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Design and Evaluation of Three Metering Devices for Planting of Sugarcane Billets

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ABSTRACT

In sugarcane production, the mean condition for high productivity depends on billets located in the furrow with uniform distribution. The focus of this paper was on development and evaluation three types of a new prototype of sugarcane metering device to plant the sugarcane billets with desired spacing. Accordingly, a prototype of the precision metering device for sugarcane was developed. The model of the metering device was designed with CATIA R21. The performance indices of the device, including quality of feed index (QFI), multiple index, miss index and precision have been taken as a set of criteria for billet spacing accuracy and were investigated under laboratory conditions using a test stand with camera system. There was significant difference of miss index, multiple index and quality of feed index among different tooth length while precision affected by speed. Four row cylindrical metering device showed a better performance compare to other types of metering device. Analytical hierarchy process (AHP) was used and 1.5 cm teeth length with forward speed of 15 m min⁻¹ was best found for selected sugarcane billet metering device with 91.67% for quality of feed index with 5.03% precision.

Keywords: Sugarcane billets; Metering device; Analytical hierarchy process; Image processing; Performance indices

Şeker Kamışı Dikiminde Üç Tip Dikim Ünitesinin Tasarımı ve Değerlendirilmesi

ESER BİLGİSİ

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ÖZET

Şeker kamışı üretiminde yüksek verimin ön koşulu çeliklerin sıradaki dağılımının düzgün olmasıdır. Bu çalışmanın amacı şeker kamışı çeliklerinin istenilen aralıkta dikilmesi için 3 tip dikim ünitesinin tasarımı ve değerlendirilmesidir. Bu amaçla hassas dikim ünite ilk örneği geliştirilmiştir. Model örneğinin geliştirilmesinde CATIA R21 programı kullanılmıştır. Ünite performansının değerlendirilmesinde besleme kalite indeksi (QFI), çoklu indeks, kayıp indeksi ve

hassaslık olmak üzere pek çok ölçüt göz önüne alınmış ve denemeler laboratuvarında kameralı deney düzeneğinde yapılmıştır. Farklı diş uzunluğunda besleme kalite indeksi (QFI), çoklu indeks ve kayıp indeksi arasında önemli farklılıklar elde edilirken hassaslığın hızdan etkilendiği belirlenmiştir. Dört sıralı silindirik dikim ünitesi diğer ünitelerden daha iyi performans göstermiştir. Sonucun değerlendirilmesinde analitik hiyerarşi (AHP) yöntemi kullanılmış olup 1.5 cm diş uzunluğu, 15 m min⁻¹ ilerleme hızı en iyi koşul olarak belirlenmiş, bu koşulda besleme kalite indeksi % 91.67 ve hassaslık % 5.03 bulunmuştur.

Anahtar Kelimeler: Şeker kamışı çelikleri; Dikim ünitesi; Analitik hiyerarşi yöntemi; Görüntü işleme; Performans ölçütleri

1. Introduction

Precision seeders place seeds at the required spacing and provide a better growing area per seed (Karayel 2009). Usually, plant scientists use hand dibblers to achieve this accuracy (Singh et al 2005). Thus, it is important to improve the planting operation by reducing human effort, and increasing stand accuracy and field capacity (Ebrahim et al 2009). It is necessary for seeds to be placed at equal intervals within rows with uniform spacing so the roots can grow uniformly (Karayel & Ozmerzi 2001). Seed flow evenness and in-row seed distribution uniformity of top delivery normal type straight fluted roller were examined in the laboratory experiments for the random seeding of uncoated onion, carrot, canola and coated canola seeds by Önal and Ertuğrul (2011). Uniform spacing also results in better germination and emergence and increases yield by minimizing competition between plants for available light, water, and nutrients (Griepentrog 1998; Karayel & Ozmerzi 2002). For different plants, both seed population and seed spacing at planting time have effects on harvested yield and size of stalks (Robinson et al 1981).

Sugarcane (*Saccharum officinarum* L.) is an important economic crop in the tropics and sub-tropics due to its high sucrose content and bioenergy potential (Gilbert et al 2008; Sampietro et al 2006). Sugarcane provides about 65% of the sugar produced in the world (Zambrano et al 2003) and is used as a feedstock in the ethanol industry (Dias et al 2012; Murali & Hari 2011) with potential as a renewable energy source (Santos et al 2006). Sugarcane is produced in 106 countries

and the global production exceeds 1060 million tons per annum (FAO 2011). Sugarcane production is highly laborous which requires 3,300 man hours for doing different operations per hectare (Murali & Balakrishnan 2012). Stalks are cut in 30 to 40 cm long pieces, called billets, each of which must contain at least one bud (Mandal & Maji 2008). These billets are then placed or planted in an orderly manner in soil furrows (Srivastava 2004). Thus, the special metering devices are needed for planting sugarcane billets.

Most reported studies on sugarcane mechanized planting were experiments with no scientific method for evaluation. Carlin et al (2004) considered the most important factor for good yield to be the quality of planting, which should provide a good stand of buds per meter. Stolf et al (1984) studied the influence of mechanized planting on germination rate of sugarcane. The results showed no significant difference between the germination rates under the conventional system (38%) and mechanized system (37.2%). Ripoli (2006) reported that the excessive variability in production of sugarcane is not only due to genetic factors, but it depends on soil preparation for planting and so mechanical planters should reduce variability. Bachche et al (2007) studied economic comparisons between semi-mechanized sugarcane billet planters and traditional methods. The cost of operation for mechanized planting was as 6.67 \$h⁻¹ and for conventional planting cost of operation was found as 10.72 \$h⁻¹. Bhal & Sharma (2001) presented that there was a substantial labour requirement reduction of 73.33% from conventional method to machine planting. Yadav &

Choudhuri (2001) reported that the overall labour requirement for sugarcane cultivation is 3300 man-hours per hectare and the labour requirement for planting is 238 man-hours per hectare. Dafa'alla & Hummeida (1991) evaluated the performance of one of the sugarcane planters and studied the effect of forward speeds on machine planting. They found the forward speed of 4 km h⁻¹ would result in higher field machine capacity and a reduction in required seed material without considerable yield losses. Patil et al (2004) evaluated two semi-mechanized sugarcane planters and found forward speeds of 1.8 and 2.5 km h⁻¹ to facilitate effective working and the billet requirement was observed to be above 9.0 tonnes per hectare. Salassi et al (2004) estimated the cost differences between whole-stalk and billet sugarcane planting and found billet planting to be more cost effective than whole stalk planting. Ripoli & Ripoli (2010) evaluated five sugarcane planters and compared them based on a standard method under the same field conditions and in terms of cost effectiveness. They found that the mechanized system was significantly cheaper than the semi-mechanized one and also reported that neither of the planters that seeded billets showed an adequate distribution mechanism for the prime matter. There are some studies that only investigated the performance of metering devices for different agricultural crops.

The focus of this article was to develop and evaluate three model types for evaluating sugarcane metering devices and to find the best operating conditions among them. Thus, a laboratory measurement system (LMS) was developed in order to determine equidistance billet spacing distribution on a belt, based on four performance parameters: multiples index, miss index, quality of feed index, and precision.

2. Material and Methods

2.1. Billet preparation

Sugarcane stalks were harvested in October, 2011 from a field in Debel Khazaie, Ahvaz, Iran and were transferred to the Physical Properties of

Materials Laboratory, Department of Agricultural Machinery Engineering, Faculty of Engineering and Technology, University of Tehran, Karaj, Iran. 40 samples of sugarcane stalks, of approximately 30 cm in length, were cut with a fine-bladed bandsaw. In tests moisture content of billets was about 70 percent and average weight of billets measured 0.24 kg for each billet.

2.2. Description of the sugarcane metering device

The importance of modeling by Computer Aided Design (CAD) or virtual prototyping has long been recognized (Dupac 2012) and it provides a perfect tool for easily design (Kamboj et al 2012). Catia V5 R21 software was used to design and develop a CAD model of our sugarcane metering device.

The metering device consists of inclined surface, 10 fixed bolts, three different types of rotary units, bearings, a pulley and adjustable bolts (Figure 1). At the end of a 21 degree inclined plate, 10 bolts are pitched and located between the bolts pitched on rotary unit. The length of the bolts on the rotary unit is adjustable and anchor bolts permit the effective tooth length on rotary unit to be increased or decreased. Three rotary unit types were designed and evaluated. Figure 2 shows the laboratory sugarcane planter that was used for the tests. The speeds of the rotary unit of the metering device were set at 15, 30, 45 and 60 rpm for square and cylindrical rotary units with 4 rows and 7.5, 15, 22.5 and 30 rpm (to allow for the simulation of the same forward speed as 4 the row metering devices) for the cylindrical rotary unit with 8 rows at a simulated travelling speed of 15, 30, 45 and 60 m min⁻¹ for belt. At these speeds combinations, average frequencies of the falling billets were 60, 120, 180 and 240 billets min⁻¹ for sugarcane billets. Based on the reported mean sugarcane billet diameter of 2.075 cm (Taghinezhad et al 2012), tooth lengths of 1.5, 2 and 2.5 cm were used on the rotary units during tests. An electro motor with 1.75 hp power was used as a driving metering device and an LG iG5A variable frequency drive was used to control and set the electro motor speed.

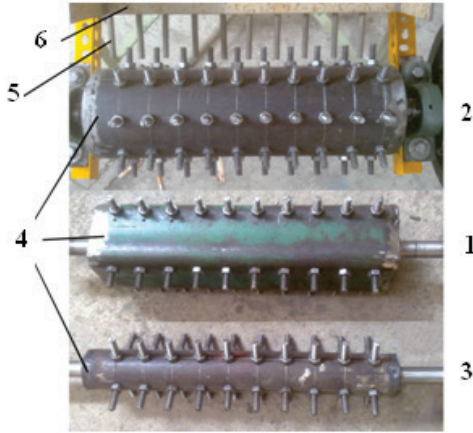


Figure 1- Three different rotary unit of sugarcane metering device and its parts: 1, square type with 4 rows; 2, cylindrical type with 8 rows; 3, cylindrical type with 4 rows; 4, rotary units; 5, fixed bolts; 6, inclined surface

Şekil 1- Dikim ünitesindeki 3 farklı döner eleman ve parçaları: 1, dört sıralı kare tip; 2, sekiz sıralı silindirik tip; 3, dört sıralı silindirik tip; 4, döner üniteler; 5, sabit parmaklar; 6, eğimli yüzey

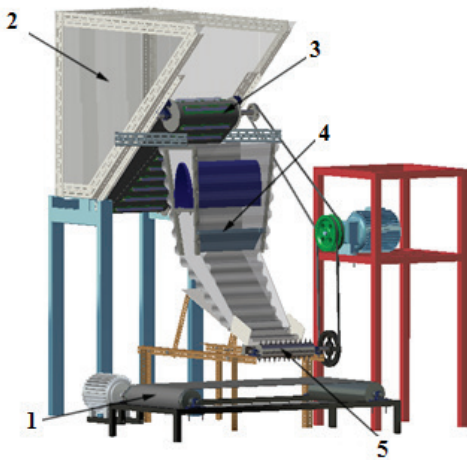


Figure 2- A graphical view of laboratory planter with equipments: 1, ground belt; 2, hopper; 3, conveyor belt; 4, secondary hopper; 5, metering device

Şekil 2- Laboratuvar tipi dikim düzeni ve parçaları: 1, alt bant; 2, depo; 3, iletili bant; 4, ikinci depo; 5, dikim ünitesi

2.3. Evaluation of the billet spacing distribution

Multiple index, miss index, quality of feed index, precision, and mean and standard deviation of billets spacing were determined to quantify the distribution of plant spacing using the methods described by Kachman & Smith (1995). The multiple index is the percentage of billet spacing that was less than or equal to half of the theoretical (nominal) spacing and indicates the percentage of multiple billet drops. The miss index is the percentage of occasions where billet spacing was greater than 1.5 times the theoretical spacing and indicates the percentage of missed billet locations or skips (Karayel 2009). Quality of feed index (QFI) is the percentage of occasions where billet spacing was more than half but no more than 1.5 times the theoretical spacing and is a measure of the percentage of single billet drops. The QFI is calculated via following equation:

$$QFI = 100 - (\text{Miss index} + \text{Multiple index}) \quad (1)$$

Larger values of QFI indicate better performance than smaller values (Celik et al 2007). Precision (PREC) is the coefficient of variation of the spacing (length) between the nearest plants in a row that are classified as singles after omitting the outliers consisting of misses and multiples (Singh et al 2005). According to Kachman & Smith (1995), the theoretical upper limit for precision is 50% and this distribution of spacings would indicate that the theoretical spacing was incorrectly specified and, therefore, this level of precision is unfavorable. A practical upper limit on the value of precision is 29%. While there is a theoretical upper limit of 50% on the precision, values consistently greater than 29% should be viewed with suspicion (Karayel 2009).

2.4. Performance measurement procedure and data analysis

The metering device was installed on a 2.7 m long, 40 cm wide, belt test rig. Also, a semi-professional digital camera recorder system (Samsung) with 26x optical zoom and 25 frame s⁻¹ was installed 1.23 m above the belt. The system included of three main components: a digital camera to record the passing

canes, a motion analyzer for image analysis, and a computer for data processing and monitoring. The system was capable of recording motion up to 30,000 full frames in DVD to be replayed from memory for instant viewing. The capture of unpredictable events was readily accomplished using the electronic triggering features of the Motion Analyzer. The 720×576 pixel sensor produced sharp images with 256 levels of RGB. High light sensitivity of the system reduced the need for supplemental lighting. For image processing, ImageJ 1.44 p software was used and Adobe Photoshop CS (6) Timeline software was used for converting videos to frames. The metering device, belt, and digital camera combination with a simulated metering device and travel speed of 15, 30, 45 and 60 m min⁻¹ was run with sugarcane billets. The metering device and belt were started and run for 20 second to reach steady-state operating conditions before the digital camera system was signaled to start recording billets, and then 12 frames were captured. The captured images were transferred to computer and processed via ImageJ software. Within each image, the edge of billets determined via software and middle band was selected and separated from the rest of it and processed immediately and amount of spacing between billets were calculated as follows:

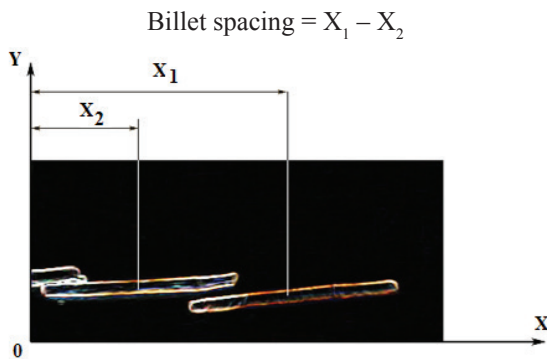


Figure 3- Billet location on a sample

Şekil 3- Örnek üzerindeki çeliğin konumu

Three types of the sugarcane metering devices and belts were used to simulate forward speeds of 15, 30, 45 and 60 m min⁻¹, with three metering device tooth lengths (1.5, 2 and 2.5 cm). Three

replications of each test were performed. We aimed to determine the optimum set-up from among the 36 combinations of metering device, forward speed, and tooth length. There are two important scales in tests, quality of feed index and precision percent. We used the Analytical Hierarchy Process (AHP) method for selecting the best condition in sugarcane billet metering device. Microsoft Excel 2010 and SPSS 20 software were used to analyze data. Analyses were performed in three stages: (1) Hierarchy decision tree making, (2) Priority evaluation, and (3) System consistency ratio calculation.

3. Results and Discussion

Tests were performed using combinations of three sugarcane metering device types, three tooth lengths, and four forward speeds. Each combination was replicated in triplicate.

3.1. Effect of tooth length on miss index, multiple index, quality of feed index and precision

The mean miss index, multiple index, quality of feed index, and precision values for different metering device tooth length are given in Table 1, ANOVA tests were applied to data to find significant differences among different tooth lengths.

According to Table 1 the differences among tooth length were statistically significant at the 5% level, for miss index, multiple index and quality of feed index but no significant differences was found for precision. Miss index decreased as tooth length of metering device increased. As the tooth length of metering device was increased from 1.5 to 2 and 2.5 cm, the quality of feed index was decreased from 74.7 to 68.6% and 65.3%, and multiple index increased from 16.81 to 26.18% and 33.61%, respectively.

Larger tooth length resulted in more billet in each cells of metering device, and consequently a decrease in miss index and quality of feed index. Since the fewer billets space in the metering device cells at the lower tooth length of metering device, multiple index of performance was increased as tooth length of metering device increased.

Table 1- Performance values for different sugarcane metering device tooth lengths*Çizelge 1- Farklı diş uzunluğuna sahip dikim ünitesi performans verileri*

Tooth length (cm)	Performance values						
	Miss index (%)		Multiple index (%)		QFI (%)		Precision (%)
	Value	SD	Value	SD	Value	SD	Value
1.5	8.5a	0.8	16.806 a	1.584	74.7 a	2	15.476
2	5.2 b	0.7	26.181 b	0.882	68.6 b	1	16.413
2.5	1 c	0.4	33.611 c	0.633	65.3 c	0.7	15.973

a, b and c indicate significant differences at 5% levels

Table 2- Performance values for different speed of sugarcane metering device*Şekil 2- Şeker kamışı dikim ünitesinin farklı hızlarındaki performans değerleri*

Speed (m min ⁻¹)	Performance values						
	Miss index (%)		Multiple index (%)		QFI (%)		Precision (%)
	Value	SD	Value	SD	Value	SD	Value
15	4.63	0.9	25.28	1.94	70.09	2.1	10.1a
30	5.65	1.1	26.11	1.95	68.24	1.6	13.71 b
45	3.7	0.9	25.93	1.59	70.37	1.4	18.97 c
60	5.74	0.9	24.81	1.88	69.44	1.6	21.04 d

a, b, c and d indicate significant difference at 5% levels

3.2. Effect of speed on performance indices

The effect of metering device speed on miss index, multiple index, quality of feed index (QFI) and precision values are shown in Table 2. There is no significant difference in miss index, multiple index and quality of feed index (QFI) between different speeds (in 5% level). However, a significant difference for precision between different speeds was observed. Precision increased as the speed of

metering device increased. According to Karayel (2009), upper limit on the value of precision is 29% and with respect to Table 2, there is an acceptable precision for metering device in different speeds.

Some researchers have studied the effect of speed on the precision of metering device. Singh et al (2005) found the speed of metering device much more effective than other parameters in considering precision. Önal et al (2012) evaluated precision for maize and cotton to be 10.75 and 20.6%, respectively. Ebrahim et al (2009) determined a precision of about 8.63% for a sugar beet metering device.

3.3. Comparison of the metering devices

Sugarcane billet distribution patterns were analyzed with respect to the type of metering device used, and the results are shown in Table 3. An ANOVA test showed that miss index, multiple index and quality of feed index are significantly different at the 5% level among the three different type of sugarcane metering devices. Also there was a significant difference between cylindrical 4 row (3) compared to the cylindrical 8 row (2) and square 4 row types (1) in precision performance values.

Table 3- Performance values for different type of sugarcane metering device*Çizelge 3- Farklı dikim ünitelerinin performans değerleri*

Metering device type	Performance values						
	Miss index (%)		Multiple index (%)		QFI (%)		Precision (%)
	Value	SD	Value	SD	Value	SD	Value
1 Square 4 row	4.72a	0.8	30.76 a	0.07	64.51a	0.9	16.81 a
2 Cylindrical 8 row	7.08 b	0.9	24.17 b	1.57	68.75b	1.1	16.48 a
3 Cylindrical 4 row	2.99 c	0.7	21.67 c	1.84	75.35c	1.7	14.57 b

a, b, c and d indicate significant difference at 5% levels

Lower precision values indicated better metering device performance. As reported by Kachman & Smith (1995), the precision value is preferred to be less than 29%-30%. On the other hand, Önal (2006) proposed 4.75% for the upper limit of miss index values. An optimal metering device would have a low miss index, low multiple index, high quality of feed index and low precision index. According to these standards, Table 3 shows that metering device type 3 (cylindrical 4 row) had the best performance among the three different types of sugarcane metering devices tested.

3.4. Selecting the best operating condition for sugarcane metering device

Since there are different factors involved in sugarcane metering device efficiency, the Analytical Hierarchy Process (AHP) was used to determine the suitable tooth length and speed for a given sugarcane metering device recommended by Saaty (1980).

Two parameters were used to determine optimum metering device efficiency, quality of feed index (QFI) and precision. Since lower precision values indicate better performance, the inverse of this index was used. Analyses were performed via below stages:

1. Hierarchy decision tree making
2. Priority evaluation
3. System consistency ratio

3.4.1. Hierarchy decision tree making

The first stage in AHP is making a graphical view of the tests such as hierarchy shown in a diagram (Figure 4) with the goal at the top, the two criteria in next step, and three levels of alternative combinations which resulted to thirty six alternatives at the bottom ways to determine the best conditions for sugarcane billet metering device. Table 4 shows performance indices values for each alternative with the metering device type, tooth length and speed.

3.4.2. Priority evaluation

Analytical hierarchy process evaluate the priority of each alternative in relation with its criteria through a pairwise comparison that is named local priority.

Then, with incorporation of local priorities, the overall priority of each alternative is specified. First alternative is compared with respected to its criteria separately and the priority of each alternative in relation to its criteria is evaluated. Afterwards, the priority of criteria in relation to the goal was specified and the overall priorities of the alternatives were determined via this incorporation.

All comparisons in the analytical hierarchy process were performed pairwise. For example, if we compare alternatives with respect to number of filled cells, first alternative 1 (type 1, 1.5 cm tooth length and 15 m min⁻¹ simulated forward speed) compared with alternative 2 (type 1, 1.5 cm tooth length and 30 m min⁻¹ simulated forward speed) and then this comparison performed with alternatives 1 and 3 (type 1, 1.5 cm tooth length and 45 m min⁻¹ simulated forward speed and also with 2 and 3. Because pairwise comparison matrixes had 36 rows and 36 columns, it was not possible to present the matrix in this article.

The importance of quality of feed index for planting billets was evidenced by, QFI criteria in compare to precision criteria was preferred with 3 to 1 ratio and priority of each alternative spotted its gain ratio in tests for the measured values and there is no need for validating numbers. In the pairwise comparisons, the priority of each alternative in relation with own is 1 thus all numbers on diameter of pairwise comparison matrix equaled 1. Also, if the priority of A to B was 2, the priority of B to A to would be the inverse, 0.5.

Simple mean was used to calculate the weight of each cell in the pairwise comparison matrix (local priority). In this step the matrix was normalized by totaling the numbers in each column. This method includes three stages:

1. The sum of each column is computed.
2. Each entry in the column is then divided by the column sum to yield its normalized score. In the normalized matrix the sum of each column is 1.
3. The next stage is to compute the average values of each row and use these as the local weights in the Objective Hierarchy.

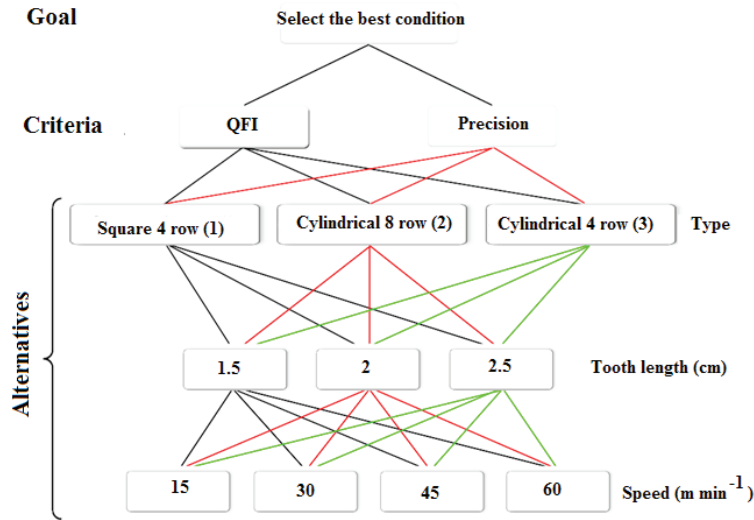


Figure 4 - AHP hierarchy for choosing the best condition for sugarcane metering device

Şekil 4- Şeker kamışı dikim ünitesinin en iyi koşulunun belirlenmesi için AHP hiyerarşisi

Table4- Measured values for performance indices in metering device system for each alternatives

Çizelge 4- Her bir alternatif için dikim ünitesinin performans göstergelerinin ölçüm verileri

Alternatives	Type	Tooth length (cm)	Speed (m min ⁻¹)	QFI (%)	Precision	Alternatives	Type	Tooth length(cm)	Speed(m/min)	QFI (%)	Precision
1	1	1.5	15	59.17	0.1	19	2	2	45	66.67	0.05
2	1	1.5	30	62.5	0.05	20	2	2	60	72.5	0.05
3	1	1.5	45	65.83	0.04	21	2	2.5	15	64.17	0.09
4	1	1.5	60	61.67	0.04	22	2	2.5	30	64.17	0.08
5	1	2	15	62.5	0.09	23	2	2.5	45	63.33	0.06
6	1	2	30	59.17	0.08	24	2	2.5	60	61.67	0.04
7	1	2	45	69.17	0.07	25	3	1.5	15	91.67	0.2
8	1	2	60	67.5	0.05	26	3	1.5	30	86.67	0.17
9	1	2.5	15	66.67	0.09	27	3	1.5	45	84.67	0.06
10	1	2.5	30	65.83	0.08	28	3	1.5	60	86.67	0.06
11	1	2.5	45	69.17	0.05	29	3	2	15	77.5	0.11
12	1	2.5	60	65	0.05	30	3	2	30	71.67	0.06
13	2	1.5	15	80	0.1	31	3	2	45	70.83	0.05
14	2	1.5	30	68.33	0.08	32	3	2	60	70.83	0.05
15	2	1.5	45	76.67	0.06	33	3	2.5	15	63.33	0.08
16	2	1.5	60	72.5	0.05	34	3	2.5	30	66.67	0.08
17	2	2	15	65.83	0.1	35	3	2.5	45	67.5	0.06
18	2	2	30	69.17	0.05	36	3	2.5	60	66.67	0.05

Final weights of each alternative in its criteria were calculated. These weights were used in summing the measures as required in the evaluation of the objective hierarchy.

Then, one must determine the weight of each criterion in relation with goal and the need to pairwise comparison of criteria. With respect to importance of precision in performance of metering device, weight of precision and QFI criteria were calculated as 0.75 and 0.25, respectively.

3.4.3. Evaluating overall priorities of alternatives

After computing the weight of criteria in relation with goal and the weight of alternatives in relation with criteria (matrixes not included), we were able to determine the priorities of alternatives in relation with our goal (overall priorities). The weight of each criteria shows its importance in the goal. Also the weight of each alternative in the criteria is of important. The overall priority of each alternative computed via total of weight of criteria multiple the weight of alternative in criteria. Finally, the overall priority of each alternative was computed with respect to local priorities (Table 5).

Table 5- Overall priorities of each alternative

Çizelge 5-Her bir alternatif için genel öncelikler

Alternative	Overall priority (10^{-2})	Alternative	Overall priority (10^{-2})	Alternative	Overall priority (10^{-2})	Alternative	Overall priority (10^{-2})
1	2.73	10	2.73	19	2.43	28	3.12
2	2.37	11	2.56	20	2.65	29	3.35
3	2.34	12	2.44	21	2.77	30	2.73
4	2.26	13	3.35	22	2.67	31	2.62
5	2.74	14	2.85	23	2.48	32	2.57
6	2.52	15	2.85	24	2.24	33	2.69
7	2.72	16	2.61	25	4.66	34	2.78
8	2.50	17	2.93	26	4.19	35	2.55
9	2.83	18	2.59	27	3.12	36	2.49

According to Table 5, alternative 25 (type 3, Cylindrical 4 row), 1.5cm tooth length and 15 m min^{-1} simulated forward speed) is the best condition

for sugarcane billet metering device with 91.67% and 5.03% for quality of feed index and precision respectively. Alternatives 26, 13 and 29 are the next best.

3.4.4. System consistency ratio analysis

In the last stage of the AHP method, the system consistency ratio must be calculated. The acceptable value for inconsistency of a matrix or a system dependent on the decision maker but Saaty (1980) indicated 0.1 or below is considered acceptable and any higher value at any level indicates that the judgments warrant re-examination. After calculating, inconsistency of system determined 0.001 that is lower than 0.1 and acceptable and there is no need for test repetition.

4. Conclusions

Three type of metering devices were developed and constructed for planting sugarcane billets and tested in the laboratory. Image processing was used to acquire the data. Evaluation of the metering device based on the optimized design and operational parameters leads us to a higher value of quality of feed index (QFI) with a lower miss index. The effects of rotary unit tooth length, simulated forward speed and metering device type on different performance indices were verified. With increasing in tooth length, miss index and quality of feed index decreased, while the multiple index increased significantly. There is a significant direct relationship between precision index and speed. Comparisons among three different metering devices showed that the cylindrical rotary unit with 4 rows has the best performance indices. Finally, an analytical hierarchy process was used to process data and it was observed that a 4-row cylindrical metering device with 1.5 cm tooth length and 15 m min^{-1} simulated forward speed were the best working conditions for a sugarcane billet metering device with a 91.67% quality of feed index, 0.83% miss index, 7.5% multiple index and 5.03% precision. Also, a 4-row cylindrical metering device with 1.5 cm tooth length and 30 m min^{-1} simulated forward speed is the next most suitable alternative. A consistency ratio evaluation value of

0.001 confirmed the results. The findings of this article can be used to improve sugarcane planters' yield by optimizing the conditions for metering device of billets in uniformity of distance between planted billets and filling of metering device cells.

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