA, 1984) in northwestern Paraná, and in Mato Grosso do Sul, São Paulo and Parana States (SALLUN et al., 2007, SALLUN et al., 2008), did not benefit cassava root yield, as occurs in areas of temporary crops such as oats, forage turnips or millet (WATANABE et al., 2002; PEQUENO et al., 2007). For this reason, cassava continues to be cultivated under conventional tillage for pastureland reclamation. Usage of these soils through conventional soil tillage accentuates the physical degradation (GUIMARÃES et al., 2013) and soil losses due to water erosion (SOUTO et al., 2013).

Since 1980's, there has been research demands to reduce soil tillage intensity for cassava cultivation (HOWELER et al., 1993). After three decades, Fasinmirin and Reuchert (2011) presented a literature review on soil tillage for cassava production, confirming the viability of cassava planting under zero tillage.

Cassava root yield responses in Paraná under conventional, minimum and no-till soil tillage are contradictory between and among basalts (GABRIEL FILHO et al., 2000) and sandstone (PEQUENO et al., 2007) formations. In basalt areas there was no difference

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in cassava root productivity of clay textures soil tillage, even though Gabriel Filho et al. (2000) verified that the minimum tillage can replace the conventional tillage on black oats**,** or vetch residues because these cover crops reduced the compaction at the 0.0-0.1 m layer.

In sandstone soils of the Northwest of Parana, the cassava tuberous roots preferentially develop within a cohesive granular structure soil layers, 0.0-0.1 0.1-0.2 m deep (EMBRAPA, 1984), because the stems are planted horizontally 0.1 m deep maximum tuberous roots yield (GABRIEL FILHO et al., 2003). After black oats cover crop, Tormena et al. (2004) and Pequeno et al. (2007) observed a decrease of tuberous roots yield under no-tillage due to the excessive soil penetration resistance values and reduced values. For Iderawumi and Mubo (2014) the cassava roots productivity is inversely proportional to soil bulk density.

Studies on soil tillage systems for cassava cultivation do not specify whether physical attribute evaluations were made or between planting rows. This work intended to verify whether zero tillage, or minimum tillage systems would not be failing to correct the soil physical attributes between and within planting rows in comparison to the conventional tillage soil tillage systems influence cassava production components (FIGUEIREDO et al., 2014).

At present, when pastureland requires restoration in northwestern Parana sandy soils, farmers go for conventional tillage due to lack of research information to substitute conventional tillage**,** even though there is negative effect on soil, due to excessive soil movement at harvest (SUMITHRA et al., 2013), and water erosion with this system (LIMA et al., 2015). In parallel, there are stimuli to conventional tillage as opposed to other soil tillage options for cassava cultivation (ODJUGO, 2008; LAMIDI, 2016).

The objectives of this work were to evaluate the physical soil attributes between and within planting rows, the cassava tuberous roots production components in soil tillage systems and the possibility to substitute cassava conventional tillage in succession to the Mombasa grass (*Panicum maximum* L.), in the northwestern Parana.

## MATERIAL AND METHODS

The experiment was installed in the Alto Paraná city at Northwestern Paraná (23º 05'S, 52º 26'W and 520 m above sea level). The climate classification in the region is *Cfa*, according to Köppen. During the experiment, minimum and maximum monthly temperatures ranges were 15 to 22ºC and 22 to 33ºC, respectively, and total rainfall was 1675 mm (Figure 1).

Soil type is a Haplorthox or Rhodic Ferralsol (SANTOS et al., 2013), sandy texture (0.0-0.2 m; 120 g kg$^{-1}$ clay) and average (0.2-2.0 m; g kg$^{-1}$ of clay). Soil chemical analysis data prior to the experiment, sampled in July 2014, at 0.2 m deep, showed 11.00 mg dm$^{-3}$ of P and 0.30 cmol$_c$ dm$^{-3}$ of $K^+$ (Mehlich$^{-1}$ Extractor); 1.60 cmolc dm$^{-3}$ Ca $^{2+}$ and 0.61 cmol$_c$ dm$^{-3}$ $Mg^{2+}$ (KCl Extractor 1 mol L$^{-1}$); 12.07 g dm$^{-3}$ of organic matter (Walkley-Black) and pH in $CaCl_2$ of 4.97 ($CaCl_2$ solution 0.01 mol L$^{-1}$) and 5.05 cmol$_c$ dm$^{-3}$ of CTC (pH 7.0).

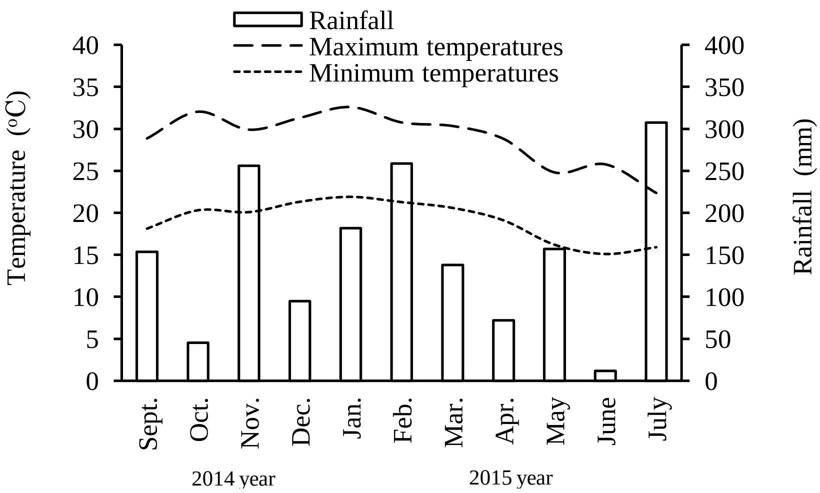


**FIGURE 1 -** Rainfall and maximum and minimum average temperatures during the experiment at Paranavaí Meteorological Station (Brazil) for 2014/2015.

The experimental area was previously occupied with *Panicum maximum* cultivar Mombasa grass for three years with beef cattle raising before the experiment setup. The pasture was desiccated in June 2014 with 3 L ha$^{-1}$ glyphosate. Subsequently, moldboard plow was passed in the total area, as the dried grass was approximately 1 m tall. The experimental design was a randomized block with three treatments (soil tillage) and five replications in plots of 270 m$^2$. Soil treatment tillages were carried out in September 2014, as follows: conventional (disc harrow, moldboard plow at 0.25 m deep and disking), minimum tillage (disc harrow and chisel plow-break-clods plow at 0.35 m) and zero tillage (without any mechanical intervention in the soil).

Cassava cultivar IAC 90 had the stems mechanically planted horizontally at the depth of 0.08-0.10 m, on September 15, 2014. The 2-row planting machine was composed of a cutting disk, two discs to open the groove, compactor wheel and cover disc, at a spacing of 0.9 m between rows and 0.6 m between plants in the row, giving a population of 18,519 $ha^{-1}$ plants. The sampling area in the plots occupied an area of 48.6 $m^2$, consisting of 6 useful rows of 9 m in length and 90 total plants. Fertilization was done with 148 kg $ha^{-1}$ of $K_2O$ as potassium chloride**,** and 52 kg $ha^{-1}$ of N as ammonium sulphate 68 days after sprouting.

Undisturbed soil samples were collected in April 2015, in each experimental plot, using a 0.05 m-high/0.05 m-diameter metallic cylinders, in the intermediate layers of 0.0-0.1; 0.1-0.2 and 0.2-0.4 m deep. Samples were taken between and in planting rows, avoiding samples with cassava tuberous roots. Subsequently, these soil samples were saturated and submitted to 60 hPa in a tension table. These samples were oven dried at 105°C for 24 h to determine soil macroporosity and bulk density (DONAGEMA et al., 2011).

The experiment was harvested on June 17, 2015, and the number of plants, number of tuberous roots per plant (number of total roots of the plot divided by the number of plants) and fresh and dry masses of the tuberous roots were evaluated. The dry matter of the roots was obtained through a sample of 0.5 kg of fresh roots, which were dried in air forced circulation oven at 60$^{o}$C until constant weight. The physical attributes of soil and the components of cassava production were submitted to analysis of variance, tests of means comparisons and Pearson simple correlations (BANZATTO and KRONKA, 2006), using a confidence level of 5%.

## RESULTS AND DISCUSSION

Soil bulk density and macroporosity between cassava rows did not differ among the three treatments (Table 1). This meant that the traffic of machinery and equipments between the rows used to manage the cassava crop equally impacted the physical attributes of soil, both in the treatments with soil movement (minimum and conventional tillage) as in the treatment without soil movement (zero tillage). Gabriel Filho et al. (2000) also did not find differences in soil density between conventional and minimum tillage. However, such results diverge from work done in similar soils by Tormena et al. (2004). These results differences may be related to the crop existing before cassava planting**.** In the present study cassava succeeded a 3-year Mombasa pasture, whereas in the works carried out by Tormena et al. (2004) black oats had been grown previously.

**TABLE 1 -** Soil bulk density and macroporosity between (BPR) and within cassava planting rows (WPR) in three soil layers, for zero tillage, minimum tillage and conventional tillage.

| Treatments | Density | | Macroporosity | |
|---|---|---|---|---|
| | BPR | WPR | BPR | WPR |
| | ------------------ kg $dm^{-3}$ ----------------- | | ------------------ $dm^3$ $dm^{-3}$ ------------------- | |
| | | Layer (0.0-0.1 m) | | |
| Zero tillage | 1.64 a* | 1.51 a | 0.21 a | 0.26 a |
| Minimum tillage | 1.56 a | 1.38 b | 0.24 a | 0.32 a |
| Conventional tillage | 1.55 a | 1.37 b | 0.22 a | 0.31 a |
| | | Layer (0.1-0.2 m) | | |
| Zero tillage | 1.74 a | 1.67 a | 0.12 a | 0.17 b |
| Minimum tillage | 1.70 a | 1.59 a | 0.16 a | 0.23 a |
| Conventional tillage | 1.72 a | 1.60 a | 0.15 a | 0.22 a |
| | | Layer (0.2-0.4 m) | | |
| Zero tillage | 1.75 a | 1.71 a | 0.06 a | 0.08 a |
| Minimum tillage | 1.76 a | 1.63 a | 0.06 a | 0.15 a |
| Conventional tillage | 1.75 a | 1.71 a | 0.07 a | 0.10 a |

*Means followed by the same letters do not differ for the Tukey test at $P \leq 0.05$.

Within planting rows, the minimum and conventional tillage had lower soil density in the 0.0-0.1 m layer (Table 1). In similar soils, no-tillage after cassava cultivation maintained a higher soil bulk density in the superficial layer at depth of 0.15 m (OLIVEIRA et al., 2001; WATANABE et al., 2002; TORMENA et al., 2004). Cassava in zero tillage (without soil movement) increased the frequency of soil samples with density above the critical levels in the 0.0-0.15 m layer**,** in similar soil cultivated with cassava in succession to black oat (CAVALIERI et al., 2006; GUIMARÃES et al., 2013). Therefore, there is a consensus that without soil tillage there is a negative effect of the soil surface layer physical attributes when sandy soils are cultivated to cassava in northwestern Parana (OLIVEIRA et al., 2001; WATANABE et al., 2002; TORMENA et al., 2004; CAVALIERI et al., 2006; GUIMARÃES et al., 2013).

A macroporosity reduction within cassava rows in the 0.1-0.2 m soil layer was observed in the zero tillage compared to conventional and minimum tillage (Table 1).

This result confirms the low influence of the equipment used for soil tillage on the physical attributes in the 0.1-0.2 m layer**,** as it constitutes a transition between the surface horizon of sandy texture with granular structure and Bw horizon of sandy loam texture (FIDALSKI, 2015).

The conventional and minimum tillage reduced the soil bulk density in the 0.0-0.1 m layer within planting rows, as well macroporosity in the 0.1-0.2 m layer when compared to zero tillage (Table 1). The results of this study were similar to those obtained by other authors in soil tillage systems with the use of cover crops (OLIVEIRA et al., 2001; GABRIEL FILHO et al., 2000; WATANABE et al., 2002; TORMENA et al., 2004; SILVA et al., 2008). Only zero tillage presented physical limitations within planting rows of the physical attributes in different positions of the undisturbed soil samples.

The number of cassava plants was higher in minimum tillage than in zero tillage, with conventional tillage being intermediate (Table 2). Regarding the number of roots per plant, conventional tillage showed higher values than zero tillage and both were not different from the minimum tillage. For this production component**,** zero tillage showed the lowest fresh and dry cassava roots yields (r = 0.99) as compared to conventional and minimum tillages. These results differ from those obtained in similar soil by Watanabe et al. (2002) and Pequeno et al. (2007), where they obtained higher cassava productivity in conventional tillage system. These differences are due to the temporary culture preceding cassava (GABRIEL FILHO et al., 2000). For this reason, farmers of northwestern Parana do not adopt zero tillage for cassava in areas of pasture reform**,** opting for conventional soil tillage**,** with disc harrow, moldboard plow and disking, to improve soil conditions.

**TABLE 2 -** Cassava root yield components in zero tillage, minimum tillage and conventional tillage.

| Treatments | Number of plants(1) | Cassava root | | |
|---|---|---|---|---|
| | | Number(2) | Fresh mass | Dry mass |
| | (%) | | ---------------- t ha$^{-1}$ ---------------- | |
| Zero tillage | 76.35 b* | 2.08 b | 13.93 b | 5.26 b |
| Minimum tillage | 83.81 a | 2.74 ab | 21.03 a | 7.98 a |
| Conventional tillage | 81.27 ab | 3.09 a | 25.13 a | 9.42 a |

(1)Proportion in relation to total plants, (2)Total tuberous root number in plots, divided by the number of plants. *Averages followed by the same letters do not differ for the Tukey test at $P \leq 0.05$.

The choice of the cassava planting machine with disc systems without furrow-opening shaft is probably due to the difficulty of equipment adaptation**.** There is a need to adapt the chassis and the distance between the discs and the respective shaft. However, the disc-only planter was not efficient to provide adequate soil physical conditions for cassava sprouting-in zero tillage (Table 1).

The number of plants negatively correlated with soil density at the 0.0-0.1 m layer between the rows of the minimum tillage**,** and within planting rows of zero tillage, however, there was negative correlations between soil density and fresh root masses only in zero tillage (Table 3). These correlations confirm that cassava fresh and dry roots decreased with higher soil bulk density within planting rows (Tables 1 and 2), similarly to the observed by Iderawumi and Mubo (2014).

Soil macroporosity correlated with number and fresh and dry roots in the minimum tillage 0.1-0.2 m layer (Table 3). These correlations are associated to the higher values of the cassava root yield components under minimum tillage than under zero tillage (Table 2), benefiting from the increase of soil macroporosity with minimum tillage (Table 1). Improvement of the physical quality for similar soil in the 0.1-0.2 m layer was verified by Fidalski (2015), for establishing greater soil porosity continuity between A and Bw horizons in Haplorthox or Rhodic Ferralsol.

The correlations between the dry matter of cassava roots and the physical attributes of the soil at 0.2 m depth (Table 3) enabled to confirm that zero tillage negatively affects of cassava roots productivities in sandy soil in northwestern Parana, being more apropriate the minimum tillage in these soils (OLIVEIRA et al., 2001; WATANABE et al., 2002; TORMENA et al., 2004; CAVALIERI et al., 2006; GUIMARÃES et al., 2013).

Cassava under minimum tillage in succession to established pasture is an option that would meet the assumptions of less physical limitation within planting rows and higher cassava root yields (Tables 1, 2 and 3). Suggestions to substitute the conventional for minimum tillage were reported by Gabriel Filho et al. (2000), Pequeno et al. (2007) and Otsubo et al. (2008), in order to minimize soil losses due to erosion losses when cassava succeeds established pastureland (SOUTO et al., 2013, LIMA et al., 2015).

For management of similar sandy soils in the states of Mato Grosso do Sul, São Paulo and Paraná (SALLUN et al.; 2007, SALLUN, 2008), differentiated soil tillage could be considered for cassava depending on the previously usage of the soil, in accordance with results of the present study: a) minimum soil tillage in pasture areas and b) zero tillage when soil has been used in cropping-husbandry integration systems, when annual pasture is planted in fall to be managed in winter, in succession to soybean (WATANABE et al., 2002; PEQUENO et al., 2007; FASINMIRIN and REICHERT, 2011). Thus, the farmers and technical assistance would be reducing risks of soil physical degradation and cassava tuberous root yield reduction, taking the technical decision reducing the management intensity of the conventional tillage in areas requiring pasture reclamation and areas cultivated in zero tillage with oats, millet and annual forages.

**TABLE 3 -** Correlations between soil bulk density and macroporosity with cassava root yield components, between (BPR) and within (WPR) planting rows, in two soil layers under zero tillage (ZT), minimum tillage (MT) and conventional tillage (CT) systems.

| Treatments | Soil layer | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (0.0-0.1 m) | | | | (0.1-0.2 m) | | | |
| | Density (kg dm$^{-3}$) | | Macroporosity (dm$^3$ dm$^{-3}$) | | Density (kg dm$^{-3}$) | | Macroporosity (dm$^3$ dm$^{-3}$) | |
| | BPR | WPR | BPR | WPR | BPR | WPR | BPR | WPR |
| | Number of plants (%) | | | | | | | |
| ZT | -0.82$^{ns}$ | -0.95$^{*}$ | 0.09$^{ns}$ | 0.70$^{ns}$ | 0.54$^{ns}$ | -0.33$^{ns}$ | -0.81$^{ns}$ | 0.47$^{ns}$ |
| MT | -0.99$^{*}$ | 0.40$^{ns}$ | 0.61$^{ns}$ | -0.69$^{ns}$ | -0.80$^{ns}$ | -0.59$^{ns}$ | 0.62$^{ns}$ | 0.66$^{ns}$ |
| CT | -0.45$^{ns}$ | -0.69$^{ns}$ | 0.47$^{ns}$ | 0.25$^{ns}$ | -0.30$^{ns}$ | -0.21$^{ns}$ | 0.03$^{ns}$ | 0.13$^{ns}$ |
| | Root number | | | | | | | |
| ZT | -0.48$^{ns}$ | -0.64$^{ns}$ | -0.48$^{ns}$ | 0.14$^{ns}$ | 0.03$^{ns}$ | -0.83$^{ns}$ | -0.49$^{ns}$ | 0.87$^{ns}$ |
| MT | -0.83$^{ns}$ | 0.91$^{*}$ | 0.53$^{ns}$ | -0.86$^{ns}$ | -0.65$^{ns}$ | -0.80$^{ns}$ | 0.50$^{ns}$ | 0.90$^{*}$ |
| CT | -0.51$^{ns}$ | 0.08$^{ns}$ | 0.49$^{ns}$ | -0.40$^{ns}$ | -0.40$^{ns}$ | 0.19$^{ns}$ | 0.32$^{ns}$ | 0.12$^{ns}$ |
| | Root fresh mass (t ha$^{-1}$) | | | | | | | |
| ZT | -0.37$^{ns}$ | -0.46$^{ns}$ | 0.55$^{ns}$ | -0.05$^{ns}$ | -0.11$^{ns}$ | -0.91$^{*}$ | -0.35$^{ns}$ | 0.87$^{ns}$ |
| MT | -0.86$^{ns}$ | 0.96$^{*}$ | 0.50$^{ns}$ | -0.76$^{ns}$ | -0.54$^{ns}$ | -0.75$^{ns}$ | 0.44$^{ns}$ | 0.88$^{*}$ |
| CT | -0.44$^{ns}$ | 0.23$^{ns}$ | 0.40$^{ns}$ | -0.19$^{ns}$ | -0.28$^{ns}$ | -0.11$^{ns}$ | 0.17$^{ns}$ | 0.36$^{ns}$ |
| | Root dry mass (t ha$^{-1}$) | | | | | | | |
| ZT | -0.43$^{ns}$ | 0.52$^{ns}$ | 0.50$^{ns}$ | 0.01$^{ns}$ | -0.03$^{ns}$ | -0.90$^{*}$ | -0.42$^{ns}$ | 0.84$^{ns}$ |
| MT | -0.86$^{ns}$ | 0.95$^{*}$ | 0.50$^{ns}$ | -0.76$^{ns}$ | -0.54$^{ns}$ | -0.75$^{ns}$ | 0.44$^{ns}$ | 0.88$^{*}$ |
| CT | -0.49$^{ns}$ | -0.18$^{ns}$ | 0.46$^{ns}$ | -0.25$^{ns}$ | -0.35$^{ns}$ | -0.09$^{ns}$ | 0.24$^{ns}$ | 0.32$^{ns}$ |

* = significant, $^{ns}$ = not significant for the T test at $P \leq 0.05$.

## CONCLUSIONS

The soil physical attributes within the planting rows negatively affected the production of cassava tuberous roots in zero tillage in succession to the Mombasa grass pasture.

The minimum and conventional tillage systems did not present soil physical limitations to the cassava yield components in succession to Mombasa grass pasture.

Minimum tillage may be an alternative to conventional tillage without compromising soil physical attributes and cassava root yield in the Mombasa pastureland reform areas, in northwestern Paraná.

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