A Robot and precision greenhouse farming

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Abstract: - The purpose of this paper is to summarize an integrated project that included an algorithm to calculate Nitrogen percent (N%) by image processing, to use it as a tool for a decision support system (DSS) and to load the system on an autonomous robot. The robot moves along crop's rows and performs foliar fertilization. The system presented in this project unifies two very different areas – robotics and agronomy. The robot is controlled by a "computerized manager" that provides several tasks. 1st task is to control the movement of the robot including moving direction (or angle), number of steps between plants in a row and the distance between steps. The 2nd task is to take photos of the crop automatically, by a digital color camera. The camera is mounted on a long rod that carries it above the canopy. Then, via the internet cloud, the robot send the photo to a "server" that is to a located elsewhere for N% analysis. The 3rd task of the robot is to receive the output from the "server" and to perform quantitative foliar fertilization according to the output of the "server" analysis. The agronomic decisions are controlled by the algorithm of the server. The "server" is the "brain of the system". It also has several tasks: 1st task is calculate N% from the photo by its built-in algorithm; 2nd task is to approximate actual N content (kg N ha^{-1}) from the product of N% and potential canopy weight. The potential canopy weight is stored within the "server" as a part of a list of best crop production functions vs. days after planting (DAP) for many different crops. The production functions are based on well documented experiments and are given together with N% vs DAP. The 3rd task is to use the actual nitrogen content and compare it with the potential N contend in order to estimate N deficiency or surplus actual N availability of the crop. The 4th task is to release the calculated results to the "computerized manager" that is expected to response by foliar fertilization at appropriate dose. This unified robotics-agronomy system can grant a good representation and a better understanding of the robot labor in agricultural activities for researchers and engineers from different areas, who could be involved in the design and application of precision agriculture techniques.

Key-Words: - proximate sensing, Nitrogen percent in leaves, RGB camera

1 Introduction

Unified robotics-agronomy system (RAS)is widely used in the field of precision agriculture. It is a methodology that aim to optimize agricultural field management focusing on the enhancement and obtaining optimal yield .However most RAS's are focusing on saving labor without observing and responding to the crop's physiological conditions. They do follow field variations by using modern technologies, such as global positioning systems (GPS) and geographic information systems (GIS). These techniques offer a great benefits for saving manpower. The advantage of RAS is its capability to apply the management principles to in-field changes in crop nutritional conditions and prevent yield variability and yield decline.

To manage yield variability within a field the strategy behind the development of RAS was to expose it to multiple users and not necessarily to those who are using the robot. The principle is to split between the moving part called a "computerized manager" and a "server" that is located at a headquarter and responding to the crop's condition using the simplest sensor [digital RGB (Red Green Blue) camera or smart phone] that is available to almost everybody and everywhere. The server is equipped with a software that provides the grower the percent of nitrogen in the leaves, a comparison with expected N% and how much to fertilize if necessary. This calculation is based on stored production functions of several (20) major crops. The function describes the optimal dry matter yield of the crop from DAP harvest.

1.1 Objectives

a) Demonstrate an integrated project that includes of N% from image processing. b) Use N% data as a tool for decision support system (DSS). c) Load the system on autonomous robot that moves along crop's rows and performs foliar fertilization according to computerized instructions from the DDS.

2 Materials and methods

2.1 System description

A computational environment named after a combination between green and robot “GREENBOT" for nitrogen fertilization tasks has been developed to study and evaluate the execution of the autonomous robot prototype. The moving element is based on a battery operated vehicle that is frequently used by elderly people. It enables the analysis of cooperation, and interaction of a set of autonomous tasks in a greenhouse. This prototype is capable of operating automatic control of moving direction, proximate sensing and automatic response to image processing algorithm**.** Fig. 1 displays the GREENBOT. It is an autonomous robot operated by a controller. The input contains information on the coordinates of field, crop ID, DAP and moving distance and direction.

Other inputs for the controller are the information obtained from on-board camera, fertilizer tank and properties of the fertilizer that interact with the crop.

2.2 Experimental calibration of the robotics-agronomy system (RAS)

The major segment of chlorophyll molecule in all plants is based on Mg^{++} in the center of the molecule surrounded by four N atoms. Therefore a legitimate test is to compare chlorophyll content in the leaf and N%. An experiment was conducted in 3 replicates in a lay out after the method of De Malach et.al.[1] in a complete randomized design. Chlorophyll content was estimated according to Lichtenthaler HK [2].

2.3 The production function model

Nitrogen application rate has a significant effect on biomass accumulation. Nitrogen concentration declines or dilute during the growing period. A critical *N* dilution curve is usually estimated for the above ground canopy and is given by:

$$Nc = a \cdot W^{-b} \tag{1}$$

where *Nc* (kg *N*/ kg dry matter) is a critical nitrogen concentration and it is related to canopy weight accumulation *W* (ton/ha.). "*a*" and ”*b*" are the coefficients of the regression curves. *N* and *Nc* are estimated through the image analysis algorithm that is stored in the "server" while *W*, the production function, obtained on the basis of DAP by the Hill equation:

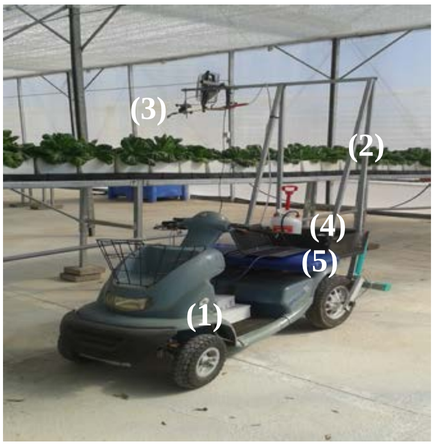


Fig.1 The prototype of a GREENBOT: (1) the battery operated vehicle; (2) the lifting arm; (3) digital color camera and a sprayer; (4) fertilizer container; (5) the operating computer.

$$W=A\cdot DAP^{B}/(C^{B}+DAP^{B}), \tag{2}$$

where A, B, and C are the coefficients. The multiplication of leaf nitrogen concentration and dry canopy mass per unit area made it possible to predict leaf nitrogen weight and to determine fertilization policy. Optimal fertilization: Translating target N% in the leaves (e.g., defined from the image) to kg/ha N application in the field based on optimal production (yield) curve.

3 Results and discussion

3.1 Experimental calibration

The technology of N% evaluation is based on the correlation between green color (crop greenness), chlorophyll amount, and %N. The green level or greenness of the leaves is increased (or decreased) according to their nutritional status. Fertilization management is provided on by monitoring the crop nitrogen conditions. Percent N is obtained by the digital color camera.

A comparison between lab results and image-based algorithm for N% in the leaves of lettuce is displayed in Fig.2.

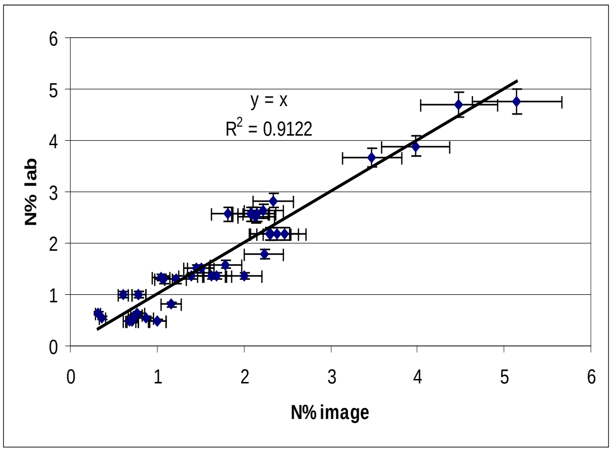


Fig. 2 Comparison between laboratory test and image analysis.

3.2 The production function model

The production function and its associated calculation is displayed in the following set of three figures (3, 4 and 5). An example of the stored production function for maize is displayed in Fig.3

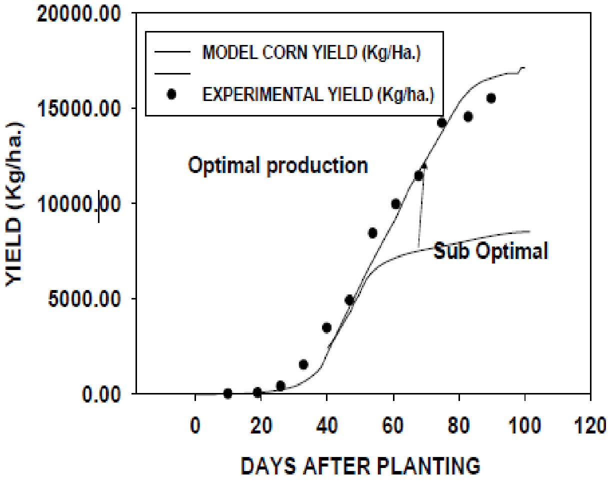
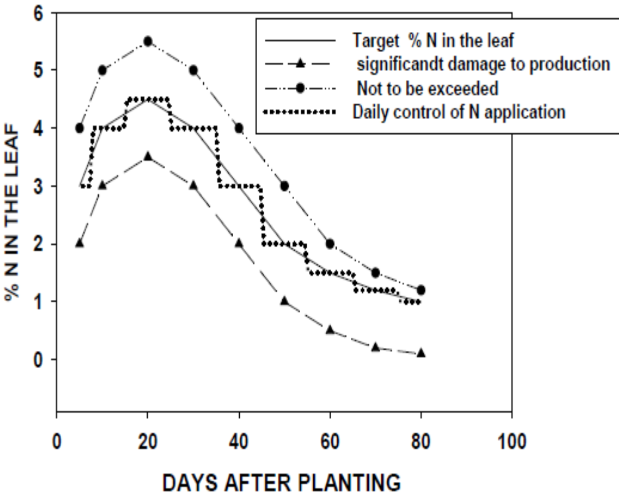


Fig. 3 Predicted and measured DM of maize as a function of days after planting. In the case of suboptimal yield the aim is to improve it upward to the target function.

The leaves nitrogen percent is displayed in Fig.4. It is stored in the "server" and is accompanied by an upper and lower tolerance range. The step function for optimal nitrogen percent. Figures 3 and 4 were obtained from literature and stored in the server. The amount of *N* in the field is the product of Figs 3 and 4 and it is displayed in Fig 5.



as a function of time.

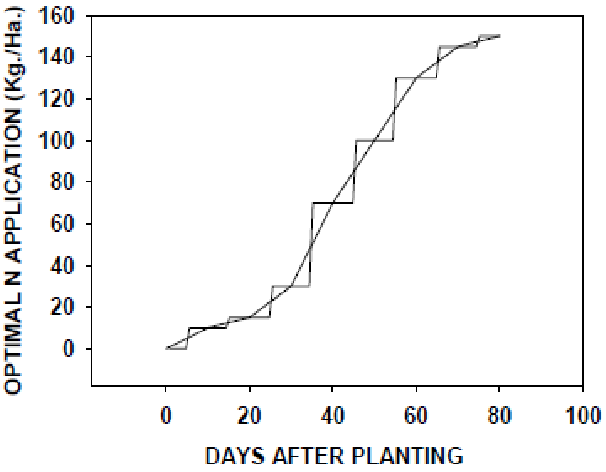


Fig. 5 Optimal N consumption (expressed as cumulative application).

4 Conclusion

Having noted the new scientific developments in agriculture over recent years, we can envisage a trend towards the increasing use of computer and autonomous robots to perform high precision irrigation and fertilization tasks. Following these trends, and based on a powerful computational tools (MATLAB, C/C++, etc.) fast estimation of a crop nutritional conditions by color imaging has enabled us to combine precision agriculture and a robot equipped with a camera to support agronomic decision.

In this paper we have presented a robot called "GREENBOT" that was tailored specifically for precision agriculture. Example of its application is autonomous crop spraying for precision fertilization.

Laboratory and photographic forms agreed with one another such that Nitrogen percent can be easily obtained without the need to use laboratory analysis. High frequency determination of *N* deficiency of can be determined and corrected fast before damage occurs to the crop. Equations (1) and (2) show that by recording DAP and *Nc* with a camera the critical N concentration at a given DAP provides a reference for assessing the status of N nutrition during the growing season. It helps to obtain maximum yield. Critical N is a reference for nutritional conditions. Below *Nc* nitrogen is deficient and should be fertilized. Above *Nc* there is no need to apply nitrogen.

References:

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