YYÜ TAR BİL DERG
(YYU J AGR SCI)
2015, 25(1): 1- 12

Geliş Tarihi (Received): 27.12.2013
Kabul Tarihi (Accepted): 10.12.2014

Araştırma Makalesi/*Research Article (Original Paper)*

Fabrication and Evaluation of a Metering Device for a Sugarcane Billet Planter

Moslem NAMJOO[1*], Jalil RAZAVI[2], Ali KHANI[2]

[1] : Department of Agricultural Machinery Engineering, Faculty of Agriculture, University of Jiroft, 78671-61167, Jiroft, Iran.
[2] : Department of Agricultural Machinery Engineering, College of Agriculture, Isfahan University of Technology, Isfahan, Iran.
[*]e-mail: moslem.namjoo@ujiroft.ac.ir; Tel: +989173152535; Fax: +983483260065

Abstract: Metering device is the most important part of any planter that is responsible for precise counting and uniform distributing the seeds or billets over ground surface. In this research a new metering unit was designed and fabricated for sugarcane billet planter. The prototype is mainly consisted of an endless chain conveyor with some holding cupboard for conveying the billets to the surface of the planting furrows. An effective and efficient design of this chain conveyor system enables it the precise timing for the billet to be planted with desirable overlap. As result, a more uniform crop coverage can be achieved after sprouting. Using a laboratory test rig, the effects of planting speed, cane variety and angle of chain structure on filling percentage of the cupboards, overlapping and under overlapping of the planted billets were evaluated. A factorial experiment in a completely randomized design was used for the tests. According to the results, the best performance of the design metering unit is found to be at planting speed of 3.5 km h^{-1} and 20º angle for conveyor chain.

Keywords*:* Billet Planter, Metering Unit, Overlap, Planting Uniformity, Sugarcane

Şeker Kamışı Çelik Dikim Aleti İçin Ölçüm Cihazı İmalatı ve Değerlendirilmesi

Özet: Ölçüm cihazı, toprak yüzeyinde tohumların veya çeliklerin kesin sayım ve bir örnek dağıtımından sorumlu olan herhangi bir ekici-dikicinin en önemli parçasıdır. Bu araştırmada yeni bir ölçüm ünitesi, şeker kamışı çelik dikim aleti için tasarlanmış ve imal edilmiştir. Prototip, esas dikim karıkları yüzeyine çelik taşınması için bazı tutma dolabı ile sonsuz bir zincir konveyörden oluşmaktadır. Bu zincirli konveyör sisteminin etkili ve verimli bir tasarımı, çubukların istenen bir örtüşme ve kesin zamanlama ile dikilmesini sağlamaktadır. Sonuç olarak, filizlenmeden sonra daha muntazam bir ürün kaplanmasının elde edilebilmektedir. Bir laboratuar test teçhizatı kullanarak, dikim hızı, şeker kamışı değişim ve dolapları yüzdesini doldurmasında zincir yapısının açısı, örtüşme ve dikili çelik altında örtüşme etkileri değerlendirilmiştir. Testler için tamamen tesadüfi faktöriyel deneme deseni kullanılmıştır. Sonuçlara göre, tasarım ölçüm ünitesinin en iyi performansına, konveyör zinciri için 20º açı ve 3.5 km/h dikim hızı olduğu durumdadır.

Anahtar kelimeler: Çubuk Dikim aleti, Ölçüm Birimi, Örtüşme, Dikim birörnekliği, Şekerkamışı

Introduction

Sugarcane, (*Sacharum officinarum L.*) as a biennial crop and native of warm climates, is considered to be a source of 62% of world produced sugar in a year (Razavi and Khani 2008). The most important part of the sugarcane is its stalk which sugar extracted from it (Salassi et al. 2004). Depending on geographical location and climate condition, the sugarcane may be harvested up to six years. Seed planting is often used for developing new varieties of sugarcane while whole stalk and or billet planting is used for producing the sugar (Hoy et al. 2006, Rípoli and Rípoli 2010). The planted billets in the furrows may be overlaped or non-overlapped. Non overlapping state occurs when billets are place horizontally on the soil surface one after another, without longitudinal overlapping. If billets are placed with some degree of covering each other, then the planting is performed by an overlapping pattern (Hoy et al. 2002, Razavi and Khani 2008).

Each planted billets has 3 to 5 nodes at each one the billets buds appear and grow as stalk. So, a 10 to 15 cm overlapping will result in a more uniform crop coverage after germination (Hoy et al. 2011). The numbers of billets planted depend on various factors, including planting methods, environmental conditions, variety, rate and method of irrigation. They may be 15 to 20 thousands billets per hectare (Johnson et al. 2011).

Planting may take place manually or by machine. Because of labor shortage and high production cost, the manual planting is just practiced in small scale farming or for re-plantation of areas left with gaps; therefore, the mechanized planting is a real necessity.

Various planting machines used for sugarcane cultivation, can be categorized as the two main groups: billet planters and cutter planters. In billet planters, whole stalk cane are fed in to rotary cutters by labors to be cut in to certain desired length and then placed on furrows (Rípoli and Rípoli 2010). In billet planters, billets of equal length go through metering devices and are distributed over ground surface. Depending on precision of metering devices, the billets are either planted uniformly or planted with a mixed or an irregular pattern.

Stiff and Baker (1985) developed a pulled type sugarcane planter which had three separate holding tanks for pre-cut billets. Through a drop tube, these tanks were fed by three workers. Mandal and Maji (2008) designed a metering device with two rotating drums capable of cutting whole stalk cane. The cane were fed through and inclined channel and cut into billets of 35 to 36 cm length. The average overlap length of consecutive billets placed on soil surface varied from 15 to 18 cm. A one row planter with a billet holding tank of 750 kg and 75 to 150 cm row width was designed in Iran (Rezaee et al. 2011). The overlap amount of planted billets was 25 percent of the billets length. In Pakistan, a planter was designed and developed for mechanized sugarcane planting operations. A planter was equipped with furrow openers and disks for covering the planted billets with soil. The metering device of the machine was capable of receiving billets from the tank and putting them in the furrows (Binder 1982). The Australian company of Austof developed a pulled type, double row planter with planting capability of 8 ton/ha of sugarcane billets. The wheel driven metering device of the machine had a 1 m belt and metal cupboards to pick billets up from the tanks (Populin et al. 1976).

The billet length is a very important factor which has considerable effects on planting process and mechanical damage to the billets. Damage to the billets with an average length of 50 cm in manual planting is reported to be 11.4. For higher lengths, in mechanized planting, the damage will increase (Johnson et al. 2011). Overlap planting and accelerating germination process will contribute to more uniform coverage and elimination of replanting operations.

The rate of billet dropping by the metering device is a crucial factor for economic assessment of any planter machine. It is evident that over dropping needs to additional number of billets and higher production expenditure. On the other hand, lower amounts of consumed billets lead to reduction in crops per planted area (Robotham and Chappell 2002).

In this research, a single cupboard metering device is designed to have the capability of planting billets of 50 cm length. By this way, a considerable reduction in the production cost and mechanized damage to billets would be achieved.

Material and Methods

Metering Device Design

Design of agricultural machinery with specific goal of offering a solution for current problems in an agricultural region should consider certain important factors. The machine being designed should have simple flexible mechanisms with high degree of reliability and the least production costs. In next step, each and every component of the machine should have enough strength and be able to hold various loads exerted on them and at the same time have a good appearance in construction. Metering device is the most important part of any planter because it should precisely count and uniformly distribute the seeds or in this case the billets. For billet planters, they should be able to plant billets with an overlap pattern or without any overlap. A metering device based on the mentioned goals and objectives above was designed and developed (Figure.1-A).

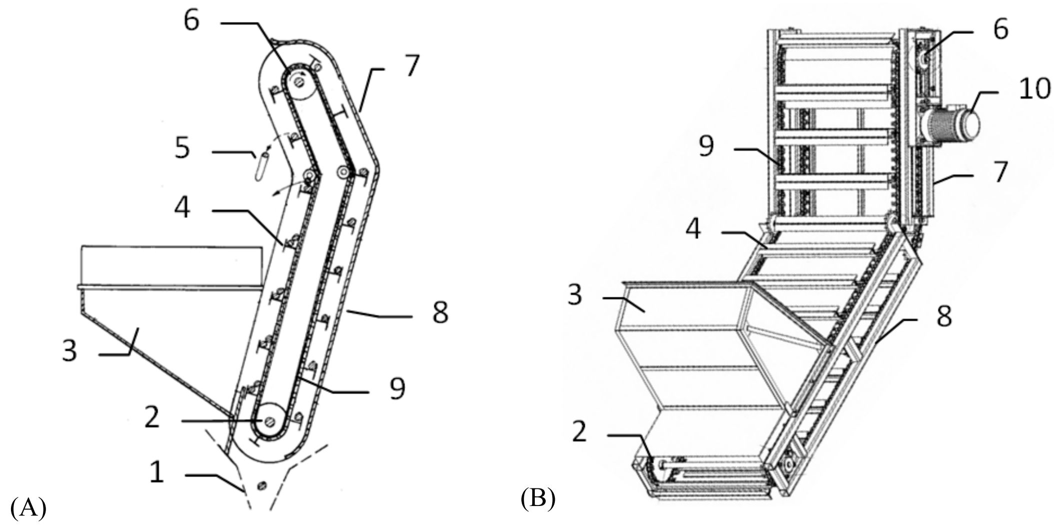

Figure 1. Components of sugarcane planter metering device: 1- Dropping Tube, 2- Sprocket, 3- Holding Tank, 4- Billet Cupboards, 5- Extra Separated Billets, 6- Driver Sprocket, 7- Upper Chassis, 8- Lower Chassis, 9- Conveyor Chain, 10- Electric Motor.

Each metering device consisted of two upper and lower chassis hinged in the middle to each other. This provided the possibility of changing the vertical angle of the upper chassis related to lower chassis which facilitates detachment of extra billets on each cupboard and transferring to holding tank. Timing of billets placement on furrows as desired with necessary overlap was made possible by combination of cupboards and chains matched with upper and lower chassis. The cupboards on conveyor chain had the job of carrying billets. Each billet was singularly picked up from the holding secondary tank and if more than one billet was in the cupboards, the additional one would be dropped out and returned back to the tank as the cupboard reached the middle section of the two chassis. When each billet reached top section of the upper chassis, it would drop on the back of the previous cupboard to be conveyed towards the soil surface. In this way, the job of detachment of extra billets would take place only in one point and by changing the vertical angle of the upper chassis.

To improve the quality of fabrication of the machine and higher dimensional accuracy, the metering device was modelled in Mechanical Desktop software (Figure. 1-B) and then was designed and fabricated based on biophysical properties of sugarcane billets.

Required Mechanical Power of Metering Device

Maximum power required to run the conveyor chain should be calculated when the chain system is at the position as shown in figure 2. To select power train components, mechanical power (P_m) required by conveyor chain was calculated using equation (1) (Silva 2006).

$$P_m = 2vL_cW_cF_c + Q(LF_m + H) \quad (1)$$

Where:

V: Linear chain speed (m/s) L_c: Laid out horizontal length of the chain (m)

W_c: Linear mass of chain (N/m) F_c: Chain rolling frictional coefficient

Q: Chain load capacity (N/s) L: Laid out length of chain section under load (m)

F_m: Coefficient of friction of billets and metal surface

H: Height of billet conveyance (m).

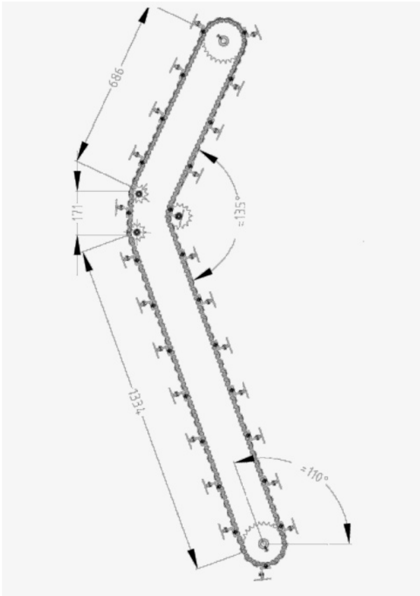

Figure 2. Metering device conveyor chain mechanism in maximum power utilization position

Linear speed of the conveyor chain at its highest level was considered to be 0.54 m/s equivalent to 4 km/h for the test rig on which all experiments were to be conducted. Linear mass of the chain was calculated using equation (2).

$$W_c = \frac{2L_c w_c + nw_l}{L_c} = \frac{2\times 4.584\times 1.96\times 9.8 + 24\times 3.39\times 9.8}{4.584} = 212.26(N/m) \quad (2)$$

Where:

L_c: Length of the chain (m) W_c: Linear mass of chain (N/m)

N: Number of cupboards carrying billets W_l: Mass of each cupboard (N).

Billet carrying capacity for 30 billets in 10 cupboards is calculated using equation (3) in which W_s is average mass of each billet.

$$Q = \frac{30w_s}{t} = \frac{30\times 0.4\times 9.8}{3.56} = 33.03\,(N/S) \quad (3)$$

Having coefficient of friction for billets on metal surface (0.42) and rolling coefficient of friction for the chain (0.39) and substituting for all variables in equation (1), we will have power needed to run the conveyor chain as being:

$$P_m = [2\times 0.54\times 1.2\times 212.26\times 0.39] + [33.03\times(1.127\times 0.42 + 1.88)] = 0.185(kW) \quad (4)$$

Power Unit and Power Train System

Figure 3 illustrates different components of the power unit and power train system for transmitting power to the input power shaft of fabricated metering device. This combination of power train system was selected to facilitate input shaft adjustment and to provide better flexibility of working conditions for the metering device itself. A 1.5 kW single phase AC electric motor with 1400 rpm was used to power the metering device.

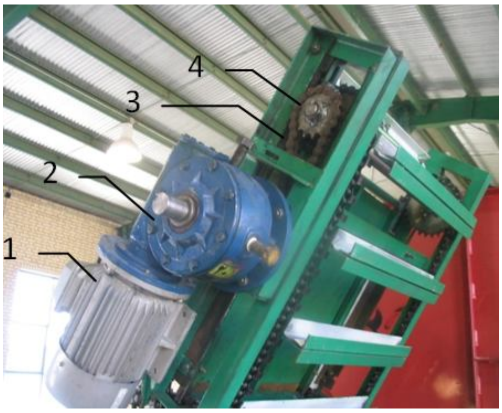

Figure 3. Components of power train system: 1- Electric Motor, 2- Spiral Gear Box, 3- Sprocket, 4- Chain

To reduce electric motor rotational speed to lower required speeds, a spiral gear box was chosen considering lower cost, smaller size, satisfactory performance and easier assembly as advantages of this type of gear box. Other factors to be considered in selecting spiral gearboxes are input and output power and torque, speed ratio and efficiency. Rated speed of the electric motor at 60 Hz frequency was 1400 rpm. Rotational speed of metering device input shaft equivalent to 4 km/h forward speed on the test rig which is typical speed for planting operations is 62.43 rpm. Therefore, reduced speed ratio is calculated as:

$$i = \frac{1400}{62.43} = 22.42 \tag{5}$$

To achieve this speed reduction a 20:1 gear box and a set of chain and sprocket was used.

Figure 4. Fabricated metering device positioned on test rig

Operation of the Metering Device and Test Rig

As shown in figure 4, after completion of fabrication process, the metering device was positioned on a laboratory test rig having a width of 900 mm and effective length of 10 m run by a 10 hp electric motor. To prevent billets agitation and deviation at the time of contact with the test rig's conveying belt, a flume type dropping tube was installed at the point of exit of billets from the metering device and close to the belt. To control both test rig and metering device speed during experiments, electric motors voltage frequency was provided through two invertors, one 1.5 and the other 7.5 kw model Delta. Single and three phase 60 Hz AC current was used. Start and shut off of motors was done simultaneously by one person.

Experimental Design

Since experiments were conducted in a laboratory setting and conditions were constant, experiments were conducted using a completely randomized design with three replications. Factors under consideration were:

A- Forward speed

Metering device's electric motor voltage frequency for four forward speeds under experimentation (2.59, 3, 3.5 and 4 km/h) was set so that for each test rig's belt complete rotation there would be a complete rotation of metering device's chain. Also, invertors' frequency was set to obtain theoretically a billet overlap of 12.5 cm assuming a billet length of 50 cm. This would result in placement of 25 billets on the belt when motors go off to determine percent filling of cupboards, over overlap and under overlap pattern. Table 1 presents adjusted frequencies of electric motors for obtainment of desired test rig's belt speed.

Table 1. Metering device electric motor voltage frequencies and corresponding test rig's belt speed

Metering device electric motor voltage frequency (Hz)	Test rig's electric motor voltage frequency (Hz)	Test rig belt speed (km/h)
43	20	2.59
48	23	3
68	27.5	3.5
68	31.2	4

B- Sugarcane Variety

Billets used in this research were from two sugarcane varieties of CP69-1062 and CP57-614, the first having no debris and the second having debris.

C- Metering Device's Angle Related to Vertical Angle

Performance of the metering device's conveyor chain angle at three levels of 10, 15 and 20 degrees from vertical angle was evaluated. Figure 5 shows the three holes on the upper chassis which provided for change in angle.

Biophysical Properties of Sugarcane Billets

To design the metering device, certain biophysical properties of sugarcane billets were required. Fifty billets from two varieties were randomly selected and their weight, diameter and length were measured. Then, weight and average diameter were measured using equations (6) and (7).

$$\rho=\frac{1}{50}\sum_{i=1}^{50}\left(\frac{m_i}{l_i}\right) \tag{6}$$

Where:

m_i: billet weight (kg) l_i: billet length (m)

$$d=\frac{1}{50}\sum_{i=1}^{50}d_i \tag{7}$$

d_i: billet diameter (mm)
Mean and standard deviation for length, diameter and weight of billets used in experiments are given in Table 2.


Figure 5. Adjustment arm for upper chassis angle adjustment

Table 2. Summary of some physical properties of sugarcane billets

Item	W/O debris billet	With debris billet
Billet length (cm)	51.8 ± 2.45	52.1 ± 3.44
Billet diameter (mm)	26.9± 2.16	27.4 ± 3.02
Billet per length Weight (kg/m)	0.569 ± 0.18	0.612 ± 0.13

Uniform spacing or placement of the billets on the planting row and pertaining overlap are important considerations in evaluation of billet planters. This relates to elimination of thinning or replanting operations which are costly. Several factors affect billets spacing from each other. The metering device might miss picking up billets from the holding tank or being unable to release it on the furrow at proper time which results in gaps between billets planted (under overlap). On the other hand, the metering device might pick up a number of billets and deliver them to be placed on the soil surface which results in over overlap planting pattern. In this research for each experiment after placement of the billets on the test rig's conveyor belt, a tape was used to record beginning and end part of the billets to determine their longitudinal coordinates (Figure. 6). The power train system for the metering device mechanism was designed to provide 12.5 cm overlap as normal pattern of planting. Values higher and lower than 12.5 cm would result in over overlapping and under overlapping, respectively. The aim of this research was to minimize these two patterns and bring it as close as possible to normal pattern. Figure 8 demonstrates three patterns of billet placement on the test rig's conveyor belt.

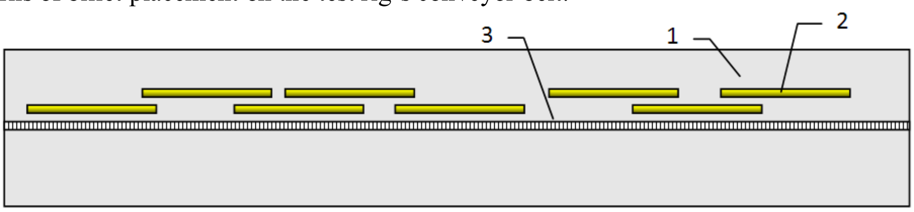

Figure 6. Billets placement after delivery on test rig's conveyor belt:1- Test rig, 2-Billets, 3-Tape

Over overlapping and its calculation

According to figure 8, if the end coordinates of billet i was $(X_2)_i$ and beginning coordinate of next billet $(X_1)_{(i+1)}$, then the overlap would be:

$$p_i = (x_2)_i - (x_1)_{(i+1)} \tag{8}$$

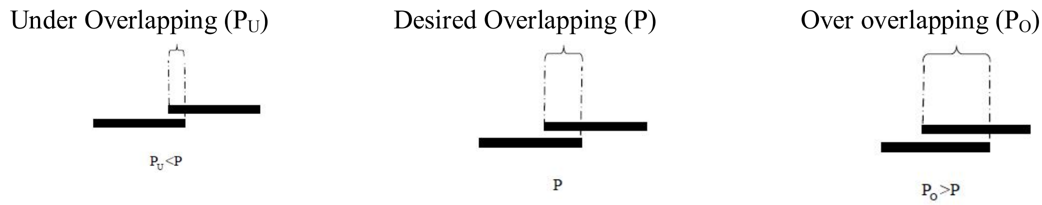

Figure 7. Patterns of placement of billets on the test rig’s conveyor belt

If the spacing was greater than this value, it would be considered over overlapping and can be calculated by equation (9).

$$O_{Over} = \left(\frac{\sum_{i=1}^{24}\left(\left((X_2)_i - (X_1)_{(i+1)}\right)\right) - 12.5}{950} \right) \times 100,\ \ if\ \ \left((X_2)_i - (X_1)_{(i+1)}\right) > 12.5 \tag{9}$$

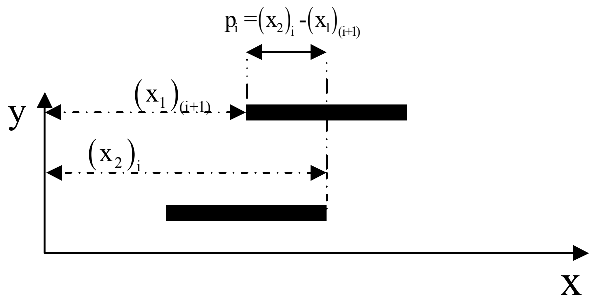

Figure 8. Calculation of under and over overlapping

Under overlapping and its calculation

If the spacing was lower than 12.5 cm, it would be considered under overlapping and can be calculated by equation (10).

$$O_{Under} = \left(\frac{\sum_{i=1}^{24}\left(12.5 - \left((x_2)_i - (x_1)_{(i+1)}\right)\right)}{950} \right) \times 100,\ \ if\ \ \left((x_2)_i - (x_1)_{(i+1)}\right) \le 12.5 \tag{10}$$

Calculation of Filling Percentage

An important parameter in evaluation of planters which plant billets singularly is the filling percentage of their metering device’s cupboards. After Data gathered from each experiment, data were entered in Excel software and percentage of filling was calculated based on equation (11). In the equation N was number of billets observed on the test rig conveyor belt as compared to number of cupboards for each experiment run (25).

$$\text{Filling Percent} = \left(\frac{N}{25}\right) \times 100 \tag{11}$$

After calculation of research parameters, data were analyzed by SAS and MSTAT-C software and results were compared using LSD at 5 percent level statistical significance.

Results and Discussion

Table 3 presents results of analysis of variance for the effect of forward speed of planting, angle of the metering device conveyor chain and sugarcane variety on filling percent, over overlapping and under overlapping.

Filling percent of cupboards:

Among factors affecting filling percentage of cupboards, effects of conveyor chain angle and planting forward speed were highly significant (P<0.01) and interaction effect of all factors became significant at 5% probability level. Effect of sugarcane variety on filling percent was not significant. This may be explained by the fact that the size of cupboards was selected properly to hold billets firmly inside and with desirable stability until they are delivered to test rig's conveyor belt, thus, no considerable effect on filling percentage due to changes in physical shape of billets as a result of sugarcane varietals characteristics.

Table 3. Results of ANOVA test for factors affecting filling percentage, under overlapping and under overlapping

Source of variation	df	Sum of squares		
		Filling percent	Under Overlapping	Over Overlapping
Angle (A)	2	262.09**	12.07	13.47
Variety (V)	1	4.15	1.47	10.5
Speed (S)	3	657.6**	9.45	2.02
A*S	2	7.5	1.48	3.48
V*S	3	93.13	6.82	5.33
V*A	6	72.49	10.76*	6.33
V*A*S	6	106.81*	10.76	2.91
Error	48	40.09	3.84	5.87

** And * indicate significance at 1 and 5 % probability level.

Figure 9 shows trends in changes of filling percentage of cupboards as affected by speed of planting. As forward speed increases from 2.59 to 3.00 km/h, filling percent decreases about 4 percent which was not significant. However, as speed reaches 3.5 km/h, reduction in filling percept becomes significant at 5% level. Between speeds of 3.5 and 4.00 km/h the reduction in filling percent was also significant. As a whole, due to increase in forward speed from 2.5 to 4.00 km/h, filling percent showed a 16.4 percent reduction. This reduction may be as a result of lesser time given to each cupboard to pick up billets from the holding tank. Figure 10 shows the change in filling percentage of cupboards based on the change in angle of chain conveyor. An increase in angle of chassis from 10 to 15 degrees decreased filling percent by 0.1 percent which was not significant. But changing from 15 to 20 degrees cause an increase in filling percent of 5.8 % which was significant at 5 percent level.

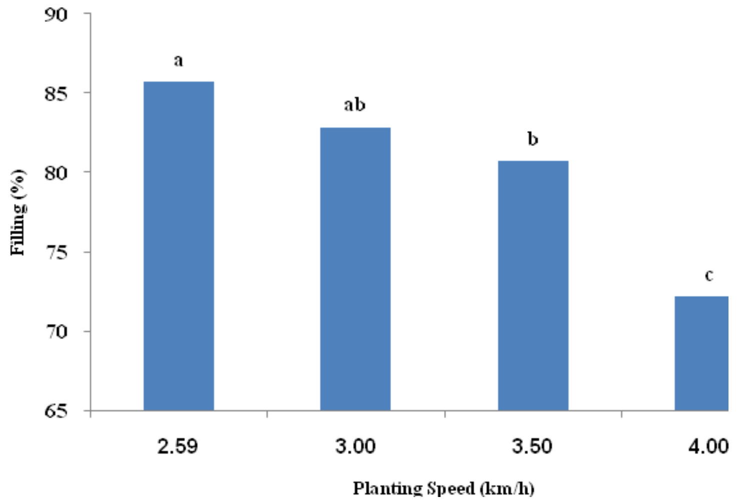

Figure 9. Effect of planting speed on cupboards filling percentage. Percentages followed by the same letters are not significantly different at the 5% level by LSD test

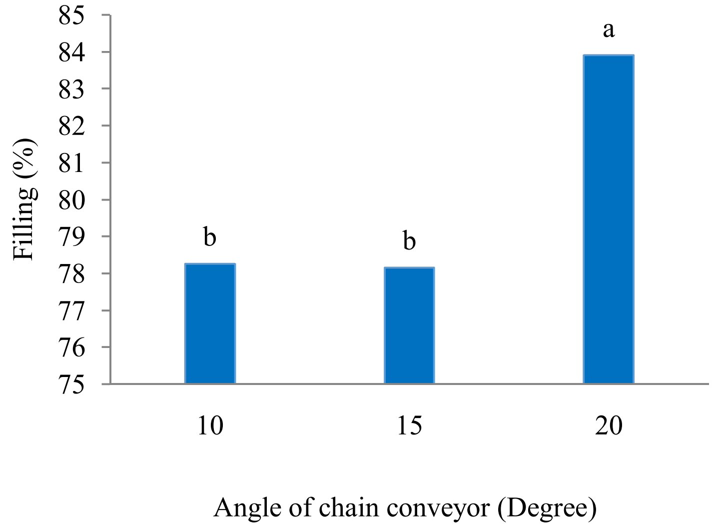

Figure 10. Effect of chain conveyor angle on cupboards filling percentage. Percentages followed by the same letters are not significantly different at the 5% level by LSD test

Percent filling of cupboards at 20 degree angle of upper section of metering unit compared to 10 and 15 degrees angle was higher. The explanation for this condition is that at 20 degree angle maybe more than one billet sits in the cupboard and also as the conveying chain rotates and any given cupboard passes the point of deflection where the lower and upper chassis are joined together, possibility of detachment of extra billets from the cupboard diminishes as compared to 10 and 15 degree angle. Transfer of more than one billet by each cupboard would increase filling percentage statistically (Razavi and Khani 2008).

Under overlapping:

Mean comparison of under overlapping as affected by experimental factors are given in Table 4. Only the interaction effect of forward speed and chain angle was significant at 5 % probability level. An increase in forward speed from 2.5 to 4.00 km/h resulted in 18.8 percent reduction in under overlapping which was a significant difference. Figure 11 shows changes in under overlapping under the influence of planting speed.

Table 4. Mean comparison of under overlapping and over overlapping as affected by experimental factors

Experimental factors	Under overlapping	Over overlapping
Speed of planting (km/h)		
2.5	7.85 [a]	5.7 [a]
3.0	7.72 [a]	5.31[a]
3.5	7.88 [a]	4.97 [a]
4.0	6.37 [b]	5.65 [a]
Angle of chassis (degree)		
10	6.66 [a]	5.58 [ab]
15	7.67 [ab]	4.58 [a]
20	8.03 [b]	6.05 [b]
Variety		
Without debris	7.6 [a]	5.79 [a]
With debris	7.3 [a]	5.02 [a]

Over overlapping:

Mean comparison of over overlapping as affected by experimental factors are given in Table 4. According to the table, difference in mean over overlapping for various speeds did not become significant. Use of conveyor chain as compared to other mechanism and also installation of short distance cone shaped dropping tube has contributed to delivery of billets without any delay. Billets preparation during harvest operations for planting purposes is critical in terms of planting uniformity and cupboards filling percentages. Billets should be of equal size in order for the cupboards to be able to pick them up at the right time without any restrictions. Cupboards designed and used in these experiments were able to pick up billets with various sizes. It should be noticed that placement of the billets on extreme right or left side of the cupboards would affect overlapping patterns under field conditions. Therefore, length of the cupboards should be enough to hold billets with different sizes.

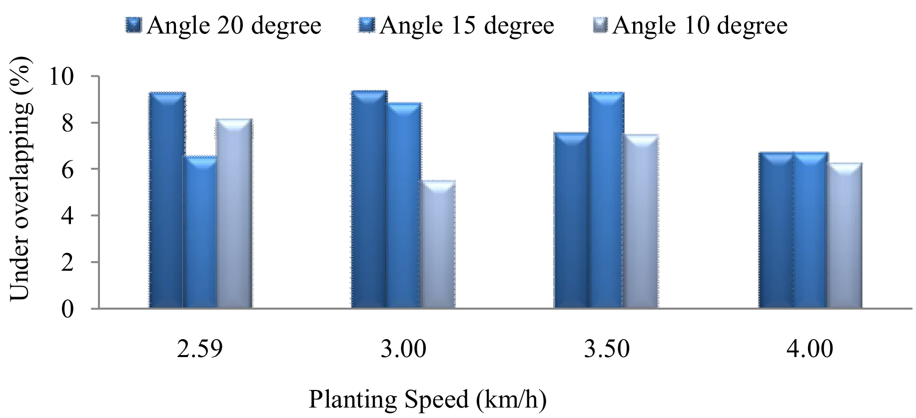

Figure 11. Interacting effect of planting speed and chain conveyor angle on under overlapping

Conclusions

Results of laboratory evaluation of the metering device indicated that:

Increase in planting speed would result in reduction of cupboards filling percent age. In this research increase in speed from 2.5 to 4.00 km/h resulted in %16.4 in filling. An increase in metering device chain angle from 10 to 20 degrees contributed to increase in filling percent of cupboards as much as 7.2 %.

The highest mean values obtained for filling percent age and lowest age mean values for under overlapping considering lower over overlapping, was with chain angle of 20° and 4.00 km/h forward speed for without derbies billets. For billets with debris speed of 3.5 km/h is more appropriate to obtain better performances. Sugarcane variety had no significant effect on experimental factors. This may be due to proper design and selection of material for fabricating cupboards.

References

Binder JV (1982). Sugar cane planter, Google Patents.

Hoy J, Arceneaux A., Savario C (2006). Effects of date and rate of billet planting on sugarcane yield. Journal of American Society of Sugarcane Technologists 26.

Hoy J, Savario C, Arceneaux A., Barrera W (2011). effects of cultivar and environmental conditions on billet planting tolerance. journal american society of sugar cane technologists 31.

Hoy JW, Arceneaux AE., Savario C (2002). Billet planting research. Sugarcane Research–Annual Progress Report: 115-117.

Johnson R, Viator R., Richard Jr E (2011). Effects of billet planting rate and position on sugarcane yields in Louisiana. Journal American Society of Sugar Cane Technologists 31: 79-90.

Mandal SK., Maji PK (2008). Design Refinement of 2 Row Tractor Mounted Sugarcane Cutter Planter. Agricultural Engineering International: The CIGR EJournal.

Populin P, Populin L., Scalia G (1976). Sugar cane planting apparatus, Google Patents.

Razavi J., Khani A (2008). Design, development and evaluation of a metering unit for a sugarcane billet planter with overlap planting pattern. Agricultural and biosystems engineering for a sustainable world. International Conference on Agricultural Engineering, Hersonissos, Crete, Greece, 23-25 June, 2008., European Society of Agricultural Engineers (AgEng).

Rezaee M, Arghand HA, Taraghi O., Fathi M (2011 (In Persian)). On the effects of passenger seat characteristics on the ride comfort of a vehicle under the random excitation. Modares Mechanical Engineering 11(3): 43-57.

Rípoli ML and Rípoli TC (2010). Evaluation of five sugar cane planters. Engenharia Agrícola 30(6): 1110-1122.

Robotham B., Chappell W (2002). High quality planting billets-whole-stalk planter billets compared to billets from modified and unmodified harvesters. Proceedings of the 2002 Conference of the Australian Society of Sugar Cane Technologists held at Cairns, Queensland, Australia, 29 April-2 May 2002., PK Editorial Services Pty Ltd.

Salassi M, Breaux J., Hoy J (2004). Estimated cost differences between wholestalk and billet sugarcane planting methods in Louisiana. J. Amer. Soc. Sugar Cane Technol 24: 250-257.

Silva VD (2006). Mechanics and strength of materials, Springer.

Stiff RA., Baker MJ (1985). Billet planter, Google Patents