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Laboratory evaluation of seed metering device using image processing method

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Abstract

Seed-metering system is an important component in row-crop planters in terms of uniform seed distribution. Numerous field and laboratory methods have been developed and used for evaluation of planter performance; each method having its own advantages and shortcomings. In the present study, a digital camera (Nikon, D70) was used for laboratory evaluation of vertical-rotor seed-metering device performance, indices such as multiple planting, feeding quality, miss planting and seed space uniformity being the major criteria. To validate the results from image processing method, the more conventional, grease-belt method, was used. The experiments were conducted on the basis of factorial randomized complete design with two types of seed-metering devices, with different numbers of cells and four levels of seed-metering speeds in three replications. Captured images were transferred to the computer via USB port and were processed by program written in MATLAB software environment. The results from two methods, namely, image processing and grease belt methods were in good agreement and analysis of variances showed that seed-metering device with 15 cells in 40 rpm performed better than seed-metering device with 21 cells and in other speeds. Comparison of the number of spaces that fell in normal domain in different seed-metering speeds showed that image processing method had higher value than grease-belt method. Since the initial falling velocity of seed and angle of its exit from metering device was unknown, thus the precision of space index was different in two methods.

Key words: image processing, precision planter, seed metering, grease belt

Introduction

Amount of seeds planted along the rows and distance uniformity between seeds are important factors in crop production which can affect uniform crop growth and yield. These parameters depend on the performance of the metering mechanism of the seed planter. There are several techniques for determining the planter performance (Jasa and Dickey, 1982; Brooks and church, 1987; Kachman and Smith, 1995; karayel et al., 2005). For determining distance between seeds, Janke and Erbach (1985) marked a section of the row, removed the soil and made direct measurements. It is time consuming and difficult to dig and locate small seeds without disturbing their locations. One of the most frequently used methods is grease belt method. Although it is accurate but impose some limitation such as: number of data that can be obtained is limited by the length of the belt, length of time required to manually measure the seed spacing and the risk of sliding or bouncing seeds on the grease belt, specially at high belt speed. But it is convenient and has been tried by some researchers for evaluating a single row seed metering mechanism (Singh et al. 2005). In field test method, distances between plants after growth are measured and performance indices are calculated (Kepner et al., 1987; Kocher et al., 1998; Rahman and Singh, 2003). In one of the latest techniques, Kocher et al. (1998) and Lan et al. (1999) used a seed detector system comprising 24 photo transistors. Results obtained by Panning et al. (2000) through this system showed that the spacing measured was 15mm greater than that of theoretical one. Inaccuracy of the opto-electronic sensor system was related to seeds with less than 3mm in diameter. Alchantis et al. (2002) used machine vision technique for evaluation of spatial distribution of seeds. Results showed that data obtained from this method were strongly correlated with the same seed spacing measurements obtained from grease belt. Raheman and singh (2003) developed a sensor based on a light interference technique for sensing the seeds dropping from the planter. Their system could evaluate performance of planter for wheat and maize with 18% and 10% error respectively. This error was due to inability of the sensor to detect multiple seeds in a short period of time. Shrestha et al. (2004) developed an algorithm to process a video image of maize rows and extract some plant features to estimate density and spacing of maize plants during its early stage of growth. According to the results obtained from experiments, there was no significant difference between means of manually measured plant spacing and those of estimated from images. Karayel et al. (2005) used a high-speed camera system for planter performance evaluation. It was capable of recording motion up to 40500 frames/s. They determined the velocity of fall by consideration of the seed locations on 20 frames. The objective of the present research was to study the possibility of using a digital camera for laboratory evaluation of seed metering device performance.

Materials and methods

The planter used in this research, was designed in agricultural machinery department at University of Tabriz. Its seed metering device is of vertical- roller type with 118 mm diameter. The planter was installed on the 11m long, 40 cm wide grease belt

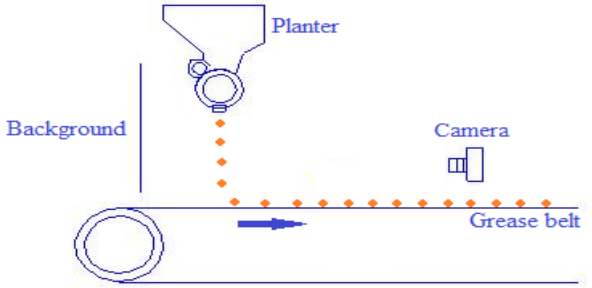

Fig 1. Planter rig test

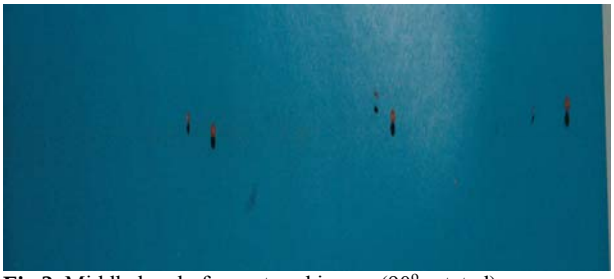

Fig 2. Middle band of a captured image (90° rotated)

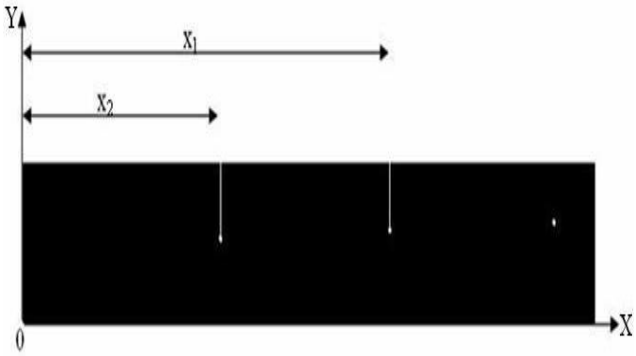

Fig 3. Seeds location on a sample

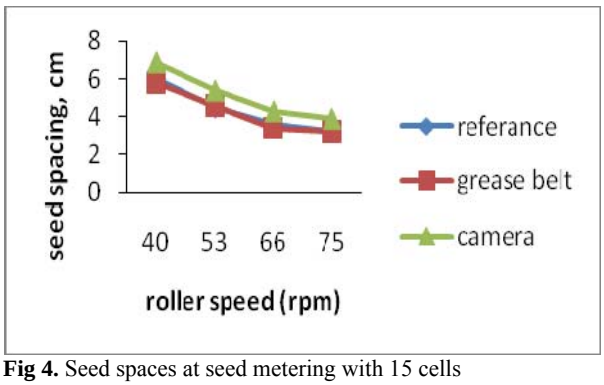

Fig 4. Seed spaces at seed metering with 15 cells

test rig. Also, a semi-professional digital camera (Nikon D70) was installed at 1 m ahead of the planter and above the belt (Fig. 1). Orange colored pelleted tomato seeds (sun f1) were used during experiments with blue background for easy detection of seeds. The factorial experiments with three replications were conducted on the basis of completely randomized design with two levels of number of seed cells (15 and 21) machined on vertical-roller and four levels of seed metering device speed(40,53,60 and 66 rpm). For each replication, the planter was started and run for 20 seconds until it reached to its steady state condition. Then 12 frames were captured. The captured images were transferred to computer and processed via MATLAB software. Within each image, the middle band was selected, separated from the rest of it and processed immediately (Fig. 2). Seed images appeared as small orange spots on black background. The image type was RGB. The following formula was used:

$$C = 2r - g - b \qquad (1)$$

Where
C- Image matrix included 3 layers
r- red layer matrix
g- green layer matrix
b- bleu layer matrix
C matrix was normalized by dividing it into maximum value and multiplying by 255. Matrix values ranged from -255 to +255. Negative values eliminated from matrix, because they showed background pixels. Then seed color was white on black background (Fig. 3). Small sized spots created by broken seeds were eliminated from processed images. To evaluate how accurate the camera method was, experiments were repeated using grease belt method and results were compared to those of from image processing method. In each replication, location of seeds on 4 m long grease belt was specified. x_1, x_2, x_3 … indicate the locations of seeds on the images (Fig. 3). These values were used to calculate distances between consecutive seeds. But comparison could not be made between these results and results obtained from grease belt method due to acceleration of seeds that caused different distances to be recorded for the same time intervals in camera method. To overcome the problem, belt speed assumed to be 0.6 m/s and the times for two consecutive seeds placed on belt were recorded. Then the following formula was used to calculate distance between seeds:

$$\Delta x = V \times \Delta t \qquad (2)$$

Where, V is assumed to be belt speed.
The time elapsed until a seed was displaced at location x_2 after the previous seed that had been displaced at location x_1 was calculated as following:

Table 1. Analysis of variance of feed quality and miss planting

Sources	df	SS			
		Grease belt		Camera	
		Feed quality	Miss planting	Feed quality	Miss planting
Type of metering system	1	1162**	855.6**	6443**	5905**
Speed	3	626.7**	566**	712.3**	536.6*
Speed *Type of metering system	3	174.8*	118.5*	115.2	166
Error	16	37.97	29	108.7	138
C.V		8.04	24.4	15.9	35

* and ** Significant at 5% and 10% level of significance respectively

$$\Delta t = \sqrt{\frac{2s}{1000\ g} \times (x_1 - x_2)} \qquad (3)$$

Where:

S Resolution power (0.16 mm/pixel)
g gravity acceleration (9.81 m/s^2)
x_1 the first seed location in image (pixel)
x_2 the second seed location in image (pixel)

Results

Analysis of variance showed that in both methods (namely image processing method and grease belt method) the effect of type of metering device (number of cells) and speed was significant on seed feed index (at P<0.01). But their interaction was significant (at P< 0.05) in grease belt method and non-significant in image processing method (Table 1). Alchanatis et al. (2002) compared the methods by comparison of average distances obtained from the experiments. Average distances in our experiments are shown in Figs. 4 and 5 for each metering system. The seed spacing measured on grease belt was in good agreement with reference distance, but the seed spacing obtained from image processing had constant difference with reference distance; therefore a program can be written to accommodate these differences and be used for evaluation of seed metering device. A comparison of seed spacing values measured on grease belt with those values estimated from related images (see Figure 6) indicated that there was a linear relationship between these values (R^2=0.97) and the true values for seed spacings can well be approximated from video images if the intercept value of the regression line is known (a coefficient of x is approximately equal to unity). It was assumed that seeds fell freely, whereas it was released by trajectory action with θ° relative to horizon with initial speed of v_0 (Fig.7). As this figure shows, B and D are the seed actual locations which differ from B' and D' in the image, thus BD≠B'D', bearing in mind that BD- B'D'=Constant throughout the experiments. Since the image processing algorithm processes the images based on seed surface color, any broken seed may be eliminated if the inner white color section of seed be in front of the camera, thus affecting the seed spacing. If the broken seed is to be evaluated, two or more cameras must be used. In this research, we used the tomato seeds with orange color, if the seed color changes, background color must also be changed. In this research 12 images were used; it is obvious that the greater the number of images and the shorter the distance between cameras and metering system, the better the results.

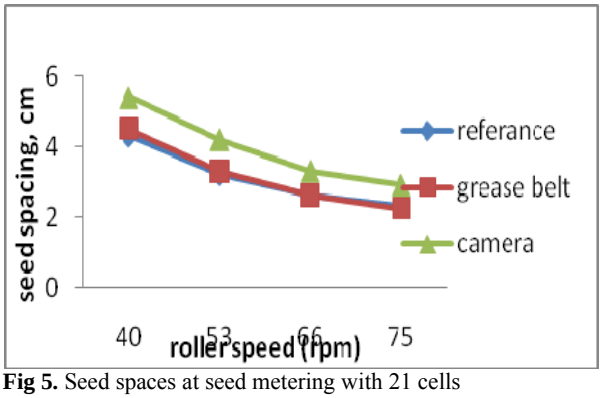

Fig 5. Seed spaces at seed metering with 21 cells

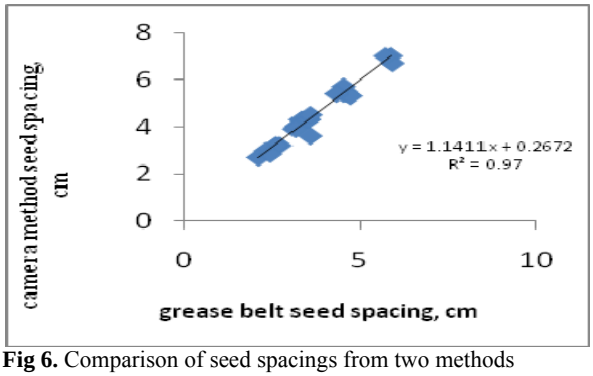

Fig 6. Comparison of seed spacings from two methods

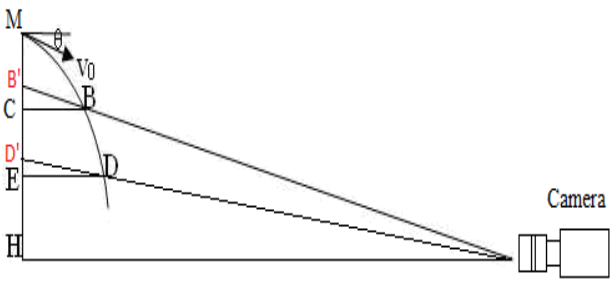

Fig 7. Seed location on background

Discussion

Image processing is a powerful tool for seed planter evaluation. Results of this research indicated that an appropriate algorithm could be developed to detect seeds falling from seed planter using image processing. Figs. 4 and 5 show that the results from

two methods, namely image processing and grease belt, were in good agreement with each other. Also the results were comparable to those btained by Kocher et al. (1998) and Karayel et al. (2005). Kocher et al. (1998) succeeded in using opto-electronic sensor to measure seed spacing with coefficient of determination, R^2=0.951. This value in Karayel's et al. (2006) experiments for wheat seeds was R^2=0.96. If the number of images increases, (Karayel et al. used 20 frames compared to 12 frames used in this work), better results may be achieved. Image process method is suitable for seeds with any size and it does not have the limitation of opto–electronic sensor system (Lan et al., 1998). Also, in this method, data handling is easier. In Rahman method (2003), 18% of seeds went undetected, whereas in the method already discussed approximately all of the seeds were detected.

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