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Low-cost smartphone camera accessory to digitally measure leaf color for crop nitrogen status assessment

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Abstract.

Crop Leaf nitrogen (N) status is a desirable information for crop nutrition management. The use of chlorophyll meters is a well-accepted practice to indirectly measure crop leaf N status. Nevertheless, chlorophyll meters are dedicated, costly devices, being unsuitable to be used amongst low budget smallholders. Aiming to address this issue, a low-cost smartphone camera adapter device was developed to measure leaf green level. The main device consists of a conical casing where the crop leaf can be partly introduced and placed on the side of an internal reference color pattern, and be compared at equal ambient light conditions by an imaging camera. To evaluate this device, a replicated maize pot experiment with five N levels was established. At crop growth stages V6 and V8, all the plants have been measured with a reference chlorophyll meter and the camera adapter device. The collected images were processed for identifying the reference color scale and leaf on the images, obtaining the value where reference scale and sample leaf match best. To compare data from both sources, univariate regression analysis has been used and the RMSE calculated. In a second evaluation step, three leaves coming from distinct N levels, were measured with the adapter device, using the cameras of nine different smartphones to evaluate the procedure's dependency from camera devices. The comparison between the values of the chlorophyll meter and the adapter device shows an R^2 of >0.8 and a RMSE of <40 chlorophyl meter units. The measurements made with the different smartphone cameras indicated that the suggested method is largely independent from camera type. Results show that the low-cost adapter could be a suitable alternative to more expensive chlorophyll meters for the estimation of crop N status in smallholder cropping systems.

Keywords.
Leaf color, crop nitrogen status, chlorophyll measurement, smartphone adapter.

Introduction

Crop Leaf nitrogen (N) concentration status is a desirable information for precise crop nutrition management. In addition to the traditional leaf sampling with subsequent laboratory analysis, the use of chlorophyll meters is a well-studied and accepted practice to indirectly measure crop leaf N status, already investigated since many years (Wood *et al.* 1992). Nevertheless, chlorophyll meters are dedicated devices that still cost at least a few hundred dollars, thus being unsuitable to large scale use among low budget smallholders. Aiming to address this issue, a new low-cost alternative smartphone camera adapter device was developed to measure green color intensity levels of crop leaves.

Material and Methods

Integrated on a clip and holding structure, the smartphone adapter consists of a conical casing, having side walls allowing diffuse light to enter. An opening at the top receives the lens of the smartphone camera and at the bottom, inside the cone, there is a plate, providing a pattern of predefined color references and an opening to allow the sample leaf to be introduced and seen from the top (Figure 1 left). To evaluate this device, a replicated maize greenhouse pot experiment (one plant per pot), with five N levels and all other nutrients on adequate amounts, was established. At crop growth stages V6 and V8, all the plants have been evaluated by measuring the middle-blade of the last fully developed leaf (visible auricles) with a reference chlorophyll meter (Yara N-Tester) and the proposed smartphone camera adapter device. The images collected with the device adapter using a Samsung Galaxy S5 smartphone were batch processed for identifying the reference color scale and the leaf on the images, labeling them, and extracting the "RGB" values for the reference and the leaf. The readings were transformed into the "L, a, b" color space, and the "color distance" between reference levels and sample leaves was calculated. A quadratic equation was fitted to derive the point of minimum "color distance" between sample leaf and reference. Figure 1.

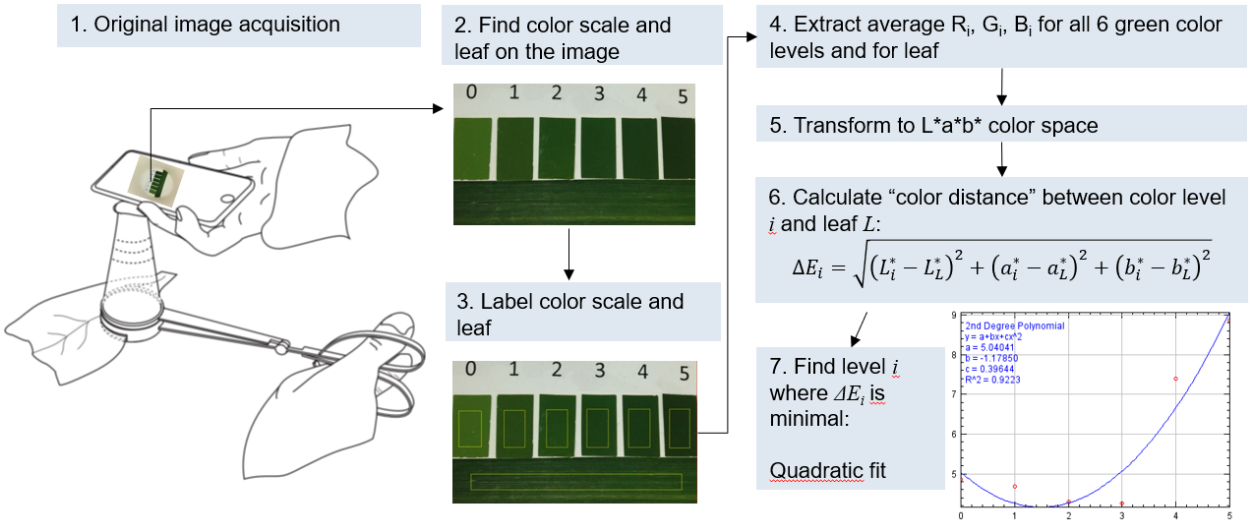

Figure 1. Crop leaf image acquisition, data extraction and analysis process.

To compare data from the chlorophyll meter and the smartphone adapter device, univariate regression analysis has been used and the root mean square error (RMSE) was calculated. In a second evaluation step, three leaves coming from middle to low N levels (where N recommendations normally are made) were measured with the adapter device, using the cameras of nine different smartphones models to evaluate whether there is any dependency of the procedure against different camera devices.

Results and discussion

The comparison between the values of the chlorophyll meter and the adapter device shows an R^2 of 0.8 and a prediction RMSE of 38.7 chlorophyl meter (N-Tester) units (Figure 2).

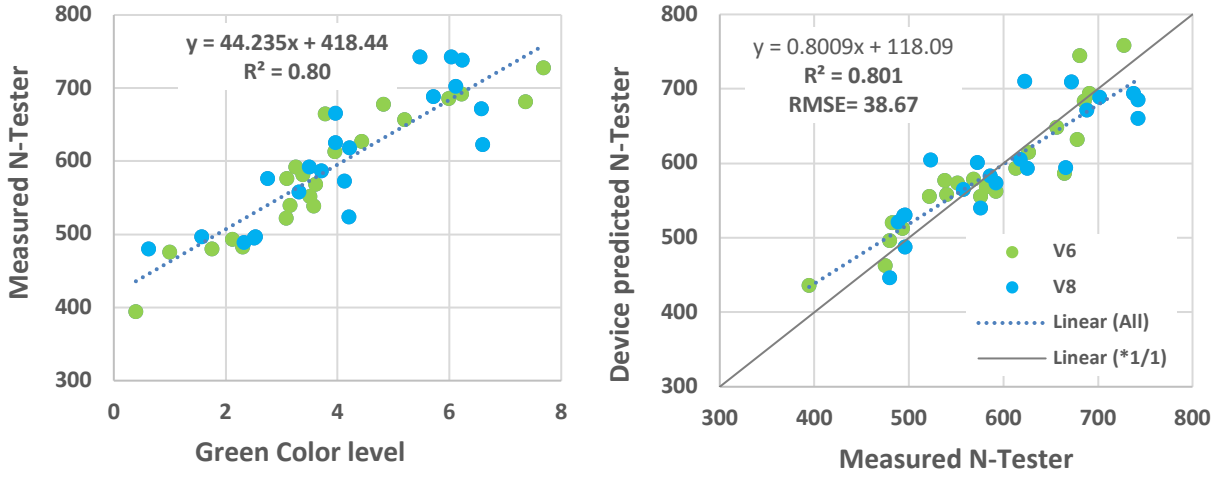

Figure 2. N-Tester vs green level (left) and N-Tester vs device-predicted N-Tester (right).

The measurements made with the nine different smartphone cameras (Table 1) showed that all the smartphones generated values of the same color class for the three N status leaves, except for the model Samsung S9 that provided a 1 unit higher reading at the lower N level (Figure 3). This indicates that the suggested method is largely independent from camera type.

Table 1. Smartphone models used / abbreviations

ID	Smartphone Model
HTC	HTC Evo 3D
HW	Huawei Y7
MT	Motorola Moto X4
NX1	Google Nexus 5 (Devise 1)
NX2	Google Nexus 5 (Devise 2)
S7	Samsung Galaxy S7
S8	Samsung Galaxy S8
S9	Samsung Galaxy S9
XP	Sony Xperia Z1

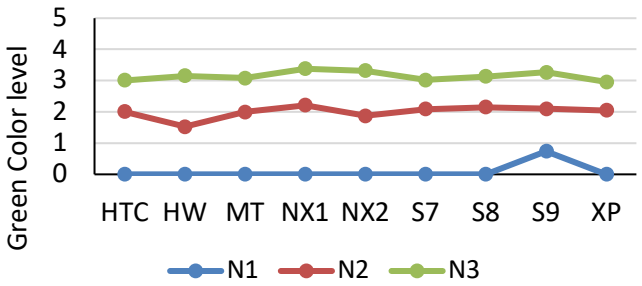

Figure 3. N green levels measured with different camera devices.

Aiming for a quick and simple user experience, all the presented values are based on single measurements with the smartphone adapter device. Asking the final user to perform more repetitions for each measurement has the potential to increase even further the accuracy of the results. A patent for the smartphone adapter device and procedure to measure leaf green as a proxy for the crop nitrogen status is pending.

Conclusions

Results show that the smartphone low-cost adapter device could be a suitable alternative to more expensive chlorophyll meters for the estimation of crop N status in smallholder cropping systems.

References

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