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Development of a Simple and Cheap Device for Peanut Peg Strength Measurements

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ABSTRACT

Peg strength is an important plant trait to avoid digging losses although it can vary due to agronomic practices and cultivar characteristics. This attribute is usually measured by exerting a mechanical force through an electronic force gauge or tension load cell until peg detachment occurs. The development of electronic platforms such as Arduino®, which have free and open-source hardware and software would allow obtaining peg strength measurements quickly and inexpensively. The goal of this work was to develop an economic electronic data acquisition system Arduino-based for measuring peg strength. To create the peg strength meter was necessary to develop hardware and software prototypes. The calibration was assessed through R^2, root mean square error (RMSE), and mean bias error (MBE). The results were 0.999, 0.014 g, and -0.003 g for R^2, RMSE, and MBE, respectively. The Peg Strength meter was able to detect differences in peg strength between treatments. Therefore, this device is an important tool to identify appropriate digging dates.

Palavras-chave: ***Digging loss; Load cell; Arduino; Datalogger.***

Desenvolvimento de um Dispositivo Simples e Barato para Medições de Força de Peg de Amendoim

RESUMO

A força da peg é uma característica importante da planta para evitar perdas na colheita. Este atributo é geralmente medido exercendo uma força mecânica através de um manómetro electrónico ou célula de carga de tensão até que ocorra o desprendimento da peg. O desenvolvimento de plataformas electrónicas como o Arduino®, que possuem hardware e software livre e de código aberto, permitiria obter medições de força da peg de forma rápida e barata. O objetivo deste trabalho era desenvolver um sistema electrónico económico de aquisição de dados baseado no Arduino® para medir a força da peg. Para o desenvolvimento de protótipos de hardware e software foi necessário criar o medidor de força da peg. A calibração foi avaliada através de R2, erro quadrático médio (RMSE), e erro de desvio médio (MBE). Os resultados foram 0,999, 0,014 g, e -0,003 g para R2, RMSE, e MBE, respectivamente. O medidor de força da peg foi capaz de detectar diferenças na força da peg entre tratamentos. Por conseguinte, este dispositivo é uma ferramenta importante para identificar melhores datas de colheita.

Keywords: ***Perda de coleheita; Célula de carga; Arduino; Data logger.***

Desarrollo de un dispositivo simple y económico para medir la resistencia de las cajas de maní

RESUMEN

La fuerza de los hilos que sujetan las vainas es un rasgo importante de la planta para evitar pérdidas durante el arrancado del cultivo, pero puede variar debido a prácticas agronómicas y características del cultivo. Este atributo se suele medir ejerciendo una fuerza mecánica a través de un medidor de fuerza electrónico o una célula de carga de tensión hasta que se produce el desprendimiento de la pica. El desarrollo de plataformas electrónicas como Arduino®, que disponen de hardware y software libre y gratuito, permitiría obtener mediciones de la fuerza de los hilos de las vainas de forma rápida y económica. El objetivo de este trabajo fue desarrollar un sistema económico de obtención de datos electrónicos basado en Arduino para medir la fuerza de las vainas. Para crear el medidor de fuerza de vainas fue necesario desarrollar prototipos de hardware y software. La calibración se evaluó mediante el R^2***, el error cuadrático medio (RMSE) y el error de sesgo medio (MBE). Los resultados fueron de 0,999, 0,014 g y -0,003 g para*** R^2***, RMSE y MBE, respectivamente. Por lo tanto, este dispositivo es una herramienta importante para identificar las fechas óptimas de arrancado del maní.***

Palabras clave: ***Pérdidas por arrancado; Celda de carga; Arduino; Registrador de datos.***

Introduction

Peanut (*Arachis hypogaea* L.) is one of the most important oilseed crops in the world. Due to the chemical composition of grains, peanuts are the fourth most important source of edible oil and the third most important source of vegetable protein (KURT *et al*., 2016). Peanut is cultivated in tropical, subtropical, and temperate regions around the world. The main peanut region of Argentina covers ca. 350,000 ha. in the temperate central provinces of Córdoba and La Pampa. Encompassing the last decade, the mean country yield was 2.7 t ha^{-1}, whereas the last growing season the yield averaged 3.45 t ha^{-1}(FAO, 2020).

To obtain the high yield and seed grade, peanut crop requires precise management practices and the optimum time to start the digging is one of them. If crops are dug too late, yield losses can partially result from pod detachments. Therefore, the weakness of the peg tissue can result in substantial yield losses, which is generally termed as “digging loss”. For this reason, peg strength is an important plant trait to avoid digging losses when peanuts are inverted and threshed mechanically (JORDAN *et al.*, 2016; KURT *et al*., 2016; COLVIN *et al*., 2018).

Peg strength can vary due to agronomic practices, biotic and abiotic stresses, peg age, and cultivar. In this sense, peanut breeding programs may improve the peg strength of some cultivars (KURT *et al*. 2016; SORENSEN *et al*., 2017; COLVIN *et al*., 2018). Peg strength is usually measured by exerting a mechanical force through an electronic force gauge or tension load cell until peg detachment occurs (SORENSEN *et al.*, 2017).

Pearce (2020) showed strong evidence of a wide range of scientific tools that save money because they contain free and open-source software. The development of electronic platforms such as Arduino®, which have free and open-source hardware and, easy to use software and hardware, would allow obtaining peg strength measurements quickly and inexpensively.

The objective of this work was to develop an economic electronic data acquisition system Arduino-based for measuring peg strength.

Material and methods

Hardware prototype

The instrument was mounted on a standard Arduino® Uno (ARDUINO, 2021), board, which is free hardware based on the ATmega328P microcontroller. It has 14 digital input/output pins and 6 analog inputs. Some pins can also be used for communication with other devices (in this case to a computer simply by connecting a USB cable and a memory card using SPI protocol to interface with Micro SD Card Module). In this project, the Arduino® UNO was powered with 5v via USB cable (**Figure 1**).

To measure the peg strength, a load cell of 1kg was used. Load cells are specially shaped metal parts that have strain gauges glued to them. The strain gauges are resistors that change their resistance when they are bent. When the metal part bends, the resistance of the load cell presents small changes. For amplifying these small signals, the load cell must be interfaced with an analog to digital (ADC) Amplifier (HX711) to a digital input pin of Arduino® (FAROOQ *et al.*, 2021).

Once the Arduino® reads a digital number from the load cell signal, it must convert to a mass value by multiplying with a calibration factor obtained by the calibration process. Then, the information is saved in a CSV format file using a micro-SD memory by means of a Micro SD Card Module interfaced with SPI protocol (**Figure 1**).

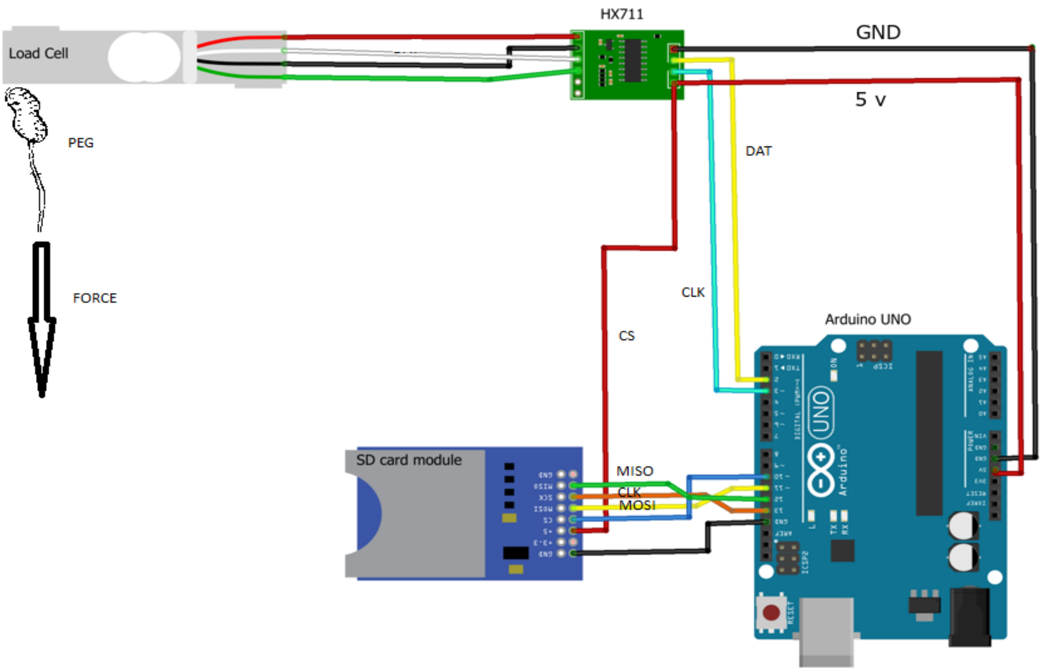

Figure 1. Schematic diagram of the circuit using Fritzing.

Software prototype

The software design includes the possibility of calibrating the load cell to obtain the calibration factor or reading 100 data values of strength. The selection is done by a user sending a Y/N letter from PC prompt to Arduino® via USB communication. If the calibration option is selected, the user has to attach a known weight (until 1 kg) into the extreme of the load cell and send this value to Arduino® using the Arduino® Integrated Development Environment (IDE). Then, the calibration factor is calculated and saved into the Electrically Erasable Programmable Read-Only Memory (EEPROM) of Arduino®. This value is used later to convert digital numbers from the ADC Amplifier (HX711) module into force (g) (**Figure 2**).

The second option allows to read 100 peg strength data values. In this case, the user has to send to Arduino® a treatment name and press enter key to start the new peg record. First a tare procedure is done, then an ADC conversion is read and multiplied by a calibration factor and stored into the micro SD each 0.1 second. When 100 data are saved, the device is ready to start a new peg record (**Figure 2**).

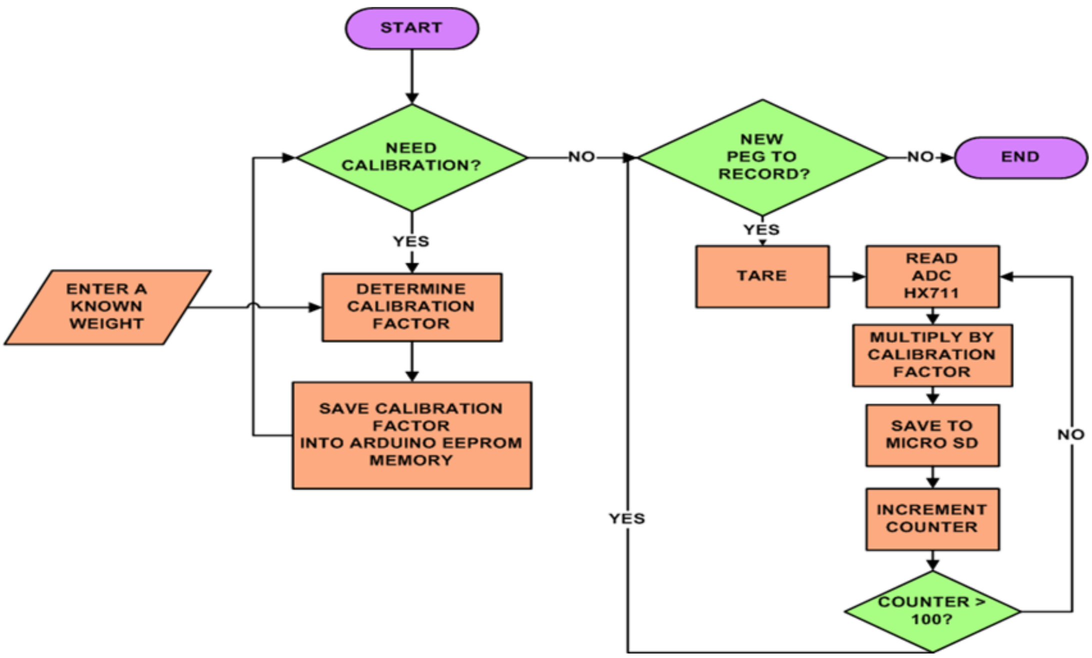

Figure 2. Flow chart diagram of peg strength software.

Calibration

Calibration is an indispensable stage to maintain instrument accuracy. The process consists of configuring an instrument to provide a reliable result. Eliminating or minimizing factors that lead to inaccurate measurements is a fundamental aspect of instrumentation design. Before determining the peg strength of pods, a procedure of calibration was necessary. To calibrate, a known weight is put first into the load cell to achieve the calibration factor, then this operation is repeated with ten objects of variable known weights. The accuracy of calibration was evaluated through R2, root mean square error (RMSE), and mean bias error (MBE).

Crop experiment design and peg strength measurement

A field experiment was conducted during 2020-2021 at Manfredi (31º49'S, 63º46'W), Argentina, on a silty loam Typic Haplustoll soil. Cultivar ASEM 400 INTA was sown on October 17th using a stand density of 14 plants m^{-2} at 0.70 m row spacing. For weed control, Imazetapir (1,000 $mL.ha^{-1}$) and Cletodim (800 $mL.ha^{-1}$) were used. Chlorantraniliprole (4.5%) and Abamectin (1.8%) combined (100 $mL.ha^{-1}$) were used as insecticides. Foliar diseases were well controlled using picoxystrobin 20% and cyproconazole 8% (400 $mL.ha^{-1}$). The evaluated treatments were: (i) Control (no application of plant growth promoting rhizobacteria, PGPR), (ii) *Bacillus* sp. (SC6) and (iii) *Bradyrhizobium* spp. (Rhizo). The bacteria were cultured in a Tryptic Soy Broth fluid medium at 28-30°C for 48 h until reaching $1x10^9$ $CFU.ml^{-1}$. PGPRs were placed at sowing and at the beginning of the pod set in the plants row.

From the peg stage and once a week, pegs of 5mm (≈ age) located near (0-5 cm) and distal (+20 cm) distance from the main stem were identified in ten plants per plot. The treatments were arranged in a completely randomized block design with three replicates and plots were always four rows wide and 15 m long. Each previous identified pod was placed in a "U" shaped metal bracket that was attached to an electronic force gauge. The force was generated by a DC motor with an endless screw and a 1mm stainless steel wire rope for pulling the peg until cutting.

Results and discussion

Calibration

The good agreement between predicted and observed values evidenced a correct calibration of the device (**Figure 3**). A linear regression was fitted between observed and predicted weights and low residual values were determined. Moreover, a low negative value of MBE indicates slight underestimation of values.

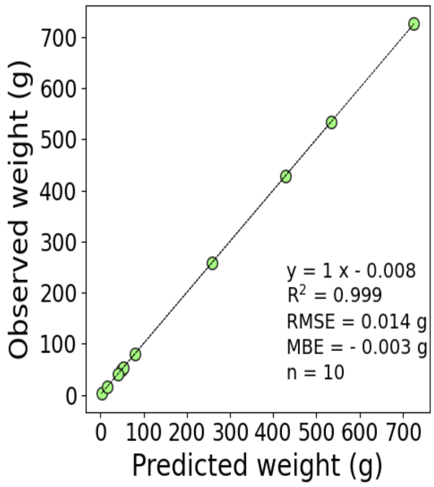

Figure 3. Observed and predicted weight values of objects used during calibration process.

Peg Strength measurement

Identified pods of the same age were measured with the peg strength meter. Two contrasting responses between pods growing at 0-5 cm and +20 cm from the main stem were found (**Figure 4**). Focusing on the analysis of identified pods between 0-5 cm, plants inoculated with SC6 (198 g) recorded higher cutting force values of pods respect to Control (148 g) and Rhizo (146 g).

This aspect would suggest that SC6 affected the anatomic constitution of pegs (e.g., tissues, storage of tannins, anthocyanins). Also, pegs of SC6 showed an intermediate cutting time compared with the other treatments (0.43 s for SC6-05, 0.34 s for Control and 0.48 s for Rhizo). The analysis of pods farther than 20 cm from the main stem evidence two responses: (i) the cutting forces for pods growing under PGRs (Rhizo: 693 g, SC6: 658 g) were higher than Control (552 g) and, (ii) pegs of Rhizo (0.30 s) and Control (0.29 s) presented higher elasticity of pods respect to SC6 (0.26 s).

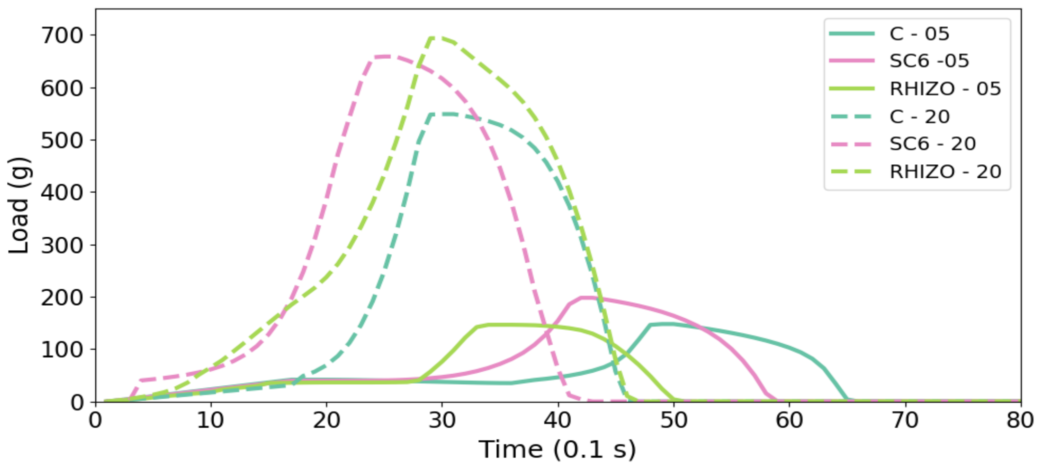

Figure 4. Peg strength determination at 5 and 20 cm from the main stem in PGPR treatments.

If we compare only the peg strength measurements without considering the evaluated treatments with the obtained by COLVIN *et al*. (2018), there were consistent. On average, the authors found a 510 g similar to us 400 g – 500 g.

SORENSEN *et al.* (2017) documented strength measurements for multiple cultivars at different harvest dates, locations, and years. In these experiments, they have obtained an average strength equivalent to 400g. That indicates the ability of the device to perform the measurements accurately. To accurate digging date in the base of peg strength measurements for Argentinian peanuts cultivars, further determinations under multiple environmental crop conditions would require.

Conclusions

We developed and evaluated a low-cost Peg Strength meter mounted in an Arduino® Uno board. The use of a set of objects with weights allowed an efficient calibration of the Peg Strength meter, which was confirmed by suitable statistical values. Peg strength information is a useful trait to determine optimal harvest date, preventing digging losses. The system developed and evaluated here detected differences between treatments validating its capacity to measure the strength of peanut pegs.

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