
# Temporal Analysis of Correlation of NDVI with Growth and Yield Features of Rice Plants

**Oscar Barrero[1] , Luis A. Castilla[2]**

[1]Facultad de Ingeniería, Research Group D+TEC, Universidad de Ibagué, 730002 Ibagué, Tolima, Colombia.

[2] Federación Nacional de Arroceros de Colombia, 730002 Ibagué, Tolima, Colombia.

**A paper from the Proceedings of the**
**14th International Conference on Precision Agriculture**
**June 24 – June 27, 2018**
**Montreal, Quebec, Canada**

***Abstract.*** *In this paper we present a temporal correlation analysis of NDVI with with Growth and Yield Features of Rice Plants. A half ha experimental rice field was established south-west of Ibagué, Tolima, Colombia (4°22'54.192"N, 75°09'17.222"W. For the experimental design in the plot, four rows were established for nitrogen, three for phosphorous and three for potassium. For nitrogen, each row contained five treatments allocated randomly. The nitrogen treatments were defined as: $T_1$ = 0 kg/ha, $T_2$ = 50 kg/ha, $T_3$ = 100 kg/ha, $T_4$ = 150 kg/ha, and T5 = 200 kg/ha. For phosphorous and potassium, each row contained four treatments allocated randomly. The treatments were defined as: T1 = 0 kg/ha, T2 = 50 kg/ha, T3 = 100 kg/ha, T4 = 150 kg/ha. Each treatment block had a size of 36 $m^2$ approximately. The experimental plot was flew weekly, using a fixed wing UAV with a multispectral camera,* *from emergence to harvest; however, due to problems with the plane and weather, the days after emergence (DAE) the data could be collected were: 24, 38, 60, 66, 104, 111, 117, and 124. At the same time there were sampled in situ; plant height, number of tiller and panicles, and SPAD. The results show that NDVI is highly correlated with the amount of nitrogen in rice plant at the vegetative and reproductive stages, but is not for phosphorous and potassium. Furthermore, there exist a high correlation of NDVI with SPAD and plant height; contrary to number of tiller and panicles. However, more research has to be done to make final conclusions about the correlation between NDVI and growth features.*

***Keywords***

*Rice Nutritional Stress, UAVs, Multiespectral Images, NDVI*

## 1. Introduction

Technology is driving the current world and agriculture has not been oblivious to the impact it has generated in: new production models, and techniques in which multiple analyzes are carried out in plants (physiological, morphological and nutritional), soil and the environment. Likewise, in a technological framework there are elements that provide a better perception regarding the development of the plant under specific conditions. Currently, production models seek to be sustainable and productive, capable of competing and facing social problems, such as food demand and the limitations that have been created by climate variability. That is why agriculture is in need of finding tools that allow it to be more efficient and reliable when making decisions regarding the problems that may exist within a crop.

Now days, precision agriculture techniques have been adopted in order to identify nutritional problems in rice cultivation quickly and accurately. For example, one of the tools of precision agriculture is the reflectometry systems that are increasingly used to determine the nutritional status of the crop. With a GreenSeeker equipment can be established a normalized vegetation differentiation index (NDVI), whose interpretation can contribute to the rapid and targeted diagnosis of nutritional conditions (especially nitrogen) and the potential yield of the crops (Inman, Khosla, Reich, & Westfall, 2008; Lan, Y., D.E., & Hoffmann, 2009).

On the other hand, unmanned aerial vehicles (UAVs) have shown to be an important tool for precision agriculture. In Zhou et al (2016) authors used small UAVs to study abiotic stress in irrigated pinto beans, Ayala-Silva & Bey (2005) investigated changes in spectral reflectance of wheat leaves in response to specific macronutrient deficiency. Another authors as Laacouri, Kaiser, & Mulla (2016) made a comparison between high resolution spectral indices and SPAD meter estimates of nitrogen deficiency in corn.

Therefore it is important to develop rice production systems based on aerial images and precision agriculture tools to improve the productivity of rice fields.

## 2. Materials and Methods

### 2.1 Experimental Plot and Image Acquisition

A half ha experimental rice field was established south-west of Ibagué, Tolima, Colombia (4°22'54.192"N, 75°09'17.222"W. For the experimental design in the plot, four rows were established for nitrogen, three for phosphorous and three for potassium, see Fig. ***1***. For nitrogen, each row contained five treatments allocated randomly. The nitrogen treatments were defined as: $T_1$ = 0 kg/ha, $T_2$ = 50 kg/ha, $T_3$ = 100 kg/ha, $T_4$ = 150 kg/ha, and $T_5$ = *200* kg/ha. For phosphorous and potassium, each row contained four treatments allocated randomly. The treatments were defined as: $T_1$ = 0 kg/ha, $T_2$ = 50 kg/ha, $T_3$ = 100 kg/ha, $T_4$ = 150 kg/ha. Each treatment block had a size of 36 $m^2$ approximately. The images were taken from the multispectral Micasense Rededge camera, 12 bit sensor, and 1.2 megapixels with spectral bands: blue, green, red, red edge, and nir, Seattle, USA. As a remote sensing platform, an autonomous fixed-wing electrically-powered plane (Phantom FX-61, Hobbyking, China) with a Pixhawk autopilot and 30 minutes of autonomy was used. The images were taken at 70 m over the rice field, the flight height was calculated based on: minimum plane flight speed that is 10m/s average, the field of view of the camera, and the overlapping needed to build the ortho-mosaic map, which was defined as 60% horizontal and 60% vertical. Hence, the resolution of the multispectral was 47.7 mm/pixel at 70 m height.

The experimental plot was flew weekly from emergence to harvest; however, due to problems with the plane and weather, the days after emergence (DAE) the data could be collected were: 24, 38, 60, 66, 104, 111, 117, and 124. The free GNU license software Mission Planner by Ardupilot project was used to define the plane path trajectory, as well as the flight height. The images were taken between 8 to 10 am to avoid wind speeds over 10 km/h. For the multispectral camera, white radiometric calibration was done by taking a picture of a white Teflon board before flying, as indicated in the Micasense user's manual.

## 2.2 Spectral Signature

To obtain the spectral signature of rice plants for each nutrition treatment and DAE, first the reflectance maps using the software Pix4DMapper Pro software (Pix4D SA, Switzerland) were generated. Then, the average reflectance value per treatment block and channel is computed without taking into account negative values, which correspond to soil reflectance.

## 2.3 Sensitivity Analysis of Reflectance

In order to study the sensitivity of the rice plant's reflectance to the nutrition treatments, it was compared the variation of the band reflectance of treatments that used nutrients with respect to the band reflectance of the treatment that used zero nutrients. It was computed using Eq. (1), where $V$ is the percentage of variation, $T_n$ the $n$-th treatment, with $n = 2,3,4,5$.

$$V = \frac{\left(Reflectance_{Tn} - Reflectance_{T1}\right)}{Reflectance_{T1}} \times 100\% \qquad (1)$$

## 2.4 NDVI Temporal Function

Once the reflectance maps are generated and analyzed, the normalized difference vegetation index (NDVI) is computed (Rouse et al. 1973), see Eq. (2).

$$NDVI = \frac{NIR-R}{NIR+R}\ , \qquad (2)$$

where, $NIR$ is the near infrared reflectance band, and $R$ is the red band. Afterwards, a second order polynomial function is fitted to the temporal $NDVI$ data as shown in Eq. (3).

$$NDVI(t) = a_0 + a_1 t + a_2 t^2 \quad (3)$$

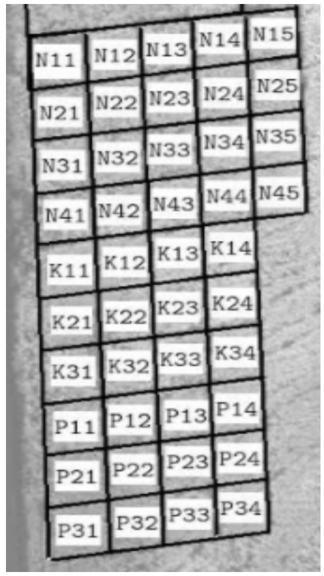



**Fig. 1** Experimental design plot. $N_{ij}$ represent the ij-th nitrogen treatment block, $K_{ij}$ the ij-th potassium treatment block, and $P_{ij}$ the ij-th phosphorous treatment block.

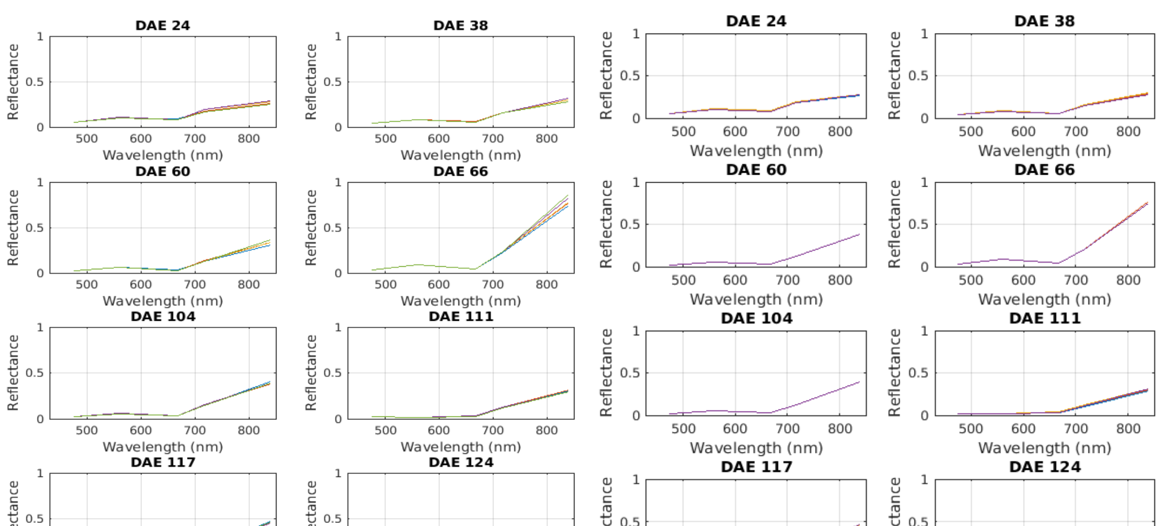
### 2.5 In Situ Plant Sampling

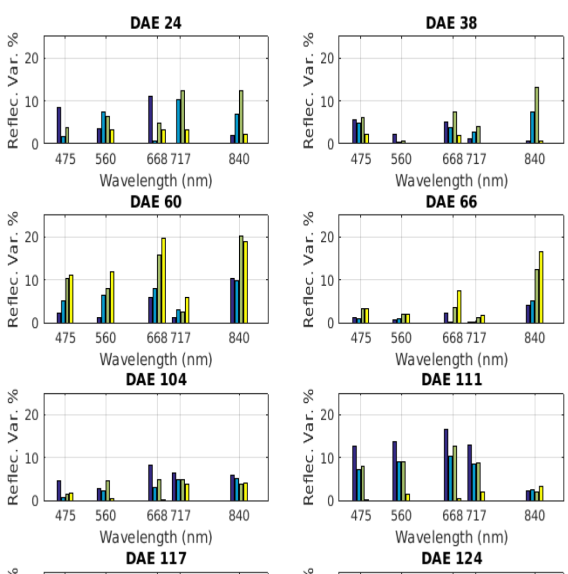
To sample the number of tiller and panicles per plant and its height it was used a frame of 0.5m × 0.5 m. Each treatment block was sample four times randomly.

For SPAD measurement it was used the SPAD 502 Plus Chlorophyll Meter. There were taken five sample per treatment block.

## 3. Results

shows the spectral signature of nutrient treatments on sample dates. It can be seen that reflectance for wavelengths below 668 nm is similar in values for whole treatments and DAE. However for wavelength over 668 nm, the reflectance values start increasing up to approximately the 80 DAE, when the reproductive stage finished. Afterwards the reflectance values start decreasing. On the other hand, it was found that the nitrogen nutrient treatments showed more reflectance variability than the other nutrient treatments, as shown on the 66 DAE spectral signature image.




DAE 24
DAE 38
DAE 60
DAE 66
DAE 104
DAE 111
DAE 117
DAE 124
Reflec. Var. %
Wavelength (nm)
475
560
668
717
840

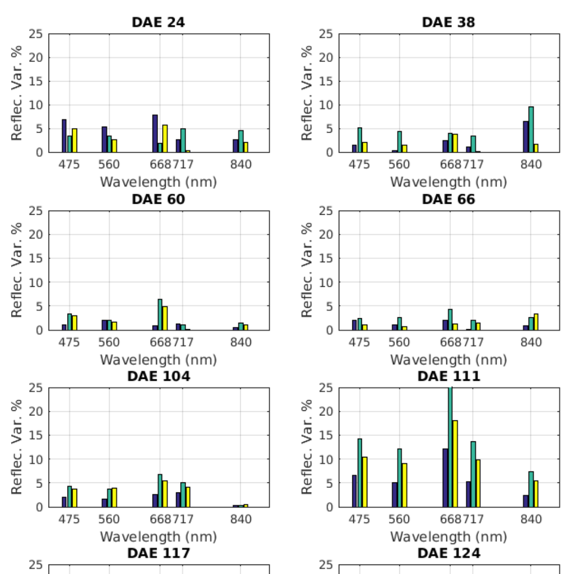
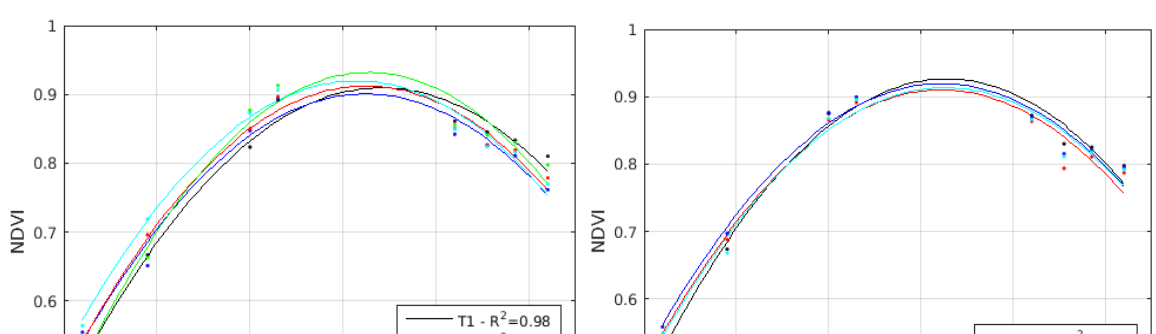

DAE 24
DAE 38
DAE 60
DAE 66
DAE 104
DAE 111
DAE 117
DAE 124
Reflec. Var. %
Wavelength (nm)
475
560
668717
840

**Fig. 3** Spectral variation respect to zero nutrient treatment. (a) Nitrogen spectral variation, (b) Phosphorous spectral variation, and (c) Potassium spectral variation. From left to right, 1st bar represents the variation of treatment 2 respect to 1, 2nd 3 respect to 1, 3rd 4 respect to 1, and 5th 4 respect to 1.

In **Error! Reference source not found.** it is shown the reflectance variation respect to the 1st treatment, which is the one with zero nutrients. In general, the nutrient that show more variation is nitrogen, moreover, during the 60 and 66 DAE this variation is direclty proportional to the amount of nutrient used. On the other DAE, eventhough the variation is high for nitrogen, there are not correlation between the reflectance with the amount of nitrogen applied to the plants.

Furthermore, since it was observed in

and **Error! Reference source not found.**, the more sensitive spectral bands to the nutrient treatments were the ones over 668 nm, namely: red, rededge, and nir bands. Hence, the NDVI could be an appropriated index to detect problems with nutritional stress. In **Error! Reference source not found.** is shown the NDVI curves fitting to 2[nd] order polynomials for each nutrient treatment. As it can be seen, the best fitting is for the nitrogen and phosphorous treatments. However as shown above, for phosphorous and potassium there is not an important reflectance variation, neither correlation between reflectance and nutrient treatment, this also can be noticed in Fig. **4**. On the contrary, for nitrogen it can be highlighted that between 60 and 80 DAE, the NDVI is directly proportional to the nutrient treatment, which corresponds to the end of the reproductive stage. As a result, it can be stablished that NDVI can be used to detect nitrogen nutritional stress during the reproductive stage of rice plants.



Moreover, in the plot were sampled for the nitrogen treatment: plant height, number of panicles, number of tillers, and Soil-Plant Analyses Development (SPAD) value. These values were correlated with the NDVI as shown in Fig. **5**. There can be seen that NDVI has a high correlation with the plant height during vegetative and reproductive stages. The correlation with SPAD is high for T1 and not for the other treatments as expected, however the tendency is similar. Furthermore, the number of tillers at the reproductive stage shows low correlation, however the tendency is similar to NDVI, this is similar to panicles at the ripening stage, where the correlation is low and inverse but tendencies are inversely similar.

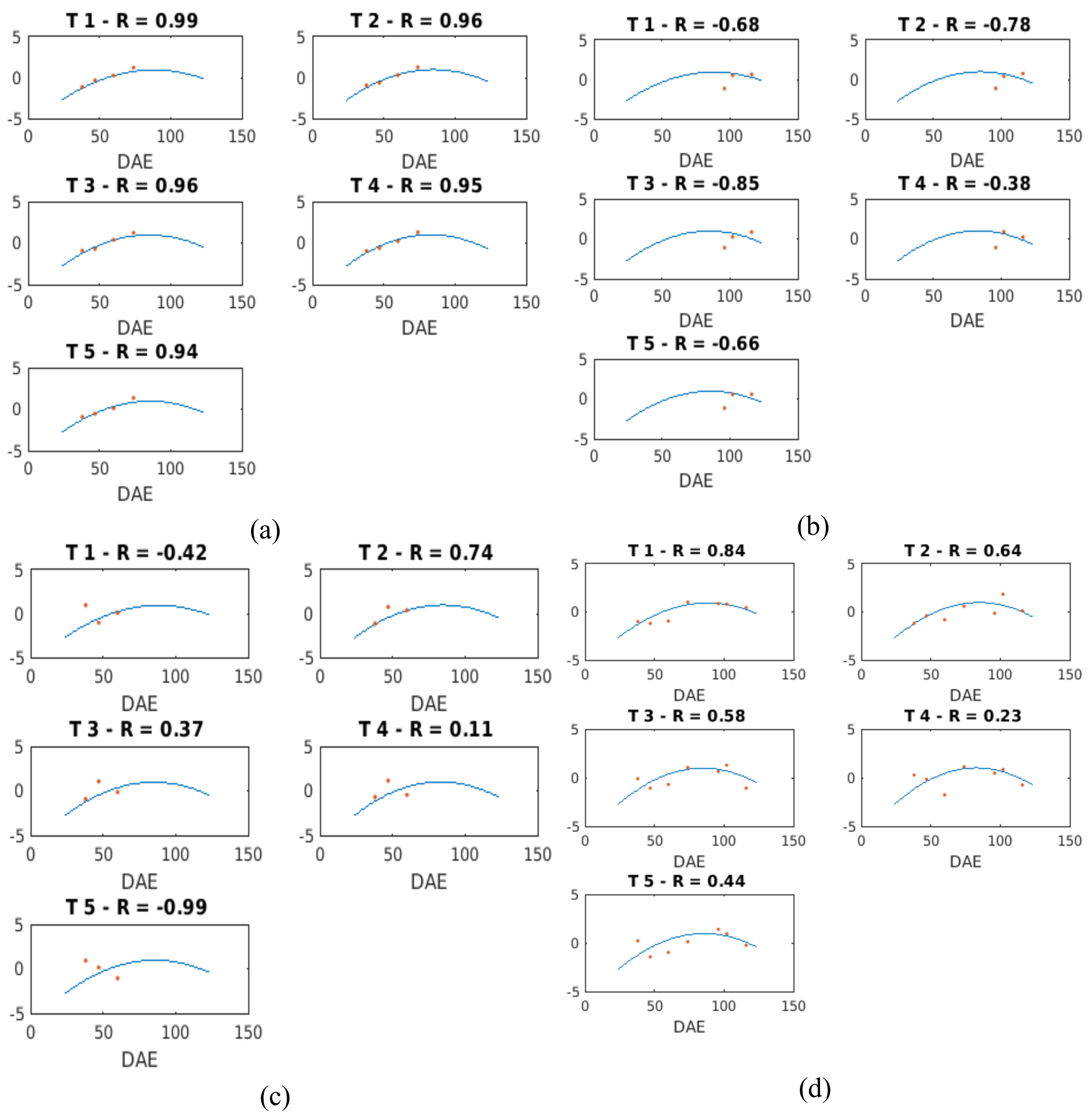



**Fig. 5** Temporal Correlation Analysis of NDVI with (a) plant height, (b) number of panicles, (c) number of tillers, and (d) Soil-Plant Analyses Development (SPAD) value for nitrogen. The values are standardized, i.e., zero mean and one standard deviation. R is the correlation coefficient. Solid lines represent NDVI curve and dots real sample data.

In Table 1 can be seen the correlation coefficients (R) and *p-values* for the correlation analysis of NDVI with growth features, $p\text{-values} < 0.05$ means that correlation is significant. Therefore, there exists significant correlation of NDVI with plant height and NDVI with SPAD in $T_1$, whereas for number of tillers and panicles the analysis show no significant correlation.

**Table 1.** Correlation analysis between growth features and NDVI

| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
|---|---|---|---|---|---|
| **NDVI Height** | R=*0.9859* | R=*0.9624* | R=*0.9602* | R=*0.9518* | R=*0.9414* |
| | *p =0.014* | *p= 0.037* | *p=0.039* | *p=0.048* | *p=0.059* |
| **NDVI No. Tillers** | R=*-0.4235* | R=*0.7402* | R=*0.3662* | R=*0.1068* | R=-*0.994* |
| | *p=0.721* | *p=0.469* | *p=0.761* | *p=0.931* | *p=0.064* |
| **NDVI No. Panicles** | R=*-0.6799* | R=-*0.7807* | R=-*0.8492* | R=-*0.3786* | R=-*0.6563* |
| | *p=0.523* | *p=0.429* | *p=0.354* | *p=0.752* | *p=0.544* |
| **NDVI SPAD** | R=*0.8353* | R=*0.6438* | R=*0.5768* | R=*0.2278* | R=*0.4430* |
| | *p=0.019* | *p=0.118* | *p=0.175* | *p=0.623* | *p=0.319* |

Finally, Fig. ***6*** shows the nitrogen nutritional yield, it can be seen that treatment 4 is the one with the best yield. Notice that this treatment used the recommended amount of nitrogen fertilizer which is 150kg/ha. Besides, the nitrogen NDVI curve at the vegetative and beginning of reproductive stages displays the highest value for $T_4$

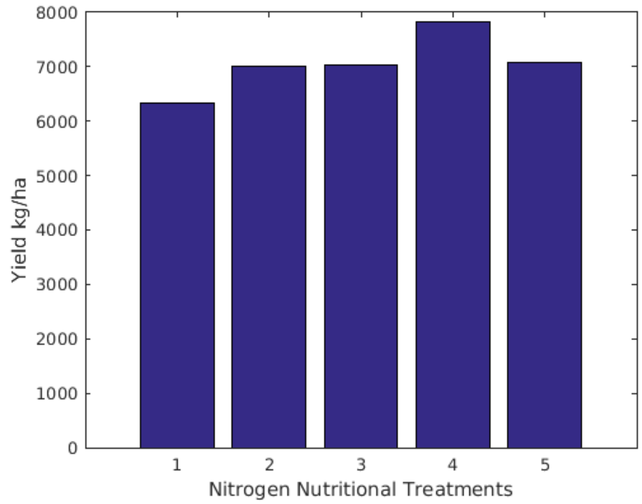



**Fig. 6** Nitrogen nutritional treatment yield in kg/ha.

## 4. Conclusions

In this paper, it was presented an analysis of correlation between NDVI with growth and yield feature in rice plants. There was prepared an experimental design plot of rice with different amounts of nitrogen, phosphorous and potassium fertilizer, keeping one treatment with zero fertilizer. By studying the spectral signature of the nutrient treatments, it is concluded that spectral band over 640 nm show more variability in function of time and nutrient treatments; thus NDVI is an appropriate index due to the fact it is based on the nir and red spectral bands. The NDVI curves for phosphorous and potassium does not indicate correlation with nutrient treatment, because they are similar; in contrast for nitrogen the curves show high correlation at the vegetative and reproductive stage. This result show the potentiality of using NDVI to detect nitrogen nutritional stress at the vegetative and reproductive stage; however, it is needed more research in order to stablish the range of NDVI values where a rice plant is suffering of nitrogen nutrient stress.

On the other hand, there exists a high correlation of nitrogen treatments NDVI with plant height and SPAD, but low with number of tiller and panicles; however, the tendencies of number of tiller and panicle in function of time display similarity with NDVI. Hence, it is needed more data to have a conclusion about this analysis.

## 5. Acknowledgement

This work was supported by project # 15-365-INT Universidad de Ibagué and FEDEARROZ.

## 6. References


Ayala-Silva, T., & Bey, C. A. (2005). Changes in spectral reflectance of wheat leaves in response to specific macronutrient deficiency. *Advances in Space Research, 35*, 305–317.

Inman, D., Khosla, R., Reich, R., & Westfall, D. (2008). Normalized difference vegetation index and soil color-based management zones in irrigated maize. *Agronomy Journal*, 100:60–66. doi:10.2134/agrojnl2007.0020.

Laacouri, A., Kaiser, D., & Mulla, D. (2016). Comparison Between High Resolution Spectral Indices and Spad Meter Estimates of Nitrogen Deficiency in Corn. St. Louis, Missouri: 13th International Conference on Precision Agriculture.

Lan, Y., Y., H., D.E., M., & Hoffmann, W. (2009). Development of an airborne remote sensing system for crop pest management: System integration and verification. *Transactions of the ASABE*, 25, 607–615.

Rouse, J. W., Haas, R. H., Schell, J. A., & Deering, D. W. (1973). Monitoring vegetation systems in the Great Plains with ERTS. *Proceedings of the Earth Resources Technology Satellite Symposium NASA SP-351*, (pp. Vol. 1, pp. 309-317.). Washington D.C.

Zhou, J., Khot, L. R., Boydston, R. A., Miklas, P. N., & Porter, L. (2016). Small UAS integrated sensing tools for abiotic stress monitoring in irrigated pinto beans. St. Louis, Missouri, USA: 13th International Conference on Precision Agriculture.