Correlation between vegetation indices and nitrogen leaf content and dry matter production in *Brachiaria decumbens*

Mario Cupertino da Silva Júnior[1], Francisco de Assis de Carvalho Pinto[2], Daniel Marçal de Queiroz[3], Enrique Anastácio Alves[4], Luis Manuel Navas Gracia[5], Jaime Gomez Gil[6]

[1] *Graduate student, Universidade Federal de Viçosa (UFV) / Universidad de Valladolid (UVa), Agriculture Engineering (UFV)/ DTSCI y Telemática (UVa) Valladolid, Spain*
[2] *Researcher, PhD, Universidade Federal de Viçosa (UFV), Agriculture Engineering Viçosa, Brazil*
[3] *Researcher, PhD, Universidade Federal de Viçosa (UFV), Agriculture Engineering Viçosa, Brazil*
[4] *Graduate student, Universidade Federal de Viçosa (UFV), Agriculture Engineering Viçosa, Brazil.*
[5] *Researcher, PhD, Universidad de Valladolid (UVa), Departamento de Ingeniería Agrícola y Forestal,Palencia – Spain*
[6] *Researcher, PhD, Universidad de Valladolid (UVa), DTSCI y Telemática,Valladolid – Spain*
Corresponding author: cupertinojunior@yahoo.com.br

Abstract: *The goal of the present work was to evaluate the correlation between vegetation indices and nitrogen (N) Leaf content values, and also with dry matter production in Brachiaria decumbens forage at different periods after fertilization. The treatments consisted of five nitrogen rates (0, 50, 100, 150 e 200 kg ha^{-1}), with six replications, evaluate in a completely randomized design. A system composed of two digital cameras, cables, framegrabber and microcomputer was used, with a metal framework of three meters above ground for camera positioning. The system acquired images in two spectral bands, simultaneously, in two phases. In the first phase, accomplished during the period of February to March 2006, the images were acquired at 15, 21 and 32 days after fertilization. In the second phase, accomplished during the period March-May 2006, the images were acquired at 28, 36, 45 and 53 days after the reapplication of the same nitrogen rates. From the original images were determined different vegetation indices, which were submitted to correlation analyses. The correlation values between vegetation indices and N leaf content obtained in laboratory ranged from 0.63 to 0.83 in the first studied phase and from 0.64 to 0.75 in the second phase. The correlation values between vegetation indices and values of dry matter production in the first phase ranged from 0.62 to 0.66 and those in the second study phase from 0.72 to 0.75. The correlation values between all vegetation indices and the tested variables tended to decrease with the days after fertilization. The best index was GNDVI.*

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1 Introduction

Managing the nitrogen (N) input in pasture fields can outcome higher yields without polluting the groundwater. A reasoning crop nitrogen management also can decrease the fertilization costs. However, for a correct N input decision, one needs its either determination or determination accurately.

Some research studies have proposed ways to identify the nutritional status related with nitrogen in many crops. Most of those researches have been using the crop spectral response as indicator of N status.

Chlorophyll portable meters estimate the chlorophyll level present in the plant, being this value proportional to the nitrogen content. This method demands physical contact with individual leaf, what is time demanding for using in the context of site specific management.

Others promissory methods are the remote sensing techniques that also acquire spectral information of the plant pigments through sensors, but without physical contact with the plants, using the crop reflectance. The crop reflectance can be evaluated by radiometers, orbital, aerial and terrestrial images. It is believed that with the digital cameras popularization the use of these cameras to measure crop reflectance can turn one of the most economic viable methods (SENA JÚNIOR 2005).

Studies of remote sensing applications in agriculture have used vegetation indices to evaluate the crop reflectance. These indices are used to enhance the vegetation features and also decrease soil, atmospheric and angled effects (EPIPHÂNIO *et al.* 1996).

The goal of this present work was evaluate the correlation among vegetation indices and nitrogen leaf content evaluated in laboratory and also with the dry matter yield in different periods after the fertilization in *Brachiaria decumbens* forage.

2 Material and methods

This study was conducted in an established pasture field with *Brachiaria decumbens* of the Animal Science Department of the Federal University of Viçosa, in Viçosa- MG, Brazil. The project was executed in the period of January to May of 2006.

In the beginning of January was realized the delimitation of the study fields and the soil sampling. The pasture was cut to standardize the plants at a height of 10 cm. Then, 30 plots of 3 x 3 meters which received the treatments were established.

The treatments was arranged in a completely randomized design, consisted of five nitrogen rates (0, 50, 100, 150 e 200 kg ha^{-1}), with six replications. The nitrogen was applied in the form of urea. Before the nitrogen application, based on the soil chemical and physical analyses, and as recommended by CANTARUTTI *et al.* (1999), single superphosphate rate of 50 kg ha^{-1} was uniformly applied to all plots.

After the nitrogen fertilization, began the first study phase acquiring the digital images by two cameras, model STH-DCSG-VAR/-C stereo head by Videre Design Company (California, EUA), mounted in a three meters metallic support. One camera was monochrome and was attached with a near infrared (NIR) longpass optical filter of 695 nm to 1050 nm of wavelength and the other camera was a color (RGB) camera.

The lens was a C-mount with a focus distance of 2,8 mm. The images were saved in the BMP format with 480(V) x 640(H) pixels using the software SRI's Small Vision System (SVS) supplied by the camera maker. The sensor of the cameras that formed the images was the CMOS MT9V022 in the 1/3" format. Each image represented an area of 3.18 x 4.87 m with a spatial resolution about 7 mm. pixel^{-1}. Thus, the whole 3 x 3 m plot was placed on each image.

The images were acquired between noon and 2:00 PM in clear sky conditions. Assuming that the illumination was kept constant during the image acquisition, the pixel value was due to only the spectral properties of the target.

An image block of 240 x 240 pixels was used to represent each research plot. Instead of using of the original pixel values, vegetation indexes were used to highlight the information with respect to the nutritional status of the plants and attenuate the influence of the natural illumination variation in the image. It was assumed that the crop reflectance was equal to the average of the image block pixels.

The image processing was accomplished using the software Matlab (The MathWorks, EUA) version 6.5, with the digital image processing toolbox. The studied indexes were NDVI (normalized difference vegetation index), GNDVI (green normalized difference vegetation index) and SAVI (soil adjust vegetation index) according to the equations 1, 2 and 3.

$$NDVI = \frac{IV - Vm}{IV + Vm} \tag{1}$$

$$GNDVI = \frac{IV - Vd}{IV + Vd} \tag{2}$$

$$SAVI = \frac{IV - Vm}{IV + Vm + L}(1 + L) \tag{3}$$

Being that,

Vm	- pixel value in the red band;
IV	- pixel value in the near infrared band;
Vd	- pixel value in the green band;
L	- adjust coefficient;
NDVI	- normalized difference vegetation index;
GNDVI	- green normalized difference vegetation index; and
SAVI	- soil adjust vegetation index.

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The “L” coefficient value was assumed 0.5, that is the value used for vegetation with intermediate density and, according HUETE (1988), this value minimizes the influence of background soil for a large variation of leaf area indices.

Besides the images, leaves were collected to analyze the N leaf content at 15, 21 and 32 days after the fertilization (DAF). The N leaf content was measure by 30 different leaves collected along of each plot and the chosen leaves were the newest completely expanded. These leaves were packed in paper bags to determinate the N content in the laboratory.

At 32 DAF, 1 m^2 in each plot was cut to 20 cm of height and weighted. A sample of 300 to 500 grams was placed in paper bags, weighted and left in an oven at 65°C for 72 hours for moisture content and dry matter yield determination.

The non harvested area was also cut to 20 cm height and a second experimental phase was initiated on March 28, 2006 when the same nitrogenous treatments were applied with a 60 kg ha^{-1} concentration of potassium chloride.

During the second phase, the digital images and the leaves to analyze the N leaf content were acquired at 28, 36, 45 e 53 DAF. At 53 DAF, the plants were once again cut to measure the dry matter yield, using the same procedure as the first phase.

Irrigation was not necessary during the experimental periods because of adequate rainfall and weed was controlled manually in all sections whenever needed.

The acquired data were submitted to correlation analysis.

3 Results and discussion

The correlation values among vegetation indices (NDVI, GNDVI and SAVI) and N leaf content and the dry matter (DM) are presented in **Tables 1** and **2** for the first and second experimental phases, respectively. All correlation values were significant at 1% of probability by the t-test.

Table 1: Correlation among vegetation indices and N leaf content and dry matter (DM) at 15, 21 and 32 days after fertilization (DAF) on the first experimental phase.

INDICES	15 DAA	21 DAA	32 DAA	
	N leaf content	N leaf content	N leaf content	DM
NDVI	0,74**	0,81**	0,63**	0,62**
GNDVI	0,76**	0,83**	0,66**	0,66**
SAVI	0,74**	0,81**	0,63**	0,62**

** Significant correlation at 1% of probability; NDVI: normalized difference vegetation index; GNDVI: green normalized difference vegetation index; SAVI: soil adjust vegetation index; N Leaf Content: analyze of nitrogen leaf content; DM: dry matter produced in ton ha^{-1}.

Table 2: Correlation among vegetation indices and N leaf content and dry matter (DM) at 28, 36, 45 and 53 days after fertilization (DAF) on the second experimental phase.

INDICES	28 DAA	36 DAA	45 DAA	53 DAA	
	N leaf content	N leaf content	N leaf content	N leaf content	DM
NDVI	0,74**	0,64**	0,64**	0,59**	0,72**
GNDVI	0,75**	0,65**	0,68**	0,62**	0,75**
SAVI	0,74**	0,64**	0,64**	0,59**	0,72**

** Significant correlation at 1% of probability; NDVI: normalized difference vegetation index; GNDVI: green normalized difference vegetation index; SAVI: soil adjust vegetation index; N Leaf Content: analyze of nitrogen leaf content; DM: dry matter produced in ton ha^{-1}.

The correlation among indices, N leaf content and DM tended to decrease with the progress of the days after fertilization. This was due to the increasing in the number of the leaves, yielding into saturation of the indices values. This fact also was observed by MENESES & MADEIRA NETO (2001), in a study of spectral comportment of plants.

Other important fact to observe when comparing **Table 1** to **Table 2** was that the correlation values decreased from phase 1 to 2. This decreasing of the linear relationship between those variables was probable due to the temperature and luminosity reduction observed in the second phase, which propitiated less response of the plants to nitrogen fertilization.

The highest correlation values with leaf N content and DM were obtained with the GNDVI index in all data acquisition periods and both experimental phases. This result was also obtained by GITELSON *et al.* (1996), where the authors verified that GNDVI was more sensible than NDVI to identify different concentration rates of chlorophyll, which is highly correlated at nitrogen, in two species of plants.

The NDVI and SAVI indices presented correlation values similar in all periods and phases studied. These indices have the same spectral band relation; however the SAVI has the L constant multiplied in the equation that, according HUETE (1998) assist to reduce the soil reflectance influence. Since the soil was totally covered by the forage in all plots, the soil influence on the indices values was minimized. This fact could explain the similarity of the correlation of the NDVI and SAVI.

4 Conclusions

All tested vegetation indices presented significant correlations with N leaf content and DM in all studied periods.

The GNDVI presented the best correlation with all analyzed variables in all periods and phases studied, indicating that the use of green spectral band was more efficient than the red spectral band to discriminate nitrogen.

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