Universidade Federal Rural do Semi-Árido
Pró-Reitoria de Pesquisa e Pós-Graduação
http://periodicos.ufersa.edu.br/revistas/index.php/sistema

ISSN 0100-316X (impresso)
ISSN 1983-2125 (online)

EFFICIENCY OF SIMPLE SUPER PHOSPHATE IN THE VETIVER GRASS DEVELOPMENT SUBJECTED TO SOIL BIOENGINEERING[1]

RENISSON NEPONUCENO DE ARAÚJO FILHO [2*], FRANCISCO SANDRO RODRIGUES HOLANDA[3], IGHOR DIAQUINO MATIAS SANTANA[3], TIAGO DE OLIVEIRA SANTOS[3], DÁRIO COSTA PRIMO[4]

ABSTRACT- The development of vetiver grass (*Chrysopogon zizanioides* L.) has been evaluated under different levels of phosphorus on slopes of the right-side bank of the San Francisco River, in the municipality of Amparo do São Francisco, SE. Techniques of soil bioengineering were used, characterized by the combination of vegetated riprap with stakes, seedlings of vetiver grass and sediment retainers. The experimental design was randomized blocks with five doses (0, 4, 8, 12, and 16 g pit^{-1} of simple superphosphate) and five replicates. The growth of vetiver seedlings were observed in periods of 30, 60, 90, e 180 days, carrying out the following parameters: number of roots, external root surface, root density, root length, root length density, root and shoot dry weight, root and shoot fresh weight, and shoot length, at each evaluation period. The phosphorus doses and periods of morphological development interacted in all variables of plant biomass mentioned above. Higher superphosphate doses than 9.0 g pit^{-1} did not offer advantages in terms of cost-benefit for the production of vetiver seedings.

Keywords: Bank erosion. C*hrysopogon zizanioides*. Phosphorus. Root system.

EFICIÊNCIA DO SUPERFOSFATO SIMPLES NO DESENVOLVIMENTO DO VETIVER ASSOCIADO À TÉCNICA DE BIOENGENHARIA DE SOLOS

RESUMO - Avaliou-se o desenvolvimento do capim vetiver submetido a diferentes doses de fósforo em taludes da margem direita do rio São Francisco no município de Amparo de São Francisco-SE. Foram utilizadas técnicas de bioengenharia de solos, caracterizada pela associação do enrocamento vegetado com estacas de sabiá, mudas de capim vetiver e retentores de sedimentos. O delineamento experimental foi em blocos casualizados, com cinco doses (0, 4, 8, 12 e 16) g pit^{-1}de super fosfato simples no momento de plantio das mudas e cinco repetições. O crescimento do vetiver foi avaliado em 30, 60, 90 e 180 dias, realizando-se avaliações quanto ao número de raízes, superfície externa de raízes, densidade de raízes, comprimento de raízes, massa seca de raiz e massa seca da parte aérea dentro de cada período de avaliação. As doses de fósforo e os períodos de desenvolvimento morfológico interagiram nos parâmetros massa seca da parte aérea, massa seca da raíz, densidade de raíz, densidade de comprimento da raiz, numero de raíz, superfície externa, comprimento da parte aérea, comprimento de raíz. Doses de super fosfato simples maiores que 9.0 g pit^{-1} não apresentaram vantagens em custo-benefício na produção de mudas de vetiver.

Palavras-chave: Erosão marginal. C*hrysopogon zizanioides*. Fósforo. Sistema radicular.

*Autor para correspondência
[1]Recebido para publicação em 26/02/2014; aceito em 29/01/2015.
Parte da Dissertação de Mestrado do primeiro autor apresentada à Universidade Federal de Sergipe- UFS.
[2]Departamento de Agronomia, UFRPE, 52.171.900, Recife – PE, nepoaraujo@gmail.com.
[3]Departamento de Engenharia Agronômica, UFS, 49100-000, São Cristovão - SE, fholanda@infonet.com.br, ighordiaquino@hotmail.com, tiagoosantos@yahoo.com.br.
[4]Departamento de Energia Nuclear, UFPE, 50.740-540, Recife-PE, darioprimo@gmail.com.

INTRODUCTION

The lower course of the San Francisco River needed to have its hydrosedimentological behavior altered by changes in the river channel, through reservoirs dams for deployment of hydropower projects. Such disturbance resulted in the regularization of the flow and discharge of sediment, flood control, sediment retention, degradation of riparian vegetation, bank erosion, decline in margins, and loss of arable land (HOLANDA et al., 2008).

To control the erosion process, is necessary to use techniques with simple solutions, but with extensive operations in the watershed, to promote visual, ecological, and production improvements in the area (MONTEIRO et al., 2010). Among various techniques used to control erosion on the banks of streams, the soil bioengineering is presented as an alternative that allows the recovery of riparian vegetation, and has a low cost when compared to the works of civil engineering, being widely used in the stabilization of unstable slopes (HOLANDA et al., 2010).

This biotech is the use of biologically active elements formed by vegetation in soil, and sediment stabilization, combined or not with inert elements such as rock or geotextile materials, in order to contain the erosion on embankments of roads or watercourses (PHILLIPS; MARDEN, 2006). Vegetation plays an important role in controlling erosion on marginal slopes, since the ground cover with grass or herbaceous vegetation provides the most efficient protection against surface erosion by reducing the impact of rainfall on the bare soil (CHENG et al., 2003). Additionally, vegetation increases water infiltration and gives resistance and cohesion to the soil, provided by the root system (STOKES et al., 2009).

The vetiver grass (*Chrysopogon zizanioides* (L.) Roberty syn. *Vetiveria zizanioides* (L.) Nash), classified in the Poaceae family, is a perennial grass that is present in various climates, especially tropical and subtropical, commonly used in the recovery of degraded areas, especially in erosion control due to the presence of small rhizomes, and thin and matted root system, that can reach great depths, allowing the plant resistance to drought and runoff, permitting them to remain adhered to the soil aggregates (MICKOVSKI et al., 2005).

Among the features of the root system that can interfere in the soil stability and consequently on its erosion, are: the number of root (N), external root surface (S), root density (RD), and root length density (RLD). In this context, different recipients can change the morphological characteristics of the root and shoot system of seedlings (REUBENS et al., 2007). The knowledge of plant nutrient uptake mechanisms is an important tool used in the selection of fertilization to obtain full production. Phosphorus is a macronutrient present in the soil, which increases the production of the root system, stimulating the plant growth (HOLANDA et al., 1999).

Phosphorus deficiency in grasses causes decrease in the transport of assimilates, resulting in reduced leaf area and consequent low production, directly affecting the process that remove carbon dioxide from the atmosphere. According to Vance et al. (2003) plants with phosphorus deficiency develop mechanisms that help in the absorption of it, as root growth and expansion of its surface.

The objective of this study was to evaluate the development of vetiver grass under different levels of phosphorus on slopes of the right bank of the San Francisco River in the municipality of Amparo de São Francisco, SE.

MATERIAL AND METHODS

The experimental test was performed on the right-side bank of the San Francisco River lower course, located in the municipality of Amparo de São Francisco, Sergipe State, Brazil (UTM coordinates N=8,868,789.506/E=736,583.864). The slope had an average inclination of 89.7%, height of 6 m, with dimensions of 100 m long by 15 m wide, giving a total area of 1500 m^2.

The soil of the experimental area is classified as Fluvic Neossol (EMBRAPA, 2013). The climate of the sedimentary section of the Lower San Francisco, according to the Köppen classification, is the type Am (tropical monsoon climate) with an average annual temperature of 25°C and average annual rainfall of 744 mm yr^{-1} (CODEVASF, 2010).

The experimental area was previously identified to implement soil bioengineering techniques, to reduce or, control erosion on the riverbanks. The chosen criteria took into account the degradation level of erosion, physical characteristics of the soil (texture and structure), the slope topography (height, inclination, and ramp length), absence of vegetation cover, distance from the thalweg (main channel of the river), area available for testing, and access to the location of the experimental area. Soil samples were collected randomly in the study area at depths of 0-20, 20-40, and 40-60 cm, followed by chemical and physical characterization (Table 1).

Seedlings of vetiver production

Vetiver grass seedlings were produced at the Nursery of the Federal University of Sergipe (FUS), Located in São Cristóvão, SE, during the period between February and April 2011. The seedling of vetiver grass was produced from tillers extracted from the matrix tussock, with each tiller size standardized to approximately 20 cm height on the aerial part, cut in bevel. Their roots were cut and the seedlings were planted in polyethylene tubes with volume capacity of 280 cm^3, with a conical shape and a hole at the bottom for drainage of excess water. The substrate used in tubes was composed of black soil, washed coconut (*Cocos nucifera* L.) powder, and lime, in the proportion of 30:60:0.06 kg, and 73 g of fertilizer NPK (3-12-6) per m³ of substrate. The planted seedlings were irrigated whenever necessary, to keep moisture in about 60% of the total pore volume.

Table 1. Chemical and physical properties of soil sampled at depth of 0-60 cm in the experimental area before deployment tests.

Properties	Depth (cm)		
	0 – 20	20 – 40	40 – 60
pH (H_2O) (RBLE)	5.7	6.2	6.1
MO (g dm^{-3}) [1]	9.46	8.88	3.37
Ca ($cmol_c dm^{-3}$) [2]	7.29	7.15	2.88
Mg ($cmol_c$ dm^{-3}) [2]	1.91	4.25	2.53
Al ($cmol_c$ dm^{-3}) [2]	0.45	0.12	< 0.08
Na ($cmol_c$ dm^{-3}) [3]	0.15	0.26	0.09
K ($cmol_c$ dm^{-3}) [3]	0.06	0.07	0.05
H + Al ($cmol_c$ dm^{-3}) [4]	2.44	2.03	1.24
P (mg dm^{-3})	2.5	4.3	2.4
pH in SMP [4]	6.4	6.6	7.0
SB ($cmol_c$ dm^{-3})	9.41	11.70	5.56
CTC ($cmol_c$ dm^{-3})	11.90	13.70	6.80
PST (%)	1.2	1.9	1.4
V (%)	79	85	81
Fe (mg dm^{-3}) [6]	374	397	301
Cu (mg dm^{-3}) [6]	4.5	2.4	4.4
Mn (mg dm^{-3}) [6]	60.0	64.8	22.1
Zn (mg dm^{-3}) [6]	4.1	6.7	3.5
Grit (g kg^{-1})	4.5	0.7	145.6
Fine sand (g kg^{-1})	6.09	4.26	65.82
Silt (g kg^{-1})	479.7	506.5	103.9
Clay (g kg^{-1})	454.9	450.2	92.3

[1]Walkley-Black Method; [2]KCl;[3]Mehlich–1;[4]SMP; [5]MAQS– EMBRAPA; [6]Mehlich – 1 AA (EMBRAPA,2009).

Implementation of the soil bioengineering technique

The deployment of soil bioengineering in the experimental area, to control the erosion process in the marginal slope, occurred in July 2011. It started by fencing the area after reshaping the slope with the required inclination 1V:2H, using appropriate machinery, such as hydraulic backhoe.

The technique of vegetated riprap was applied at the base of the slope, using layers of rocks to protect the base of the slope and planting live cuttings of sabiá (*Mimosa caesalpiniaefolia* Benth) on the spaces between rocks. In the upper and middle thirds of the slope, the seedlings of vetiver grass were planted, and in the top of the slope, small pits were made, where the retaining sediment Bermalonga® D-10 were placed, consisting of pressed and dehydrated vegetable fibers, surrounded by photodegradable polypropylene mesh (DEFLOR, 2011).

After the standardization of vetiver grass tillers and the installation of inert elements of soil bioengineering, the planting was performed in the river talude. It was carried out in holes with dimensions of 0.3x0.3x0.3m in spacing of 0.3x0.9 meters for protection and stabilization of soil with different doses of simple superphosphate as form of phosphorus (P_2O_5) with formulation (0-18-0), according to Sobral et al. (2007).

Experimental design

The experimental design was a randomized block design (RBD) with the following doses of simple superphosphate per hole: T_0: control, without fertilizer application; T_1: 4 g; T_2: 8 g; T_3: 12 g; T_4: 16 g. The experimental plots presented borders of 40 cm, and each treatment was repeated five times. Each plot consisted of 100 plants; the experiment was carried out for five months, and the evaluations of seedlings were performed at 180 days after planting. The seedlings were selected and evaluated in a destructive way, where five plants of each plot was randomly collected, totaling 125 plants for each review.

Evaluations of the experimental test

For collection of vetiver, cylindrical PVC tubes with 15.708 cm^3 of volume were used. The tubes had dimensions of 50 cm height and 20 cm diameter with a thickness of 2 mm. These cylinders were driven into the soil, taking undisturbed soil samples along with roots and shoots, for all five replicates of each treatment.

A ruler graduated in centimeters was used to determine the length of the roots, with reference to the distance from the cervix to the apex. The values of the external surfaces (S) were determined using the product of the average diameter (top, center, and bottom) by its length. The root and shoot fresh weight (RFW and SFW) were measured separately, in an analytical balance, accurate to 0.01 g. To have the accurate root weigh, the exceeded soil was removed using a 0.5 mm strainer. Then, the material was placed in paper bags and in an oven with forced circulation at a constant temperature of 60°C for 72 hours, until the stable weight be achieved, to obtain the values of RFW and SFW.

The following variables were evaluated: a) number of roots (N); b) external root surface (S), which is the part of the root that touch the soil; c) root density (RD), expressed in dry mass of living roots by volume of soil; d) root length density (RLD); total length ratio of roots per soil volume; e) root fresh weight (RFW); f) root dry weight (RDW); g)shoot fresh weight (SFW); h) shoot dry weight (SDW); i) root length (RL); and j) shoot length (SL).

Statistical analysis

The results obtained were subjected to analysis of variance (ANOVA) and depending on the significance level of F-test to the doses of simple superphosphate; a study on polynomial regression was performed, choosing the model that best fit the doses used. (BANZATTO; KRONKA, 2006). Data were statistically analyzed using the statistical program Sisvar (FERREIRA, 2011).

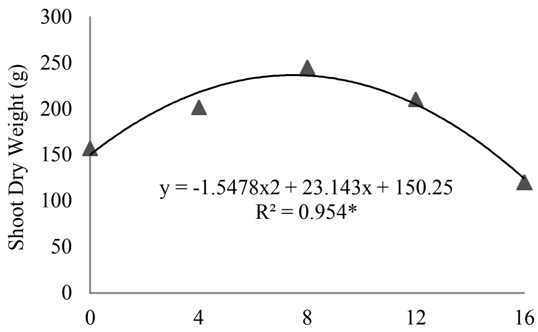
RESULTS AND DISCUSSION

Root dry weight (RDW) and shoot dry weight (SDW) production

The results showed that the vetiver grass dry matter production, both for root and shoot systems, was significantly affected by doses of simple superphosphate in the soil (Figure 1A; Figure 1B). The regression equations of dry matter production with doses of simple superphosphate had adjustments to the quadratic model.

Deriving the regression equations, it was found that the maximum dry matter production of shoot and root were obtained at doses of 7.47 and 8.41g pit^{-1} of superphosphate, with 236.75 g of SDW and 88.75 g of RDW, respectively. According to Gomes et al. (2003), this performance seems to occur for around 90 days, when external surface data reach its maximum, being the lower values between 30 and 60 days.

(A)



(B)

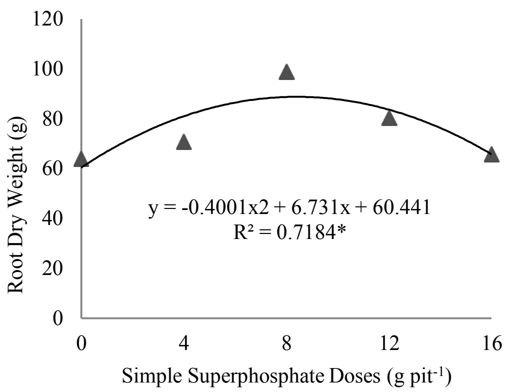


Figure 1.Shoot dry weight (A) and root dry weight (B) of vetiver grass with simple superphosphate (g pit^{-1}).* Significant at 5% probability.

This result can be explained by the better formation of the seedlings root system due to soil-incorporated doses, which promote root formation (COSTA et al., 2008). The increase of dry mass of the fertilized vetiver with simple superphosphate is related to the available doses, the effect of soil pH, and the increase in base saturation. According to Franco et al. (2004), the dry matter production is related to the effects of phosphate doses, improving the plant's development, both for shoot and root system.

According to the observed results to dry mass, production was influenced by fertilization with superphosphate. Similar results were found by Ferreira et al. (2008), with *Panicum maximum* cv. presenting rapid development and increasing its SDW production when the levels of phosphorus were increased.

The observed response of the vetiver grass under simple superphosphate doses, show that the amount of superphosphate, established by calculating the doses according to Sobral et al. (2007), for pasture, is sufficient to meet the requirements for expression of the full potential of vetiver.

Root density (RD) and root length density (RLD)

Root Density and Root Length Density are important variables because they enable us to know the plant ability to fetch water and nutrients in the soil solution. In this way, differences in function of simple superphosphate doses were identified. The most appropriate model for the regression equation was quadratic to root density, and the maximum dose for the development was 7.54 g pit^{-1}, with an average maximum gain of 9,520.7 g cm^{-3} (Figure 2). As a result, with a lower dose than the recommended, it was possible to obtain the maximum productivity.

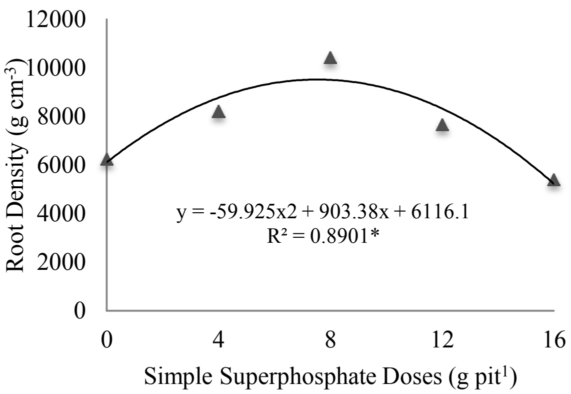


Figure 2. Root density production of vetiver grass, regarding the simple superphosphate (g pit^{-1}).* Significant at 5% probability.

Analyzing RLD, a maximum average increase of 12,033.53 mm cm^{-3}was observed, corresponding to 7.67 g pit^{-1}of simple superphosphate, a significant quadratic model (Figure 3). Consequently, it is only necessary to apply half of the recommended dose of simple superphosphate to obtain the desired root length density (Figure 2), similar to the root density production.

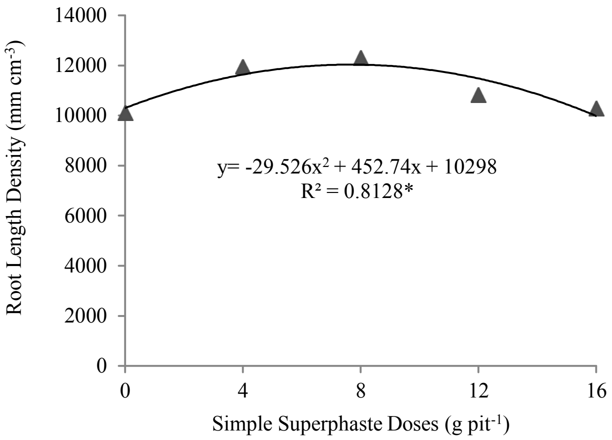


Figure 3. Root length density production of vetiver grass, regarding the superphosphate simple (g pit^{-1}).* Significant at 5% probability.

According to Santos Junior (2004), several factors are required for growth to occur, including light, nutrients, and CO_2. The increase in any of these factors, ranging from efficiency to sufficiency, promotes differentiated rates of growth and production.

Plants with larger root length density are likely to present higher initial resistance to floods and landslides, since they allow a greater soil structure by the higher concentration of carbon, fulvic acids, humic acids, and humin, in grasses cultivated soils, as reported by Barreto et al. (2008). Moreover, they are also able to promote greater absorption of water in the subsurface layers of the ground (STOKES et al., 2009), directly influencing the stability of these layers and hence the resistance to breakage of the roots in critical moments.

Number of roots (N) and external root surface (S)

The parameters analyzed for number of roots and external root surface showed the best fit for the quadratic regression model. To number of roots, the dose of 5.921 g pit^{-1} presented the maximum number of vetiver grass roots (68.06) (Figure 4). To external root surface, the quadratic model best fit, obtaining 156.29 mm of outer surface, at a dose of 8.398 g pit^{-1} (Figure 5).

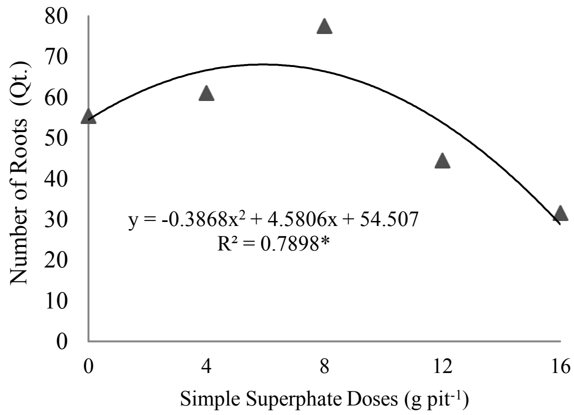


Figure 4. Numbers root production of vetiver grass, regarding the simple superphosphate (g pit^{-1}).* Significant at 5% probability.

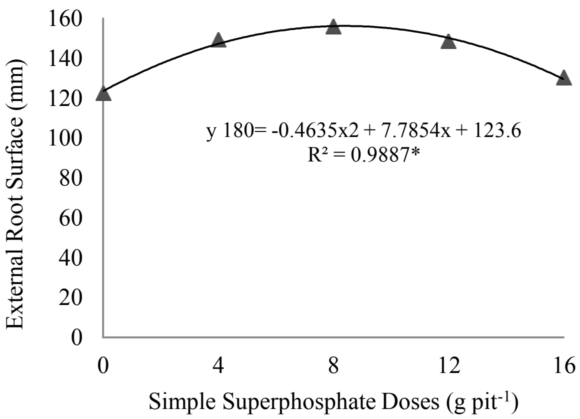


Figure 5. External root surface production of vetiver grass, regarding the simple superphosphate (g pit^{-1}).* Significant at 5% probability.

According to Vance (2003), when the supply of phosphorus is small, reaching its critical limit, plants develop mechanisms to improve the absorption of it, as root growth with changes in its external surface and with larger distribution. Doing this, the plant goes back to its metabolic process by reducing the growth rate and sending carbon to the roots (remobilization of phosphorus).

This behavior seems to occur for around 180 days, when data of external surface reaches at most, decreasing after 60 and 90 days. This result can be explained by better seedlings root formation, which grown in places with higher amounts of nutrients, less folding, and lower formation of fibrous root.

Rubens et al. (2007) point out that the external root surface, in particular the ones smaller than 3 mm, is an important parameter in controlling erosion, because the higher the external surface, the greater the area of contact with the ground.

According Mickovski and Van Beek (2009), the roots of vetiver grass have higher tensile strength with decreasing diameter of the same. However, as the external root surface is influenced by the number of roots, and its lengths and diameters, decreasing root diameter may decrease the external surface, reducing its contact area with the ground. Thus, it is desirable that the root system of a vetiver grass seedling has more fine roots (> 3 mm).

Shoot and root length

The values of shoot and root length were best fit to the quadratic model. Regarding shoot length, a dose of 8.238 g pit^{-1} yielded a root length of 106.38 cm (Figure 6).

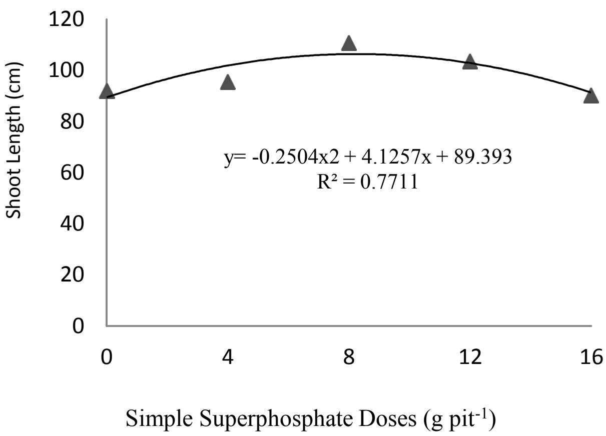


Figure 6. Shoot length production of vetiver grass, regarding the simple superphosphate (g pit^{-1}). * Significant at 5% probability.

The total root length is an essential trait for the vetiver grass absorption process. The maximum total root length values best fit to the quadratic model, being 199.9 mm the maximum length, achieved at a dose of 7.692 g pit^{-1} (Figure 7).

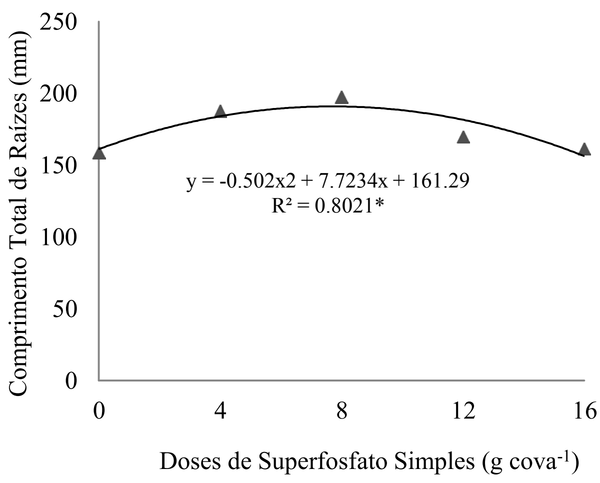


Figure7. Total root length production of vetiver, regarding the simple superphosphate (g pit^{-1}).* Significant at 5% probability.

According to Vance (2003), the greater the length of the root system, the greater its surface area, improving the phosphorus absorption. The root system of plants, including its length and distribution, facilitates the exploration of the substrate on which it was planted. Silva et al. (2011), assessing the biomass production and phosphorus uptake by plant species coverage subjected to different sources of phosphorus in soils, found that the grasses produced more roots dry weight (RDW) when subjected to more soluble sources of phosphorus in the form of triple superphosphate. To Rao et al. (1997), the efficiency of phosphorus uptake and the utilization of grasses as vetiver, is due the longer root system, when compared with other species such as legumes.

CONCLUSIONS

The fertilization with superphosphate proved to be effective in increasing all the variables: number of roots, external root surface, root density, root length, root length density, root and shoot dry weight, root and shoot fresh weight, and shoot length. Higher superphosphate doses than 9.0 g pit^{-1} did not offer advantages in terms of cost-benefit for the production of vetiver seedlings.

REFERENCES

BARRETO, A. C. et al. Fracionamento químico e físico do carbono orgânico total em um solo de mata submetido a diferentes usos. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 32, n. 4, p. 1471-1478, 2008.

BANZATTO, D. A.; KRONKA, S. N. **Experimentação agrícola**. 3. ed. Jaboticabal: Funep, 1995. 247 p.

CHENG, H. et al. Study on the performance and mechanism of soil reinforcement by herb root system. In: Proceedings of the 3rd International Vetiver Conference, 2003. **Proceedings**...Guangzhou, 2003.

COMPANHIA DE DESENVOLVIMENTO DO SÃO FRANCISCO E VALE DO PARAÍBA. Disponível em: <http://www.codevasf.gov.br>. Acesso em: 11 maio 2010.

COSTA, S. E. V. G. et al. Crescimento e nutrição da braquiária em função de fontes de fósforo. **Ciência e Agrotecnologia**, Lavras, v. 32, n. 5, p.1419-1427, 2008.

DEFESA FLORESTAL LTDA. **Catálogo de produtos e serviços de bioengenharia.** Disponível em:<www.deflor.com.br>Acesso em: 20 maio 2011.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. **Manual de análises químicas de solos, plantas e fertilizantes**. Brasília, DF: Embrapa Informação Tecnológica, 2009.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. **Sistema Brasileiro de Classificação de Solos.** 3.ed. Rio de Janeiro: Embrapa Solos, 2013. 353 p.

FERREIRA, D.F.S. **SISVAR** 4.3. 2003. Disponível em: <http:://www.dex.ufla.br>. Acesso em: 25nov. 2011.

FERREIRA, E. M. et al. Características agronômicas do Panicum maximum cv. "Mombaça" submetido a níveis crescentes de fósforo. **Ciência Rural**, Santa Maria, v. 38, n. 2, p. 484-491, 2008.

FRANCO, H. C. J. ; COUTINHO, E. L. M. Avaliação da eficiência agronômica de fontes de fósforo utilizando diferentes métodos. **Científica**, Jaboticabal, v. 32, n. 1, p. 58-64, 2004.

GOMES, J. M. et al. Crescimento de mudas de *Eucalyptus grandis* produzidas em diferentes tamanhos de tubetes e fertilização N-P-K. **Revista Árvore**, Viçosa, v. 27, n. 2, p. 113-127, 2003.

HOLANDA, F. S. R. et al. Avaliação da sensibilidade de alguns parâmetros em um modelo de absorção de fósforo e potássio pela cultura do milho (*zea mays* L.). **Ciência e Agrotecnologia**, Lavras, v. 23, n. 1, p. 24-30, 1999.

HOLANDA, F. S. R.; ROCHA, I. P.; OLIVEIRA, V. S. Estabilização de taludes marginais com técnicas de bioengenharia de solos no Baixo São Francisco. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 12, n. 1, p. 570-575, 2008.

HOLANDA, F. S. R. et al. Crescimento inicial de espécies florestais na recomposição da mata ciliar em taludes submetidos à técnica da bioengenharia de solo. **Ciência Florestal**, Santa Maria, v. 20, n. 1, p. 157-166, 2010.

MICKOVSKI, S. B.; VAN BEEK, L. P. H.; SALIN, F. Uprooting of vetiver uprooting resistance of vetiver grass (*Vetiveria zizanioides*). **Plant and Soil,** UK, v. 103, n. 278, p. 33-41, 2005.

MICKOVSKI, S. B.; VAN BEEK, L. P. H. Root morphology and effects on slope stability of young vetiver (*Vetiveria zizanioides*) plants grown in semi-arid climate. **Plant and Soil**, UK, v. 324, n. 1, p. 43-56, 2009.

MONTEIRO, J.S.; LEITE, M. B.; WINK, C.; DURLO, M. A. Influência do ângulo de plantio sobre a brotação e o enraizamento de estacas de *Phyllanthussellowianus* (Klotzsch) Mull. Arg..**Ciência Florestal**, UK, v. 20, n. 1,p. 523- 532, 2010.

PHILLIPS, C.; MARDEN, M. Use of plants for ground bioengineering and erosion e sediment control in New Zealand. In: Proceedings of "Soil e Water. Too good to lose".Joint Annual Conference NSW Stormwater Industry Association and the Internatioanal Erosion Control Association, 2006, Parramatta. **Proceedings**...Parramatta, 2006.

RAO, L. M. et al. Adaptive attributes of tropical forage species to acid soils. III. Differences in phosphorus acquisition and utilization as influenced by varyingphosphorus supply and soil type. **Journal of Plant Nutrition**, New York, v. 20, n. 1, p. 155-180, 1997.

REUBENS, B. et al. The role of fine and coarse roots in shallow slope stability and soil erosion control with a focus on root system architecture: a review. **Trees - Structure and Function**, v. 21, n. 34, p. 385 -402, 2007.

SANTOS JUNIOR, J. D. G.; MONTEIRO, F. A.; LAVRES JUNIOR, J. Análise de crescimento do capim-marandu submetido a doses de nitrogênio. **Brazilian Journal of Animal Science**, Viçosa, v. 33, n. 6, p. 1985-1991, 2004.

SILVA, T. O. et al. Plantas de cobertura submetidas a diferentes fontes de fósforo em solos distintos. **Semina: Ciências Agrárias**, Londrina, v. 32, n. 4, p. 1315-1326, 2011.

SOBRAL, L. F. et al. **Recomendações para o uso de corretivos e fertilizantes no Estado de Sergipe.** Aracaju: CPATC/EMBRAPA, 2007. v. 1, 251 p.

STOKES, A. et al. Desirable plant root traits for protecting natural and engineered slopes against landslides. **Plant and Soil**, UK, v. 324, n. 1, p. 1-30, 2009.

VANCE, C. P.; UHDE-STONE, C.; ALLEN, D. L. Phosphorus acquisition and use: Critical adaptations by plants for securing a nonrenewable resource. **New Phytologist**, v. 157, n. 8, p. 423-447, 2003.