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YOSHISUKE KISHIDA

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TOKYO

Yoshisuke Kishida, Publisher & Chief Editor

EDITORIAL STAFF
(Tel.+81-(0)3-3291-3674)
Yoshisuke Kishida, Chief Editor
Shinjiro Tetsuka, Managing Editor
R. Lal Kushwaha, Editorial Consultant

ADVERTISING
(Tel.+81-(0)3-3291-3674)
Yuki Komori, Director (Head Office)
Advertising Rate: 300 thousand yen per page

CIRCULATION
(Tel.+81-(0)3-3291-3674)
(Fax.+81-(0)3-3291-5717)
Editorial, Advertising and Circulation Headquarters
1-12-3, Kanda Nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan
URL: http://www.shin-norin.co.jp/english/
E-Mail: ama@shin-norin.co.jp

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EDITORIAL

This year, Japan has been hit with a large typhoon many times and brought major disasters to various places. A huge damage in the agriculture sector was also very serious.

For example, in Chiba Prefecture, which is adjacent to Tokyo, strong winds caused serious damage to agricultural facilities such as vinyl houses that were also affected by the floods. The maximum wind speed was unprecedented dimensions before, and some typhoons exceeded 250 km/h of wind speed. Therefore, a very problematic situation occurred in hospitals and other facilities that did not secure the emergency power supply.

The power failure occurred due to the knocked down of the tower of the large transmission line. The elevators of the high-rise apartments became non-functional because the electric equipment in the basements were flooded. Even in the high-rise apartments in Tokyo and the elevator of the high-rise apartment which had been stopped dozens of times became nonoperational.

The previous typhoons occurred in the southern region far away from Japan and landed in Japan after some time however, recently due to climate changes, the place generating the rise in sea surface temperature has moved considerably north and is quite close to Japan. Therefore, it is now very soon in about 22 hours from the time the typhoon is generated that it lands in Japan.

According to meteorologists, typhoons coming to Japan will become larger and larger and the maximum wind speed will also increase. Japan must be prepared for these typhoons. The cause of this is the global warming is that is still increasing. That is why such a thing is happening.

Abnormal weather is occurring not only in Japan but also in many parts of the world. In these extreme weather conditions, the farmers must plan for the future. We need to perform faster farm work than ever before.

In order to do so, progress in the higher level of agricultural mechanization is essential globally. There is now a debate around the world about the Sustainable Development Goals (SDGs), however, the agriculture is also among them. Research and countermeasures are being carried out in various places on how to better farm in the midst of global warming. The progress as well as sophistication of agricultural mechanization is essential.

In April 1971, AMA (Agricultural Mechanization in Asia, Africa and Latin America) was published under the title “Agricultural Mechanization in Southeast Asia.”

From the second issue, it was published under the title of AMA (Agricultural Mechanization in Asia, Africa and Latin America), including other Asian regions, and it lasted for 10 years. Since 1981, AMA (Agricultural Mechanization in Asia, Africa and Latin America), including Africa and Latin American countries, and the last A represents three continents.

It will be 50 years next year since the first issue was published. In commemoration of the 50th anniversary, a special issue called SDGs and the world’s agricultural mechanization will be published twice next year in spring and autumn.

Thank you for your cooperation.

Yoshisuke Kishida
Chief Editor
November, 2019

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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★ ★ ★

Development of an Efficient Fruit Cum Vegetable Grader for Spherical Commodities

by
S. Mangaraj
Senior Scientist (AS & PE)
ICAR - Central Institute of Agricultural Engineering
Bhopal - 462038
INDIA
sukhdev0108@gmail.com

R. K. Pajnoo
Chief Technical Officer
ICAR - Central Institute of Agricultural Engineering
Bhopal - 462038
INDIA
rkpajnoo@yahoo.co.in

Abstract

After harvesting of fresh produce, a group of unit operations are carried out before it reaches ultimate users. In these groups of unit operations, grading is one of the most important operations. Grading on the basis of size is important for marketing uniform high quality produce. Hence a fruit cum vegetable grader has been developed that can be used for grading of different spherical fruits and vegetables having equivalent diameter from 35 mm to 120 mm. The principle is that along the length of movement of the produce the roller diameter is decreasing in steps, thereby the opening space between the rollers is increasing which facilitates the sorting of commodity in different size lots uniformly. The rollers moving in opposite directions are mounted in slope for ease of forward movement of commodity during grading. The main components of the grader are feeding unit, elevator unit and grading system. The feeding unit is of pentagonal plan view with a capacity of holding 100 kg of fruits and vegetables. The outlet of this unit is fitted with a rubber flap to ensure safe placement of the produce on the elevator flaps. The elevator uniformly feed the produce to the grading unit through a sloppy platform meant to eliminate the impact force. The grading system consists of two sets of rollers each set having two round pipes with reducing diameters along the forward movements resulting in increasing the gap between the rollers. In each set the rollers rotate in opposite direction giving a slight lift to the produce being graded. This mechanism eliminates any possibility of physical damage to the product as well as places the produce in between the rollers in its natural shapes resulting to efficient grading. The roller unit is mounted in slope with the horizontal to make the produce rolls in between the rollers and then drop in the collecting trays based on size and gaps of rollers. Collecting trays have been mounted beneath the grading unit for collection of graded produce. The distance between the rollers and the bottom of trays is 125 mm there by eliminating the chance of any impact damage of the produce. The grader has been glued with polyfoam and rubber sheet in all contact surfaces of the fruits to avoid any impact damage during grading. The grader has the advantage of high capacity (2 t/h), efficient grading (92-95%), less energy requirement (0.283 kW/t), grading of multiple fruits and vegetables, low cost (Rs. 45,000), option of manual function, capacity enhancement with slight modifications and simple in manufacturing and operations. The machine separates the fruits and vegetables in five grades with conveyor speed of 4 m/min.

Introductions

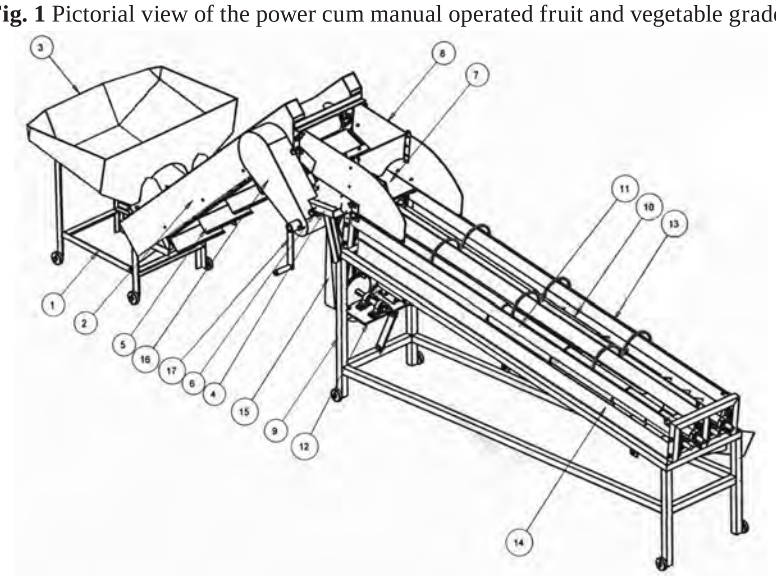
Adoption of horticultural crops has improved the economic status of Indian farmers considerably. The horticulture sector contributes more than 20% from mere 10% of area to the gross domestic product of agriculture. India accounts for 10.5% of total world production of fruit crops. India has been exporting fresh fruits and vegetable for several decades, however, export promotional activities have received more attention in the recent past (Mangaraj and Varshney, 2006). Normally fruits and vegetables are grown in one particular region depending upon its agro-climatic conditions and transported to other parts of the country or world to cater to the need of consumers (Grover and Pathak, 1972; Varshney et al., 2006). After harvesting of fresh produce, a group of unit operations are carried out before it reaches ultimate users. In this group of unit operations grading is one of the most important operations. Grading involves overall balanced assessment of all those properties of a material, which affects its acceptance as a food and as working substance for the processor. It adds value of the product and gives better economic gains to the producer (Brennan et al., 1976; Bruter et al., 1983; Erickkasner, 1979). Grading on the basis of size is important for marketing uniform high quality produce.

Few organizations are engaged in the research and development activities in the field of grading of fruits and vegetables of various types depending upon the need of the farmers of the country. A mango grader developed at IIHR, Bangalore sorts the fruits on the basis of rolling of mango around the axis of minimum mass inertia. The fruits are fed at higher end of machine and the fruits roll down under gravity in an expanding opening created by a set of rolls placed divergently (Varshney et al., 2002). The slope of rolls is 14º with the horizontal which can be varied depending upon the roundness of the fruits. The machine has a provision to separate mangoes into four grades in the size range of 50-56, 57-63, 64-70 mm and > 70 mm. The National Research Centre for Citrus Fruits, Nagpur has developed a grading and packaging line for citrus fruits. This set up has a capacity of 1 t/h to separate fruits in six grades by rotating disc separator. The size grader works on the principle of rolling of fruits (Varshney et al., 2005; Mangaraj et al., 2005). Pratap Sons Engineering, Jalandhar has fabricated a fruit grader which consists of series of expanding pitch rollers mounted on a frame. The rollers rotate at their axes, which in turn move the fruits forward. The conveyor is inclined to facilitate easy forward movement of fruits. The spacing between the rollers has to be changed for different fruits. The capacity of the machine is limited by the fact that fruit of smooth surface slip on roller surface and hamper the forward movement of fruits (Varshney et al., 2002; Ingle, 1997; Mangaraj, 2014).

The fruit grader developed at CIPHET, Ludhiana, segregates the fruits on the basis of size difference. By this machine fruits can be separated in six different sizes at 90 % efficiency with capacity of 1.5-2 t/h (Varshney et al., 2002; Mangaraj, 2014). Punjab Agricultural University, Ludhiana has also developed a potato grader consisting of a frame, an elevator, feed conveyor, an intermediate receiving conveyor, a sizing conveyor with rubber spools and two identical driving rollers with helical grooves of gradually increasing pitch. The capacity of machine is 2.5 t/hr. The grading efficiency is better for round shaped varieties than oblong or irregular shapes (Singh, 1980; Mangaraj et al., 2009). State Horticulture Board of U P installed and demonstrated a grading and packaging line at Malihabad, Lucknow. The line consisted of pre-inspection conveyor, fruit washing conveyor, size grader and platform for packaging of graded material separated into four grades (Mangaraj and Varshney, 2006; Mangaraj and Singh, 2006a, 2006b). An apple grader has been developed at GBPUAT, Pantnagar for grading of potato (Singh, 1980; Verma and Kalkat, 1975). The grader is driven by 2 hp (1.5 kW) electric motor and the capacity of grader is1.5 t/h. A fruit grader based on the principle of changing the flap spacing along the length of movement of fruits was designed and developed at ICAR-Central Institute of Agricultural Engineering, Bhopal (Mangaraj et al., 2005; Mangaraj et al., 2010). The main components of the fruit grader are grading unit, elevator feeding unit and inspection plat form. The grader has the provision to separate fruits into four grades by changing the flap spacing between 45 to 140 mm by adjusting the height of wheel track. The capacity of the grader was 4.00 t/h at grading conveyor speed of 2 m/min.

Agricultural produce being the delicate commodity any external or internal damage to the produce would bring the faster physiological changes vis a vas reduced its storability and market value. The skins of some fresh produce are thin and fragile needing proper handling during post-harvest operation (More, 1999; Mandhar and Snthil Kumar, 1999; Von Beckmann and Bulley, 1978). In order to ensure no physical damage during grading operation the momentum as well as the impact of the produce with the hard surfaces needs to be avoided. In India fruits and vegetables are graded manually, which is non-uniform,

Fig. 1 Pictorial view of the power cum manual operated fruit and vegetable grader

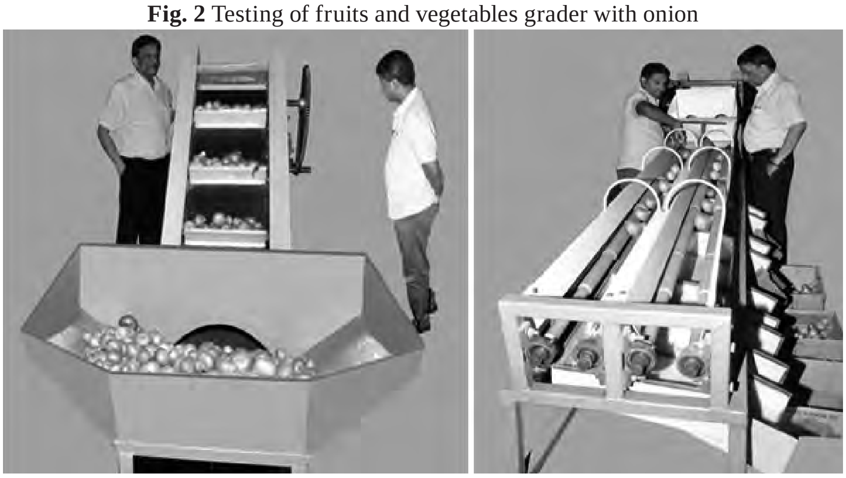


Part/Assembly name: 1. Feeding trough stand assembly, 2. Conveyor frame assembly, 3. Feeding trough assembly, 4. Conveyor frame assembly, 5. Conveyor belt assembly, 6. Bearing housing sub assembly, 7. Tray assembly, 8. Slagging plate assembly, 9. Grading frame assembly, 10. Grading roller assembly, 11. Grading roller assembly, 12. Motor support assembly, 13. Grading cover sheet assembly, 14. Collecting tray assembly, 15. Chain cover assembly of grader, 16. Chain cover assembly of elevator, 17. Handle assembly labour intensive and time consuming. Some mechanical fruits and vegetables graders are also available mostly confined to sorting of specific commodities. These graders are of high of cost and mostly suitable for large-scale industries. At present there is no mechanical grading unit available for grading of wide range of fruits and vegetables at farmers or small-scale food processors. Hence a power cum manual operated multiple fruits and vegetables grader without causing damage to the commodity is a viable option to cater the need of growers cultivating different crops and Mandi's at which various horticultural commodities are marketed.

Materials and Methods

The concept of grading is that the onward rotating rollers are placed parallel to each other and the diameter of the roller is decreasing steps wise. Hence the gap between the rollers is increasing which enables the separations of fruits and vegetables in various size lots uniformly. The main components of the grader are grading unit, elevator unit and feeding unit (**Fig. 1**). The grading unit consists of oppositely rotating rollers of variable pitch diameters, power transmission system and collection tray etc. The elevator unit is mounted for constant and uniform feeding of commodity into the grading unit. The feeding system is provided for loading of fresh commodity to be graded as well as for removal of unwanted products before they are fed to the elevator. Cushioning material in the grader has been glued to all contact surfaces of the fruits to avoid impact damage at the time of grading. The multi faced feeding unit has been fabricated with respect to surface area and angle of each face to ensure natural movement of produce towards the outlet of the unit eliminating the over loading of produce on the elevator generally encountered in the conventional rectangular feeding unit. The materials and size of flap at the interface of the feeding unit and elevator has been optimized for smooth and safe placement of produce on the flaps of the elevator. The grading system has been developed with a innovative approach that along the length of movement of the commodity the roller diameter is decreasing in steps, thereby the opening space between the rollers is increasing which facilitates the sorting of produce in different size lots uniformly. The dynamic variables i.e. speed and slope of roller unit was optimized to make the produce rolls smoothly in between the rollers and have sufficient retention time on each section of the grading unit to enhance the grading efficiency.

Fig. 2 Testing of fruits and vegetables grader with onion



Testing of the Grader

Testing of developed grader was done with onion and sweet lemon (**Fig. 2**). Care was taken to present all the sizes of commodities for testing. Commodities were fed to the grading unit uniformly by feed conveyor. About 500 kg each commodities were used for grader testing. The commodities were graded into five grades. The random samples of 50 numbers were drawn from each grade. The physical dimensions of the individual sweet lemon and tomato like major '*a*', intermediate '*b*' and minor '*c*' were measured with Vernier Caliper and recorded. The average geometrical mean diameter (*GMD*) was calculated using the following formula.

$$GMD = (abc)^{1/3}$$

Determination of Grading Efficiency

From the GMD values all those commodities which are not included (undesirable in that particular grade) in a particular size category, whether oversize or undersize, were considered as misclassified produce (Mangaraj et al., 2010; Von Beckmann and Bulley, 1978; O'Brien, 1968). The numbers of the misclassified produce were calculated from the geometrical mean diameter data. The above procedure was replicated, three times and average separation efficiency of a particular grade was calculated using the following formula:

$$E_s = \frac{N_t - N_u - N_o}{N_t} \times 100$$

Where,

E_s = Separation efficiency of a particular grade, %

N_t = Total number of sample of a particular grade

N_u = Total number of undersize in that sample

N_o = Total number of the oversize in that sample

The overall Grading efficiency of the grader was calculated by the following formula[16]:

$$E_s = \frac{N_{to} - N_{m}}{N_{to}} \times 100$$

Where,

E_s = overall separation efficiency of the grader, %

N_{to} = Total number of the sample of all grade commodity

N_{tm} = Total number of the misclassified commodity in all the samples

Calculation of Fruit Damages

The skin damage, cutting damage and bruising damage are defined and are calculated as follows:

Skinning Damage

It is defined as the percentage damage caused to the commodity by the action of grader on the basic of the percent skin of the commodity removed. It was calculated as follows:

$$D_s = \frac{N_s}{N} \times 100$$

Where,

D_s = Skin damage, %

N_s = Number of commodity in a sample

N = Total number of the commodity in a sample

Cutting Damage

It is defined as the percentage damage caused to the commodity due to the cut injuries resulting from the action of the grader. It was calculated as follows:

$$D_c = \frac{N_c}{N} \times 100$$

Where,

D_c = Cutting damage, %

N_c = Number of cut commodity in a sample

N = Total number of the commodity in a sample

Bruising Damage

It is defined as the percentage damage caused to the commodity as a results of the bruising sustained to the commodity due to the operation of the grader. Bruising essentially implies the damage or rupture of the tissues of commodity without breaking of the skin. A bruised commodity develops a dark spot at the place of bruising after a few days. It is calculated as follows:

$$D_b = \frac{N_b}{N} \times 100$$

Where,

D_c = Bruising damage, %

N_c = Number of bruised commodity in a sample

N = Total number of the commodity in a sample

Results and Discussions

The average geometrical mean diameter of onion and sweet lemon samples collected in five grades are presented in **Table 1**. The average geometrical mean diameter of sweet lemon, and onion discharged from the collecting chutes of Grade I, Grade II, Grade III, Grade IV and Grave V were 48.37, 56.24, 67.90, 77.38 and 86.19 mm; 36.66, 46.76, 58.21, 67.49 and 77.36 mm, respectively. It may be seen that the average geometrical mean diameter of sweet lemon and onion discharged to a particular grade chute was less than the spacing between the rollers for sweet lemon and onion.

The number of misclassified commodity, separation efficiency for different grades, overall separation efficiency of the machine etc. is presented in **Table 2**. In the case of sweet lemon the maximum number of misclassified fruits was 9 (6 undersize and 3 oversize) in all the grades. The separation efficiency of particular grade ranged from 94% (Grade II) to 97% (Grade V) for sweet lemon. The overall separation efficiency of sweet lemon was 95%. In the case of onion, the maximum number of misclassified fruits was 17 (9 under-

Table 1 Average geometrical mean diameters of graded sweet lemon and onion in different grades

Commodity	Geometrical mean diameter, mm				
Sweet lemon	Grade I (50)*	Grade II (60)	Grade III (70)	Grade IV (80)	Grade IV (90)
	48.37	56.24	67.90	77.38	86.19
Onion	Grade I (40)*	Grade II (50)	Grade III (60)	Grade IV (70)	Grade IV (80)
	36.88	46.76	58.21	67.49	77.36

* Numerical value in parenthesis is spacing between the rollers in each grade in mm

Table 2 Performance data of the fruit and vegetable grader

Commodity	No. of commodity in category	No. of misclassified commodity		Separation efficiency of particular grade, %	Overall separation efficiency, %	Skinning damage, %	Cutting damage, %	Bruising damage, %
		Under size	Over size					
Sweet lemon								
Grade I	50	---	2	96.00	95.00	2.00	0.00	0.00
Grade II	50	1	2	94.00				
Grade III	50	2	---	96.00				
Grade IV	50	2	1	94.00				
Grade V	50	1	---	97.00				
Onion								
Grade I	50	---	3	94.00	92.00	3.00	0.00	0.00
Grade II	50	3	1	92.00				
Grade III	50	3	2	90.00				
Grade IV	50	3	1	92.00				
Grade V	50	2	1	94.00				

size and 8 oversize) in all grades. The overall separation efficiency of onion was 92%. The details features of the grader have been presented in **Table 3**. The capacity of the grader was 2 t/h at grading conveyor speed of 4 m/minutes. There was no cutting damage and bruising damage to the fruits except only 2-3% of skin damage while grading.

Conclusions

The developed multipurpose fruit and vegetable grader can be is used for grading of different spherical fruits and vegetables having equivalent diameter from 35 mm to 120 mm. The concept of two rollers rotate outward giving a slight lift to the produce being graded, thereby eliminates any possibility of physical damage to the produce as well as places the produce in between the rollers in its natural shapes resulting to efficient grading of multiple fruits and vegetables. The testing of the grader with onion and sweet lemon showed the grading efficiency of 92-95% with a capacity of 2 t/h at conveyor speed of 4m/min. The developed grader is very much suitable for grading of multiple fruits and vegetables having option of manual as well as electrical function with less energy requirement.

Table 3 Specific features of the fruits and vegetable grader

Parameters	Value
Model	Central Institute of Agricultural Engineering (CIAE)
Type	Power cum manual operated
Power requirement, W/t	283
Motor speed, rpm	1,440
Mechanism for machine	The roller diameter is decreasing in steps thereby the opening space between the rollers is increasing. The rollers moving in opposite directions are mounted in slope for ease of forward movement of commodity while grading.
Overall dimension (L × B × H), mm	5012 × 964 × 1172
Feeding unit	Multifaceted (11 faces) system at an angle of 21° attached to elevator
Elevator unit	
Overall dimension (L × B × H), mm	1617 × 342 × 1172
Nos. of flap on elevator belt	11
Flap height, mm	105
Flap to flap distance, mm	305
Total belt length, mm	3500
Grading unit	
Overall dimension (L × B × H), mm	2700 × 520 × 1000
Nos. of grading rollers	4
Nos. of grading steps	5
Nos. of chute in fruit collection tray	5
Overall weight, kg	220
Capacity, t/h	2
Nos. of sorting channels	2
Nos. of grades	5
Cost of grader, Rs.	45000/- (≈ 70 Rs. = 1 $US)
Grading efficiency, %	92-95

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■■

In Memoriam of Oleg Marchenko

Dear Dr. Yakov Lobachevsky

It was two month ago, I was informed the message of the death of Dr. Oleg Marchenko through your mail last April. I was really shocked. I have been friend for long time since 1990.

After graduation of the university, I worked for designing new machinery at an agricultural machinery manufacture. Dr. Oleg Marchenko was also a designer for new agricultural machinery in a manufacture, so we had often opportunity to discuss about agricultural machinery. I met him at various international conferences and had a variety of discussions about agricultural machinery.

He was a really excellent agricultural machinery engineer. He was not just a researcher in university or research institute, but a person who had the ability to design agricultural machines that farmers actually use. He was also excellent for theoretical analysis of agricultural machines, and conducted theoretical analysis of the rotary tiller, and the book was published by ASAE. His last big job was the multi-purpose power unit. It has the advantage that the initial investment can be reduced rather than buying a lot of specialized machines. This machine could be used in many parts of the world, the manufacturer of the Belarus actually produced his machine. Moreover, in Japan, he tried to build a new machine for Japanese use, based on his design, however he has passed away without achieved it.

He was a middleweight all-Soviet boxing champion in his school days, so he kept holding an extremely strong grip even on his old age, and when I first met him, I felt it would break my hand during a handshake of greetings.

He was very humorous and made people laugh at various places. He had many friends all over the world. Every time I think of his death, I feel sad. Recently, I just had a dream of Dr. Oleg Marchenko. In the dream, we discussed about agricultural machinery and various subjects. It is really a pity that we cannot meet him again. I would like to go to Moscow and to visit his grave.

I started AMA journal for promoting agricultural mechanization in developing countries in the world in 1971. He has been helping me as co-editor for longtime since 2003. I am deeply appreciated for his excellent contributions. I hope you will follow Dr. Oleg Marchenko's intention, and I expect your continuous cooperation as a co-editor for AMA. I think your VIM in Moscow is a very important institution. Please do your best for not only Russia but also the agricultural mechanization in the world. I would also like to visit Moscow at an opportunity. You are also welcome to visit Japan.

Thanking you in advance.

Yoshisuke KISHIDA
Editor in Chief of AMA, President of Farm Machinery Industrial Research Corp. President of Shin-Norinsha Co., Ltd.

Design and Experiment of a Fertilizer Deep Applicator for Twin-row within One Ridge

by

Wu, XueMei
Department of Mechanical Engineering,
Guizhou University,
Guiyang 550025
CHINA

Guy Fipps
Department of Bio and Agricultural Engineering,
Texas A&M University,
College Station, 77843-2117,
USA
Corresponding author: g-fipps@tamu.edu.

Fugui Zhang
Department of Mechanical Engineering,
Guizhou University,
Guiyang 550025
CHINA

Xu Li
Department of Mechanical Engineering,
Guizhou University,
Guiyang 550025
CHINA

DeLong Fu
Bijie Branch of Guizhou Provincial
Tobacco Corporation,
Bijie 551700
CHINA

Abstract

This paper presents a new design for a fertilizer deep applicator that is suitable for twin-row application within one ridge row as is commonly used in flatland regions of Guizhou, China for tobacco production. The applicator is capable of finishing tilling, ridging and precise fertilization at the same time. The fertilizer applicator implement is coupled with a control system that regulates fertilizer application based on operation speed. The implement was tested in a series of field experiments. Results show that the implement is capable of tilling, ridging and fertilizer application at the same time, can apply fertilizer deep and precisely with the variable coefficient of fertilization uniformity of 12.3% and the operation efficiency of 0.41 hm^2/h with deviation of fertilizer amount under 4.58%, and can make well-shaped ridges with the ridge height, top width and base width of 28 mm, 1,318 mm and 1,755 mm, respectively, which are within the acceptable range of the target values of 30 mm, 1,300 mm and 1,700 mm, respectively.

Keywords: tobacco, twin-row within one ridge, ridging; tilling, fertilizer deep applicator

Introduction

Tobacco is one of the dominant crops in Guizhou Province, Southwest China. In general, tobacco is planted in a single row on each ridge, with ridging and fertilization application completed successively by different implements. Use of two separate implements for these operations costs lots of time and work, characterized by intensive labor and low efficiency. Two tractor passes also cause damage to the physical structure of soil, resulting in soil compaction and poor crop production (Fu et al., 2016). Use of single row ridges increases crop production inputs and results in undesirable economic benefit per unit area ratio, as the furrow is occupied and unavailable for planting.

In Guizhou Province, agricultural mechanization is low and manual operation is common. Excessive and uneven fertilizer application is common and often results in crop damage and environmental pollution. Low fertilizer use rates are also common which may lead to unbalanced soil fertility and harden soil over the long term (Yuan et al., 2015). Shallow depth application of fertilizer often leads to volatilization of fertilizer and low use rates, which unfavorably affects absorption of fertilizer by the root system of crops and makes production and income increase impossible (Ji et al., 2002). In the mechanical application of fertilizer, it is important to achieve uniformity application in each row and over the entire field (Bansal and Leeuwestein, 1987). It is critical to deep tillage the soil and place the fertilizer below the root of the tobacco plants at the proper depth. Tilling operations can break up the compacted layers. The deep placement of fertilizer below the plant roots can help tobacco roots penetrate deeper into the soil that contributes root growth. These authors found that applying fertilizer at a depth of 250-300 mm was optimal.

Review of Literature

Vepraskas et al. (1986) evaluated the relationships of soil physical and chemical properties, and subsoiling on tobacco root distribution in 10 Ultisols. Subsoiling resulted in increased root development as measured approximately 10 d after transplanting. The authors found that analyzing for these properties was useful in determining whether subsoiling should be used for increasing root development in specific fields.

Smith et al. (2012) assessed the effects of different tillage and fertilizer placement practices in a corn cropping system. They found that fertilizer placement can impact greenhouse gas emissions. A deeper placement or low rates of fertilizer applied by subsurface banding would reduce the soil efflux of these important greenhouse gases (CO_2, CH_4, and N_2O).

Wan et al. (2015) studied the effects of soil management measures on the incidence of tobacco bacterial wilt disease (TBWD) by ploughing depth, soil amendment type and application method and their relationships to soil physiochemical properties. They recommended that, for the purpose of reducing the incidence of TBWD, the depth of ploughing should be controlled within 40 cm.

Mandal et al. (2010) designed and developed a subsoiler-cum-differential rate fertilizer applicator which was able to to place fertilizers up to a 500 mm soil depth using the main winged tine and up to 250 mm depth using the leading tines, thereby place fertilizer at different depths in the vertical soil profile in a single pass. The equipment was field tested on sugarcane with results showing an increase of 16.2-35.4% in yield as compared to conventional ploughing with in-furrow fertilizer application. The equipment had functions of both subsoiling and fertilizer placing, but could not perform ridging.

Wang et al. (2011) developed a series of machines for deep furrowing, ridging, mulching, fertilizing and seeding for alternating ridge and bare furrow systems. A plough was designed to till the soil properly, to bury the straw deep, and to form ridge with a suitable shape. A shaping unit was mounted to make the ridge into the required shape. However, the ridge produced was only 150 mm high, well below the 300 mm height as required for tobacco.

Jin et al. (2012) designed an easy to install mini-ridging machine for tobacco planting in hilly smaller plots; but its function is only ridging. Kathirvel et al. (2012) developed a two row subsoil organic mulch and fertilizer applicator which allowed for precise application of the limited available organic mulch in the subsoil at the desired application rate and depth. A novel variable rate pneumatic fertilizer applicator was developed for granular fertilizer in oil palm plantations by Ishola et al. (2014). It differs from conventional variable rate applicators, as it does not depend on GPS signals that are unavailable under palm oil canopies. The applicator was equipped with a speed feedback mechanism to minimize fertilizer waste.

Commercial available machinery for fertilizer application in Guizhou Province are only capable of applying fertilizer at shallow depths on single row ridges, due to their use of micro rotary cultivators. In this paper, we present a combination twin-row within one ridge equipment for deep tilling and precise applying of fertilizer according to twin-row within one ridge planting pattern in Guizhou Tobacco Planting Base.

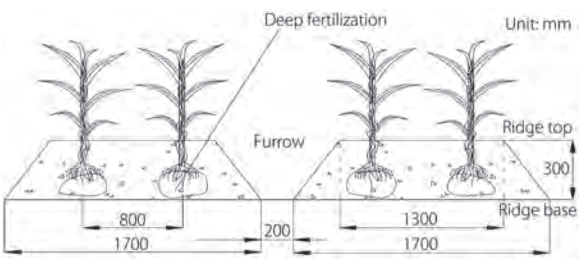
Material and Methods

General Structure and Working Principles

The objective of this study was to solve problems in mechanical ridging and fertilization of tobacco plants. Twin-row within one ridge planting pattern is showed in **Fig. 1**. The ridges serve as the planting zone and the furrows as pathway for machinery wheels. This pattern is good at increasing the area available for tobacco plants and decreasing the compaction of soil due to less frequent tractor passes as compare to a single row per ridge pattern. The ridge height of 300 mm ensures the deep placement of fertilizer.

Fig. 2 shows a schematic of the implement and major components,

Fig. 1 Twin-row within one ridge planting pattern of tobacco



and **Table 1** lists the main technical parameters. The implement is connected to the tractor with a three-point hitch, and the tractor pulls the implement and drives the rotary blade through a cardan joint. As the fertilizer applicator travels, a velocity sensor mounted on the rear wheel of the tractor collects speed signals. The control system matches the travel speed of the applicator with the speed of the direct-current fertilizer discharge motor to achieve precise fertilization (Gu et al., 2011). Adjustable fertilizer discharge tubes are located on left and right sides of the implement, which set the injection depth. The fertilizer discharge axle injects fertilizer with the help of DC motor; the ridge-forming edge plank and the ridge-forming top plank scrapes the soil and forms the desired shape of the ridge. With this equipment, rotary tillage, ridging and fertilization can be completed in one time.

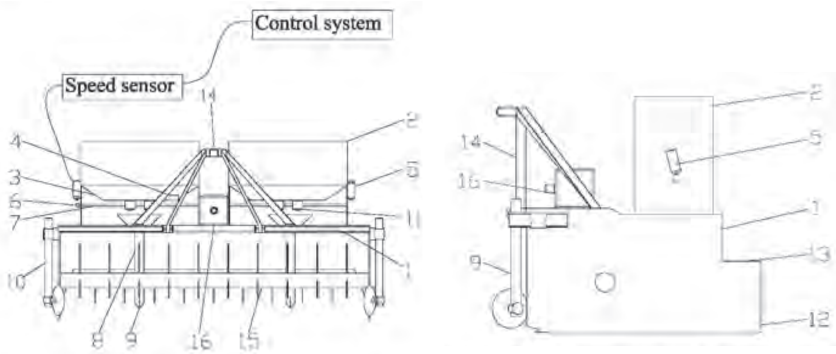
Table 1 Major technical parameters of fertilizer deep applicator for twin-row within one ridge

Details	Value
Over all dimensions, (L × W × H) mm	2100 × 880 × 1420
Supporting power, kw	51.5
Operation speed, km/h	4.5-7
Linkage	Three point linkage (rear)
Operation width, mm	1900
Operation row	Twin-row within one ridge
Ridging height, mm	Adjustable from 200 to 350
Fertilization interval, mm	800-1300
Fertilization depth, mm	Adjustable from 250 to 300
Fertilizing amount, kg/hm^2	Adjustable from 450 to 1050
Fertilization pattern	Row fertilization and deep fertilization
Driving method for fertilization	DC motor
Fertilizer device type	Outer geneva wheel
Operation efficiency, hm^2/h	Adjustable from 0.2 to 0.5

Main Components

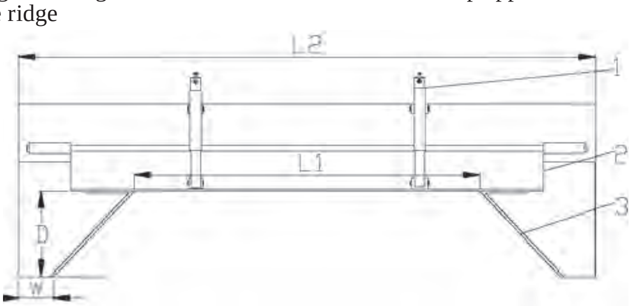
The ridge-forming device consists of ridge-forming edge planks on both sides of the implement, a ridge-forming top plank holder and a ridge-forming top plank as illustrated in **Fig. 3**. The soil is tilled and loosen with the traveling of the applicator and ridges are formed by the ridge-forming device. The ridge-forming edge plank holder sets the height of the ridge. The results are a well-formed ridge, with flat and firm ridge surfaces, which provide good conditions for tobacco planting.

Fig. 2 Structure of fertilizer deep applicator for twin-row within one ridge



Note: 1. Rack, 2. Fertilizer box, 3. Cantboard, 4. Fertilizer opening, 5. DC motor, 6. Speed sensor, 7. Fertilizer discharge axle, 8. Fertilizer discharge tube, 9. Opener, 10. Covering roller, 11. Outer geneva wheel, 12. Ridge-forming edge plank, 13. Ridge-forming top plank, 14. Suspension bracket, 15. Rotary blade, 16. Speed changing box

Fig. 3 Ridge-forming device mounted on the fertilizer deep applicator for twin-row within one ridge



Note: 1. Ridge-forming top plank holder, 2. Ridge-forming top plank, 3. Ridge-forming edge plank

The depth of rotary blade into soil can be determined as follows:

$$H \geq \frac{(L_1 + L_2 - 2W)D}{2L_2} \quad \text{(Eq. 1)}$$

Where,

H is working depth (mm), L_1 is top width of ridge (mm); L_2 is rack length (mm); w is edge width (mm); and D is the height of ridge (mm).

According to the above formula and related requirements of tobacco cropping, the smaller the edge width and the top width of ridge, the smaller the depth of rotary blade into the soil provided that the depth of fertilization remained unchanged. Then the ridge-forming device can easily get enough soil to form the ridge and achieve deep placement of fertilizer.

For example, for the case of L_1 = 1300 mm, L_2 = 1900 mm, w = 100 mm, and the height of ridge D = 300 mm, H must be greater or equal to 237 mm (Eq. 1). Thus, an injection depth at 250 mm meets these requirements.

Fertilizer Discharge System

In traditional fertilizer devices, the fertilizer discharge axle is driven by the land wheel, which may be impacted by soil moisture and other factors. In addition, due to large fluctuations in transmission ratio and poor reliability, the land wheel can sink, slip and cause great deviation in fertilizer discharge (Jiang, 2015). To overcome these problems, our system includes a 12V DC control system with an outer Geneva wheel as illustrated in **Fig. 4**.

Fig. 5 shows the fertilization control system and wiring diagram. Based on the operation speed and the set fertilizer discharge amount, the PLC control circuit calculates the pulse count needed and inputs it into the DC motor driver to control the motor speed. In this manner, fertilizer discharge amount is controlled, and fertilizer can be discharged as neededd (Hou et al., 2015). Since soil fertility varies, the touch screen includes both manual and automatic operations to control the discharge amount. The control system consists of a Siemens CPU 224xp PLC, which connects to the 12v DC power provided by tractor accumulator (Shao et al., 2007).

Considering that existing fertilizer feed technology is well developed, we selected a fertilizer feed system employing an outer geneva wheel, because it is a simple structure, capable of evenly applying fertilizer, and applicable for loose fertilizer and composite particles with good mobility.

Field Trial

A field-test of the implement was conducted on June 20, 2016 at Huangnitang Base, Bijie, Guizhoun Province. The test site covers a 1400 m^2 area with no stubbles. Two locations were chosen randomly for soil moisture analysis at three depths (top, middle and subsoil). Soil moisture content was determined by weighing samples before and after drying (**Fig. 6**). The absolute moisture content can be calculated by:

$$W = \frac{m_1 - m_2}{m_2 - m} \times 100\% \qquad \text{(Eq. 2)}$$

Where,

m_1 = mass of soil sample and beaker before drying, g;

m_2 = mass of soil sample and beaker after drying, g;

m = mass of the beaker after drying, g;

The average absolute moisture content of topsoil was found to be 17.46%, suitable for ridging and fertilization.

The porotype was attached to the tractor (GengWang RM-804 tractor) though a three-point linkage and tested in the field to determine the effect of deep tillage, ridging and deep placement of fertilizer. The test fertilizer was compound fertilizer special for tobacco.

Fig. 6 Measure of Soil Moisture Content

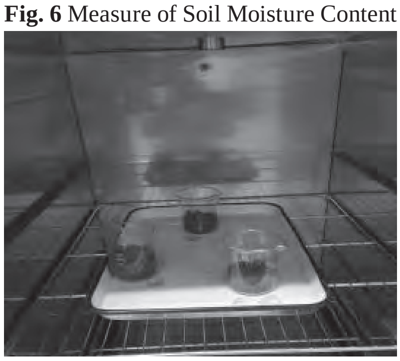
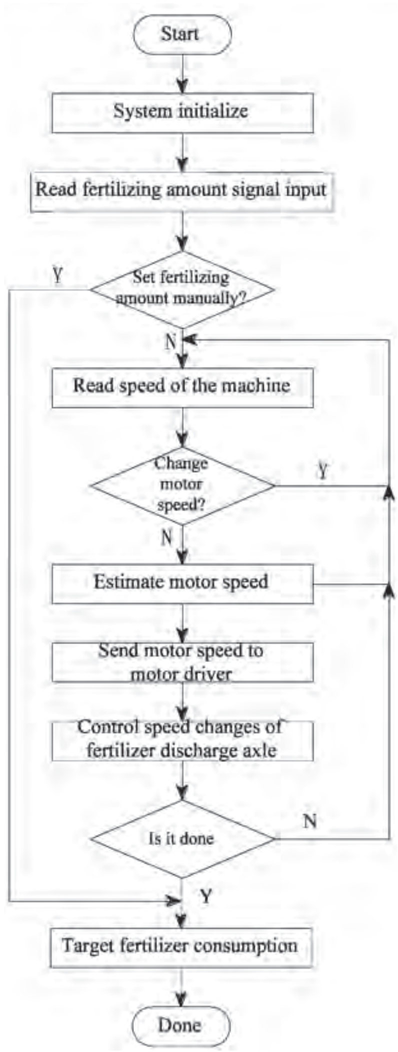


Fig. 5 Control system flow and wiring diagram



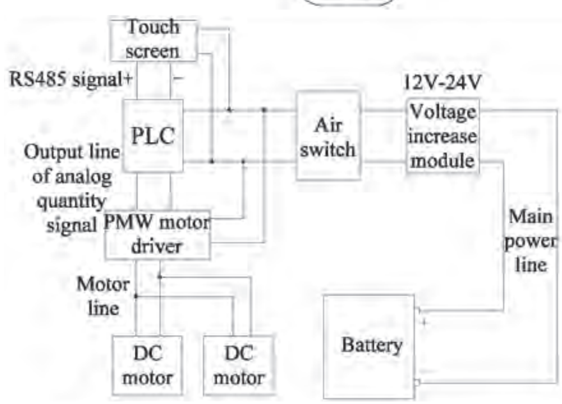
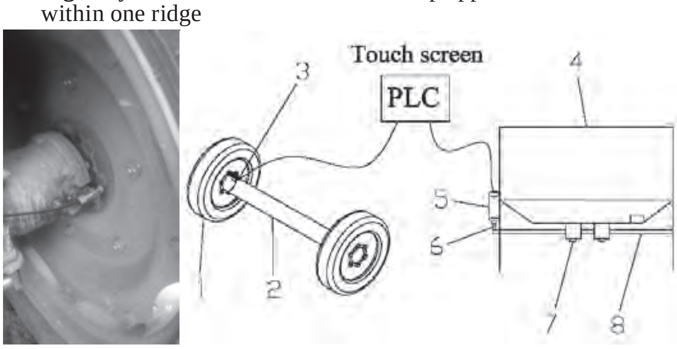


Fig. 4 System structure of fertilizer deep applicator for twin-row within one ridge



Note: 1. Rear-wheel of tractor, 2. Driveshaft of tractor, 3. Speed sensor, 4. Fertilizer box 5. 24v DC motor, 6. Turbine worm, 7. Fertilizer feed, 8. Fertilizer discharge axle

Table 2 Ridging parameters of the fertilizer deep applicator for twin-row within one ridge

Item	Mean, mm	Standard deviation, mm	Variable coefficient, %	Qualification rate, %
Ridge height	281.8	18.0	6.4	92
Top width	1,318.1	19.4	1.5	93
Base width	1,754.5	13.8	0.7	98

Before the field test, lime powder was used to mark out four test zones (**Fig. 7**). Following the national standard - *GB/T5262-2008 General Rules for Test Conditions and Methods of Agricultural Machinery,* five sampling locations were chosen randomly in each test zone. After adjusting the prototype for tobacco planting requirements, the fertilizer applicator was advanced with a speed of under 7 km/h with automatic operation mode on. The total mass of fertilizer in fertilizer box before and after test were weighed and recorded. Ridges were cut through on each test site, and the height, top width, and base width of the ridge, as well as the placement depth of fertilization were measured with tape, steel rule and calipers

Results and Discussion

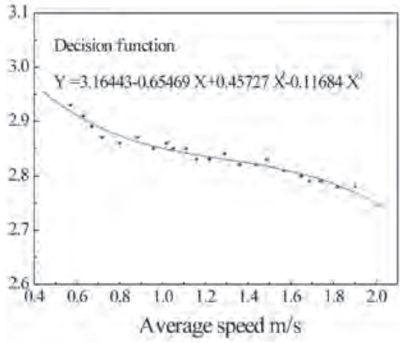
The Decision Function of Fertilizer Control System

For the purpose of determining the decision function of fertilization control system, a calibration test was conducted on hard ground surface. The fertilizing amount for one Mu was 45 kg and 2.8 kg / 30 m was chosen for debugging and verification after conversion based on plant spacing of tobacco. The travel speed of the fertilizer applicator did not exceeds 2 m/s. Fertilizer discharge was collected with a plastic bag and weighed; and the average speed of the fertilizer applicator was calculated. Motor speed was varied, and 22 sets of fertilizer amount data were obtained (**Fig. 8**). Fertilization deviated less than 5% (2.66-2.94 kg). The decision function of fertilization was determined as $y = 3.16443 - 0.65469x + 0.45727x^2 - 0.11684x^3$.

Ridge Height, Top Width and Base Width

According to standard tobacco planting requirements, the ridge should be shaped as an isosceles trapezoid, with an adjusted ridge height of 300 mm, top width of 1300 mm and base width of 1700 mm. Parameters within ±10% of the above standard requirements are considered acceptable. The variable coefficients of ridge height, top width and base width can be calculated as:

Fig. 6 The decision function of fertilizer control systemt



$$\begin{cases} V = \dfrac{S}{\overline{Q}} \times 100\% \\ S = \sqrt{\dfrac{\sum (a_i - a)^2}{n-1}} \times 100\% \\ \overline{Q} = \dfrac{\sum Q_i}{n} \times 100\% \end{cases} \quad \text{(Eq. 4).}$$

V = variable coefficient of ridge height, top width or base width, %;

S = standard deviation of ridge height, top width or base width, mm;

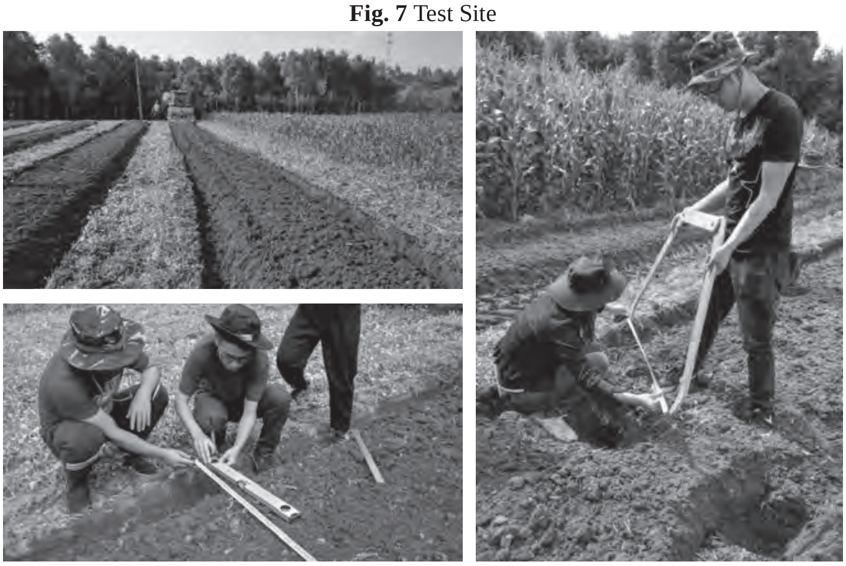
$\overline{Q}$ = average value of ridge height, top width or base width, mm;

Q_i = individual measured value of ridge height, top width or base width, mm;

n = sites measured for every single indicator.

Table 2 shows the actual versus theoretical fertilizer amounts for the case of a ridge height, top width and base width of 18.0 mm, 19.4 mm and 13.8 mm, respectively. The variability in ridge height, top width and base width were 6.4%, 1.5% and 0.7%, respectively, with corresponding qualification rates of 92%, 93% and 98%. Ridges were observed to be shaped well and solid, and completely meeting agricultural requirements. The effectiveness of the implement was affected by uneven slopes in the test site, causing a larger variable coefficient in ridge height than expected. The variable coefficient of base width was better than that for the top width due to

Fig. 7 Test Site



some hard soil sections where there was insufficient soil for the rotary blade to shape the ridges.

Fertilization Efficiency

Uniformity of fertilization application was analyzed on hard ground. The fertilizer applicator was adjusted to desirable parameters and run 4 times back and forth at different speeds. For each run, the middle pass that had stable travel speed was further divided into 5 segments. Uniformity data was analyzed within these segments. The tests showed that the variable coefficient of fertilization uniformity was 12.3%. This is significantly lower than the 40% minimum requirement value as specified in the Guizhou Assessment Indicator System for Agricultural Machinery for Tobacco. In addition, fertilization deviation was analyzed for the 5 segments of each pass by collecting and measuring fertilizer amounts. Results indicated that the control system had high degree of accuracy and strong stability.

Fertilization efficiency and actual fertilizer amounts were measured at the test field. The fertilizer mass in fertilizer box before and after each run were measured. The time for middle pass was recorded to calculate the fertilization efficiency in each test zone (See **Table 3**). The experimental results showed that the fertilizer applicator was efficient in fertilization, with a maximum fertilization deviation of 4.58%.

Table 3 Fertilizing parameters of the fertilizer deep applicator for twin-row within one ridge

test zone	theoretical fertilizer amount, kg	actual fertilizer amount, kg	deviation of fertilizer amount, %	Fertilization efficiency, hm^2/h
1	23.75	22.85	3.79	0.40
2	17.63	17.10	3.01	0.41
3	25.52	24.35	4.58	0.38
4	22.37	21.55	3.67	0.39

Conclusions

A tractor operated fertilizer deep applicator for twin-row within one ridge was developed at the desired rates of application and depths of placement. The performance of the prototype was evaluated in field conditions and compared to the special agricultural requirements for tobacco planting in Guizhou provinve, China. The ridge height, top width and base width formed with the implement were 28 mm, 1318 mm and 1755 mm, respectively, which are within the acceptable range of the target values of 30 mm, 1300 mm and 1700 mm, respectively. The implement was able to apply fertilizer at a depth of 350 mm which exceeds the minimum depth requirement of 250 mm. Field experiments showed that the fertilizer applicator made good ridges at a high pass rate. Variable coefficients of three indicators all met tobacco operation requirements. Deviation of fertilizing application amounts did not exceed 4.58%, which is lower than the industry standard 8%. The maximum fertilization efficiency was measured at 0.41 hm^2/h. The fertilizer deep applicator for twin-row within one ridge design includes a precise fertilization control system, which is capable of finishing ridging and providing deep fertilization in one pass. Labor saving, cost reduction and efficiency improvement were achieved as compared to conventional machinery.

Acknowledgements

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■■

Current Situation and Perspectives of Education for Agricultural Mechanization in the Republic of Buryatia of the Russian Federation

by
Mikhail Dorzhiev
Graduate School of Science and Technology,
Niigata University
JAPAN

Hideo Hasegawa
Institute of Science and Technology
Niigata University, Niigata
JAPAN
Corresponding author: g-fipps@tamu.edu.

Tsyden Sandakov
Graduate School of Science and Technology,
Niigata University
JAPAN

Nadezhda Sandakova
Graduate School of Science and Technology,
Niigata University
JAPAN

Konstantin Luzbaev
Buryat State Academy of Agriculture
named after Filippov V.R.
RUSSIA

Abstract

The article is devoted to the history and development of higher education in the Republic of Buryatia, Russian Federation. The current state of higher education in the Republic of Buryatia has its roots in the Soviet period, which originates the opening of the first agricultural institute. A comparative analysis of the three periods: the Soviet, post-Soviet and present is presented. The article deals with problems of quality of higher education, discusses the causes of the existing problems and their possible solutions in the long-term perspective. The paper studies the curriculum and state educational standards in the "Mechanization of agriculture" specialty.

Keywords: USSR, the Republic of Buryatia, agricultural education, mechanization, higher institutions.

Introduction

Higher education in Siberia and the Far East occupies an important place in the Russian education system, because the quality and effectiveness of the services provided to the population depends on the training and professional competence of specialists. Various public and private institutions of higher education, such as universities, institutes and academies, are located in the Republic of Buryatia. Republic of Buryatia has large research and production capacity, ramified infrastructure and agricultural development. Agricultural science has historically been an essential part of Russian science, closely related to the practical side of the economy, aimed at the study of agricultural production. Natural climatic and geographical conditions of the Republic of Buryatia defined livestock and crop production as the priority sector of agriculture. Thus, agricultural science was aimed at the development of the animal husbandry and crop cultivation, to provide practical assistance to agricultural enterprises in the effective management of agricultural production (Igumnov, 2000). Higher agricultural education in Eastern Siberia began its development in 1931, with an opening of an Agricultural Pedagogical Institute in the

Buryat-Mongol Autonomous Soviet Socialist Republic (ASSR), which was renamed to Buryat Agricultural Institute in 1960. In 1961 Faculty of Agricultural Mechanization was opened in the Institute (Balkhaeva, 2011; Zangeeva, 2012). Higher education in the USSR was fully funded by the government. Close connection between enterprises and specialized educational institutions were established. This meant that the company participated in the financing, and the graduates were required to work in these enterprises the first three years after graduation. Thereby, company had planned in advance, what kind of specialists they need (Vinokourov, 2012). The system provides the possibility of social success of the least prosperous sections of society. However, the post-perestroika period and then the crisis came. Funding has decreased dramatically; universities have received some autonomy and a quota on places with tuition fees. Students who received the highest marks in the entrance exams studied free of charge. The rest of the students were trained at their own expense. Enterprises ceased to finance higher education; however the state again assumed the role of Russia in the beginning of the twenty-first century. Since 1992, the higher education system has been restructured on the principles of university autonomy and academic freedom (Zaitseva and Yakovlev, 2012).

Table 1 Graduation of specialists of state higher educational institutions in agricultural specialties until 2006 in the USSR and in Russia

	Years				
	1990	1998	2000	2003	2006
Graduation of students, total	401,100	395,500	436,200	578,900	860,200
of which agricultural specialties	29,700	20,600	21,800	24,800	30,200

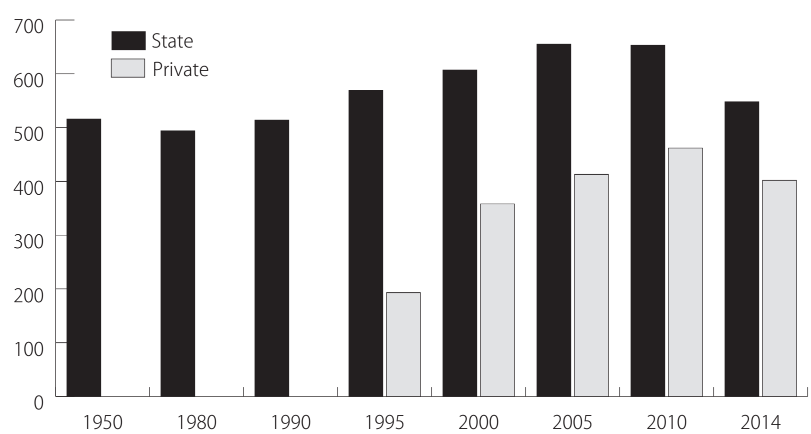
Source: Federal State Statistic Service, 2008

Higher vocational education in Russia is growing rapidly. The educational system depends on the current state and development of the government universities at the regional and local levels. Therefore, the purpose of this study is to clarify the history of the formation and development of agricultural science in the Republic of Buryatia in the Soviet and post-Soviet period, as well as to consider ways of solving problems.

Materials and Methods

Research papers in the sphere of agricultural education were used as a theoretical and methodological basis of the study. The analysis of the educational system specifics in the area of agricultural mechanization was conducted based on the 1995 State Educational Standard "Mechanization of agriculture" of Buryat State Academy of Agriculture named after Filippov V. R. and on the study of curriculums of the years 1955 and 2016.

Fig. 1 The number of higher institutions in the USSR and Russian Federation in 1950-2014



Source: Federal State Statistic Service, 2015

Results and Discussion

After signing the Bologna declaration Russia received an opportunity to educate and graduate experts according to the European requirements and standards, based on the demand of the world labor market (Novikova, 2009). Education is one of the major systems which enable a person to acquire knowledge and skills to use them effectively in professional activity.

According to the Russian Federal Service of State Statistics, the number of higher education institutions varied annually (**Fig 1**). In 1950, only 516 higher education institutions were functioning, the main increase occurred in 1995, by increasing private institutions opening. In 2010, state higher educational institutions were opened 653, and private higher education institutions 462 that could not affect the quality of Russian education as a whole.

It results in reduction of the number of applicants entering agrarian universities, leading to the decrease in the engineer faculty students (**Table 1**). According to the Russian Federal Service of State Statistics in 1990, the output of specialists was 401,100 people, and the output of agricultural specialists was 297,000 people. In 1998, the total number of graduated students was 395,500 people and the number of released agricultural profile was 20,600 people. In 2006, the total number of graduates was 860,200 people, and the graduates of the agricultural profile amounted to 30,200 people.

Another problem is reduction of the domestic demand in agricultural mechanization experts, which is followed by the low level of employment of graduates. Insufficient involvement of students in decision-making and designing of the educational environment, use of outdated methods, and the inability of existing educational programs to meet the requirements of employers negatively contribute to the quality of education (Abakumova, 2007).

To address the given problems, it is necessary to apply modern and effective approaches which will allow creating new working places for university graduates, and will increase their interest in getting higher education without departing to other regions. It is necessary to strengthen the practical side of the educational process, by introducing more practical disciplines in the educational programs and applying experience of practicing professors. It is also beneficial to set up workshops and seminars by experts and company representatives. The curriculum needs to be based on the relevant requirements of employers. The education system of the Republic of Buryatia exists in accordance with the requirements for specialists. Thus, there is a considerable number of higher educational institutions in the capital of the republic - Ulan-Ude (**Fig. 2**). One of the best and modern educational centers in the agrarian field is Federal State Educational Institution of the Higher Education the "Buryat State Academy of Agriculture named by V. R. Filippov" (Zangeeva, 2009).

Ministry of Agriculture of the Russian Federation regulates activities of the Academy, and develops educational programs for bachelor and master degrees, and postgraduate studies. Educational standards contain timetables and curricula (Nehlanova, 2006).

The historical analysis of curricula since 1955 and to the present shows that the educational programs underwent considerable changes (**Table 2**). According to the data in the **Table 1** the number of studied disciplines in 1955 amounted to 30 subjects. The majority of disciplines in the curriculum was aimed at general vocational training of the specialists and consisted of 18 professional subjects. It is necessary to note that humanitarian block of disciplines in the curricula of that time was practically absent. The humanities section of the in the curricula was mainly focused on the ideological education of the future specialists, and included subjects such as, for example, "Fundamentals of Marskizm and Leninism" and "Political Economy".

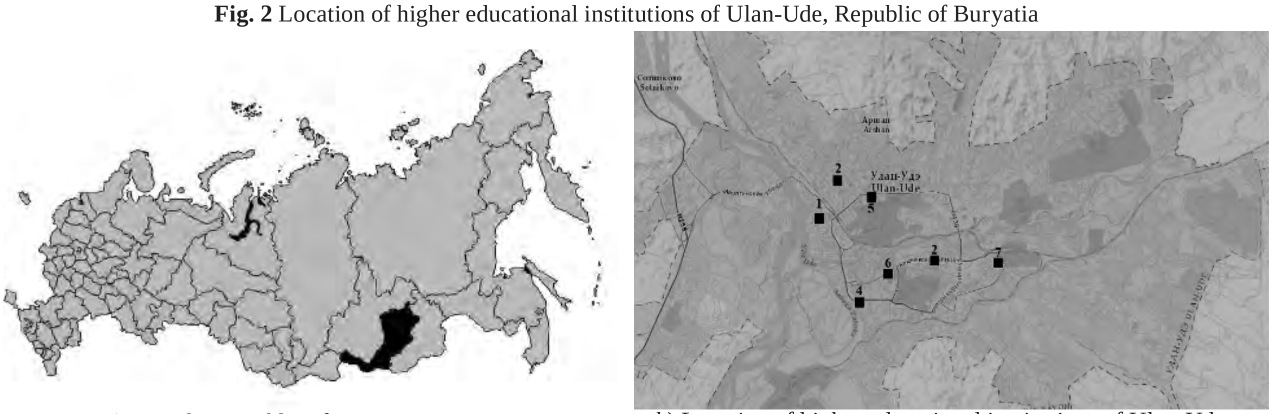
Moreover, students obtained skills in economics and accounting in the agricultural organizations. The number of natural science disciplines in the curricula of 1955 was negligible.

After the collapse of the USSR the Russian Federation introduced state educational standards, which aimed to preserve a common educational space within the country and to simplify the content of educational programs in all higher educational institutions of the Russian Federation (Dyukarev and Karavaeva, 2013).

The first generation of state educational standards (SES-1) were introduced in the late 1990s and left little freedom for higher educational institutions to design their educational programs. The second generation of state educational standard (SES-2) was adopted in 2000. SES-1 and SES-2 established requirements to the minimum content of the education programs, defined a number of compulsory subjects, and specified the number of hours for mastering the disciplines. In 2011 the Russian Federation developed and adopted a new generation of standards - federal state educational standards (FSES), which were fundamentally different from SES-1 and SES-2.

The list of subjects of the state educational standard 1995 with a degree in Agricultural Engineering is presented in **Table 3**. The list of studied disciplines was distributed over several cycles. The first cycle included social sciences of 1,800 hours. The second cycle of math-

Fig. 2 Location of higher educational institutions of Ulan-Ude, Republic of Buryatia



a) Map the Republic of Buryatia, Russia

b) Location of higher educational institutions of Ulan-Ude, Republic of Buryatia

(1. Buryat State University, 2. East-Siberian State University of Technology and Management, 3. Buryat State Agricultural Academy named after Filippov V.R, 4. East-Siberian State Institute of Culture, 5 Irkutsk State University of Railway Transport, 6. Siberian State University of Telecommunications and Informatics, 7. Russian State Humanitarian University)

Table 2 Analysis of curricula, educational programs, training of engineers for agriculture in 1955 and 2016

Form	Subject	1955 year	2016 year	
		"Mechanization of agricultural production"	"Agroengineering"	
		Speciality (5 years)	Bachelor (4 years)	Master (2 years)
Disciplines	Natural science	6	8	-
	Humanitarian sciences	2	8	1
	Specialized subjects	19	45	18
	Social Sciences	3	3	1
	Total items	30	64	20
Control forms	Exam	99	79	20
	Course projects	9	6	4
	Test	-	13	6
	Total control	108	98	30
Type of lessons	Lectures	2,340	1,338	134
	Laboratory	920	1,464	220
	Practical	1,260	910	24
	Independent work	130	3,150	1,888
	Control	120	1,026	110
	Total hours	4,770	7,888	2,376
Practices	Training practice	4	4	-
	Industrial practice	28	16	36
	Total weeks	32	20	36
	Holidays (week)	33	17	17
	State final examination (week)		6	6

Source: Comparative analysis of the curricula of August 10, 1955 and the curriculum 2016-2017

ematical sciences amounted to 1,850 hours. Specialized science accounted for 2,000 hours of the total educational time.

Professional disciplines included engineering graphics, technology of structural materials, materials science, theory of mechanisms and machines, strength of materials, machine components, lifting and transport machinery, metrology, standardization, electrical engineering, and automation. Special subjects comprised of crop production technology, mechanization and technology of animal husbandry, electric drive and electrical equipment, tractors and machinery, fuel and lubricants, and others. Optional disciplines occupied 500 hours in the plan. An analysis of 1995 state standard on "Mechanization of agriculture" reveals that in comparison with the curriculum of 1955 the number of hours allocated for the training sessions increased almost by two times. However, the amount of forms of control dramatically decreased.

At present, the state educational program in "Agricultural Mechanization" has the following characteristics: the whole theoretical course amounts to 8,370 hours, and it is designed for 155 weeks of training. Educational and industrial practice is designed for 25 weeks while 22 weeks are allocated for examination period and the holidays for the last 54 weeks. Therefore, the whole course of training in the specialty "Mechanization of agriculture" amounts to a total of 256 weeks.

General analysis of the curricula and the state educational standard illustrates the most significant changes agricultural specialists training took place in the beginning of the 21 century. These changes are presumably connected to the transition of Russia to a two tier education system, since Russia became a full member of the Bologna process in 2003 (Dyukarev and Karavaeva, 2013).

Geographic remoteness of the Buryat Republic from the largest of universities located in the western part of the Russian Federation entails both positive and negative effects. Nowadays, the imbalance between the major universities in the European part of Russia is clearly evident. While the higher education institutions of the "center" operate effectively and are included in various international ratings, universities of the farthest Russian regions are significantly lagging behind in terms of education quality. Thus, for instance, the Buryat State Agricultural Academy is the oldest university in the Republic of Buryatia, and has the largest scientific potential in the whole Baikal region. However, since the Academy is the major, and usually the only institution preparing specialists for the regional economy, its research activities have become more and more isolated and concentrate mainly on the needs of the region. Scientific achievements of the Academy often cannot be applied outside the region, and it is scientific and research activity does not fully correspond with the tendencies of the modern science. Therefore, to solve this problem the Academy needs to integrate into the system of international programs and focus more on the requirements and demand of the national and global

Table 3 Analysis of the state educational standard of 1995 to specialty 311300 - "Mechanization of agriculture"

Number of disciplines		Hours
1	Social sciences	1,800
2	Mathematical sciences	1,850
3	Specialized science	2,000
4	Special subjects	2,220
5	Facultative subjects	500
Total		8,370

Source: State educational standard, Moscow of April 9, 1995 economy, rather than necessities of one region.

Conclusions

In conclusion, further development of the Russian higher education system is possible only the state addresses a number of challenges and domestic problems. In the Soviet period government undertook unprecedented steps to boost industrial development, therefore the years 1930-1940 were associated with a mass construction of industrial enterprises, which were in need of qualified engineering personnel (Hoshimova, 2013). Thus, the state made a significant effort to eliminate illiteracy and create secondary and higher education institutions, in order to provide qualified specialists. Educational establishments were equipped with necessary laboratory equipment, of academic and scientific literature. In the post-Soviet period the quality of education decreased slightly, as a result of restrained political situation and socio-economic challenges. At the beginning of the 2000s, when Russia became the member of the Bologna Process, Russian government has revised the classification of areas and specialties of higher professional education to meet European education standards. A new generation of educational standards was created, applying the credit system. Bologna education system in Russia suggests that bachelor is an operative engineer and master is a researcher engineer, a design engineer is for technical industries of economy. To address complex problems of education system in the region it is necessary to strengthen interuniversity cooperation in curriculum development, to design and adopt joint education programs, conduct joint research projects and internships. With regards to enhancing international activities it is necessary to promote exchange of students and academic staff with the foreign universities. It will contribute to the flow of new knowledge and experience to the universities and, therefore, improve quality of education and research activities.

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Design and Development of Thresher for Onion Umbels *(Allium Cepa Variety Aggregatum L.)*

by
M. M. Pragalyaashree
Assistant Professor
Karunya University,
Coimbatore -641114
INDIA
shreepragalyaa@gmail.com

R. Kailaapan
Professors
Department of Food and Agricultural Processing,
Tamil Nadu Agricultural University,
Coimbatore - 641003, Tamil Nadu
INDIA
Corresponding author: g-fipps@tamu.edu.

Z. John Kennedy
Professors
Department of Food and Agricultural Processing,
Tamil Nadu Agricultural University,
Coimbatore - 641003, Tamil Nadu
INDIA

Abstract

Threshing of freshly harvested, sun dried onion umbels was carried out in a farm level thresher to overcome the drudgery in the conventional threshing method which resulted in more seed damage and affected the germination and vigor index. High quality seeds can be produced through effective threshing and separation process. The thresher essentially consists of a pre thresher, thresher and blower. Peg tooth type pre thresher separates the florets from the hard umbel heads further florets are conveyed to the thresher for separation of seeds from the florets. The rasp bar type thresher separates seeds from the florets and the blower separates good seeds from dust and chaffy materials. The performance of the threshing unit was evaluated in terms of florets threshing efficiency, percent good seeds collected, percentage seed loss and seed damage at different feed rate, peripheral speed and cleaning air velocity. It was concluded from the evaluation that 100±5 kg/h feed rate, 7 m/s peripheral speed, 6 mm concave clearance with 4.5 m/s cleaning air velocity gave good results. The thresher recorded the maximum threshing efficiency, percentage of good seeds collected, seed damage and cleaning efficiency as 99.85, 97.70, 1.75 and 96.46%, respectively.

Keywords: Thresher, umbels, seed damage, feed rate, peripheral speed, tractor treading, peg tooth, rasp bar, vigor index, seed loss, etc.

Introduction

Onion (*Allium cepa var. aggregatum L.*) is an important commercial horticultural crop and is grown all over the world. It is an edible spicy vegetable, rich in sulphur containing compounds, which are responsible for pungent odour and imparts many health benefits. Onion is grown in many parts of the world over a period of time. India ranks second in the world next to China and occupies 24.47% of area and 20.2% production (NHB, 2013) in the world. India the second major onion producing (16.81 MT) country in the world has a productivity of 16.0 MT/ha (NHB, 2013). Lower productivity is due non availability of quality planting material. It is reported that in India, the area, production and demand of onion are in increasing trend. Among the states, Maharastra accounts for 28% (maximum) of the country's production and the productivity of onion is maximum in Gujarat (24.4 MT/ha). Tamil Nadu accounts for 3.5% of country's onion area and more than 70% of this area is under aggregatum onion (small onion). Perambalur district of Tamil Nadu occupies 24% of the area under onion cultivation.

Bellary onion (*Allium cepa var. cepa*) and multiplier onion (*Allium cepa var. aggregatum L.*) are the two major onion types cultivated in India. The commonly known small onion or multiplier onion is predominantly grown in Tamil Nadu and part of Karnataka. CO 1, CO 2, CO 3, CO 4, CO (On) 5, MDU 1 and Bangalore rose are the important small onion varieties raised by farmers of Tamil Nadu. According to onion seed traders, more than

30% increase is observed in adoption of hybrid onion CO (On) 5 seeds for raising onion crop.

Cultivation of onion through seeds reduces onion crop in the main field by 40 days. This helps to save minimum four irrigations and two weeding. Onions produced by seed propagation results in larger and uniform size bulbs than the crop raised using bulbs. Hence, bulbs produced using seeds are highly suitable for export purpose. With vegetative (bulb) propagation, possibilities for the occurrence of diseases like root rots or wilt during summer and rainy seasons are more. Raising onion crop using seed eliminates these disease problems by treating the seeds properly. Cultivation of onion crop using onion seeds gives higher yield than using onion bulbs. Hence, farmers started adopting onion cultivation through seeds.

Conventional method of onion umbels involves selective picking and sun drying till desired moisture content is reached, then detachment of seeds from umbel is done by traditional methods. Due to non-availability of suitable machinery for post harvest operations, farmers are following the traditional methods. Traditionally, the farmers use tractor treading methods, rubbing the umbels using rubber slippers on hard concrete surface and beating with sticks. These methods results in more seed damage which affects the seed germination and vigor index. Moreover this method is labour intensive, tedious and costlier. Keeping the above points in mind a lab model thresher was developed. The lab model thresher resulted in more seed damage, more seed loss, and lower cleaning efficiency. To overcome these difficulties, a farm level thresher was developed to thresh the onion umbels with a modification in the lab model. A pre thresher with peg tooth is introduced to separate the florets from umbel heads and a thresher with rasp bar thresher to thresh the seeds from florets and a cleaner (blower) to clean the seeds. This paper deals with the performance evaluation of the thresher under different feed rate, peripheral speed and concave clearance and cleaning air velocity. The machine was evaluated in terms of floret threshing efficiency, per cent good seeds collected, seed loss and seed damage.

Materials and Methods

Fabrication of Onion Umbels Thresher

The onion umbel thresher basically works on the principle of impact force of pegs in pre thresher, which detaches florets from umbel heads, rubbing and impact forces of rasp bars in thresher to separate seeds from the florets. The blower by the action of aerodynamic forces cleans the seeds from other light weight trashes. Hence, the machine was divided in to three essential components; that is Pre thresher, thresher and pre-cleaner to perform the threshing and partly cleaning operations. The farm level thresher consisted of the following components as shown in **Fig. 1**. A feed hopper is an inward converging square shaped design to hold 5 to 7 kg of umbels and the sides were fixed at an angle slightly higher than the angle of repose of dried onion umbels for self-emptying of umbels from the feed hopper to the pre threshing chamber. From feed hopper umbels were delivered directly into the pre threshing chamber.

Pre threshing cylinder consists of 80 numbers of pegs arranged in four rows on the threshing cylinder, circular concave made of perforated sheet having holes to retain larger size umbel heads and allow the florets to pass through the hole to the thresher. Threshing chamber consists of rasp bar type threshing cylinder, circular concave made of perforated sheet and top cover. Discharge chute are used for conveying threshed materials from threshing chamber to cleaning zone in the blower chute, trash outlet, seed outlet. The main frame is used to fix all the above said working components and power transmission system.

The thresher was made to operate continuously by varying the feed rate, peripheral speed, concave clearance and cleaning air velocity of the pre thresher, thresher and blower. During operation, trays were introduced at all outlets and the materials were collected exactly for 5 minutes. The tests were replicated thrice and the average values were recorded. The readings were recorded and statistically analyzed using AGRESS and the results are discussed.

Performance of pre thresher, thresher and pre cleaner in terms of threshing efficiency, cleaning efficiency, seed loss and seed damage were calculated using the following formulae.

Pre Thresher

Florets threshing efficiency (%) = $[(A' - B) / A'] \times 100$ .....(1)

Florets separation efficiency (%) = $[(A' - C) / A'] \times 100$ .....(2)

Florets loss (%) = $[(C + D' + E') / A'] \times 100$ .....(3)

Fig. 1 Thresher for onion umbels

Seed damage (%) = $[(E + H) / A''] \times 100$ .....(4)

Thresher

Threshing efficiency (%) = $[(F - K - P) / F] \times 100$ ...(5)

Seed damage (%) = $[(J + O - H) / F] \times 100$ .....(6)

Good seeds obtained (%) = $(I / F') \times 100$ .....(7)

Blower

Cleaning efficiency (%) = $[M / (L + M)] \times 100$ .....(8)

Seed loss at the blower = $(N / F') \times 100$ .....(9)

Where,

A = weight of umbels taken

A' = weight of florets obtained from umbels, *A*

A" = weight of good seeds obtained from *A*'

B = weight of attached florets collected at umbel head outlet along with umbel head

C = weight of florets collected from pre thresher at umbel head outlet

D = weight of good seeds collected from pre thresher at umbel head outlet

E = weight of broken seeds collected from pre thresher at umbel head outlet

D' = weight of florets equal to good seeds, *D*

E' = weight of florets equal to broken seeds, *E*

F = weight of florets discharged from pre thresher to thresher *F*

F' = weight of seeds obtained from florets, *F*

G = weight of good seeds discharged from pre thresher to thresher

H = weight of broken seeds discharged from pre thresher to thresher

I = weight of good seeds collected at thresher seed outlet

J = Weight of broken seeds collected at thresher seed outlet

K = Weight of florets collected at thresher seed outlet

L = weight of dusts collected at the thresher seed outlet

M = weight of dusts collected at the dusts outlet of thresher

N = weight of good seeds collected at dusts outlet of thresher

O = weight of broken seeds collected at dusts outlet of thresher

P = weight of florets collected at dusts outlet of thresher

Results and Discussion

Performance of the unit was carried out at different feed rate, peripheral speed, concave clearance and cleaning air velocity and evaluated based on the floret threshing efficiency, floret separation efficiency, seed damage, floret loss, per cent good seeds collected, seed loss. The performance of pre thresher is represented in **Table 1**.

Table 1 Performance of Pre thresher

Feed rate, kg/h	Peripheral speed, m/s	Concave clearance, mm	Pre thresher Performance			
			Floret threshing efficiency, %	Floret separation efficiency, %	Florets loss, %	Seed damage, %
100±5	7	6	99.93	99.17	0.83	0.25
		7	99.84	98.77	1.23	0.24
		8	99.76	98.50	1.50	0.20
	8.5	6	99.91	98.85	1.25	0.26
		7	99.77	98.23	1.77	0.23
		8	99.28	98.09	1.91	0.21
	10	6	99.23	97.84	2.16	0.27
		7	99.04	97.62	2.18	0.25
		8	99.18	97.44	2.56	0.23
125±5	7	6	99.94	97.45	2.55	0.26
		7	99.91	97.32	2.68	0.24
		8	99.62	97.24	2.76	0.23
	8.5	6	99.89	97.12	2.88	0.28
		7	99.82	97.02	2.98	0.26
		8	99.34	96.89	3.11	0.23
	10	6	99.51	96.91	3.09	0.30
		7	99.23	96.78	3.22	0.26
		8	98.94	96.53	3.47	0.24
150±5	7	6	98.70	96.78	3.22	0.61
		7	98.18	96.41	3.59	0.55
		8	97.83	96.32	3.68	0.50
	8.5	6	97.85	96.54	3.46	0.70
		7	97.27	96.05	3.95	0.65
		8	96.86	96.01	3.99	0.58
	10	6	97.01	95.84	4.16	0.72
		7	96.54	95.70	4.30	0.64
		8	96.07	95.52	4.48	0.58

Performance Evaluation of Pre Thresher

Pre thresher for onion umbel was operated with feed rates of 100±5, 125±5 and 150±5 kg/h. During the experiments, peripheral speed and concave clearance were changed to 7, 8.5 and 10 m/s and 6, 7 and 8 mm, respectively. Samples were collected, analyzed and the results are presented in **Table 1**.

Effects of feed rate, peripheral speed and concave clearance on florets threshing efficiency of pre thresher

Pre-thresher recorded the highest floret threshing efficiency of 99.93% at 7 m/s peripheral speed with 6 mm concave clearance for the feed rate of 100±5 kg/h. From the table it is clearly seen that changes in peripheral speed from 7 to 10 m/s and clearance from 6 to 8 mm recorded only 0.75% decrease in floret threshing efficiency. Hence, changes in peripheral speed and concave clearance did not influence floret threshing efficiency.

Feed rates of 125±5 and 150±5 kg/h, 7 m/s peripheral speed and 6 mm clearance recorded 99.94% and 98.70% floret threshing efficiency. It is clear that, an increase in feed rate, peripheral speed and concave clearances decreased the floret threshing efficiency from 0.75% to 1.82%. This may be due to less residential time of onion umbels within the pre thresher (threshing chamber) due to higher forward speed.

Similar results were reported for threshing of chickpea seeds (Sinha et al., 2009) and for cow pea thresher by Irtwange (2009). Sinha et al. (2009) reported that increase in feed rate from 150 kg/h to 200 kg/h at 8.94 m/s peripheral speed decreased the threshing efficiency from 99.99% to 98.67% in cow pea. Irtwange (2009) reported that increase in feed rate from 101.19 kg/h to 110.86 kg/h at 500 rpm beater speed, decreased the threshing efficiency from 98.26% to 96.29%.

Effects of feed rate, peripheral speed and concave clearance on florets separation efficiency of pre thresher

Among three clearances studied, 6 mm concave clearance recorded the highest floret separation efficiency of 99.17% for the feed rate of 100±5 kg/h and 7 m/s peripheral speed. For the same operating condition, increase in concave clearance from 6 to 8 mm recorded a reduction in floret separation efficiency by 2.29%.

For the feed rate of 125±5 kg/h changes in peripheral speed (7 to 10 m/s) and concave clearance (6 to 8 mm) recorded a reduction in the floret separation efficiency by 0.95%. In general it is seen that irrespective of increase in peripheral speeds and concave clearances, increase in feed rate recorded decrease in floret separation efficiency. However, changes are much less (97.45% to 96.53%). Similar results were obtained for a increased feed rate of 150±5 kg/h, with a maximum and minimum floret separation efficiency recorded was 96.78% and 95.52%.

Increased feed rate recorded a decrease in floret separation efficiency with increase in peripheral speed and concave clearances. This may be due to the reason that at higher peripheral speed, the residential time of umbels in the pre threshing chamber got reduced and hence chance for separation of florets got decreased. Similarly increase in concave clearance resulted in lesser mixing effect in the layer of materials present in between tip of pegs of pre thresher and concave surface and hence resulted in lower floret separation efficiency.

Performance Evaluation of Thresher

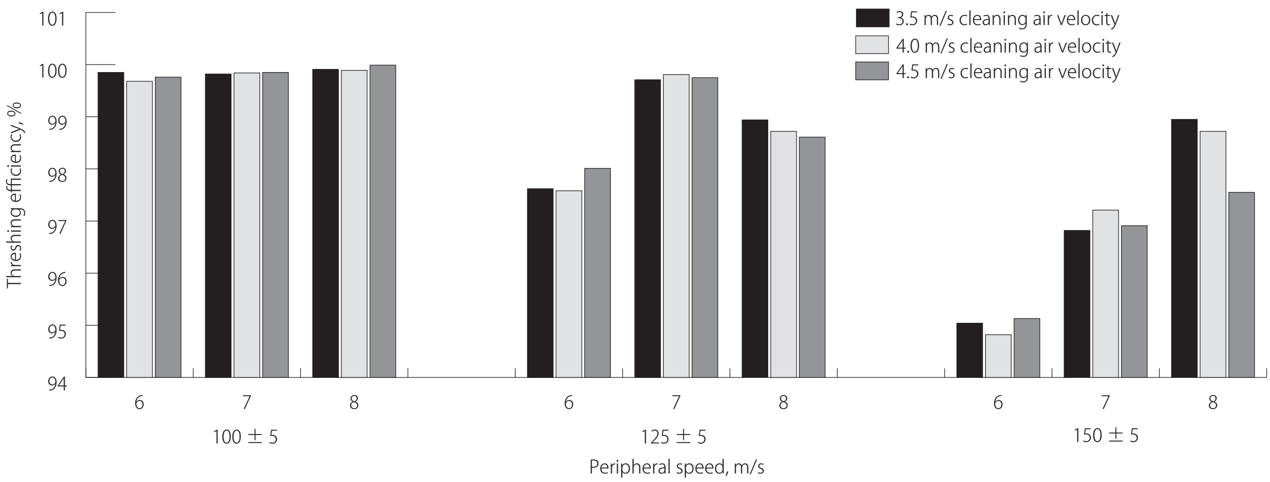
Thresher, attached below the pre thresher, received all florets, threshes them and separates husks, broken flower parts, hairy stem portion etc. and partly clean the seeds with the help of a blower and collect the seeds at the seed outlet and dusts through dust outlet.

Effects of feed rate, peripheral speed and cleaning air velocity on threshing efficiency of florets

Results of performance evaluation of thresher for the feed rate of 100±5, 125±5 and 150±5 kg/h feed rate, peripheral speeds of 6, 7 and 8 m/s and cleaning air velocities of 3.5, 4.0 and 4.5 m/s are shown in **Fig. 2**. It is seen that at 100±5 kg/h feed rate, irrespective of peripheral speed, the thresher recorded a maximum and minimum threshing efficiency of 99.91% and 99.68%. All the peripheral speeds are found suitable to give higher threshing efficiency, with an average value of 99.795±0.115%.

When the feed rate increased from 100±5 to 125±5 and 125±5 to 150±5 kg/h, the thresher recorded a maximum threshing efficiency of 99.81% at 7 m/s peripheral 98.95% at 8 m/s peripheral speed. This decrease in threshing efficiency with increase in feed rate clearly indicates that the designed thresher is unable of handle 150±5 kg/h umbel feed rate efficiently. As compared to 125±5 kg/h, 100±5 kg/h recorded higher

Fig. 2 Effects of feed rate, peripheral speed and cleaning air velocity on threshing efficiency of florets



average threshing efficiency.

The results of the present study are similar to the one reported for threshing of chickpea seeds (Sinha et al., 2009) and for cow pea thresher by Irtwange (2009). Sinha et al. (2009) reported that increase in feed rate from 150 to 200 kg/h at 8.94 m/s peripheral speed decreased the threshing efficiency from 99.99% to 98.67% in cow pea. Irtwange (2009) reported that increase in feed rate from 101.19 to 110.86 kg/h at 500 rpm beater speed, decreased the threshing efficiency from 98.26% to 96.29%. These results are in line with the results of present study.

A similar effect on threshing efficiency was reported for threshing of sorghum by Desta and Mishra (1990) and for okra using rasp bar threshing cylinder by Ajav and Adejumo (2005). Desta and Mishra (1990) reported that increase in peripheral speed from 10.1 to 12.6 m/s at 7 mm of concave clearance with 6 kg/min feed rate increased the threshing efficiency from 98.30% to 99.96%. Ajav and Adejumo (2005) reported that increase in peripheral speed from 4.2 to 4.4 m/s at 10 mm concave clearance with 10 kg/h of dried okra pods increased the threshing efficiency from 95.34% to 96.58%. The results of the above studies confirmed the findings reported in the present study.

Effects of feed rate, peripheral speed and cleaning air velocity on per cent good seeds collected at seed outlet

During threshing process, it is expected that the seed outlet should contain maximum quantity of good seeds, minimum brokens and dusts for better performance. It is evident from the **Fig.3** that designed thresher recorded a maximum good seeds collection of 98.05% and a minimum of 95.69% as the feed rate increased from 100±5 to 150±5 kg/h. It is seen that a minimum cleaning air velocity of 3.5 m/s, 6 m/s peripheral speed recorded higher quantity of good seed collection as compared to higher cleaning air velocity and peripheral speed of 4.5 m/s and 8 m/s due to loss of seeds along with dusts. It was observed that increase in peripheral speed slightly increased the seed damage, which in turn affected the per cent good seeds collected at seed outlet. The variables on per cent good seed collected were found to be significant at one per cent level.

Effects of feed rate, peripheral speed and cleaning air velocity on per cent seed damage

During threshing of florets

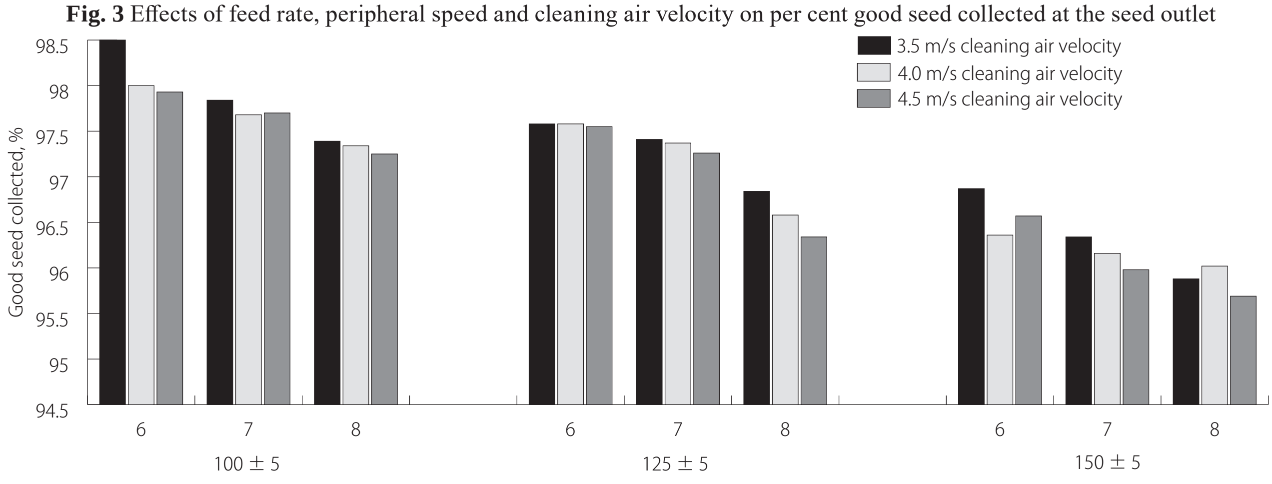
Seed damage is considered as one of the important thresher performance evaluation parameter. Increased seed damage results in decreased good seed collection. It is seen from the **Fig. 4** that seed damage was higher at lower clearance of 6 mm and lower at higher clearance of 8 mm.

Minimum seed damage observed was 1.57% at 6 m/s peripheral speed and maximum of 2.12% at 8 m/s peripheral speed. The increase in seed damage with increase in peripheral speed may be due to higher impact and rubbing forces caused by the rasp bars fixed on threshing cylinder during threshing of florets in the threshing chamber. The feed rate (100±5 kg/h) recorded an average seed damage of 1.845±0.275%. As the feed rate increased, the per cent seed damage was also increased from 2.345% to 2.97%. This is clearly indicates that 100±5 kg/h feed rate recorded a minimum seed damage for the designed thresher.

Sinha et al. (2009) reported that increase in peripheral speed from 8.94 to 10.62 m/s at 200 kg (chick pea)/h increased the seed damage from 3.37% to 4.18%. The results of present study are in line with published results. This confirms correctness of the results reported here. The results of statistical analysis showed that they were found to be significant at one per cent level.

Effects of feed rate, peripheral speed and cleaning air velocity on

Fig. 3 Effects of feed rate, peripheral speed and cleaning air velocity on per cent good seed collected at the seed outlet



cleaning efficiency of florets

Fig. 5 shows the effect of different variables on cleaning efficiency of thresher. Thresher recorded a maximum of 96.46% cleaning efficiency at 7 m/s peripheral speed with 4.5 m/s cleaning air velocity at 100+5 kg/h. It is evident that at higher peripheral speed, the floret husks were made into powder and blown well away from the seed outlet by blower and hence recorded higher cleaning efficiency at 8 m/s peripheral speed with higher cleaning air velocity 4.5 m/s as compared to 6 m/s peripheral speed and 3.5 m/s cleaning air velocity.

This less cleaning efficiency is due to some broken flower parts with same properties (terminal velocity) of onion seed, which posed difficulties to separate broken flower parts from onion seeds and higher clearances resulted in more number of larger size broken trashes clubbed with an air velocity, which is less than the terminal velocity of broken flowers parts made cleaning inefficient.

These findings are similar with those reported by Ajav and Adejumo (2005) and Sinha et al. (2009) for sunflower, cow pea and chick pea threshing, respectively.

Sinha et al. (2009) designed and evaluated a chickpea seed crop thresher. Results revealed that increase in peripheral speed from 8.94 to 10.62 m/s at 150 kg/h feed rate increased the cleaning efficiency from 95.63% to 97.20%. These reports confirmed the findings reported in the present study.

Effects of feed rate, peripheral speed and cleaning air velocity on per cent seed loss during florets threshing

In a thresher, seed loss is mainly due to higher cleaning air velocity, seed damage by threshing cylinder or combination of both. The seed loss should be minimum for better performance. From **Fig. 6**, it is seen that the designed thresher, in general recorded minimum seed loss at 100±5 kg/h and maximum seed loss at 150±5 kg/h. It is clear that for the given feed rate, increase in peripheral speed and increase in cleaning air velocity increased the seed loss.

The rise in seed loss at higher feed rates may be due to more material passed through the cleaning zone than its capacity, which in turn reduced effective separation, and

Fig. 4 Effects of feed rate, peripheral speed and cleaning air velocity on per cent seed damage during threshing of florets

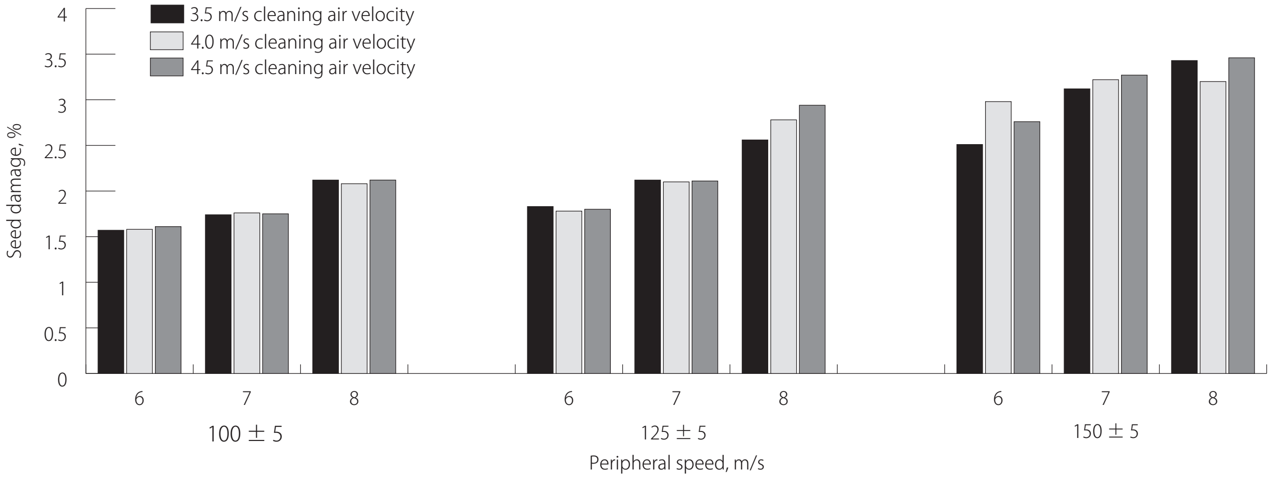
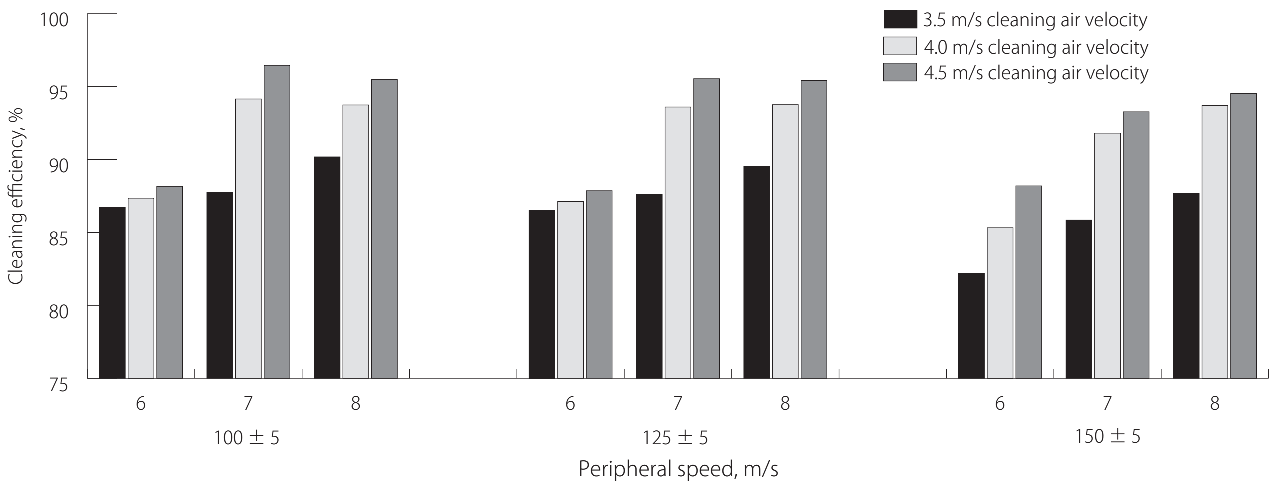


Fig. 5 Effects of feed rate, peripheral speed and cleaning air velocity on per cent cleaning efficiency of florets



Tabel 2 The best operating conditions obtained by statistical analysis

Parameters	Pre-thresher	Thresher
Feed rate (kg/h)	100±5	100±5
Peripheral speed (m/s)	7	7
Concave clearance (mm)	6	3
Cleaning air velocity (m/s)	-	4.5

outflow of some good seeds along with trashes through blower outlet.

Similar results were found during threshing of chickpea seed crop (Sinha et al. 2009) and in glory lily by Suganya (2010). Sinha et al. (2009) studied the machine parameters of an axial flow thresher for threshing of chick pea. They reported that an increase in the feed rate from 150 to 200 kg/h at 12.29 m/s peripheral speed increased the seed loss from 3.40% to 3.62% and Suganya (2010) reported that increase the feed rate from 200 to 250 kg (glory lily)/h at 6.5 m/s peripheral speed with 25 mm concave clearance increased the bean loss from 0.10% to 0.13% This confirms the findings of seed loss reported in the present study.

Conclusions

Based on the results obtained, it was decided to thresh onion umbels and separate the seeds by using a pre thresher, thresher and blower to blow the broken flower parts and separate the good seeds. This helps to thresh onion umbels with minimum materials handling process. The set up (pre thresher, thresher and blower) was operated by varying the feed rate from 100±5, 125±5 and 150±5 kg/h, pre thresher peripheral speed by 7, 8.5 and 10 m/s and concave clearance by 6, 7 and 8 mm.

The best operating conditions obtained by statistical analysis of different performance evaluation parameters are given below **Table 2**.

The performance of the pre thresher was recorded in terms of the floret separation efficiency (99.17%), floret threshing efficiency (99.93%), floret loss (0.83%) and seed damage (0.20%). The thresher recorded the maximum threshing efficiency, percentage of good seeds collected, seed damage and cleaning efficiency as 99.85%, 97.70%, 1.75% and 96.46%, respectively. The above results were obtained at the best operating conditions for the pre thresher and thresher. The newly designed pre thresher, thresher and pre cleaner costs Rs.85, 000 and recorded 91.31% saving in cost and 97.89% saving in time as compared to conventional method of umbel threshing.

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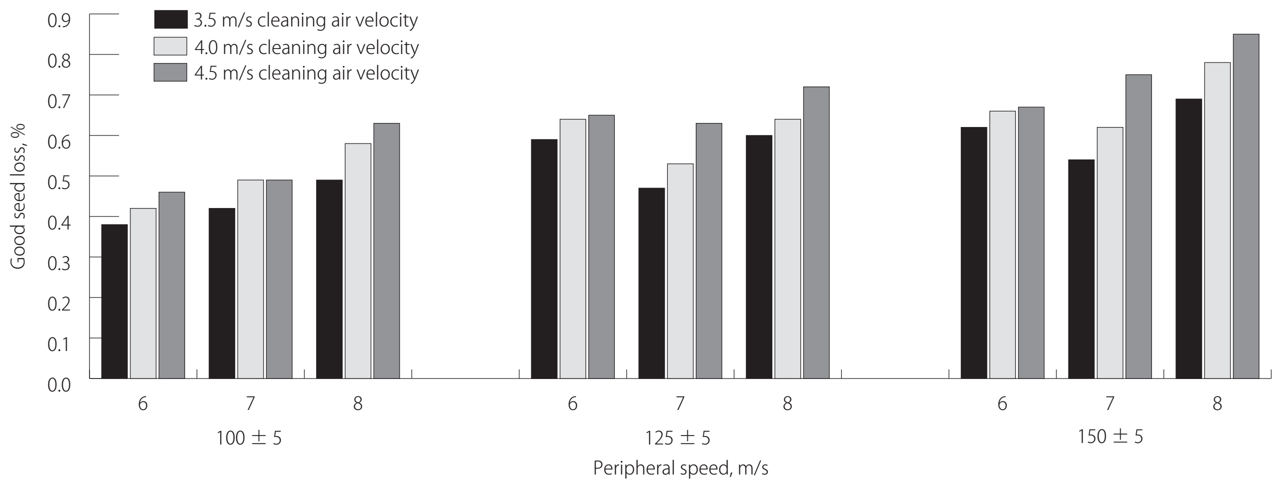
Fig. 6 Effects of feed rate, peripheral speed and cleaning air velocity on per cent seed loss during florets threshing



Influence of Surface Hardening with Carbon Nanotubes- Hard Chrome Composite on Wear Characteristics of a Simple Tillage Tools

by

A. M. Zein El-Din
Professor and Dean
Dept. of Agricultural Engineering and Bio Systems
Faculty of Agriculture
Alexandria University
EGYPY

Saad F. Ahmed
Professor Emeritus
Dept. of Agricultural Engineering and Bio Systems
Faculty of Agriculture
Alexandria University
EGYPY.

M. A. Khattab
Professor
Department Material Science
Institute of Graduate Studies and Research
Alexandria University
EGYPY

R. G. Abdel Hamied
Ph.D. Candidate
Dept. of Agricultural Engineering and Bio Systems
Faculty of Agriculture
Alexandria University
EGYPY

Abstract

The objective of this study was to reduce wear behavior of soil working tools by coating and treating processes of the tool surfaces. Three different carbon steel materials: API 52, M238 and K110. Some of the previous specimens were treated with two different coating materials: Hard chrome, HCR, and carbon nanotubes- hard chrome composite, CNTs + HCR. The other specimens were treated by: conventional heat treatment, HT, and nirtocarborizing treatment, NC. Both the coated and treated tool specimens were mounted on a circular soil bin containing sandy clay loam soil at 14% moisture content. The working speed was adjusted at 5 km/h (1.39 m/s). The coating thickness and the mass of tools were measured before and after each test. The test duration of tillage operation was conducted for 200 h for both coated and treated tools. Results obtained from all tests showed that, the wearing rate of coated specimens by carbon nanotubes-hard chrome composite CNTs + HCR were the minimum compared with other treatments. Results also showed that the surface roughness was the minimum.

Introduction

The major problem of the wear loss in agricultural soil tools could be attributed to the action of soil sliding over the metal surfaces of these tools. The a mount of soil moved each year by these tools is enormous, even though the depth seldom exceeds 10 cm. Thus it is important to assess the abrasive characteristics of the soil. In general, wear is the main component that determines the life span of the soil tool engaging. The interaction of soil and metal during abrasion is highly complex. Victor and Warounma (2013).

Abrasive wear is a major cause for the premature failure of many agricultural ground tools especially engaged in some dry land of agricultural areas. Heavy agricultural equipment operators and farmers always faced with the frequent labor, equipment downtime and reinstating costs of worn out earth engaging components. The tillage capacity of the worn out tools decreases whereas the fuel penalty increases Fernandez et al. (2001).

Wear of soil tools components occurs because the materials used are normally softer than the natural abrasives in the soil. Most of the agricultural tools are manufactured by the small scale industries. Due to improper materials and hardening of surface treatments, quality of the tools are not consistent with the "Indian Standards", it has led to high rates of wear and reduced life, which is barely a whole with the standards that affect the practical life of the plowing tool. So, there was a need to study wear characteristics of agricultural tools, as to provide the suitable tools. Punamchand et al. (2016).

The rate of wear depends on the soil texture and also on the working conditions such as the cultivation depth. The soil moisture content significantly influences of wear of soil tools. Other influencing factors are the pressures imposed on the tools during the process and hardness of materials that are manufactured from the tool. Natsis et al. (1999).

The wear of tillage tools not only affects its working life but directly changes its initial shape, which is one of the most important factors influencing plowing quality, Horvat et al. (2008). The wear rate of tillage tool is higher in soils with increased sand fraction. The major factors affecting wear rate include chemical composition, hardness, and soil physical factors, with sand content and tools hardness become the most dominant. Bobobee et al. (2007).

The most effective factors associated with field working conditions appear to propose that wear is more than a simple process that can be explained by the mechanical properties of a material such as hardness. It is necessary for the materials that will be used in the soil - engaging components hard enough corrosion resistance, but also tough and strong enough to resist the impact of the distortion. Wear soil - the involvement of components has been reduced to a minimum by providing an optimal integration of hardness and durability, and is inversely proportional mechanical properties for a material, as reported in Muammer and Tufan (2011).

Coatings have been used in recent years for surface hardening to increase wear resistance, especially for industrial cutting tools. However, there are very few studies found in the literature about the coatings used for tillage tools. Vang and Levy (1988) made mass loss measurements on various hard coating materials for soil-engaging implements in soils of different types and moisture content using full-size implements under field conditions. Wear was found to diminish using flat-type coatings on the wear surfaces.

Materials used in soil-engaging tools should be hard enough to resist wear but also tough enough to resist impact and distortion Foley et al. (1984). The toughness and hardness of plowshare material, which is subject to high wear, should be optimized to satisfy the working conditions. A suitable solution requires a tradeoff between the surface properties and the strength of the material. Several methods have been investigated to increase the wear resistance of soil tillage tools. Teflon coating, liquid emulsion, electro-osmosis, hard chrome and other surface hardening techniques have been tried. However these techniques are difficult to apply in the agricultural industry because of their cost and inconvenience.Nitriding, carburizing, heat treatment Instead, conventional heat treatment techniques (e.g., quenching and tempering) are widely used to improve the mechanical characteristics of tillage tools.

The heat treatment and carburization has been acknowledged by some means of improving the various properties of metals and alloys. The mechanical and wear behaviors of mild steels carburized at different temperature range of 850, 900 and 950 °C have been studied by Jaykant (2009) he found that the simple heat treatment greatly improves the hardness, tensile strength and wear resistance of the mild steels.

Many technologies have been developed over the years to increase the wear resistance of soil tools; for example, applied to the surface by coating with new materials such as ceramic, alumina to reduce the abrasive wear and also to reduce the draft force of tillage tools, Fielke (1996).

Recently, the application of carbon nanotubes (optimization) as a new reinforcement for composite coating has been applied due to the excellent mechanical properties and high thermal conductivity. As (Cr) exhibits high wear resistance, good ductility, and ferromagnetism, (CNTs - HCR) composite coatings have potential applications not only for wear-resistance coatings but also for the coating corrosion resistance. Chen et al. (2006).

In this study, the abrasive wear behaviors of plowshares material with different coating were investigated before and after 200 tillage operations. The wear behaviors of plowshares were evaluated by mass and thickness loss measurements after tillage.

Materials and Methods

In order to increase the hardness of tool surface material and to achieve a good scouring property, it was suggested to use an alternative techniques based on four treatments used in the standard industrial methods. The first technique was a conventional heat treatment (HT) which is commonly used to improve the surface properties of ferrous materials to decrease wear and abrasion resistance of the materials. The second technique was by increasing the carbon content at the surface of the substrate using a standard nirtocarborizing process (NC). The third technique was by coating the specimens with a layer of hard chrome (HCR). The last technique was coating the specimens with a layer of carbon nanotube-hard chrome composite (CNTs + HCR). The tillage tools were produced from different types of steel, with equal sized dimensioned metal (25 × 5 × 1) cm. The different basic carbon steels used were API 52, M238 and K110. The bottom edge of each specimen was beveled at an angle of 30° to provide a sharp cutting edge. The chemical composition of tillage tool used in this study was measured by spectrometer to determine the spark analysis as shown in **Table 1**.

The tillage operation was carried out in laboratory of soil mechanics, Agricultural and Bio Systems Engineering department, Faculty of Agriculture, Alexandria University.

Where,

C = Carbon element, *Si* = Silicon, *Mn* = Manganese, *P* = Phosphorus, *S* = Sulphur, *Cr* = Chromium, *Mo* = Molybdenum, *Ni* = Nickel and *V* = Vanadium

Treatments Carried Out on Tillage Tools

Equal sized specimens of tillage tools were produced from different carbon steels: low carbon (API52), medium carbon (M238) and high carbon (K110), and classified into five groups (each group three specimens) as follows:

Group 1, untreated specimens (as reference)

Group 2, surface treatment by conventional heat treatment (HT)

Group 3, surface treatment by nitrocarburizing (NC)

Group 4, coated with hard chrome (HCR)

Group 5, coated with hard chrome-carbon nanotube composite (CNTs + HCR).

Conventional Heat Treatment (HT)

Annealing: 800 to 850 °C - slow controlled cooling in the furnace at a rate of 10 to 20 °C/h down to approximately 600 °C further cooling in air.

Stress relieving: 650-700 °C slow cooling in furnace intended to relieve stresses set up by extensive machining, or in complex shapes, after through heating hold in neutral atmosphere for 1 to 3 hours. Hardening: 1020 to 1040 °C, complex shapes air simple shapes/ air blast oil, salt from (220-250 °C or 500-550 °C). Holding time after temperature equalization: 15 to 30 minutes. Tempering: slow heating to tempering immediately after a period in furnace: 1 hour for each 20 mm of work piece thickness but at least 2 hours / cooling in air. (This treatment was according to Böhler Edelstahl & CO. Cairo).

Nitrocarburizing Treatment (NC)

This treatment is a surface treatment applied to the finished steel surface to increase both adhesive wear resistance and fatigue limit of steel material. After nitriding, stress relieving at about 300 °C is recommended. If salt bath nitriding is to be effected, it is recommended at elevated hardening temperature (1060-1080 °C) with subsequent tempering in two cycles 1st at 520 °C. 2nd at 30-50 °C below 1st tempering temperature. Then bath nitriding. Tuffride process is carried out at 570 °C; holding time 30 minutes for a depth of nitration of about 0.03 mm. (This treatment according to Böhler Edelstahl GmbH & CO. Cairo)

Coating with Hard Chrome (HCR)

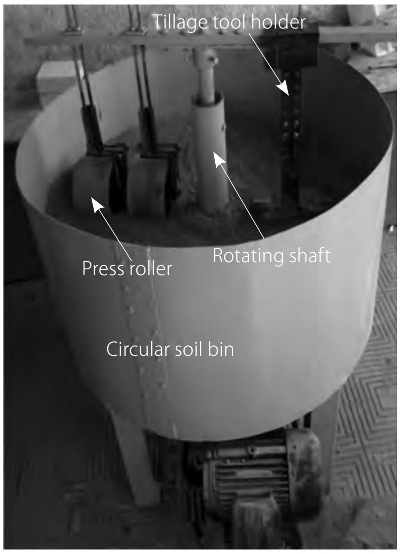
Industrial coatings take advantage of the special properties of chrome, including resistance to heat, hardness, wear, corrosion, and erosion, and a low coefficient of friction. Even though it has nothing to do with performance, many users want their functional chrome deposits also to be decorative in appearance. Functional deposits are also used on parts such as cutting tools and strip steel and are even thinner than decorative deposits. In order to ensure the satisfactory adhesion of chromium deposits, the parts must be almost perfectly clean and free of any grease. In this experiment the operational conditions were:

- Bath solution containing 250 g L^{-1} chromic acid + 2.5 g L^{-1} catalyst.
- Current density 50 A / dm^2 at 55°.
- Thickness of coating: 30 micron.

Coating with Carbon Nanotubes-Hard Chrome Composite (CNTs + HCR)

The invention discloses an electro deposition method for preparing a chrome-carbon nanotube composite coating in chrome plating solution. The invention adds a carbon nanotube in a basis electrolyte comprising chromic chloride to prepare the chrome-carbon nanotube composite coating with smooth surface and firm combination with the substrate by controlling the proper process conditions. The electro deposition process of the present invention is a metal surface of carbon steel plating, the plating of the work piece before the pretreatment using conventional plating processes. Trivalent chrome electro deposition of chrome - carbon nanotube composite coating bath formula is (per liter of electrolyte contains): chromium chloride 100-210 g, bromide 40-50 g, sodium chloride 20-35 g, boric acid 20-30 g, formic acid (or acetic acid, oxalic acid, amino acetic acid, formate, acetate, oxalate), and carbon nanotubes 0.1-10 g/l. High-purity titanium or graphite was used as anode. After the first routine of plating pretreatment of steel or copper plating work piece as a cathode, PH value of electrolytic solution was controlled at 2-3, using a constant temperature means for controlling the plating temperature at 20-40 °C. Mechanical stirring speed was ap-

Fig. 1 Prototype of circular soil bin



propriate (also available ultrasonic stirring and air agitation).The deposition process to control the current between the cathode was 10-50 A/dm^2. The current density was too low or the quality of the coating was not so good. Electrodeposition time required was 40 minutes to deposit a thickness of (30) µm chromium - carbon nanotubes composite coatings. (This method is according to Patents CN 101768772 A).

In determining the wear of the tillage tools after 200 hrs, a circular soil bin as an abrasive wear unit was constructing and used to test the wear of tillage tool in the laboratory. The function of the equipment was to allow the tool to move in the soil under controlled conditions. The main components of the testing unit are: soil bin, rollers, tool-older, a rotating shaft and a fixed lever on sides, a standing frame as well as the power transmission system as shown in **Fig. 1**. The circular soil bin was formed out of a 3mm mild steel plate. The diameter of the soil bin is 160 cm, two pulleys of different sizes 160 and 260 mm in diameter were used.

Table 1 The Chemical Composition of steel (Average %)

Type of steel	C%	Si%	Mn%	P%	S%	Cr%	Mo%	Ni%	V%
API52	0.063	0.13	1.12	0.002	0.008	0.010	0. 03	0.011	0.002
M238	0.42	0.26	1.47	0.006	0.001	1.93	0.21	0.99	0.007
K110	1.55	0.30	0.31	0.018	0.019	11.30	0.75	0.15	0.75

Where, C = Carbon element, Si = Silicon, Mn = Manganese, P = Phosphorus, S = Sulphur, Cr = Chromium, Mo = Molybdenum, Ni = Nickel and V = Vanadium

Table 2 Effect of different types of tool treatments on wearing rate before and after 200 hours of tilling operation

Steel code	Type of Treatment	Wearing rate		Loss in thickness (%)
		Thickness before tillage (µm)	Thickness after tillage (µm)	
API52 (0.06% C)	Ref	1.87	1.80	3.74*
	HT	1.87	1.82	2.67
	NC	1.88	1.84	2.13
	HCR	1.95	1.92	1.01
	CNTs + HCR	1.96	1.95	0.50**
M238 (0.42% C)	Ref	1.92	1.85	3.65*
	HT	1.93	1.88	2.59
	NC	1.93	1.89	2.07
	HCR	1.97	1.96	0.51
	CNTs + HCR	1.98	1.97	0.50**
K110 (1.55% C)	Ref	1.85	1.79	3.24*
	HT	1.85	1.80	2.70
	NC	1.86	1.82	2.15
	HCR	1.91	1.88	1.57
	CNTs + HCR	1.92	1.91	0.52**

Table 3 The average surface roughness at different treatments before and after 200 hours of tilling operation

Steel code	Type of Treatment	Average Surface Roughness (Rf), µm	
		Before tillage	After tillage
API52 (0.06% C)	Ref	5.5	8.0*
	HT	2.5	5.0
	NC	2.0	5.5
	HCR	1.5	2.5
	CNTs + HCR	0.5	1.2**
M238 (0.42% C)	Ref	2.5	5.5*
	HT	1.9	1.5
	NC	1.0	1.0
	HCR	0.4	3.5
	CNTs + HCR	0.3	0.8**
K110 (1.55% C)	Ref	1.9	3.5*
	HT	1.4	2.5
	NC	0.9	1.5
	HCR	0.6	1.5
	CNTs + HCR	0.12	0.5**

Where, HT = Heat treatment, NC = Nirtocarborizing, HCR = Hard chrome, CNTs + HCR = Carbon nanotubes - hard chrome composite
* Maximum loss (%), ** Minimum loss (%)

Laboratory Testing

Experiments were conducted with a sandy clay loam soil type, containing 78.90% sand, 13.40% silt, and 7.70% clay. The soil bin was filled with soil to a depth of 15 cm. The soil was compacted by passing the press rollers on it. The tillage tool was fixed onto its levers and set for the unit to operate. The tool was operated at a depth of 15 cm anti-clockwise direction inside the soil bin. The time per test run was 200 hours, at an average speed of 3 km/h.

The total mass loss due to wearing of coating thickness from the tool bar was measured after 200 hours of tillage operation using an electronic scale. Surface roughness values were determined by Surtronic instrument. Tests were repeated three times, cut off length of 0.75 mm from the sample.

Results and Discussion

Effect of Different Treatments on the Wearing Rate of Tillage Tool

Wear loss of tillage tools were determined, since it affects seriously production planning, quality of plowing process, energy consumption and cost of agricultural products. The abrasive wear of soil tillage tool depends on the mechanical and microstructural properties of the used material. Wear was determined by measurements of the changes of dimensions and weight before and after 200 hours of tillage operation. Results showed that the dimensions and weight losses were lower for the both types of coating materials compared to hardfaced shares. The wearing effects were determined by determining the new dimensions and compare it with the original sample. Also percentage loss in mass was determined as shown in **Table 2**. It is clear that the lowest values of percentage loss was in the samples treated by carbon nanotubes - hard chrome composite (CNTs+HCR) than any other treatments of carbon steel (API52, M238, and K110).

Effect of Different Treatments on Surface Roughness of Tillage Tool

The average surface roughness of the experimental specimens for different treatments was measured before and after tillage as presented in **Table 3**. In order to determine the effect of different coating and heat treatments on the surface roughness of long term 200 hours it is clearly seen from **Table 3**, there is a difference in surface roughness of the material and was observed for all the measurement performed before and after 200 hrs of tillage operations.

It is obvious from **Figs. 2**, **3** and **4** that the lowest values of surface roughness was obtained with carbon nanotubes-chrome composite (CNTs + HCR) treatment after tillage operation of 200 hours followed by hard chrome, nirtocarborizing and heat treatment in the all type of steel. Also, the values of surface roughness were high after tillage 200 hours than before tillage in all types of carbon steel under different treatment.

In addition, the tillage tool which treated by carbon nanotubes-hard chrome composite (CNTs + HCR) with high carbon steel (K110) gave the lowest values of surface roughness. This result gives the indication that this treatment reduces the wearing rate of the tool surface as a result of reduced friction and soil adhesion.

The statistical analysis was performed using SAS computer program to determine the effect of different treatments and different types of carbon steel on surface roughness of plowshares (Rf) before tillage. **Table 4** showed significant differences between the different treatments of plow shares (T) and the types of carbon steel (S). Also showed a significant interaction between (S*T).

Table 4 ANOVA statistical analysis for surface roughness of plowshares

S.O.V	DF	S.S	M.S	F value	F pr
Model	20	134.289	6.714	799.45	<.0001**
Error	24	0.201	0.008		
Total	44	134.491			

Conclusion

The wear behavior of coated and treated materials of soil tool was investigated in this study. Results of this experimental study could be concluded as follows:

1. Coating by carbon nanotube - hard chrome composite (CNTs + HCR) was the most appropriate treatment for decreasing wear of tillage-tool compared with other treatments.
2. Results also showed that the lowest values of surface roughness was obtained in carbon nanotubes-chrome composite (CNTs + HCR) coating material after tillage of 200 hours, followed by hard chrome, nirtocarborizing, and conventional heat treatments in all types of carbon steel. Also, the values of surface roughness before and after tillage operation of 200 hours were higher in all types of steels treated with different materials. On the other hand, for the tillage tool coated with carbon nanotubes- hard chrome compos-

Fig. 2 Effect of different type of treatments on the average surface roughness for steel (K110)

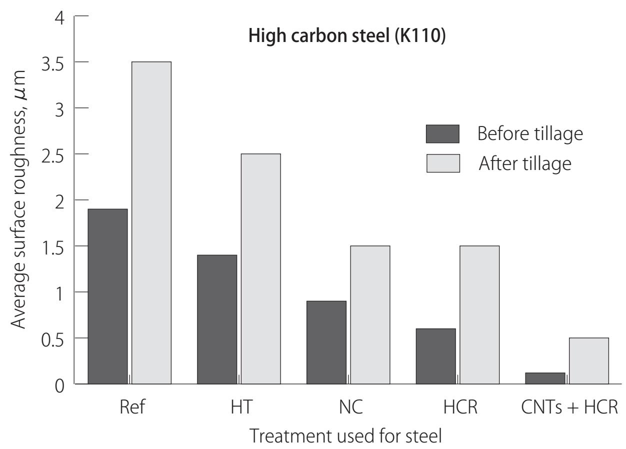
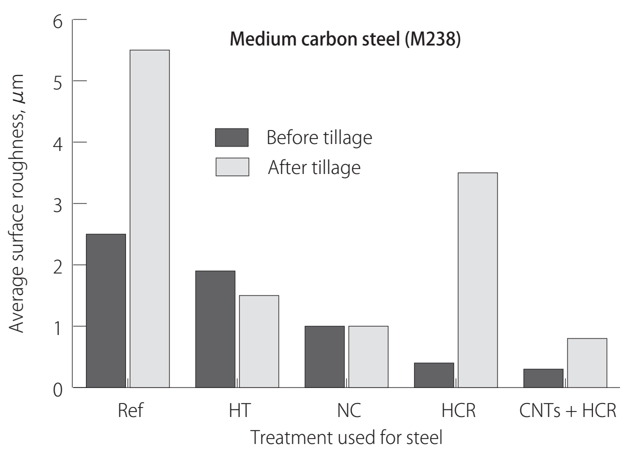


Fig. 3 Effect of different type of treatments on the average surface roughness for steel (M238)



ite (CNTs + HCR) the difference was very small, indicating that this treatment reduces the wearing of the surface of plowshares as a result of reduced friction.

3. The surface coating of tillage tools offers the potential to increase the wear strength and wear life of the plowshare and to reduce severity of abrasive wear in the soil tillage.

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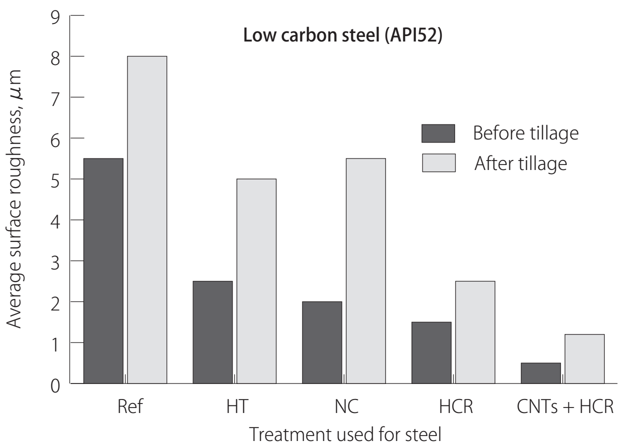
Fig. 4 Effect of different type of treatments on the average surface roughness for steel (API52)



Research on a Method to Measure and Calculate Tillage Resistance of Tractor Mounted Plough

by
Han Jiangyi
Schlool of Automotive and Traffic Engineering,
Jiangsu University,
Zhenjiang, 212013
CHINA
hanjiangyi088@163.com

Lin Cunhao
Schlool of Automotive and Traffic Engineering,
Jiangsu University,
Zhenjiang, 212013
CHINA

Abstract

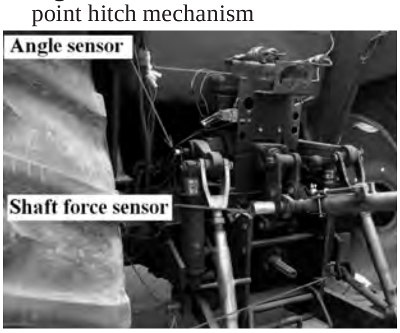
In the existing electro hydraulics hitch control system of tractors, the measuring method of the tillage resistance can not accurately reflect the tillage resistance of the mounted plough. Analysis of the measurement method of the tillage resistance is carried , and a method of is proposed to measure the tillage resistance of mounted plough by the force signal of hinge points of the upper link and lower link .The solving matrix of tillage resistance is established by using the principle of space vector force mechanics. A resistance measurement system prototype is developed on the JINMA 1204 tractor. The ill-condition of the solving matrix is analyzed, and the calculate program of the tillage resistance is developed. Field tests of tillage resistance measuring system were carried out. The test results show that the correlation coefficient between measured value and test value of tillage resistance measurement system is 0.79, which belongs to strong correlation and shows that the tillage resistance method proposed in this paper is effective. Through the calibration of the resistance measurement system, the maximum reference error between the measurement value of the tillage resistance and the resistance test value of the tillage is 5.7%, which can meet the measurement requirements of the electro hydraulics hitch control of agricultural tractor.

Keywords: Agricultural tractor, Mounted plough, Tillage resistance, Measurement method

Introduction

In electro hydraulics hitch control of agricultural tractor , the tillage resistance signal provides the work load information for draught control algorithm and draught-position mix control algorithm[1], therefore, the measurement of tillage resistance is very important.In the electro hydraulics hitch control of tractor proposed[2-3] , the force sensor is usually installed at the hinge point of the lower link and the tractor body, and the tillage resistance is achieved by the force signal at the hinge point of the lower link .Because the mounted plough is connected with the tractor through an upper link and two lower links, the force signal at the hinge point of the lower links can not accurately reflect the tillage resistance of the plough, therefore, the research on the measurement of tillage resistance of the mounted plough is of great significance to the electric hydraulics hitch control of tractors.In the field of measuring the tillage resistance , some researchers have put forward many measuring schemes for the tillage resistance, and obtained better results. The proposed measurement methods can be divided into three types.The first method is measured by installing a strain beam or force sensor on the plough body[4-5], The method has higher measurement accuracy and is often used to evaluate the mechanical properties of a single plough.The second method is to install sensors or measuring devices between hitch mechanisms and the farm implements, which are often used to evaluate the overall mechanical performance of ploughs. For traction farm tools, the force sensor is installed between the tractor drawbar and the farm implements[6], and the tillage resistance is measured directly; For the mounted plough, the measuring frame designed is connected between the tractor hitch mechanism and the plough. The load of the mounted plough is measured by strain beam[7] or force sensor[8-11] on the measuring frame, however, the measuring frame changes the installation position of the tractor and plough, which can not fully reflect the actual working conditions of the tractor plough set. The third method is to integrate force sensors into hitch links[12-13], calculate the plough tillage resistance is calculated by hitch link force signal and plough position signal; This method can fully reflect the actual working conditions of the tractor mounted plough and is used to evaluate the overall mechanical properties of plough. However, in the electro hydraulics hitch control of tractors, In electro hydraulics hitch control of tractors, it is necessary to install sensors with simple , low cost and easy to popularize the measuring method of tillage resistance on tractor. The above three methods are often used in experimental research, the first method need to install sensors in the plough body and increased the structure complexity and cost of the plough body; The second method is to add a measuring frame to tractors and ploughs, the third approach involves integrating multi-dimensional sensors into hitch links, which increases the complexity and cost of dangling links similarly. Thus, above three methods are not suitable for extension of the electro hydraulics hitch control of the tractor. Therefore, it is of great significance to study the tillage resistance measurement scheme of small change and convenient installation of sensors in application of electro hydraulic hitch control technology .This paper adopts the force of upper link and lower links hinge point to measurement of the tillage resistance .As hinge points of links and the body is fixed, the sensor installation is convenient without changing the hitch structure and plough structure, which can be applied in the electro hydraulic hitch control of tractor.

Fig. 1 Instrument of tractor three-point hitch mechanism



Nomenclature

$\mathbf{A}_i$ = force vectors of point A_i in the lower link

$\mathbf{T}_i$ = force vector of point T_i in the lower link.

$\mathbf{F}_i$ = the force vector of point B_i in the lower link

F_i = the length of force vector $\mathbf{F}_i$

$\mathbf{A}_i\mathbf{B}_i$ = the geometric vector of A_iB_i

$\mathbf{A}_i\mathbf{T}_i$ = the geometric vector of A_iT_i

F_i = the test value of the tillage resistance

$F_i(i)$ = the sample value of the tension sensor

R = the acting point of tillage force

$\mathbf{R}$ = the force vector of point R

$\mathbf{K}$ = the force vector of the hang point of the upper link

K = the length of force vector $\mathbf{K}$

DK = the geometry vector of DK

DR = the geometry vector of DR

DW = the geometry vector of DW

$\mathbf{DT_1}$ = the geometry vector of DT_1

$\mathbf{DT_2}$ = the geometry vector of DT_2

$R_y(i)$ = the sample measuring value of the tillage resistance

$F_d(i)$ = traction force value of prototype

f = the rolling resistance of the prototype

Material and Methods

Measuring Scheme of Tillage Resistance of Mounted Plough

Considering the simplicity of sensor installation, a method for measuring the tillage resistance is presented by using force signals at the hinge joint of the upper link, the lower link and position signals. The measurement scheme is shown in **Fig. 1**. Two shaft force sensors are used to replace the jointed shafts between lower links and the tractor, and the horizontal component force signal of the lower link hinge joint is obtained; A shaft force sensor is used to replace the jointed shafts between the upper link and the tractor, and the force signal of the upper link hinge joint is also obtained, the direction of the force signal is the same as the upper link. An angle sensor is used to measure the angular position of the lift arm. Because each lower link has three force acting points, the tillage resistance of the farm implements can not be obtained directly by force signal of these shaft sensors. Thus it is necessary to establish solving model of tillage resistance based on the position of three-point hitch and force signal of these shaft sensors. In the analysis, it is approximately assumed that the right lower link and left lower link are symmetrical about the longitudinal centerline of the tractor during ploughing[13], thus, the position of the three-point hitch and the position of the farm tool can be solved by the position angle of the lifting arm. The action point of the tillage resistance is located in the middle plough body or imaginary middle plough body position in longitudinal direction. According to the distribution characteristics of soil resistance in the plough[14], the seam line of ploughshare edge line and plough surface is assumed action location of tillage resistance on plough body in vertical direction.

The Tillage Force Solving Model of Mounted Plough

The running speed of tractor, depth of tillage and physical properties of soil will influence the resistance of plough in tillage process[15]. Considering the general condition of stable speed of tractor cultivation, the agronomy requirement for tillage uniformity and similar physical properties of soil in the same field, hence, the tillage resistance of plough is dominated by steady force. It is feasible to analyze the tillage force of the mounted plough with vector mechanics. For the convenience of analysis, the coordinate system O-XYZ is established with the midpoint of the rear axle of the tractor as the origin, as shown in **Fig. 2**.

The lower link in **Fig. 2** (i = 1 as the left lower link, i = 2 as the right lower link) is taken as the study object, and the equilibrium equations of force vectors are established as follows:

$$\mathbf{A}_i + \mathbf{F}_i + \mathbf{T}_i = 0\ ; \qquad (1)$$

Where $\mathbf{A}_i = [A_{ix}, A_{iy}, A_{iz}]$; $\mathbf{T}_i = [T_{ix}, T_{iy}, T_{iz}]$; The directional cosine of $\mathbf{F}_i$ is $[B_{i\alpha}, B_{i\beta}, B_{i\gamma}]$; The geometric vector of B_iE_i is $[x_{BEi}, y_{BEi}, z_{BEi}]$; Thus, $B_{i\alpha} = x_{BEi} / l$, $B_{i\beta} = y_{BEi} / l$, $B_{i\gamma} = z_{BEi} / l$.

According to the torque of $\mathbf{F}_i$ and $\mathbf{T}_i$ to the point A_i, the moment balance equation of the lower link is obtained:

$$\mathbf{F}_i \times \mathbf{A}_i\mathbf{B}_i + \mathbf{T}_i \times \mathbf{A}_i\mathbf{T}_i = 0\ ; \qquad (2)$$

Where $\mathbf{A}_i\mathbf{B}_i = [x_{ABi}, y_{ABi}, z_{ABi}]$, $\mathbf{A}_i\mathbf{T}_i = [x_{ATi}, y_{ATi}, z_{ATi}]$; According to (1) and (2), the linear independent equations can be written as following:

$$A_{ix} + F_i \bullet B_{i\alpha} + T_{ix} = 0\ ; \qquad (3)$$

$$A_{iy} + F_i \bullet B_{i\beta} + T_{iy} = 0\ ; \qquad (4)$$

$$A_{iz} + F_i \bullet B_{i\gamma} + T_{iz} = 0\ ; \qquad (5)$$

$$T_{iy} \bullet z_{ATi} - T_{iz} \bullet y_{ATi} + F_i \bullet B_{i\beta\gamma} = 0\ ; \qquad (6)$$

$$T_{ix} \bullet y_{ATi} - T_{iy} \bullet x_{ATi} + F_i \bullet B_{i\alpha\beta} = 0\ ; \qquad (7)$$

Where $B_{i\beta\gamma} = z_{ABi} \bullet B_{i\beta} - y_{ABi}$; $B_{i\alpha\beta} = y_{ABi} \bullet B_{i\beta} - x_{ABi} \bullet B_{i\beta}$.

Since the A_{iy} can be measured by the shaft sensor in the hinge joint of the lower link, the unknown parameter are A_{ix}, A_{iz}, F_i, T_{ix}, T_{iy} and T_{iz} in Formula 3 to formula 7. When i =1, 2, there are 10 equations that contain 12 unknown parameters.

As shown in **Figure 2**, R = $[R_x, R_y, R_z]$; The directional cosine of **K** is written as $[k_\alpha, k_\beta, k_\gamma]$. When the plough is taken as the study object, the force vector of the hang point T_i of the plough is opposite to the force vector of the hang point T_i of the upper link; The equation of force balance for the plough is established as follows:

$$-T_{1x} - T_{2x} + K \bullet k_\alpha + R_x = 0\ ; \qquad (8)$$

$$-T_{1y} - T_{2y} + K \bullet k_\beta + R_y = 0\ ; \qquad (9)$$

$$-T_{1z} - T_{2z} + K \bullet k_\gamma - G + R_z = 0\ ; \qquad (10)$$

As shown in **Figure 2**, $\mathbf{DK} = [x_{DK}, y_{DK}, z_{DK}]$; $\mathbf{DR} = [x_{DR}, y_{DR}, z_{DR}]$; $\mathbf{DW} = [x_{TW}, y_{TW}, z_{TW}]$; $\mathbf{DT_1} = [x_{DT1}, y_{DT1}, z_{DT1}]$ and $\mathbf{DT_2} = [x_{DT2}, y_{DT2}, z_{DT2}]$.

The torque balance equation of the D point on the plough is as follows:

$$\mathbf{K} \times \mathbf{TK} + \mathbf{R} \times \mathbf{DR} - \mathbf{T_1} \times \mathbf{DT_1} - \mathbf{T_2} \times \mathbf{DT_2} + \mathbf{W} \times \mathbf{DW} = 0\ ; \qquad (11)$$

Because the left lower link and right lower link are symmetrical about the longitudinal center line of the tractor, according to the equation (11), write the equation are written as follows:

$$K \bullet k_\beta \bullet z_{TK} - K \bullet k_\gamma \bullet y_{DK} + R_y \bullet z_{DR} - R_2 \bullet y_{DR} + G \bullet y_{DW} = 0\ ; \qquad (12)$$

$$K \bullet k_\alpha \bullet y_{DK} - K \bullet k_\beta \bullet x_{DK} + R_x \bullet y_{DR} + T_{1y} \bullet x_{DT1} + T_{2y} \bullet x_{DT2} = 0\ ; \qquad (13)$$

From (8) to (13), the K can be measured by the shaft force sensor of the upper link and the unknown parameter are T_{ix}, T_{iy}, T_{iz}, R_x, R_y and R_2. Therefore, the system of equations containing 15 equations comes from (3) to (13), and the number of unknown parameters is 15. The equations are written in the form of matrices as follows:

$$\mathbf{A} \bullet \mathbf{X} = \mathbf{b}\ ; \qquad (14)$$

Where **A** is the coefficient matrix, and

$$\mathbf{A} = \begin{bmatrix} \mathbf{R}_1 & \mathbf{R}_3 \\ \mathbf{R}_2 & \mathbf{R}_4 \end{bmatrix}$$

$$R_1 = \begin{bmatrix} 1 & 0 & B_{1\alpha} & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & B_{1\beta} & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & B_{1\gamma} & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & B_{1\beta\gamma} & 0 & z_{AT1} & -y_{AT1} & 0 & 0 \\ 0 & 0 & B_{1\alpha\beta} & y_{AT1} & -x_{AT1} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -x_{TT1} & 0 & 0 & 0 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ B_{2\alpha} & 1 & 0 & 0 & 0 & 0 & 0 \\ B_{2\beta} & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$R_4 = \begin{bmatrix} B_{2\gamma} & 0 & 1 & 0 & 0 & 0 & 0 \\ B_{2\beta\gamma} & 0 & z_{AT2} & -y_{AT2} & 0 & 0 & 0 \\ B_{2\alpha\beta} & y_{AT2} & -x_{AT2} & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 0 & z_{DR} & -y_{DR} \\ 0 & 0 & x_{DT2} & 0 & y_{DR} & 0 & 0 \end{bmatrix}$$

$\mathbf{X} = [A_{1x}\ \ A_{1z}\ \ F_1\ \ T_{1x}\ \ T_{1y}\ \ T_{1z}\ \ A_{2x}\ \ A_{2z}\ \ F_2\ \ T_{2x}\ \ T_{2y}\ \ T_{2z}\ \ R_x\ \ R_z]$;

$\mathbf{b} = [0\ \ -A_{1y}\ \ 0\ \ 0\ \ 0\ \ 0\ \ -A_{2y}\ \ 0\ \ 0\ \ 0\ \ -K \bullet k_\alpha\ \ -K \bullet k_\beta\ \ b_{13}\ \ b_{14}\ \ b_{15}]$;

Where $b_{13} = G - K \bullet k_\gamma$;

$b_{14} = K\,(k_\gamma \bullet y_{DK} - k_\beta \bullet z_{DK}) - G \bullet y_{DK}$;

$b_{15} = K\,(k_\beta \bullet z_{DK} - k_\alpha \bullet y_{DK})$;

Formula (14) is a model for solving the tillage resistance of the

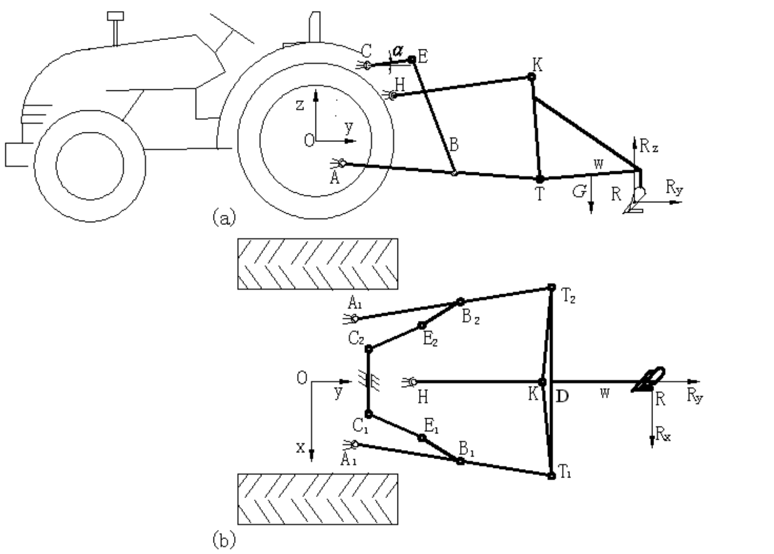


Fig. 2 Side view (a) and upper view (b) of the three-point hitch mechanism showing lower link 1; Lifting link 2 and its length is l = BE; Lifting arm 3 and its angle position is α; Upper link 4; Mounted plough 5 and R is acting point of tillage force; The hinge joint of lower link A; Hinge joint of upper link H; Hinge joint of lifting arm C; Upper hitch point of plough K; Lower hitch point T; The midpoint of lower hitch points D ; Longitudinal component of tillage force R_y; Lateral component of tillage R_x; Vertical component of tillage force R_z; Gravity center of the mounted plough W and gravity is G.

Table 1 Coordinate value of hinge joints o tractor (unit: mm)

	H	A1	A2	C1	C2
x	0	350	-350	150	-150
y	580	100	100	265	265
z	380	-250	-250	425	425

Table 2 Structure parameters of the hitch-mechanism and plough (unit: mm)

HK	AT	HK	CE	AB	KD	T_1T_2
780	1100	780	286	670	680	1100

mounted plough; The coordinate of the hitch mechanism is calculated by the position angle α of the lifting arm and the coefficient matrix **A** is derived. The A_{1y}, A_{2y} and K can be measured by the shaft force sensors, thus, vector **b** can also be solved by signal of force sensors and position coordinates of hitch mechanism. Formula (14) can be transform as:

$$\mathbf{X} = \mathbf{A}^{-1} \bullet \mathbf{b} \; ; \qquad (15)$$

Where **X** is solved and the tillage resistance R_y was obtained. Because the inversion of matrix **A** has a larger amount of computation, the tillage resistance R_y can also be solved directly from the formula (14) by the Cramer's rule that can reduce the computational complexity.

Establishment of Measuring System Prototype

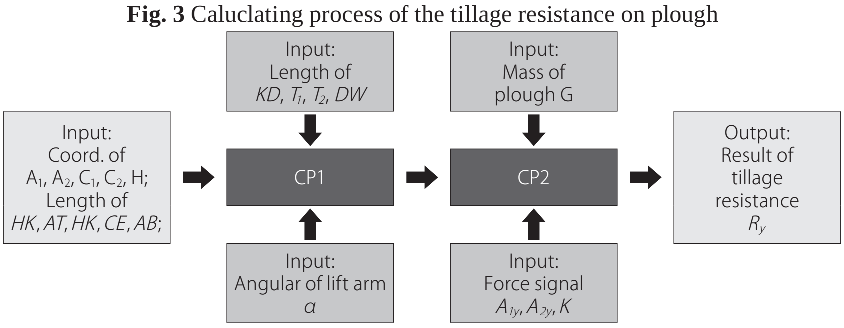
A JM1204 (power 88 kW) wheeled tractor is used as a platform to build a prototype for measuring the tillage resistance, and the type of plough adopts hydraulic reverse mounted plough (1DF435). The sensor is installed according to the measurement scheme of tillage resistance.

In the hitch mechanism of JM1204 tractor, a shaft force sensor (range -10KN~25KN, linear precision: + 0.5%, BCM company) connects the upper link and tractor, the direction of the measuring force is consistent with the direction of the upper link by a limiting device. Two pin shaft force sensors (range -30KN~30KN, linear accuracy + 0.5%, BCM company) connects the lower links and tractor, and the direction of the force measurement is horizontal by the limiting device. A non-contact angle sensor (measuring 0-200 degrees, linear accuracy + 0.3%, WDA-DP40, Miran) is mounted to measure the angle position of the lifting arm. The data are acquired by a micro-controller (MC050, Sauer, Danfoss, sampling frequency: 0~1000kHz) that supports Plus+ software (Sauer, Danfoss). Due to the plough resistance is given priority to with steady-state forces, the sampling frequency is set to 10 hz, and the force signal filtering by average filter. The PC communicates with the micro-controller through the CAN-BUS data line and record the data.

In the prototype, the coordinate parameters of the connection point between the hitch mechanism and the tractor are shown in **Table 1**, and the structural parameters of the hitch mechanism and the mounted plough are shown in **Table 2**.

According to the tillage resistance model (14) and the solution method (15), the calculation program is edited in the Matlab (R2010) software environment and the program flow is shown in **Figure 3**. The calculation program included two subroutines, the calculation result of the first subroutine (CP1) is the coordinate of the hitch mechanism and the calculation result of the second subroutine (CP2) is tillage resistance of the mounted plough.

Fig. 3 Caluclating process of the tillage resistance on plough



Results and Discussion

In the resistance measurement system, some factors will lead to errors in measurement and calculation. In calculation program, the point of resistance application on the plough is a fixed position. In fact, with the change of tillage depth, the position of the resistance application will be changed. Secondly, the position calculation error of hitch mechanism is caused by the joint clearance of the hitch mechanism. Finally, the sensor's signal error is also the source of measurement error. Therefore, it is necessary to test and calibrate the resistance measurement prototype system to improve the accuracy of the measurement of tillage resistance

Field Test on Measurement System Prototype

The test scheme of tillage resistance measurement is referred to the field traction performance test method of tractors[16-17]. A truck tractor (JM1304, Power 95.5 kW) was used to drag the prototype for cultivation, and accurate measurements of tillage resistance were obtained. The specific scheme is shown in **Figure 4**, a tractor drag the prototype with the tillage resistance measurement system by a drawbar and a tension sensor (measurement range: 0~100 kN). In the test, the transmission lever of the prototype is in neutral. The signal of the traction sensor is collected by a microcontroller in the prototype with the measurement system.

Because the tillage resistance is directly proportional to the tillage depth, the tillage resistance load of the prototype can be achieved by setting the depth of tillage. The test consisted of multiple traction distances, each of which kept the same tillage depth that can be controlled by position adjustment model from the prototype. Each traction distance is not less than 30 meters, and the traction speed is about 3 km/h .When the tillage depth reaches the set value, the resistance measuring value $R_y(i)$ of the measuring system and the traction force value $F_d(i)$ of the tension sensor are recorded, and the i is the sampling sequence in the test.

For each traction distance, the tillage resistance measuring value of measurement system can be written as:

$$R_y = \frac{1}{n}\sum_{i=1}^{n} R_y(i) \quad (16)$$

The traction force value of measurement system prototype can be written as:

$$F_d = \frac{1}{n}\sum_{i=1}^{n} F_d(i) \quad (17)$$

Since traction force includes the rolling resistance of the prototype and the tillage resistance, traction force of each traction distance can be written as:

$$F_d = f - f_t ; \quad (18)$$

Where f is the rolling resistance of the prototype, and F_t is the test value of the tillage resistance. When the tillage depth of the test distance is set to 0, in other words,the mounted plough is not tilled, F_t = 0. The rolling resistance of the measuring prototype can be obtained by this test: $f = F_d$. Therefore, a test value of tillage resistance can be obtained in the test distance that the depth setting is not 0:

$$F_t = F_d - f ; \quad (19)$$

Analysis of Test Results

The rolling resistance test curve of the prototype is shown in **Figure 5**. It shows that the rolling resistance of the prototype is fluctuating, and the reason is the unevenness in the field. The maximum value of rolling resistance is 4.21 kN, and the minimum is 3.52 kN. The average value of rolling resistance is 3.90 kN.

According to the test values of the tillage resistance and the measured values of the prototype in different tillage depths, a scatter diagram is drawn 3.2 and the reference error curve of the measured value of the prototype is drawn by taking the test value as the reference of the tillage resistance. **Figure 6** shows that there is a clear deviation between the measured values of tillage resistance and the test values. The fiducial error is greater while the tillage depth is small, and the maximum fiducial error reaches 21.7%. The fiducial error is minimum while tillage depth reaches 300 mm. This shows that, the influence of error sources on the measurement system is larger in shallow tillage conditions than in deep tillage condition.

Furthermore, correlation analysis between measurement value and test value is carried out by correlation function in Excel. The correlation between the measured value and the test value is 0.98, and the two belong to strong correlation. The measured values can reflect the change trend with the test value . This shows that the formula (14) of calculation model of tillage resistance is correct.

Calibration of Measurement Systems

Through the above test and analysis, the measurement system has a great error in measuring the tillage resistance. However, considering the high correlation between the measured value and the experimental test value, it is possible to improve its accuracy by calibrating tillage resistance measurement system. The measured values of tillage resistance were fitted by the Matlab software cftool toolbox, and the fitting equation was as follows:

$$y = 0.8894 \cdot R_y + 5.2919 \quad (16)$$

Where y is the calibration value of the resistance measuring value R_y.

According to formula (16), the calibration curve of the measured values of tillage resistance in tillage experiments was plotted (**Fig. 7**). The fiducial error curve of the calibration value is plotted for reference to the resistance test value F_t. The maximum fiducial error is 5.7%, which indicates that the accuracy of the resistance measurement is improved by the calibration resistance measurement system.

Fig. 4 Measurement schemes of tillage resistances

Conclusions

According to the requirement of electro hydraulics hitch control of agricultural tractor in measure the tillage resistance of the mounted

Fig. 5 Rolling resistance of the measurement prototype

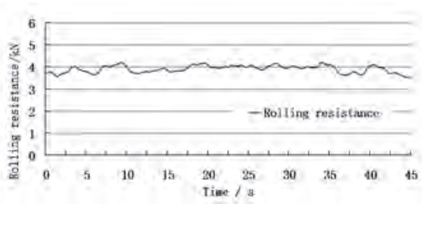


Fig. 6 Measurement value and calculated calue of tillage resistance force

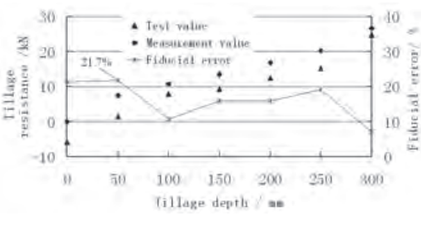
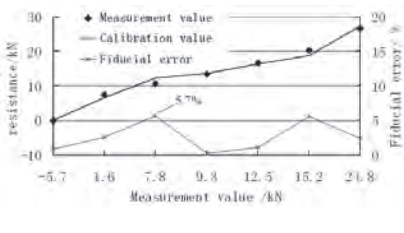


Fig. 7 Calibration of the resistance measurement prototype



plough, the measuring scheme of the tillage resistance of the hanging plough is analyzed. A scheme for measuring tillage resistance is proposed by using the force signal of joints between hitch mechanism and tractor. The scheme has small change to the hitch mechanism, and the sensor is easy to install. It is suitable for the electric control farming system. A mathematical model for calculating tillage resistance is established and a computer program is developed. Field tests of tillage resistance were carried out on the tillage resistance measuring system of the prototype. The test results show that there is a obvious deviation between the measured values of tillage resistance and the test values. However, the correlation coefficient between measured value and test value of tillage resistance measurement system is 0.79, which belongs to strong correlation and shows that the measurement method of mounted plough proposed in this paper is effective. Through the calibration of the resistance measurement system, the maximum reference error between the resistance value of the tillage resistance and the resistance test value of the tillage unit is 5.7%, which can meet the measurement requirements of the electro hydraulics hitch control of agricultural tractor.

Acknowledgment

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Automatic Seed Cum Fertilizer Drill: Modification and Performance Evaluation for Intercropping

by

Ajay Kumar Verma
Professor & Principal Scientist
Dept. of Farm Machinery and Power Engineering,
Faculty of Agril. Engineering,
IGKV, Raipur, Chhattisgarh
INDIA
ajayaverma@rediffmail.com

Mukesh Kumar Pandey
Research Associate, Niche Area of Excellence
Farm Mechanization in Rainfed Agriculture,
Faculty of Agril. Engineering,
IGKV, Raipur, Chhattisgarh
INDIA

Abstract

A plastic roller type cup feed metering mechanism of automatic seed cum fertilizer drill was modified for sowing of intercrop of wheat-chickpea (2:1) and wheat-mustard (3:1). The metering roller was selected on the basis of shape and size of seeds and number of cells on the periphery. Different type of seed flow from each cup feed roller was achieved by dividing the seed hopper in separate compartments. For the selection of the metering mechanism, calibration was done among available 7 types of cup feed metering rollers with different combination of seed box exposure length. The modified intercrop seed drill was calibrated in the laboratory for required seed rate. The required seed rate for wheat-chickpea intercropping was found 75 kg/ha for wheat with roller number 4 and 25 kg/ha for chickpea with roller number 5 at seed box exposure scale number 7. The required seed rate for wheat-mustard intercrop was found 75 kg/ha for wheat with roller number 4 and 6 kg/ha for mustard with roller number 7 at seed box exposure scale number 7. The effective field capacity of seed cum fertilizer drill for wheat- chickpea was 0.42 ha/h and 0.47 ha/h for wheat- mustard inter cropping. As per the agronomical studies the intercropping of wheat-chickpea (2:1) was performed better as compare to wheat-mustard (3:1) as well as sole crops.

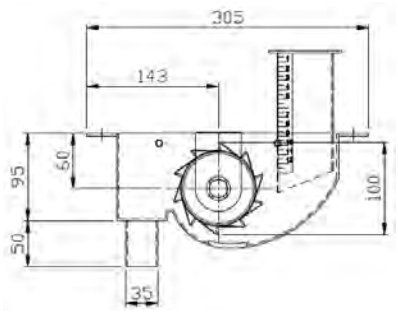
Introduction

Intercropping has gained interest because of potential advantages it offers over yield, i.e. improved utilization of growth resources by the crops and improved reliability from season to season. Intercropping gives higher income per unit area, acts as an insurance against failure of crop in rainfed situation. Intercrops maintain soil fertility as the nutrient uptake is made from both layers. It also reduces soil runoff. Intercropping system gives higher crop yield and less weed growth in comparison to sole crops. Singh and Katyal (1966) reported that the intercropping was mainly practiced to cover the risk of total failure of one of the component crops due to vagaries of weather or pest and disease incidence. Yield advantages in intercropping systems are mainly due to differential use of growth resources by the component crop. Dwivedi et al. (1992) observed that maximum net return was recorded (Rs. 6,975/ha) (1 US $ ≈ 70 Indian Rupees) with 2:1 ratio of wheat-mustard followed by 6:1 ratio of wheat-mustard as compared to sole and other inter-

Table 1 Specification of Automatic seed-cum-fertilizer drill

S. No.	Particularzs	Specification
1.	Source of power	Tractor (35 hp)
2.	Overall dimension	
	Length (mm)	2,200
	Width (mm)	660
	Height (mm)	1,360
3.	Type of Crop	Rabi & Kharif crops
4.	Depth of sowing (mm)	30-40
5.	Row to Row spacing (mm)	250, adjustable
6.	Working width (mm)	1,850
7.	No. of tines	9
8.	Types of metering device	Cup feed Mechanism
9.	Ground wheel diameter (mm)	480
10.	Type of tines	Shovel-type
11.	Power transmission	Through chain & sprocket
12.	Size of feed shaft (mm)	20 mm

Fig. 1 Cup feed roller and adjustable scale



cropping row proportions. Presently in Chhattisgarh the intercropping of seeds is performed by manual labour, it requires lot of human power. The labour availability is scares during the sowing period of Kharif (July-November: Monsoon) and Rabi (October-March: Winter) season. The cost of production also increases due the use of manual labour. On the other hand in this operation a lot of drudgery is involved. So it is felt that if this operation is performed by machine it will save time, energy, production cost and promote farmers for intercropping. In the view of need and profitability of intercropping methods under rainfed farming, a plastic roller type cup feed metering mechanism of automatic seed drill was modified for intercropping.

Materials and Method

A commercially available seed cum fertilizer seed drill name as “Automatic Seed Drill” with cup feed type roller metering mechanism was modified for intercropping.

Brief Description of Machine

In order to sow the seeds of two crops in a single run, an Automatic Seed Drill was taken for sowing of wheat-chickpea and wheat-mustard seeds for intercropping. The seed drill was operated by 35 hp tractor and it had shovel type 9 tines. Seven different sized cup feed mechanism provided with Automatic Seed Drill was used for seed and fertilizer metering, seed box height was adjusted to regulate the flow of seeds and fertilizer. Ground wheel provided for power transmission to metering unit. Row to row distance for sowing of crop was adjusted by adjusting the spacing between furrow openers. Chain and sprocket drives were used for power transmission at various stages up to seed and fertilizer metering system. An adjustable scale to expose seed box was fitted with a seed box to control the flow of seed having scale from 1 to 12 divisions. The specification of Automatic seed-cum-fertilizer drill is given in **Table 1**.

Modification in Existing Design

Intercropping is defined as growing of two or more crops on the same field at the same time. In this method, different seeds are metered in desired rows simultaneously. Different type of seed flow from each cup was achieved by dividing the seed hopper in different sections and filling the required seed in respective parts by dividing the seed box into separate compartments. The compartments were made such that it forms a complete open chamber for each seed metering unit and no mixing of seed takes place between any adjoining sections. The partitioning sheets can be removed when a single crop is to be sown. In order to sow the seeds of two crops in a single run, a seed cum fertilizer drill was taken for sowing of wheat-chickpea, and wheat-mustard seeds for intercropping. To meter seeds of different shapes and sizes, different sized cup feed mechanism was used. Seed box height was adjusted to regulate the flow of seeds and fertilizer. An adjustable scale was built-in, to control the flow of seeds. One square shaft of 20 × 20 mm size and 2200 mm length made up of mild steel was passed through centre to rotate the roller. Rotation of metering roller in housing filled with seeds causes the seeds to flow out in a continuous stream. Seed box exposure scale was provided on both sides of seed drill to control the seed flow rate by hopper of seed drill. The scale was adjusted by adjustable screw. Total four adjustable scales were provided on seed drill to regulate flow of seed and fertilizer. The scale was adjusted manually. The scale was marked on front and easily visible. Total 12 marks were marked on the scale. By adjusting one scale number exposure length of hopper increases or decreases by 5 mm. **Fig. 1** shows the seed box exposure scale. The size of cells or grooves of metering device was selected based on seed size is shown in **Figs. 2** and **3**. The metering rollers specification is given in **Table 2**.

Evaluation Procedure

In wheat-chickpea intercrop, the

Fig. 2 Different types of cup feed rollers

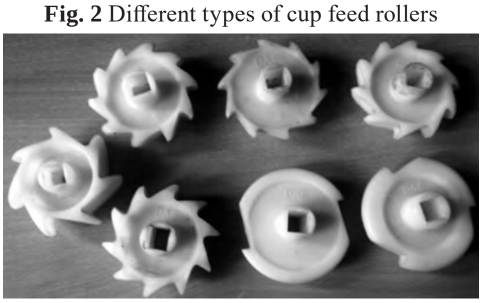


Fig. 3 Different types of metering rollers with adjustable hopper exposure scale

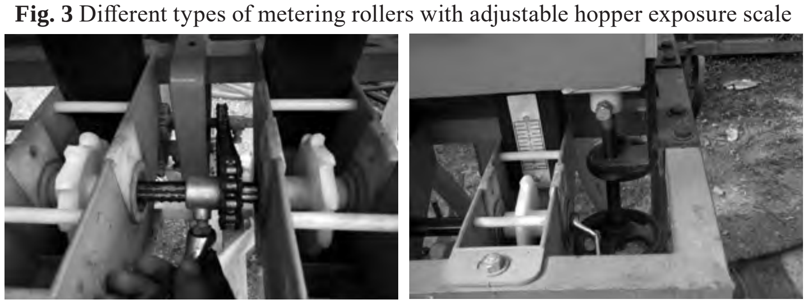


Table 2 Metering rollers specification

Metering unit roller number	Roller Thickness (mm)	Number of Grooves
2	25	10
3	14	10
4	0.8	10
5	12	10
6	23	3
7	0.7	2

Table 3 Physical properties of seeds

Crop	Variety	1000 Grain weight (g)	Moisture Content (%)	Bulk density (g/cm^3)
Wheat	GW 273	38	13.64	8
Chickpea	Vaibhav	166	12.36	7.9
Mustard	Pusa Gold	19.5	14.32	6.2

row to row spacing was 20 cm for wheat and for chickpea was kept 45 cm. In wheat-mustard intercrop the row to row distance was kept at 25 cm for wheat and 45 cm for mustard. Recommended row spacing of wheat-Chickpea intercrop and wheat-mustard intercrop under rainfed condition of Chhattisgarh is shown in **Fig. 4**.

The recommended seed rate under rainfed condition of Chhattisgarh of wheat-chickpea intercropping was 75 kg/ha and 25 kg/ha respectively. Similarly Wheat-Mustard intercropping seed rate of wheat was 75 kg/ha and mustard was 6 kg/ha.

Result and Discussion

Laboratory Test

The tests conducted as per BIS test code for sowing equipment-seed cum fertilizer drill (IS 6316:1993). The seeds were first lab tested for physical properties (**Table 3**) and then seed drill was evaluated in laboratory. For the selection of the metering mechanism, calibration was done with all 7 types of roller with different combination of seed box exposure length. The tractor drawn automatic seed drill was calibrated in the laboratory for desired seed rate by using the different size rollers, different exposure length of metering scale and different hopper filling. The available metering rollers numbers (2, 3, 4, 5, 6, 7 and 1/7) were used for the study. Roller number 6 and 7 give non-uniform seed delivery of wheat and chickpea and also the seed rate was non uniform with these rollers. Roller number 4 and 5 were found suitable for wheat and chickpea seed. For mustard roller 6 and 7 were found suitable, other rollers give higher seed rate. So calibration was done with the rollers found suitable for these crops.

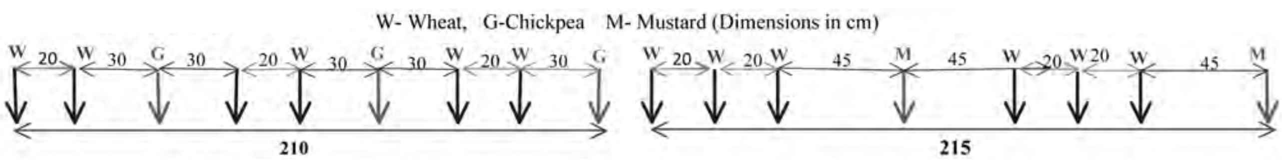
The recommended seed rate for wheat-chickpea intercrop was 75 kg/ha for wheat and 25 kg/ha for chickpea. For metering roller 4 scale exposure 7 gives nearest value of seed rate 74.9 kg/ha for wheat and for chickpea metering roller 5 exposure scale 7 gives nearest value of seed rate 24.8 kg/ha. The suitable combination of metering cups for wheat-mustard and wheat-chickpea intercrop was tested by sand bed method. An artificial leveled bed of 25 cm depth from fine sand and of a length of 5 m and the width 2.5 m was prepared. The seed drill was made to travel over this bed with seed tubes as lower as possible to use top surface of the bed. By observing the number of seeds dropped and the average distance between two seeds per meter of bed length was measured.

Effect of seed box metering roller size on seed delivery rate is given in **Table 4**. The desired seed rate of wheat (75 kg/ha), chickpea (25 kg/ha) and mustard (6 kg/ha) were observed for seed metering roller no. 4, 5 and 7 respectively at seed box exposure scale no. 7.

Effect of Hopper Filling on Seed Delivery Rate

The seed rate of wheat, chickpea and mustard for different exposure scale varied with the hopper filling (Full, 3/4th and half). It was

Fig. 4 Recommended row spacing for intercrops: (a) wheat- Chickpea, (b) wheat-mustard



(a) Wheat–chickpea intercropping (b) Wheat–mustard intercropping

Table 4 Effect of seed box metering roller size on seed delivery rate

Inter Cropping	Crop	Recommended Seed rate (kg/ha)	Seed box exposure scale No.	Metering roller No. Seed delivery rate (kg/ha)			
				3	4	5	7
Wheat-Chickpea (2:1)	Wheat	75	7	Non uniform	74.9	79.2	83.7
	Chickpea	25	7	Non uniform	19.1	24.8	30.2
Wheat - Mustard (3:1)	Wheat	75	7	Non uniform	74.9	79.2	83.7
	Mustard	6.0	7	Non uniform	2.3	3.6	5.9

Table 5 Inter row variation among the rows

Inter Crop	At exposure scale 7 Furrow opener number (F)								
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9
Wheat–chickpea (2:1)	W	W	G	W	W	G	W	W	G
Seed rate (kg/ha)	72.1	73.9	23.9	74.1	73.6	22.8	73.7	73.4	25.1
Wheat–mustard (3:1)	W	W	W	M	W	W	W	M	-
Seed rate (kg/ha)	74.1	73.9	72.9	5.6	73.7	72.1	75.1	5.8	-

Table 6 Field Performance results of Intercrop seed cum fertilizer drill

S. No.	Particulars	wheat-chickpea	wheat- mustard
1.	Effective working width, m	2.10	2.15
2.	Traveling speed, km/h	2.82	3.11
3.	Effective field capacity, ha/h	0.42	0.47
4.	Field efficiency, %	78	80.3
5.	Wheel slip of tractor, %	9.2	9.0
6.	Fuel consumption, lit/h	4.52	4.48
7.	Cost of operation, Rs/h	620	598
8.	Energy requirement, MJ/ha	1,859	1,748

Table 7 Effect of intercropping on plant height at various growth stages

Intercropping	Crop	Plant heights (cm) DAS				
		15	30	45	60	At harvest
Wheat-chickpea (2:1)	Wheat	18	34	48	62	75
	Chickpea	6	14	22	28	38
Wheat-mustard (3:1)	Wheat	15	22	34	58	72
	Mustard	8	24	67	93	146

observed that the entire sample collected for same exposure scale were nearly same and there was very little deviation among the sample i.e. (< 2.0%). The CV was also very less about in range of 0.3-2.5%.

Inter Row Variation

Table 5 indicates the seed rate of wheat, chickpea and mustard on rows for intercropping of wheat-chickpea (2:1) and wheat-mustard (3:1). It was observed that the entire samples collected for same exposure scale were nearly same seed rate. There was very little variation in seed rates amongst the row. The CV of recommended seed rates of all the crops taken for the study was in the range of 1.4-2.7%. Exposure scale 7 was found best suited for the recommended seed rate of wheat, chickpea and mustard crop for intercropping.

Field Experiment

Field experiments were conducted during the winters (Rabi) of 2013-14 and 2014-15. The general climate of the experimental site was classified as sub-humid with hot summers and mild winters. The soil of the experimental site was characterized by silt clay texture. The field was prepared using two operation of cultivator followed by a single operation of rotavator. The intercrop was sown by modified seed drill (**Fig. 5**). The experiment was laid out in a randomized complete block design (RCBD) with three replications, four treatment consisted of sole wheat, chickpea, mustard crop and intercropping of wheat with chickpea in 2:1 and wheat with mustard in 3:1 row proportion. The sowing was done just after the harvesting of paddy crop. Since then no irrigation was applied up to the harvesting of crop. The performance results of intercrop seed drill is given in **Table 6**.

Fig. 5 Sowing of wheat-chickpea (2:1) intercrop by using modified seed cum fertilizer drill

Agronomical Parameters

The yield attributes and yield showed significantly variation due to adoption of different row proportion and different intercropping with wheat. The data on plant height (cm), grain yield, straw yield and harvest index was collected. **Table 7** represents the average plant height of individual crop under wheat-chickpea (2:1) and wheat- mustard (3:1) intercropping.

The experimental field of intercrop of wheat- chickpea (2:1) at vegetative growing stage and wheat-mustard (3:1) at maturity state is shown in **Fig. 6**. While considering intercropping, grain yield for wheat in wheat-chickpea intercropping was higher than for sole cropping, similar results were obtained for chickpea. Consequences of similar fashion were obtained for wheat mustard intercropping when compared to sole cropping. The intercropping of wheat-chickpea (2:1) performed better as compare to wheat - mustard (3:1) intercropping. This may be due to synergistic effect and nutrient use efficiency particularly by chickpea through nodes to get nitrogen and better aeration. The LER value of wheat-chickpea (2:1) was found more profitable because the competition for light, moisture, space and nutrient was less than wheat -mustard 3:1 intercropping (Table 8). Again when taking intercropping in mind wheat-chickpea (2:1) intercropping and wheat-mustard (3:1) intercropping, the yield obtained were wheat (11.57 q/ha), chickpea (1.82 q/ha) & wheat (7.93 q/ha) and mustard (2.25 q/ha) (1 quintal = 100 kg) respectively which was considerably higher than sole cropping.

Conclusions

The modified design of intercrop seed drill was found to be suitable for intercropping of wheat-chickpea (2:1) and wheat-mustard (3:1). The field capacity of the machine was found to be 0.45 ha/h at field efficiency of 79%. On the basis of productivity and LER, intercropping system was found to be beneficial over solve cropping. When digging dipper into intercropping, the wheat?chickpea (2:1) intercropping was found to be better than wheat-mustard (3:1) intercropping. The machine covers large area in comparison to existing practices. The environmental resources were used properly with improve soil fertility and increase in nitrogen. The modification made in machine can be easily removed to use seed drill for single crop.

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Fig. 7 Experimental field of Wheat-chickpea (2:1) and wheat-mustard (3:1) intercrop

Manufacturing and Testing the Performance of Prototype for Grading of Dates

by

Said Elshahat Abdallah
Associate Professor of Agricultural Process Engineering
Department of Agricultural Engineering
Faculty of Agriculture, Kafrelsheikh University
Kafr Elsheikh 33516, EGYPT
saidelshahat@agr.kfs.edu.eg

H. M. Sorour
Professor and Head of Agricultural Engineering Department
Faculty of Agriculture, Kafrelsheikh University,
EGYPT.

A. M. Deris
Associate Professor
Faculty of Agricultural Engineering,
Al-Azhar University
EGYPT

Awad Ali Tayoush
Agricultural Engineer
Department of Agricultural Engineering
Faculty of Agriculture, Kafrelsheikh University,
EGYPT

Abstract

Locally-manufactured orchard crops graders specifications could not be determined without an adequate methodology takes into account the properties of graded material and also the design factors affect the grading efficiency. An investigation of the possibility of using a rotary drum screen grader prototype for grading dates was carried out, in order to determine the optimum values of affecting design factors for the maximized grading efficiency. A rotating screen grader consists of 244 × 84 cm frame was manufactured and tested in a local workshop located at Kafr Elsheikh city during the year of 2016. Maximizing grading efficiency of the grader needed to establish an interactive second-order polynomial model generated by a three-factor three-level Box-Behnken statistical design with response surface methodology to determine the effect of independent variables such as rotational speed, inclination angle and feeding rate on grading efficiency which represents the predicted response as a dependent variable. Three different varieties representing dates samples called *Bartamuda*, *Gandila* and *Shamiyya* as known in Egypt were chosen to be graded after studying their physical properties. The generated models predicted the levels of rotational speed, inclination angle and feeding rate to be (26.004 rpm; 4.720 degrees; and 1 kg/min, respectively) are the optimum levels for maximized response of grading efficiency (61.669%) for *Bartamuda* variety and (26.468 rpm; 1degree; and 1 kg/min, respectively) for maximized grading efficiency of (77.327%) for *Gandila* variety and (26.003 rpm; 1.085 degrees and 5 kg/min, respectively) for maximized grading efficiency of (40.988%) for *Shamiyya* variety. These evident differences between efficiencies for each variety have committed to study the correlation between physical properties of these varieties and maximized grading efficiency, hence principal component analysis was run. Results showed that physical properties such as fruit thickness and sphericity have the greatest negative effect on optimized grading efficiency but a property such as bulk density has a positive one. This study dealt with all factors that could effect on rotating screen graders efficiency for dates to some extent.

Nomenclature

BBD = Box-Behnken design
RSM = response surface methodology
N = rotational speed, rpm
θ = inclination angle, degree
F = feeding rate, kg/min
η_g = grading efficiency, %
PNN = probabilistic neural network
PCA = principal component analysis
PCs = principal components
Q_f = quantity of fed sample, kg
t = time, min
m_i = dates mass of size i dropping correctly into receiving tray of the size i, kg
m_t = total mass of graded dates of all sizes, kg
n = number of sizes
$\rho_{t,\, b \text{ or } w}$ = true, bulk or water density, g/cm^3
$M_{a \text{ or } w}$ = dates or water mass, g
$D_{g,\, a,\, s \text{ or } e}$ = geometric mean, arith-

metic mean, square mean or equivalent diameter, cm

L, W and T = fruit length, width and thickness, cm

Q = sphericity, decimal

S = fruit surface area, cm^2

μ = static friction coefficient, dimensionless

φ = tilt angle of friction plane, degree

2 or *3D* = two or three dimensional

R^2 = coefficient of determination

SD = standard deviation

r = correlation coefficient

P-Value = calculated probability

Subscript *ir* = galvanized iron steel

Superscript • = maximized value

Introduction

Inadequacies in processing facilities are one of the most important factors in developing countries which are responsible about food losses because preserving and processing of fresh farm products could not be done in many cases (FAO, 2011). Recent studies and reviews confirm that postharvest losses are still high at the farm (Kitinoja et al., 2011). Any attempt to transport some of these processes to the farm even though on a small-scale would be helpful to reduce these losses. Dates (fruit of the date palm, *Phoenix dactylifera L.*), are one of the most important commodities produced in Egypt. The total annual production of dates in Egypt reached 1501799 tons in 2013, so Egypt is considered the first dates-producing country (FAO, 2013). Because of its importance in many aspects in Egypt – although it is seasonal at most – any procedures or processes are conducted to the yield in farm are necessary to reduce postharvest losses or raising quality and comparative commercial value of the product such as size grading which is one of the most important postharvest processes not just for dates but for the majority of horticultural crops. In general, dates grading throughout dates producing conducted manually (Lee et al., 2008) and from between all of known types of sorters and graders, screen grader as one of the most widely used grading device has been chosen for investigating the possible use of it for an efficient grading of dates especially rotating screen grader. Rotating screens could be adequate in a developing country such as Egypt due to the simplicity of design and working principle, furthermore, they could be handily operated (Preetha et al., 2016) without any power source instead of vibrating screens that need additional vibrating and adjusting equipment. Also its sophisticated design; it is needed to two different kinds of motions, i.e., a horizontal oscillating motion and a smaller vertical motion (Henderson and Perry, 1976). Even if it was not a vibrating sizing machine such as diverging rotating rollers, it needs an adequate power transmission system allows a counter-rotating action or such as diverging belts problems like stuck of graded material to each other and the back-and-forth movement of drum pulleys and used belts elasticity (Souts et al., 2014; Ghanbarian et al. in Persian, 2015; and Souts and Olt, 2017). Therefore perforated rotary drum graders could be easily fabricated in local workshops, consequently they would be the proper type at the domestic level including rural nature zones and fit small-scaled enterprises. Approaching the optimum specifications of a local-made rotating screen grader prototype needs to investigate the impact on grading efficiency by both physical properties of graded fruits and design factors of the grader; hence the research work can be divided into two main sections. The first section is concerned with determining the optimum values of affecting design factors for the maximized grading efficiency, and this could be done by a developed mathematical model describes the effect of changing levels of rotating screen inclination angle, rotational speed and dates feeding rate as independent variables on the grading efficiency as a dependent variable. Therefore, three-factor three-level Box-Behnken Design (BBD) with Response Surface Methodology (RSM) are chosen to generate an interactive second-order polynomial model. BBD that is factional factorial design with RSM had been used previously to describe the behavior of rotating graders with some horticultural crops (Narvankar et al., 2005; Ghanbarian et al., 2010; Farhadi et al., 2012; and Gunathilake et al., 2016). The ultimate goal of RSM is to find the optima (maxima or minima) on the response surface (Ghorbani, 2008) and the interest is in finding the maxima on grading efficiency response surface which represents the optimum condition of machine performance. The second section interests in studying the correlation between maximized grading efficiency for studied varieties and physical properties of them using Principal Component Analysis (PCA); In PCA, obtained maximum grading efficiency from the surface in addition physical properties of the studied varieties could be included as measured variables in the so-called "loading plots", plots that are positioned close from or opposite of each other considered positively or negatively correlated variables, respectively (Hopfer et al., 2014). Hence, determining the properties that have a positive or a negative effect on maximized grading efficiency of the variety would be possible. PCA technique is being used widely in food science and Engineering (Lawless and Heymann, 2010; Acton, 2013; and Elmessery and Abdallah, 2014). The majority of researches that dealt with investigating rotating screen graders optimum performance conditions for horticultural crops did not take into account the effect of physical properties of graded material on grading efficiency for a better choice of varieties that fit grader behavior with indicated specifications and the current research proposing a new methodology to deal such issues.

Therefore the present investigation aims at investigating the following:

1. Manufacturing and testing the performance of prototype for size grading of dates;
2. Developing a mathematical model determining the optimum operating parameters during grading process of dates; and
3. Studying the effect of physical properties on maximized grading efficiency for each investigated variety.

Materials and Methods

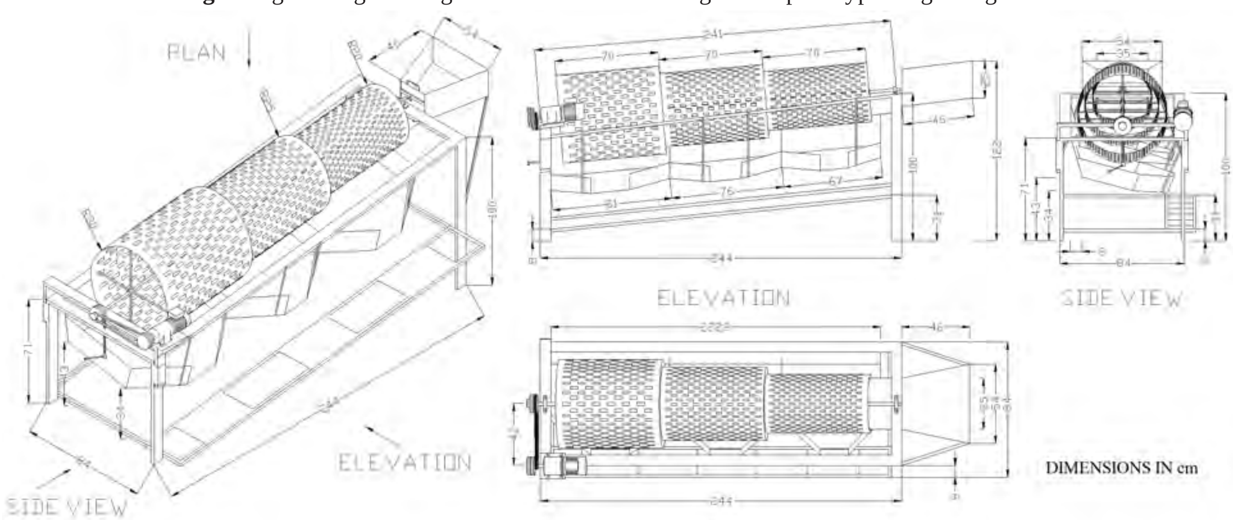
Experimentation

New prototype of rotating screen grader was manufactured and constructed in a workshop at the Industrial Region, Kafr Elsheikh city, Egypt during the year of 2016, **Fig. 1**. The prototype was installed at the Agricultural Engineering Department, Faculty of Agriculture, Kafrelsheikh University to be tested and operated during the year of 2017. Grader materials were made up of mild steel and painted with a primer paint which does not react chemically with dates. Three different varieties of dates were brought from Aswan, Egypt that have been used in this investigation, namely *Bartamuda*, *Gandila* and *Shamiyya* as known in Egypt. Basically, two different kinds of studies were done: the first one aimed at determining the optimum performance condition for maximizing grading efficiency through developing a mathematical model describes the relationship among rotating screen inclination angle, rotational speed and dates feeding rate from one side and grading efficiency from the other side. The second kind of studies including a comprehensive measuring of physical properties of the used varieties to investigate the effect of properties of each variety on maximized grading efficiency achieved by it through PCA with the aim of studying the correlation between them.

Grading Model Construction

The main structure of rotating screen with a total length of 210 cm consists of three perforated rotary drums with the same length of 70 cm and diameters of 40, 50 and 60 cm for the first, second and third grading drum, respectively as shown in **Figs. 1** and **2**. Every drum was made up of a mild steel sheet with a thickness of 2mm, sheet width is similar to drum length and its length was calculated by determining drum circumference. After that, sheets were perforated according to each grade and the two sides of it gathered together and welded to form a drum. Perforating type chosen for the screens was "side staggered rectangular", openings dimensions for the first, second and third grade were 4.5 × 2; 5 × 2.3; and 5.5 × 2.5 cm, respectively and these dimensions were determined after studying dates varieties physical properties and several attempts to raise grading efficiency by expanding openings more than planned. Side bar and end bar of perforation between openings for the first and second grade were 1 and 2 cm, respectively while they were of 1.5 and 4 cm for the third grade, respectively. Screen openings were orientated in the direction of dates travel. Perforated drums were gathered using a central shaft running through the entire length of rotating screen, it was a mild steel rod with an external diameter of 2 cm and internal one of 1.5 cm and with a length of 241cm connected to four crossed-shape 10-mm diameter steel rods by cylindrical rings have been furnished to be through of it, **Fig. 3**. The shaft is supplying drums with power for a rotational movement. The two ends of the shaft have been provided and mounted on the frame using two pushed bearings. A one horse power 3-phase 220V electric motor were used to supply rotating screen with power and it was installed on a mild steel plate using bolts and nuts on a

Fig. 1 Engineering drawing of the local-made rotating screen prototype for grading dates



base made up of 4 × 2 cm mild steel rectangular sections. So in case of changing inclination angle of rotating screen, motor and screen will move as a one unit. Power could be transmitted to the screen by two pulleys, one of them was fitted to the motor and the other one fitted to the central shaft and there is a belt transmitting power from the electric motor to the screen. To change rotational speed of rotating screen, two similar multi-groove pulleys were used and every groove has a different diameter and it was about 11.6, 8.8 and 6.7 cm. The multi-groove pulley fitted to the motor was in the opposite direction of the one fitted to the central shaft. Therefore, every two grooves will give a different rotational speed to the screen which was of 26, 54 and 82 rpm. Changing speeds was done by a V-type belt via changing its position between grooves as shown in **Fig. 4**. Although this procedure takes longer time than existence of a gear-box, but its simplicity are going to reduce effort and time of maintenance. One of the most important factors affecting grading efficiency is the screen inclination angle. As shown in **Fig. 5**, using a screw-jack was fixed and running through the frame for raising or lowering the base that is lifting both of electric motor and the other side of the central shaft at discharge end. This base moves vertically in a track which is u-shaped strip attached to the two edges of the frame (U-edging) for more stability during adjusting inclination angle. These tracks were implemented with bolts and nuts to be tied after adjusting screen slope. Three inclination angles of 1, 3 and 5 degrees were chosen to investigate their effect on grading efficiency. To reach these angles the free side of the central shaft has been raised where the base reach the heights that shown in **Fig. 5**. Feeding system was made up of mild steel welded to grader body on the same integrity, i.e., it has the same inclination angle of the longitudinal bars in upper part of the frame, also it was supplied with a gate moving in a track could be lifted or lowered using a handle welded to it and could be used for controlling feeding rate and supplied with two supports (mild steel L-section 2 × 2 cm), **Fig. 6**. Hopper takes the shape of a trapezoidal prism so its total volume was calculated to be 0.0512 m^3. Feeding process was carried out manually by pushing dates through the gate to reach a mild steel feeding tray takes the shape of a horizontal cylindrical segment welded to the frame and it supplies the screen with dates. After dates were sized, they would be received by a tray with a side slope of 0.26 and longitudinal slope of 0.09 approximately. Each grade was separated from each other using mild steel borders welded to the trays. Trays made up of mild steel sheet with a thickness of 2 mm and they were supported with 10-mm mild steel rod as shown in **Fig. 2**. After that sized dates are going to be received by baskets that have been put on a metal rack welded to grader frame. Rack has the same longitudinal slope of trays, **Fig. 3**.

Investigated Variables

Dates duration into the grader was still constant at every feeding rate, hence changing feeding rate obtained by changing input masses at constant time. Feeding rate was calculated using Equation 1 (Preetha et al., 2016):

Feeding Rate, $kg/h = Qf / t$ .....Eqn 1

Where Q_f is the quantity of sample in *kg* and *t* is the time taken for a complete grading in min. A stop-watch and counting number of screen revolutions per minute were used for each speed as depicted in **Fig. 4**. Rotational speed was measured in rpm. After making sure that grader body was totally installed horizontally,

Fig. 2 Experimental setup of the rotating screen grader

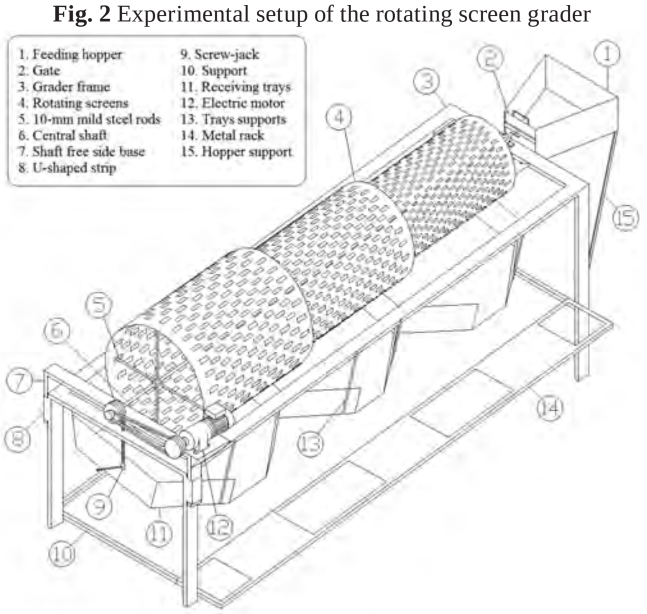
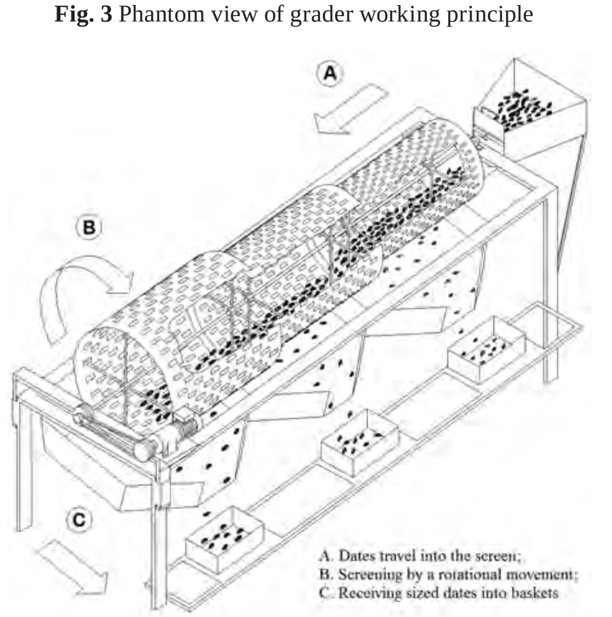


Fig. 3 Phantom view of grader working principle



heights were determined considering that inclination angle is the inverse tangent of the slope. Slopes were calculated by subtracting the height of the lower point of central shaft from the higher one and then divided by horizontal distance between them, **Fig. 5**. As previously shown in **Fig. 3**, there were three size categories of dates and a forth one consists of dates that passed from above the largest openings. Grading efficiency (η_g, %) was determined using the following equation (Kolchin in Russian, 1982):

$$\eta_g = \frac{\sum_1^n m_i}{m_t} \quad \text{....Eqn 2}$$

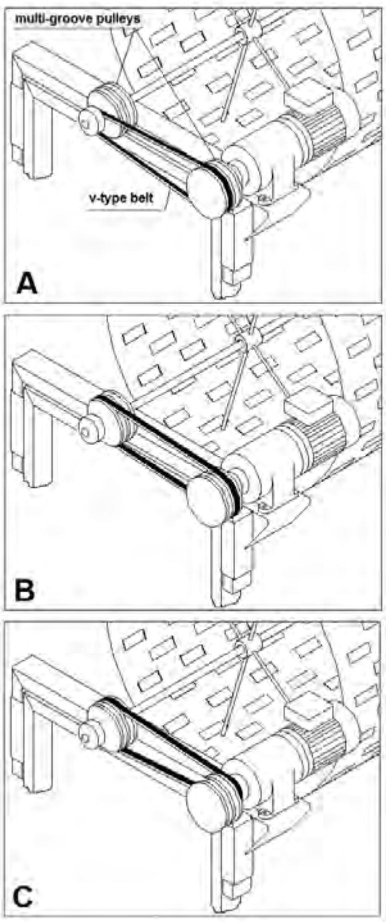
Where m_i is the mass of dates of size i dropping correctly into receiving tray of the size i in kg; m_t is the total mass of graded dates of all sizes in kg and n is the number of sizes.

For determining the best perpendicular dimension – length or width – of individual fruit that could be sized by it into four grades, the Probabilistic Neural Network classifier (PNN) used for classifying date fruits into four groups (grades) based on nine physical properties as input variables, the data consists of 300 samples of fruit individuals – from each variety 100 samples – for the training set and each sample physical properties have been determined and they were individual fruit mass, thickness, width, length, geometric mean diameter, arithmetic mean diameter, equivalent diameter, sphericity and surface area, **Fig. 7**. It was tested two times, the first one using length as a reference for classifying dates into four groups and the second one using width as a reference for classifying dates into four groups either as listed in **Table 1**. The dimension that its classification results reached the highest percent was chosen later for sizing graded dates into four categories. PNN has been used before for classifying fruits on the basis of several properties (Deshpande and Singh, 2017). For this purpose STATGRAPHICS® Centurion XVI 2009 software was used.

Determination of Date Varieties Physical Properties

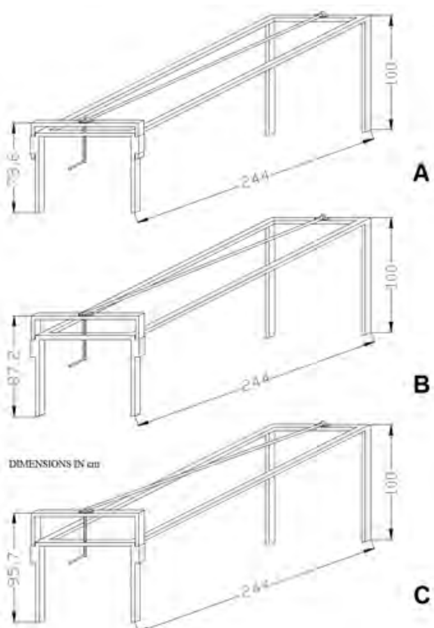
Three perpendicular dimensions of date fruit, i.e., length (L, cm); width (W, cm); and thickness (T, cm), were measured using a Vernier caliper with an accuracy of 0.01 mm. Dimensions were measured before experiment was conducted, sample containing 100-fruit individuals were dimensioned and mass of individual fruit – after dimensioning it – was determined using an electronic balance with an accuracy of 0.01 g. Water displacement method was used for measuring fruits volumes; after weighing fruits in air and lowering them into a graduated beaker containing water and dis-

Fig. 4 Schematic arrangement of the three different conditions of the belt giving three different rotational speeds



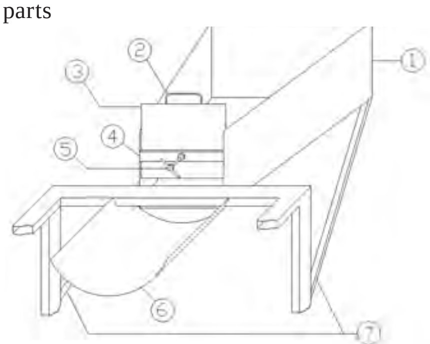
A, B and C belt positions give 82, 54 and 26 rpm, respectively

Fig. 5 Schematic arrangement of the three different heights for the free side of central shaft using screw-jack for reaching three different inclination angles of rotating screen



A, B and C conditions give 1, 3 and 5 degrees inclination angle of the rotating screen drum, respectively

Fig. 6 Schematic drawing of feeding hopper parts



1. Feeding hopper, 2. Handle, 3. Gate, 4. Gate track, 5. Bolt with a handle, 6. Cylindrical segment tray, 7. Mild steel L-section 2 × 2 cm for supporting hopper.

Table 1 Dates categories used for probabilistic neural network classifier

Dimension	Grade	Grade II	Grade III	Grade IV
Length, cm	≤ 4.3	> 4.3 - ≤ 4.7	> 4.7 - ≤ 5.1	> 5.1
Width, cm	≤ 1.8	> 1.8 - ≤ 2.0	> 2.0 - ≤ 2.2	> 2.2

place water mass by the individual fruit was recorded. Finally fruit true densities (ρ_t, g/cm^3) determined using Equation 3 (Mohsenin, 1986).

$$\rho_t = \frac{M_a}{M_a - M_W} \times \rho_W \quad \text{...Eqn 3}$$

Bulk density (ρ_b, g/cm^3) was determined using the mass/volume relationship (Fraser et al., 1978; AOAC, 1984; Suthar et al., 1996; Owolarafe et al., 2007; and Jahromi et al., 2008).

Geometric mean diameter (D_g, cm) and arithmetic mean diameter (D_a, cm) were calculated based on three perpendicular dimensions using Equations 4 and 5 (Mohsenin, 1986) while the equivalent diameter (D_e, cm) calculated using Equation 6 (Ciro in Spain, 1997; and Perez-Alegria et al., 2001).

$$D_g = (LWT)^{1/3} \quad \text{.....Eqn 4}$$

$$D_a = \frac{L + W + T}{3} \quad \text{.....Eqn 5}$$

$$D_e = \frac{D_a + D_g + D_s}{3} \quad \text{.....Eqn 6}$$

where D_s is the square mean diameter in cm calculated using Equation 7.

$$D_s = \left(\frac{LW + WT + TL}{3}\right)^{1/3} \quad \text{.....Eqn 7}$$

Sphericity which defined as the ratio of surface area of sphere has the same volume of fruit to the surface area of fruit (Simonyan et al., 2009) were calculated using Equation 8 reported by Mohsenin (1986).

$$Q = D_g / L \quad \text{.....Eqn 8}$$

where Q is sphericity (decimal). Surface area (S, cm^2) was calculated using Equation 9 (Mohsenin, 1986; Kabas et al., 2006; and Asoiro and Ani, 2011).

$$S = \pi D_g^2 \quad \text{.....Eqn 9}$$

Static friction coefficient was determined for five different surfaces that were galvanized steel, plywood, glass, rubber, cardboard and formica. The inclined plane was slowly raised and at the moment which the sample started sliding, inclination angle was read off using a protractor with an accuracy of one degree. Tangent of the angle was reported as the static friction coefficient (Dutta et al., 1988).

$$\mu = \tan \varphi \quad \text{.....Eqn 10}$$

where μ is static friction coefficient (dimensionless) and φ is tilt angle of friction plane in degree (Baryeh, 2001; Saglam and Aktas, 2005; Jahromi et al., 2008; Soliman et al., 2009; and Li et al., 2011).

Table 2 Levels and variation intervals of the factors in Box-Behnken Designr

Dimension	Levels			Variation Interval
	Low (-1)	Medium (0)	High (+1)	
Rotational speed, rpm	26	54	82	28
Inclination angle, degree	1	3	5	2
Feeding rate, kg/min	1	3	5	2

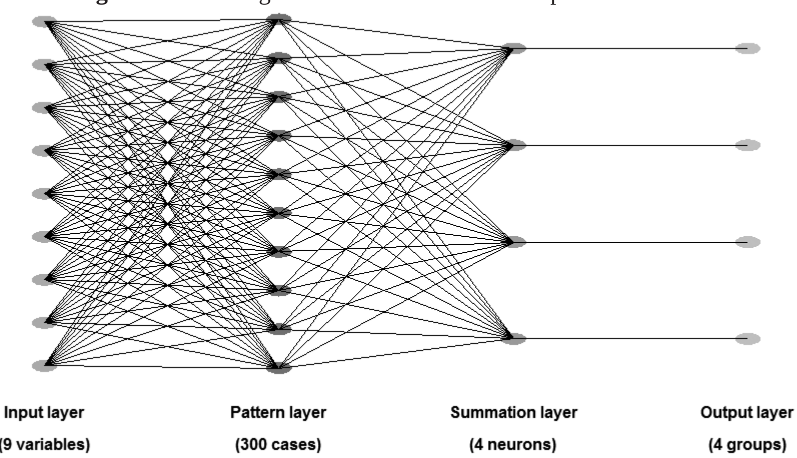
Efficiency Response Surface Modeling and Grader Optimization

Maximizing grading efficiency needed a mathematical model describes grader behavior, i.e., extracting a model describes the effect of independent variables that included rotational speed, inclination angle and feeding rate on dependent variable which represents grading efficiency. Hence, a three-factor three-level BBD with RSM was run to develop an interactive second-order polynomial model, Equation 11, to determine the main and interactive effect of N, θ and F on ηg that represents response value.

$$\eta_g = a_0 + a_1 N + a_2 \theta + a_3 F + a_4 N^2 + a_5 \theta_2 + a_6 F^2 + a_7 N \theta + a_8 \theta F + a_9 N F \quad \text{.....Eqn 11}$$

Fifteen runs were done according to BBD (Montgomery, 1991). Levels and variation intervals of the factors are listed in **Table 2**. From the generated models for each variety using contour plots and computer optimization system process, the optimum levels that give the maximized response could be determined. RSM aims at maximize, minimize or target measured responses by determining this point on efficiency response surface (the optima), Hence determining the optimum operating conditions of investigated grader would be available (Box and Wilson, 1951; Myers and Montgomery, 1995; and Baş and Boyacı, 2007). STATGRAPHICS® Centurion XVI 2009 software has been used for running statistical BBD.

Fig. 7 Network diagram illustrates the basic setup of the network



Principal Component Analysis (PCA) for Physical Properties and Maximized Grading Efficiency

Studying the effect of physical properties of investigated varieties on grader efficiency is an important interest in this study to determine the properties that have high correlation with grading efficiency at the optimum operating conditions for each variety; Hence PCA was done using a correlation matrix representing correlations between every two investigated variables. But the concern, in the present study, is the correlation between maximized grading efficien-

Table 3 Grading efficiency response models for each variety

Variety	Interactive second-order polynomial model constants										R^2
	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	
Bartamuda	89.0881	-1.43546	-3.63036	-5.0375	0.0081738	1.03958	0.902083	0.0473214	-0.875	0.03125	0.8497
Gandila	158.933	-3.23814	-7.11964	-10.0875	0.0257334	0.29375	0.80625	0.0151786	0.125	0.0625	0.9795
Shamiyya	43.7251	-0.04190	0.566964	-2.69375	-0.0006536	-0.265625	0.640625	0.0147321	-0.075	-0.03125	0.6712

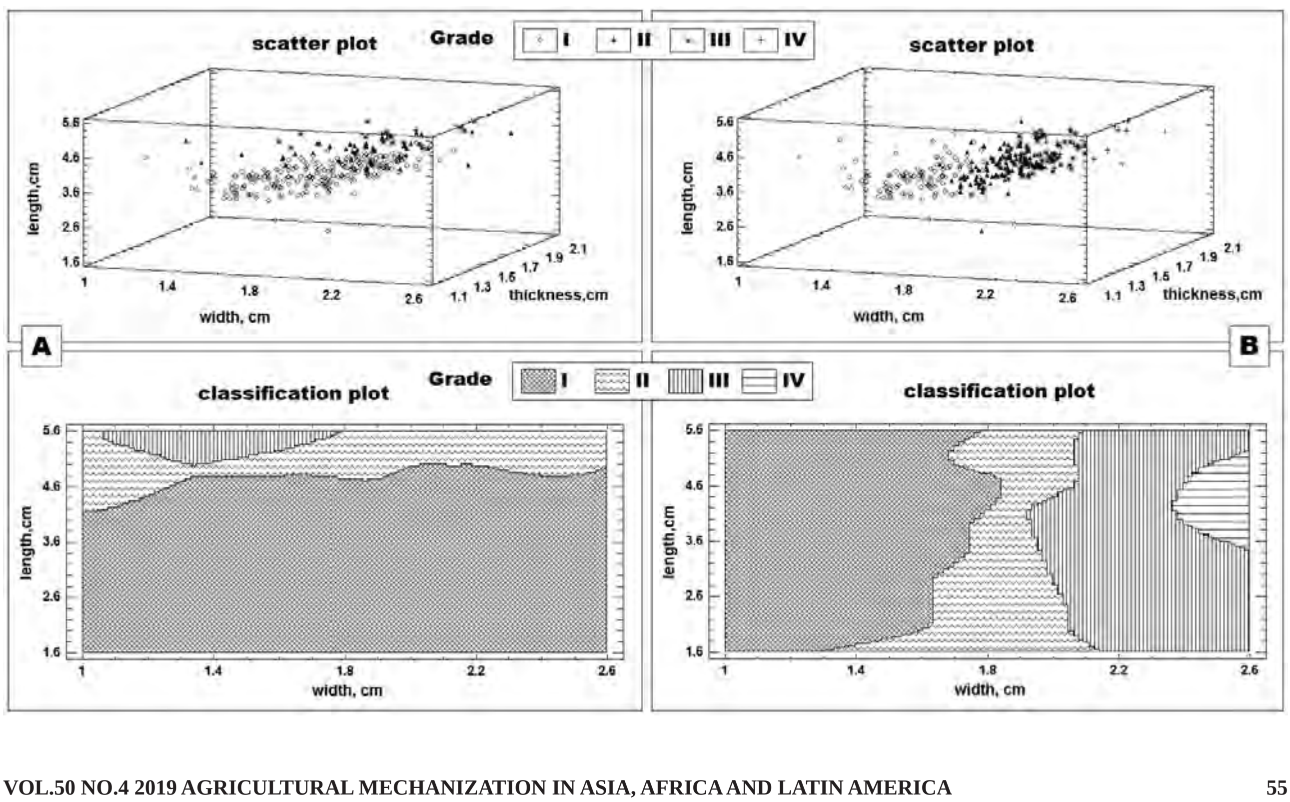
cy and physical properties. In PCA, biplot is displaying relationships between dates samples (varieties) in the so-called score plots and also relationships between physical properties and maximized grading efficiency in the so-called loading plots. Similar scores of date samples positioned close to each other, if the samples positioned further apart from each other they are then dissimilar. The same thing for variables; loadings that are close to each other are positively correlated, while those positioned opposite of each other are negatively correlated (Hopfer et al., 2014). From this exploratory method, understanding relationship between physical properties and maximized grading efficiency of investigated varieties would help to be compared with any other variety properties could probably be used with this grader in the future and modifying grader specifications to fit these properties. For running PCA and obtaining correlation matrix STATGRAPHICS® Centurion XVI 2009 software was used.

Results and Discussion

Grading Process Modeling

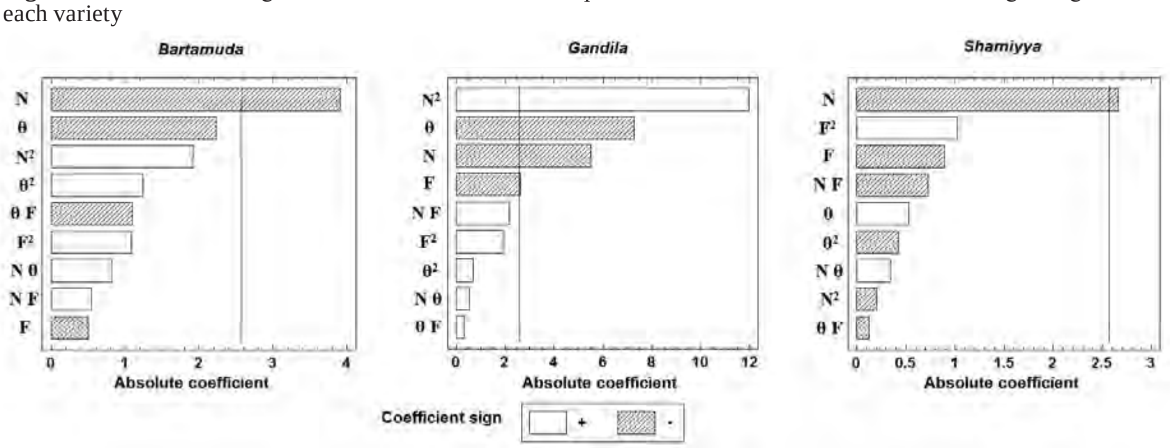
PNN classification results showed that sizing fruits by length succeeded to classify 96.33% of dates samples on the basis of nine physical properties into four categories, while sizing by width succeeded to classify 84.67% only of dates samples on the basis of nine physical properties dates into four categories. From this result, it is evident that using length to determine the correctly graded fruits by rotating screen grader is enough and efficient while using width would not give strong differences between graded samples like length. Three hundred samples were represented by the three perpendicular dimensions classified into four grades in a 3D scatter plot and 2D classification plot as depicted in **Fig. 8** for the two types of classification. BBD used three independent variables at their three levels on grading efficiency for each investigated variety. For describing the effect of the three main factors that affect the screen grader efficiency, the results of experiment approximated by an interactive second-order polynomial model, Equation 11. The model constants or coefficients and determination coefficient (R^2) of three different models used for grading efficiency determining with three operating factors for each investigated variety are presented in **Table 3**. Models were developed at

Fig. 8 3D scatter plot and 2D classification plot for dates samples classified into four grades on the basis of nine physical properties using: length (A) and width (B) as a reference for the classification



95% confidence interval. These models are representing the quantitative effect of process variables that is rotational speed, inclination angle and feeding rate and their interactions on the response (grading efficiency) of each variety. The value of R^2 for the three models is indicating a good fit but in *Shamiyya* case, it was not high. Relationship between dependent and independent variables was studied using surface, contour and pareto plots. The main and interactive effect of independent variables on grading efficiency depicted by pare to plots as shown in **Fig. 9**. Length of each bar is determining the effect of each factor on response for each variety tested with the screen, factors that exceeded the line are significant. The positive coefficients represent the positive effect on grading efficiency while negative coefficients represent the negative one. Generally, the highest factor was noticed, as shown in **Fig. 9**, was rotational speed which has a great significant negative effect on grading efficiency for each variety. In *Bartamuda* case, inclination angle after rotational speed have the second greatest negative effect but it was not significant for inclination angle. In *Gandila* variety case, the square of rotational speed have the greatest positive effect on grading efficiency and followed by inclination angle, rotational speed and feeding rate and they were all have a significant negative effect. For *Shamiyya* variety, rotational speed has the highest negative significant effect on grading efficiency. The differences between the rest of factors and their interactions were not noticeable. The effect of inclination angle and feeding rate at the middle level of rotational speed (N = 54 rpm) on grading efficiency for the three investigated varieties was shown in **Fig. 10-A**. In case of *Bartamuda* variety, grading efficiency could increase from 53 to 57% when inclination angle level became more than 4.6 degrees and feeding rate would be less than 0.2 kg/min. For *Gandila* variety, grading efficiency would be from 53 to 59% if inclination angle would be lowered to less than 1 degree and feeding rate lowered to 1 kg/min. *Shamiyya* variety grading efficiency exceeded 40% when inclination angle ranged from 0.4 to 4.6 degrees and feeding rate lower than 0.1 kg/min. The effect of rotational speed and feeding rate at the middle level of inclination angle (θ = 3 degrees) on grading efficiency is shown in **Fig. 10-B** for each variety. *Bartamuda* variety grading efficiency could exceed 57% if rotational speed level less than 28 rpm and feeding rate would be less than 0.4 kg/min. For *Gandila* variety, grading efficiency would be from 71 to 77% if rotational speed would be lowered from 28 to 26 rpm and feeding rate lowered to 0.4 kg/min. *Shamiyya* variety grading efficiency exceeded 42% when rotational speed lowered less than 40 rpm and feeding rate be less than 0.2 kg/min. Results were in agreement with Farhadi et al. (2012) in a study on a potato rotary grader. Low levels of feeding rate increased grading efficiency and when feeding rate began to increase, grading efficiency decreased to an extent and then began to increase again at high levels of feeding rate. Response surface in the previously mentioned study was similar to the one used in the present study to some extent, **Fig. 10-B**. The effect of rotational speed and inclination angle at the middle level of feeding rate (F = 3 kg/min) on grading efficiency for the three investigated varieties was shown in **Fig. 10-C**. For *Bartamuda* variety, grading efficiency increased more than 53 to 61% when rotational speed decreased from 27 to 26 rpm and inclination angle increased from 4.8 to 5 degrees. Concerning *Gandila* variety, grading efficiency increased from 71 to 77% when rotational speed lowered from 28 to 26 rpm and inclination angle decreased to be less than 0.4 degree. Grading efficiency for *Shamiyya* variety could increase from 38 to 40% if rotational speed became less than 38 rpm and inclination angle less than 4 degrees. It is evident from contour plots that the low levels of both rotational speed and inclination angle increase grading efficiency, in general, but in *Gandila* variety when rotational speed became more than 56 rpm, grading

Fig. 9 Pareto chart showing the standardized effects of independent variables and their interactions on grading efficiency for each variety

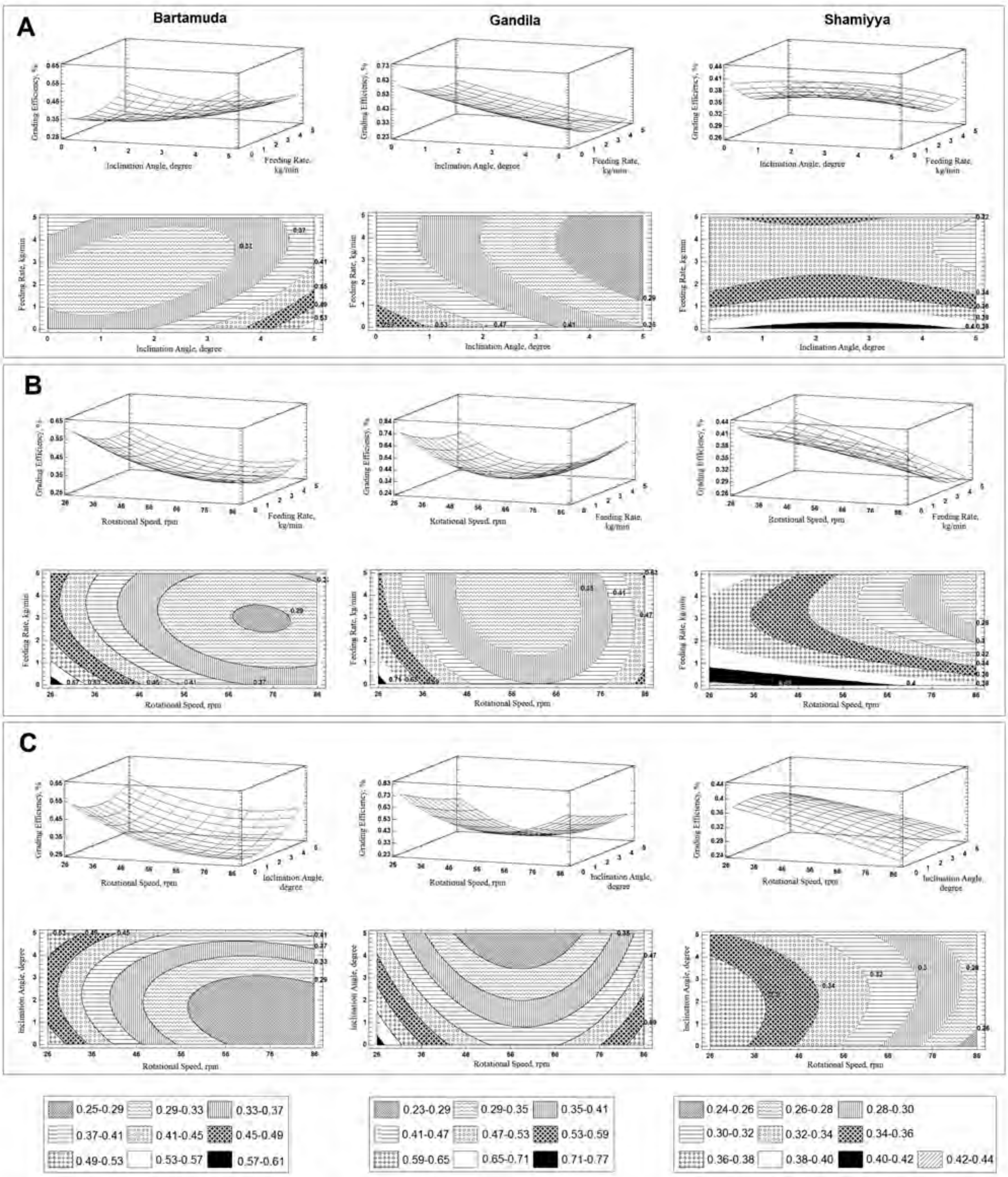


efficiency began to increase again. It could be due to small volumes of its individuals that allow fruits to stay above screen more time to be graded because of increasing in contact surface area of graded amount with the screen. Also in case of *Bartamuda* variety, high levels of inclination angle increased grading efficiency. This may help fruits for a better orientation to drop through openings due to increase in fruit length of this variety. This was generally in accordance with Preetha et al. (2016) in a study on a rotary drum grader for tomatoes.

Optimum Operating Parameters

The main purpose of modeling

Fig. 10 Effect of every two parameters on grading efficiency for each variety at (A) rotational speed = 54 rpm, (B) inclination angle = 3 degrees and (C) feeding rate = 3 kg/min



data is optimization, i.e., determining the optimum levels of independent variables that give the maximum dependent variable and in this case it could be determined from grading efficiency response surface at the point so-called “maxima” and it was determined for each variety. For *Bartamuda* variety, the maximum grading efficiency was found to be 61.669% at the optimal input settings of rotational speed, inclination angle and feeding rate and they were of 26.004 rpm, 4.720 degrees and 1 kg/min, respectively. For *Gandila* variety, the maximum grading efficiency was found to be 77.327% at the optimal input settings of rotational speed, inclination angle and feeding rate and they were of 26.468 rpm, 1 degree and 1 kg/min, respectively and finally for *Shamiyya* variety, the maximum grading efficiency was found to be 40.988% at the optimal input settings of rotational speed, inclination angle and feeding rate and they were of 26.003 rpm, 1.085 degrees and 5 kg/min, respectively.

Effect of Dates Physical Properties on Optimized Grading Efficiency

Physical properties of dates have been investigated as listed in **Table 4** for each variety in order to obtain the effect of their physical properties on optimized grading efficiency. This has been achieved using PCA by studying correlations between these properties and optimized grading efficiency of the variety. As shown in **Fig. 11**, concerning loading plot, it is evident that individual fruit mass, width, geometric mean diameter, equivalent diameter, surface area, thickness and sphericity are negatively affect the maximized grading efficiency that could be reached by the variety. Also arithmetic mean diameter affected negatively the maximized grading efficiency but it was not strong enough. Thickness and sphericity have the greatest negative effect, while dates bulk density; true bulk density and static friction coefficient with galvanized steel are positively affecting it according to the first component. Fruit length has no remarkable effect on maximized grading efficiency. These investigated properties that are correlated with maximized grading efficiency were indicated in **Table 5** from correlation matrix for a purpose of more understanding of relationship between physical properties and optimum value of maximized grading efficiency. From PCA, any variety would be chosen for grading in this prototype should have a small value, relatively, for these properties that affecting negatively the surface optima and a high value, relatively, for the properties that positively affecting the surface optima if this variety would be graded in the investigated prototype.

Conclusions

In the present investigation, a local-made rotating screen grader prototype was proposed, manufactured and tested. Grading efficiency at different operating conditions was investigated. Based on the research work described here, it is possible to derive the following conclusions:

1. The statistical BBD is efficient to be applied for modeling grading efficiency of the rotating screen prototype.
2. PNN classifier showed that using fruit length succeeded in classify-

Table 4 Physical properties of dates

Properties	Variety					
	Bartamuda		*Gandila*		*Shamiyya*	
	Number of observations	Mean ± SD	Number of observations	Mean ± SD	Number of observations	Mean ± SD
Individual fruit length, g	100	6.599 ± 1.651	100	4.746 ± 1.022	100	6.084 ± 1.049
Length, cm	100	4.161 ± 0.473	100	3.806 ± 0.380	100	3.765 ± 0.400
Width, cm	100	1.971 ± 0.227	100	1.649 ± 0.152	100	1.950 ± 0.131
Thickness, cm	100	1.561 ± 0.183	100	1.451 ± 0.124	100	1.719 ± 0.158
Geometric mean diameter, cm	100	2.332 ± 0.201	100	2.085 ± 0.157	100	2.322 ± 0.145
Arithmetic mean diameter, cm	100	2.564 ± 0.229	100	2.302 ± 0.182	100	2.478 ± 0.168
Equivalent diameter, cm	100	2.234 ± 0.176	100	2.021 ± 0.140	100	2.195 ± 0.129
Sphericity, decimal	100	0.563 ± 0.043	100	0.550 ± 0.033	100	0.622 ± 0.061
Surface area, cm^2	100	17.226 ± 2.961	100	13.750 ± 2.121	100	17.021 ± 2.079
Bulk density, g/cm^3	3	0.548 ± 0.014	3	0.577 ± 0.001	3	0.533 ± 0.005
True density, g/cm^3	3	0.940 ± 0.005	3	0.894 ± 0.040	3	0.832 ± 0.057
Static friction coefficient (dimensionless) for						
galvanized iron steel	3	0.517 ± 0.025	3	0.547 ± 0.051	3	0.516 ± 0.012
plywood	3	0.516 ± 0.012	3	0.517 ± 0.025	3	0.495 ± 0.050
glass	3	0.509 ± 0.000	3	0.480 ± 0.024	3	0.509 ± 0.037
rubber	3	0.617 ± 0.036	3	0.473 ± 0.032	3	0.495 ± 0.024
cardboard	3	0.334 ± 0.000	3	0.459 ± 0.012	3	0.334 ± 0.000
formica	3	0.424 ± 0.000	3	0.466 ± 0.021	3	0.459 ± 0.012

ing 96.33% of dates samples into four grades on the basis of nine properties while width reached only 84.67%.
3. The interactive second-order polynomial model was suitable for describing relationship between grading efficiency and operating conditions for “*Bartamuda*”, “*Gandila*” and “*Shamiyya*” varieties with R^2 of 0.8497, 0.9795 and 0.6712, respectively.
4. Developed models using RSM showed after determining grading surface maxima that the maximized grading efficiency for the previously mentioned varieties was of 61.669, 77.327 and 40.988%, respectively.
5. High levels of rotational speed, inclination angle and feeding rate decreased grading efficiency but in case of *Bartamuda* variety – the biggest between them – high levels of inclination angle increased grading efficiency also in case of *Gandila* variety – the smallest between them – grading efficiency began to increase again with high levels of rotational speed.
6. PCA showed that fruit thickness and sphericity have the greatest negative effect on the optimized grading efficiency, so varieties chosen must have small values of the previous properties, relatively. Also static friction coefficients with galvanized steel and bulk density have the greatest positive effect on optimized grading efficiency.

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Fig. 11 Score and loading plot for the first two components; PCs 1 and 2 (100%)

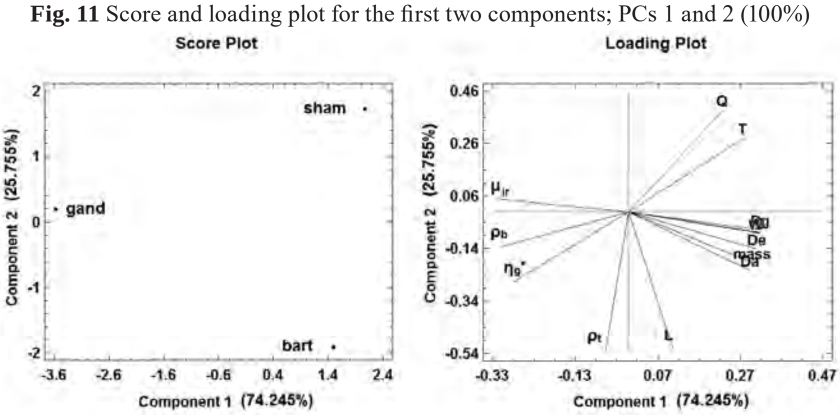

Table 5 Correlation coefficients between physical properties and optimum grading efficiency of each variety

Property	Correlation coefficient	P-Value	Number of observations	Correlation coefficient	P-Value
True density	**0.6354**	0.5616	Geometric mean diameter	**-0.8027**	0.4068
Bulk density	**0.9661**	0.1664	Thickness	**-0.9997***	0.0149
Surface area	**-0.7925**	0.4175	Width	**-0.7890**	0.4212
Sphericity	**-0.9628**	0.1743	Length	0.1730	0.8893
Equivalent diameter	**-0.7137**	0.4940	Individual fruit mass	**-0.6404**	0.5576
Arithmetic mean diameter	-0.5970	0.5927	Static friction coefficient with galvanized iron steel	**0.8251**	0.3822

* P < 0.05; **Bold**: Correlation coefficient (r) > 0.600

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Impact of Slice Size on Kinetic Behavior and Drying Time of Fresh-Cut Apple (*Malus domestica*)

by
Destiani Supeno
Dept. of Bio Industrial Machinery Engineering
Pusan National University 629-706,
KOREA
destiani.supeno@pusan.ac.kr

Pandu Sandi Pratama
Life and Industry Convergence Research Institute
Pusan National University 629-706
KOREA
pandu.sandi@pusan.ac.kr.

Won-Sik Choi
Dept. of Bio Industrial Machinery Engineering
Pusan National University 629-706,
KOREA
choi@pusan.ac.kr

Abstract

Drying is one of the common methods to preserve apples. This study was done to observe the effects of the slice size on the drying kinetics and drying time of apple (Malus domestica). An experiment was conducted with slice sizes of 2, 4, and 6 cm. The drying characteristics were investigated using a cabinet dryer at a temperature of 50°C with 720 minutes of drying. The total mass, drying rate, moisture content, and moisture ratio were monitored during the critical drying time. SPSS software was used to clarify the effects of the size on the drying time. The results show that the drying time decreased with the slice size.

Introduction

Apple cultivation in Korea dates back over 2000 years (Jotic, 1995). The first Korean apple cultivar "Nungkeum" (*Malus asiatica* Nakai) was grown in Gaeseong, a former capital city. There has been a marked increase in the Korean apple industry since the Korean War. Apples are the most common fruit crop in Korea, followed by citrus, pears, grapes, and persimmons (Lee, 2004). Apple has economic and industrial value in Korea, and to increase their value and durability, the fresh fruit can be processed in different forms, such as concentrated juice or dried slices. Drying fresh-cut apple is commonly done in post-harvest processing. This process involves heat and mass transfer phenomena and is frequently used in other applications in the food processing industry (Cohen and Yang, 1995).

The drying method is probably the most expensive step after harvesting. It extends the product shelf life without adding any chemical preservatives and it reduces both the package size and transportation cost (Meisami-asl and Rafiee, 2009). Drying of fruit and vegetables is one of the oldest known food preservation methods. The major objective in drying agricultural products is the reduction of the moisture content to a level that allows safe storage over an extended period. The removal of moisture prevents the growth and reproduction of microorganisms that cause decay, and it minimizes many of the moisture-mediated deteriorative reactions. It also reduces the weight and volume substantially and enables storage at ambient temperatures (Mujumdar, 1988). The heat source for drying can be obtained from solar energy (Chen, 2013; Manjarekar et al., 2012), kerosene (Oni et al., 2012), biomass (Sanchavat et al., 2016), etc.

The duration of the drying process of fruits and vegetables is determined to a large extent by their size. Smaller pieces take much less time to dry than large ones due to the lower amount of moisture and the shorter pathway for moisture to move to the surface. A specific amount of fresh-cut fruit can be brought to a safe residual moisture content more quickly when it is cut into small pieces due to the larger total surface area for mass transfer compared to larger pieces. Drying with smaller pieces seems to be more beneficial, but a minimum size is often prescribed depending on the application of the food product. Typical examples are whole apple chips for snacks or small apple cubes in cereals. Apart from the size, the shape of the fruit piece also plays a role in the drying kinetics (Defraeye, 2017).

In this study, the total mass, drying rate, moisture contents, and moisture ratio were monitored during the critical drying time. Furthermore, SPSS software was used to clarify the effects of the size on the drying time.

Materials and Methods

1. Material Preparation

Fresh apples were collected from a local market in Miryang city between March and April 2017. The average diameter of the fruit was 8 cm, and only bright red fruits were selected for the experiment. The fruits were thoroughly washed and sliced into various shapes using sharp, sterilized knife, as shown in **Fig. 1**. The dimensions of the fruit were measured using a Vernier caliper, and the weight was measured using a digital balance. The experiment was repeated three times.

A schematic diagram of the drying system is shown in **Fig. 2**. A cabinet dryer was used to reduce the water in the fruit. The fruit is placed inside the drying chamber with hot air blowing across the product until drying is complete. The hot air used for drying is recirculated through the dryer to conserve energy. The desired drying temperature of 50 °C is produced by electrical-resistance heating elements and controlled by a heating control unit. The air is forced by an electrical fan past the heating elements, and after reaching the desired temperature, it is passed into the drying chamber. **Table 1** shows measurement instruments and devices used in this research.

Table 1 Specification of measurement instruments and device

Instrument	Model	Accuracy	Company
Analytical scale	CPA225D	±0.001 g	Sartorius, DEU
Temperature sensor	LM35	±1 °C	NSC, USA
Vernier caliper	505-672	±0.02 mm	Mitutoyo, JPN
Forced convection oven	F-CD	-	Changsin Science, ROK

2. Measurement of Moisture Content (M_{wb})

The moisture content (M_{wb}) was investigated using an oven-drying method. Stainless steel cups were put in the oven (T = 115 °C) for 24 hours. Afterward, they were put in a desiccator for 30 minutes to cool down. Weighing was done using analytical scales. Before weighing, samples were crushed and put in the stainless steel cups (the weight of the stainless steel cup was known). The crushed samples in the stainless steel cups were put in the oven (T = 115°C) for 4-5 hours. Then, they were put in a desiccator to cool down for 30 minutes before weighing with the analytical balance. This treatment was repeated until the sample weights were steady, which was indicated by a difference in sample weight of less than 0.01 g. Based on this method, the mass of the dry matter in the product m_d in grams was obtained.

During the drying process, the total product mass m_t (in g) was measured every 30 minutes. The drying rate in g/minute can be obtained using the following equation:

$$DR = (m_{t(k)} - m_{t(k-1)}) / dt \quad ...(1)$$

where $m_{t(k-1)}$ is the product mass at time k, and $m_{t(k-1)}$ is the product mass at time $k - 1$.

The moisture content of the samples (M_{wb}) can be calculated using the following equation (Krajnc, 2013; Wiranata et al., 2016):

$$M_{wb} = m_w / (m_w + m_d) \times 100\% \quad ...(2)$$

where M_{wb} is the percentage of the sample's moisture content, m_w is the mass of water in the apple (g), and m_d is the mass of dry matter after

Fig. 1 Illustration of the three different apple shapes investigated

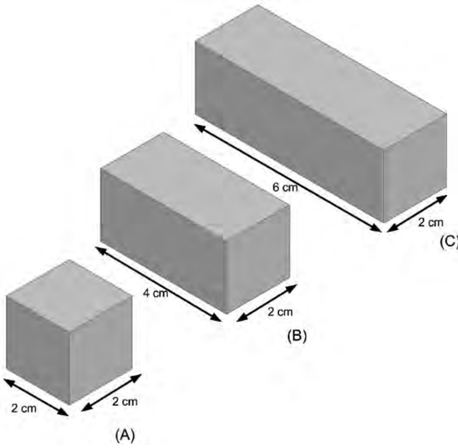


Fig. 2 Schematic diagram of the drying system for measurement of the fruit slices

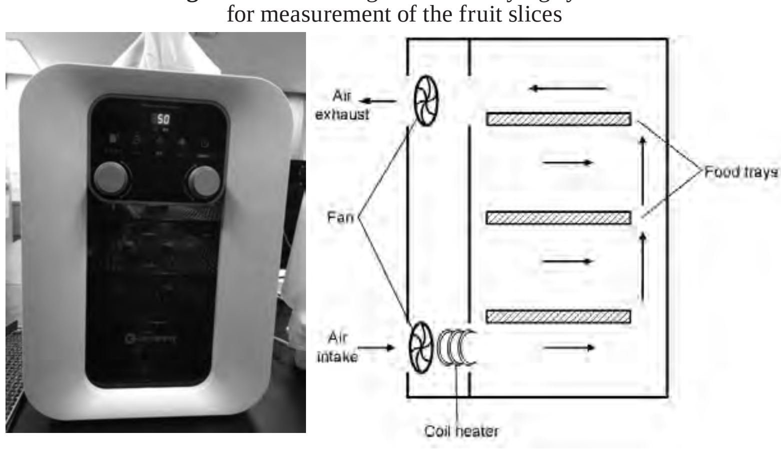


Table 2 Drying time until 40% moisture content

Slices size	Repetition		
	1	2	3
2 cm	593 min	589 min	597 min
4 cm	653 min	650 min	656 min
6 cm	670 min	668 min	672 min

ANOVA

Size

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9,944.222	2	4,972.111	573.705	.000
Within Groups	52.000	6	8.667		
Total	9,996.222	8			

oven-drying method (g).

The water mass in the apple is obtained using the following equation:

$m_w = m_t - m_d$ ...(3)

Therefore, Equation (2) can be modified as:

$M_{wb} = (m_t - m_d) / m_t \times 100\%$ ...(4)

The moisture ratio (*MR*) is:

$MR = M_{wb} / M_0$ ...(5)

where M_0 is initial moisture content before the drying process.

3. Statistical Analyses

To determine the effect of slice size on the drying time, the time to reach 40% moisture content was measured during the experiment. All collected data were analyzed using SPSS software. ANOVA was used to test whether there were significant differences among the slice sizes using a Type I (α) error rate of 0.05. LSD tests were then conducted using a 95% confidence level to determine where those differences occurred.

Results and Discussion

1. Drying Behavior Characteristics of Moisture Content (MC_{wb})

Fig. 3 shows the total product mass during the drying process. The mass of the product gradually decreases during the drying process. **Fig. 4** shows the drying rate during the drying process. Larger slice size results in a higher drying rate since the surface of the slice is bigger. **Fig. 5** shows the moisture content during the drying process. Higher slice size results in higher final moisture content. **Fig. 6** shows the moisture ratio during the drying process, which indicates that increased slice size results in an increase in drying time.

2. Drying Time Analysis Using SPSS

The experimental results are shown in **Table 2**. The analysis shows that the significance value is less than 0.05, which means that the slice size significantly affects the drying time. Moreover, bigger slice size results in a longer time to reach 40% moisture content.

Conclusions

This research was done to ob-

Fig. 3 The total product mass m_t during the drying process

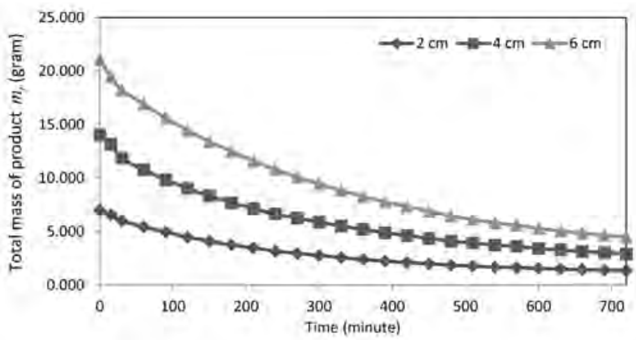


Fig. 4 The drying rate *DR* during the drying process

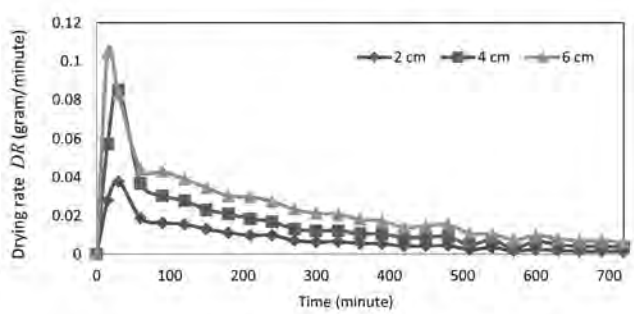


Fig. 5 The moisture content M_{wb} during the drying process

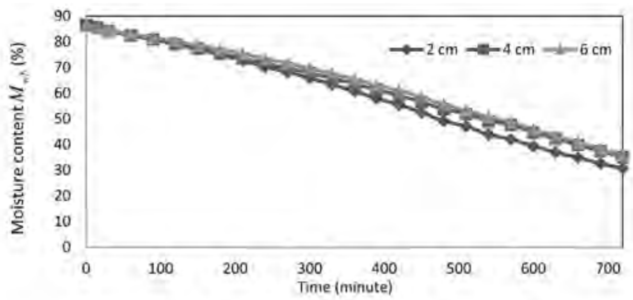
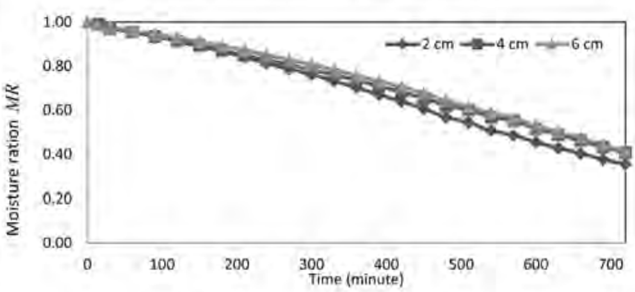


Fig. 6 The moisture ratio *MR* during the drying process



serve the effects of slice size on the drying kinetics and drying time of apple. Slice sizes of 2, 4, and 6 cm were dried in a cabinet drying system at 50 °C for 720 minutes. The total mass, moisture content, drying rate, and moisture ratio were obtained during experiment. The results showed that the drying time decreased with the slice size, and the statistical analysis showed that bigger slice size results in a longer time to reach 40% moisture content.

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EVENT CALENDAR

2020

◆ **"ORTICOLTURA – TECNICA in CAMPO"**
January 22-24, Guidizzoki – Mantova, ITALY
www.orticolturaincampo.com/

◆ **FIERAGRICOLA**
January 29, Verona, ITALY
www.fieragricola.it

◆ **AGROTICA**
January 30 - February 2, Thessaloniki, GREECE
agrotica.helexpo.gr/

◆ **FIMA**
February 25-29, Zaragoza, SPAIN
www.fima-agricola.es/

◆ **EUBCE 2020**
April 27-30, Marseille, INDIA
www.eubce.com/eubce-2020.html

◆ **5th CIGR International Conference 2020**
June 14-18, Quebec, CANADA
www.cigr2020.ca/

◆ **ASAEB 2020 Annual International Meeting**
July 12-15, Omaha, Nebraska 68102, USA
www.asaeb.org/

◆ **SIMA**
November 8-12, Paris (Nord Villepinte), FRANCE

◆ **EIMA International**
November 11-15, Bologna, ITALY
www.eima.it

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Designing and Testing an Innovative Soybean Seed Grader with Oval-hole Screen Type

by
I. K. Tastra
Indonesian Legumes and Tuber Crops Research Institute (ILETRI)
INDONESIA

Uning Budiharti
Indonesian Centre for Agricultural Engineering Research and Development (ICAERD)
INDONESIA

N. R. Patriyawaty
Indonesian Legumes and Tuber Crops Research Institute (ILETRI)
INDONESIA

Abstract

An innovative grader using oval-hole screen type has been designed and tested in order to improve the performance of existing soybean seed grader which is usually used spherical-hole screen type. Designing process was conducted in Agricultural Mechanization Laboratory while performance testing process was conducted at Muneng Experiments station of Indonesian Legume and Tuber Crops Research Institute (ILETRI), starting from January to December 2011. The grader designed using oval-hole screen type (hole size: 6, 5, and 4 mm) and spherical-hole screen type (hole size: 6, 5, and 4 mm) as comparison, with screen slope of 10°, supported with spring at both the ends and in the middle of the screen. The grader powered by 5.5 hp gasoline motor and operated at pulley rotation rate of 432 rpm. Grader performance was evaluated by utilizing large-seeded size varieties of soybean seed (Grobogan and Argomulyo) and medium-seeded size variety (Wilis). The result showed that Grader with oval-hole screen type (hole size of 6 mm, 5 mm and 4 mm) (ILETRI grader) can increase seed quality grade (Gi) for both type of soybean seed (large and medium sizes) compared to spherical-hole screen type. Capacity of ILETRI grader was higher for all large-seeded size varieties; Grobogan (656 kg/hr) and Argomulyo (678 kg/h), compared to medium-seeded size variety; Wilis (437 kg/h). Furthermore, by utilizing this grader the grade of seed can be divided into two grades for Grobogan (G1 and G2) in which the percentage of G1 and G2 was 56.6% and 37.8% with the diameter of seed on average was 9 mm and 8 mm respectively. Meanwhile, for another two varieties (Argomulyo and Wilis) the grade of seed was divided into three grades i.e. G1, G2 and G3. On average, the percentage and seed diameter of G1 was 51.9% and 6.6 mm for Argomulyo and 14.6% and 5.1 mm for Wilis. The percentage and seed diameter of G2 for Argomulyo was 33.7% and 6.5 mm, while 23.8% and 5.0 mm for Wilis. However, the percentage of G3 for Agromolyo and Wilis was 14.4% and 56.15% respectively, while the average of seed diameter for both varieties was 6.4 mm and 4.8 mm respectively. The index of seed uniformity was similar for both types of seeds with fraction of coars: medium: fine was 10: 0: 0, this suggested that the level of uniformity has reached 100%, whereas seed viability still met the standard of seed extension (70%). On average, seed viability for Grobogan, Anjasmoro and Wilis was 82.5%, 87.1 and 74.6% respectively. At the price of Rp 16 million/unit and wage of 2 operators Rp 150,000 per day, the ILETRI Grader unit cost operation is Rp 52/kg; the breakeven point is 103 t/year; the payback is 6.0 months; the net present value is Rp 73.9 million; the benefits and costs ratio is 1.67 and the internal rate of return is 199.8%, respectively. In conclusion, technically and financially the ILETRI-Grader has a beneficial prospect to be applied at soybean seed producer. The ILETRI soybean seed Grader has been patented in Indonesia with patent number: S00201200065.

Keywords: Soybean seed, grader, seed producer, financial feasibility.

Introduction

Indonesian government has planned

to achieve soybean self-supporting program in 2014, however, this requires high quality of soybean seed in a large quantity (up to 31,000 ton/year) (Harnowo, et al 2007). Although government has released more than 20 new superior varieties, vast majority of farmers in Indonesia still use soybean seed which does not meet the standard criteria (low seed viability) or not certified seed (Anonymousa, 2007). This is resulted from the delay of soybean new variety being spreaded out and adopted by farmers (Gatut Wahyu and Nugrahaeni, 2010).

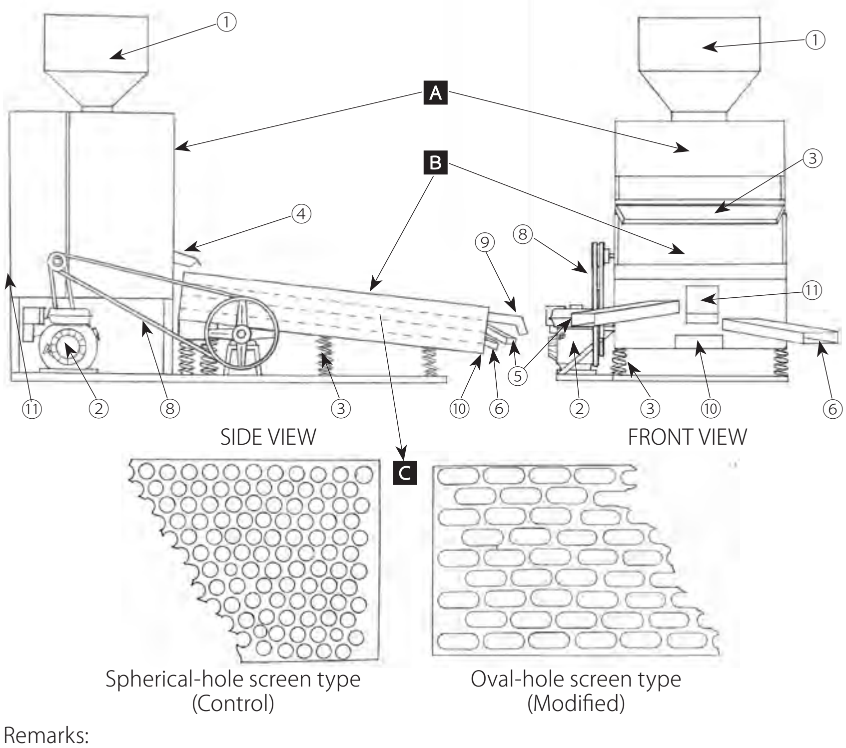
In order to increase national soybean seed production, government has created a program to develop soybean seed breeder and hence the new variety could be disseminated widely throughout the farmers. Nevertheless, soybean seed that will be adopted by farmers should be met the standard of seed quality (seed viability min 70%). Therefore, government has established the standard quality of soybean seed through applying ISO 9001:2008. Indonesian Legumes and Tuber Crops Research Institute (ILETRI) is one of government institution has a seed production unit that has already been applying ISO 9001-2008 (Certificate No. LSSM-01-B). However, in the farmer or seed breeder level applying ISO 9001-2008 remains a constraint, in which the seed produced still does not meet standard criteria particularly on the size of seed (less of uniformity). Many studies concluded that uniformity of seed is substantial as it positively correlated with seed vigor and yield (Burris et. al., 1971; Singh and Makne, 1985; Black, 1957 in Risse et al., 1991). Therefore, it is necessary to improve the innovation of soybean seed grader in farmer or seed breeder level.

Applying soybean seed grader in farmer could enhance its performance through converting sorting manual system into automatic system and ensuring the availability of soybean seed. By doing so, farmer could decrease the expense of soybean seed sorting. Nowadays, the cost for sorting of soybean seed is up to Rp 4,000/kg for breeder seed class (BS) at the level of seed price is Rp 25,000/kg, while for extension seed class (ES) the cost is Rp 500 - 600/kg at the level of seed price is Rp 8,000/kg and its capacity is only 40 kg/day (Ana et al 2001).

Currently, mobile seed grader has been designed; its capacity is up to 304 kg/hour. At the price level of grader per unit is Rp 6,500,000; the interest is 12%/year and operational hour is 1,200 hour/year, then the cost of sorting process is Rp 27/kg (Ana et al, 2001). However, its capacity relatively low and hence the feasibility level does not optimum to be applied at the seed breeder level. Besides that, there is imported grader with great capacity up to 1 ton/hour (Anonymousb, 2011), however, the price relatively expensive up to US $4,500 - 5,000/unit and hence it does not suit to be applied at the farmer level which is only produced soybean seed 25-45 ton/season. Therefore, it is prominent to design and develop soybean seed grader that technically and financially feasible to be applied at the seed producer level.

Furthermore, in order to develop grader innovation at the level of breeder seed, it is necessary to consider the difference of physical property of soybean seed at the different of moisture content level of seed (Prastiwi, 2005). Angle of repose and seed dimensions (length, width, dense) are the significant physical properties of seed which is closely related to soybean seed sorting. However, that information is not available yet in the description of variety. Currently, shape of seed (spherical or oval) is the one of physical property that available in the description of variety (Balitkabi, 2009). Therefore, the appropriate screening type that

Fig. 1 Schematic of inovative ILETRI soybean seed grader using oval-hole type screen



Remarks:
A. Seed cleaner component, B. Screen components (Hole size : 6 mm, 5 mm and 4 mm), C. Detail of screen type component.
1. Hoper, 2. Power sources (5.5 hp), 3. Spring, 4. Outlet of cleaned soybean seed, 5. Outlet of cleaned soybean seed grade 2 (G2), 6. Outlet of cleaned soybean seed grade 3 (G3), 7.Pully, 8. V-belt, 9. Outlet of cleaned soybean seed grade 1 (G1), 10. Outlet of cleaned soybean seed grade 4 (G4), 11. Outlet of dirt.

suitable for sorting of soybean seed is oval-hole screen type.

The objective of this study was to design soybean seed grader by employing oval-hole type screen, capacity up to 3 ton/day with index of seed uniformity 90% and financially feasible to be applied in the seed producer level.

Material and Method

This study was conducted in January to December 2011 at Agricultural Mechanization Laboratory and at Muneng Experimental Research Station, ILETRI. The steps of study were:

1. Build up cleaning component with the dimension of 1.0 m length; 1.2 m width; and 1.8 m height (**Fig. 1**).
2. Build up vibrated-screening component with the dimension of 1.8 m length; 0.9 m width; and 0.8 m height. This component utilized three level of vibrated-screenings with each size of oval-screens were 6 mm, 5 mm, and 4 mm. Those screens were supported by spring at both of the edges and at the middle of screens. As for the power, 5.5 hp motorized-fuels were used at the rotation of eccentrics of pulleys was 432 rpm (**Fig. 1**).
3. Adjusting cleaning component into vibrated-screening component (**Fig. 1**) at the different of slope according to angle of repose soybean seed data (**Appendix 1**).
4. Functional test of grader was used large-seeded soybean variety (Grobogan) and medium-seeded soybean variety (Wilis). As comparison, spherical-hole type screen was also used with diameter of 6 mm, 5 mm and 4 mm.
5. Verification of performance test was conducted after functional test has been succeeded at research field of ILETRI using large-seeded soybean variety (Argomulyo).
6. The impact of grader to seed viability and vigor was evaluated by performing seed germination test using sand medium (ISTA, 2008). Performance of two types of screens was analyzed by t-Student at the level of error 5%.

Grader capacity was calculated by this simple equation:

$KE = MBI / LSR$ ...(1)

Where,

KE: Effective capacity of sorting (kg/h)

MBI: Weight of soybean seed in hoper (kg)

LSR: Sorting time (h)

Uniformity and degrees of fineness of soybean seed was evaluated by method of Henderson and Perry (1976) as shown in **Tables 1a** and **1b**. By doing this, therefore, the average of soybean seed diameter can be calculated.

According to capacity data of grader, financial feasibility can be analyzed: Unit Cost of grading processes (BP), Break Even Point (BEP), Payback Period (PBP), Net Present Value (NPV), Benefit-Cost Ratio (B/C) and Internal Rate of Return (IRR) (Tastra, 1995; Manilay, 1987). This grader was feasible to be applied at seed producer if the NPV > 0, B/C > 1.0 and IRR > Bank Interest Rate (18%/year).

Financial feasibility of the innovative ILETRI soybean seed grader can be calculated as follow:

$BP = (BTT + BT) / (X \times KE)$ ...(2)

$BEP = BT / [OP - BTT / (X \times KE)]$ ...(3)

$PBP = M / KU$ ...(4)

$$NPV = \sum_{t=1}^{t=5} (Bt - Ct)/(1+i)^t - M \quad ...(5)$$

$$B/C = \frac{\sum_{t=1}^{t=5} Bt/(1+i)^t}{\sum_{t=1}^{t=5} Ct/(1+i)^t + M} \quad ...(6)$$

$IRR = DFP + [PVP \times (DFN - DFP) / (PVP - PVN)]$ ...(7)

Table 1a Example procedure for determination of uniformity index (UI) of soybean seed

Mesh	Retained material (%)	Total % divided by 10	The multi-plication result
3/8	0.0		
4	5.6		
8	24.7		**Coarse**
Total	30.3	3.03	3
14	34.4		
28	18.0		**Medium**
Total	52.5	5.25	5
48	9.1		
100	5.7		
Pan	2.5		**Fine**
Total	17.3	1.73	2
UI	(fraction coarse : medium : fine) =	**3 : 5 : 2**	

Table 1b Example procedure for determination of degrees of fineness (DF) and diameter of soybean seed

Mesh	Hole size (mm)	Retained material (%)	Multipliers factor	The multi-plication result
3/8	9.42	0.0	7	0
4	4.70	5.6	6	33.6
8	2.36	24.7	5	123.5
14	1.17	34.4	4	137.6
28	0.59	18.0	3	54
48	0.29	9.1	2	18.2
100	0.15	5.7	1	5.7
Pan		2.5	0	0
Sum		100 (A)		372.6 (B)

Degrees of fineness (DF) = B/A = 3.73

Average of seed diameter (mm) = 0.10414 * (2) ^ DF = 1.38

where,
BP: Unit grading cost (Rp/kg of soybean seed)
BTT: Variable Cost (Rp/y)
BT: Fixed Cost (Rp/y)
X: Effective working hours (h/y)
KE: Effective capacity (kg/h)
BEP: Break even point (t soybean seed per year)
OP: Grading fee (Rp/kg of soybean seed)
PBP: Payback period (year)
M: Price of grader (Rp/unit)
KU: Net benefit per year (Rp/y)
NPV: Net present value (Rp)
B/C: Benefit cost ratio (-)
Bt: Annual benefit (Rp)
Ct: Annual cost (Rp)
t: Economic life (y)
i: Interest (%/tahun)
IRR: Internal rate of return (%)
DFP: Interest rate produced PVP (%)
DFN: Interest rate produced PVN (%)
PVP: Positive net present value (Rp)
PVN: Negative net present value (Rp)

Result and Discussion

Brief Description of ILETRI Soybean Seed Grader

At designed process every slope of screen has been adjusted according to the data of angle of repose of soybean seed Grobogan and Wilis variety (**Appendix 1**); however, it did not work properly. This was caused by using oval-hole screening which was relatively longer than local grader and hence it hampered soybean seed to be moved in the surface of screen. Therefore, a spring system has been placed in the middle and both the edge of screen in order to propel and accelerate soybean seed to be moved and screened. By doing this, screening process can be done normally, although the slope of screen was only 10°, this much smaller than angle of repose of Grobogan (26.8°) and Wilis (19.2°) variety (**Fig. 2**).

Unlike imported grader that has applied ISO 9001:2008, they usually used cleaning system which used particular rubber ball (Anonimc, 2011) and nylon brush (Anonimd, 2011) to overcome sorting problem. However, compared to imported grader the screen construction of ILETRI's grader is very simple and hence it can be produced locally (**Fig. 1**). Besides that, farmer (seed producer) can be easily to maintain even though they have insufficient technical skill.

Fig. 2 View of rear corner (A), view of front part (B) and grader functional performance test (C)

(A) (B) (C)

Functional Performance of ILETRI Soybean Seed Grader

Grader Capacity

At this stage, grader capacity was evaluated by using large-seeded (Grobogan) and medium-seeded (Wilis) soybean seed variety, at eccentric drive pulley rotation filter was 432 ± 11 rpm. Oval-hole screen type (hole size: 6, 5, 4 mm) has been used and as comparison spherical-hole screen type (hole size: 6, 5, 4 mm) has also been used. The result showed that capacity of grader using spherical-hole screen type for Grobogan as good as for Wilis (**Table 8**). However, when using oval-hole screen type capacity of grader was higher for Grobogan compare to Wilis (**Table 9**). This caused by oval-hole screen type could be separated seed more compare to spherical-hole screen type. For instance, in the case of Wilis variety that separated by spherical-hole screen type could only produce two grades (G1 and G2)

Table 8 t-Student test of grader capacity in comparison between Grobogan and Wilis variety using spherical-hole screen type

Capacity (kg/h)		
Grobogan	Replication	Wilis
741.1	1	694.9
750.7	2	604.3
698.4	3	629.3
689.2	4	
4	n	3
719.9	X (mean)	642.8
4.2	CV (%)	7.3
t-counted	2.2	ns
t-Table (0.05; 5)	2.6	

ns = not significant at α 5%

Table 9 t-Student test of grader capacity in comparison between Grobogan and Wilis variety using oval-hole screen type

Capacity (kg/h)		
Grobogan	Replication	Wilis
668.6	1	466.7
692.9	2	435.3
606.0	3	409.0
3	n	3
656	X (mean)	437
6.8	CV (%)	6.6
t-counted	5.8	*
t-Table (0.05;4)	2.8	

* = significant at α 5%

Fig. 4a Material distribution pattern and averge of seed diameter of Grobogan variety usingspherical-hole screen type (G1 : seed diameter > 6 mm; G2 : seed diameter ≤ 6 mmand > 5 mm; G3 : seed diameter ≤ 5 mm and > 4 mm; G4 : seed diameter ≤ 4 mm).

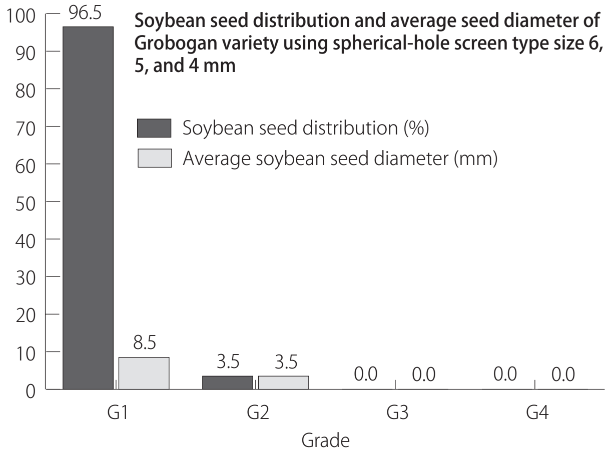
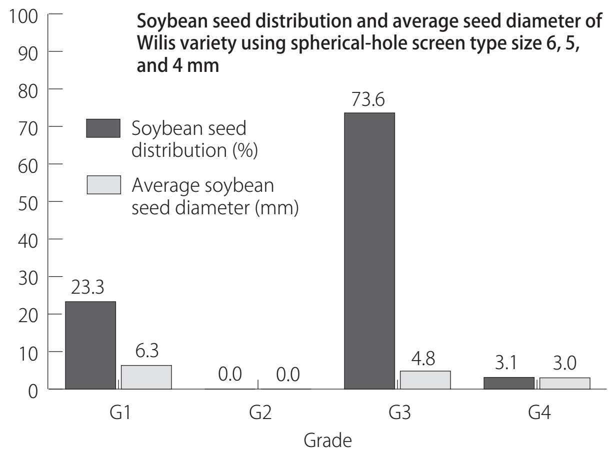


Fig. 4b Material distribution pattern and average of seed diameter of Wilis variety usingspherical-hole screen type (G1 : seed diameter > 6 mm; G2 : seed diameter ≤ 6 mm and > 5mm; G3 : seed diameter ≤ 5 mm and > 4 mm; G4 : seed diameter ≤ 4 mm)..



(**Fig. 4**), meanwhile it produced 3 grades (G1, G2 and G3) when using oval-hole screen type (**Fig. 5**). Hence, by using this type of screen required a longer time to sorting seed compare to spherical-hole screen type. As a consequence, its capacity was smaller than Grobogan when using similar type of screen. Even though capacity of grader using Wilis was smaller than Grobogan, the target of grader designing has been exceeding the expectation. It is predicted to reach its capacity up to 3.5 ton/day, with capacity 437 kg/hour and effective working hour 8 hour/day.

The practical implication is sorting medium-seeded soybean seed size such as Wilis can be done with only using oval-hole screen type sized 5 and 4 mm. Accordingly its capacity will increase as the number of screen is decreased.

Uniformity Index

Uniformity index for both type of screens showed similarity either for Grobogan or Wilis with fraction (coarse: medium: fine) = (10: 0: 0) (**Tables 10** and **11**). This pointed out that uniformity index of soybean seed has reached 100% because all seeds grouped as one coarse fraction.

Sorting Quality

a. For Spherical-hole Screen Type

In the case of Grobogan and Wilis, seed sorting with spherical-hole screen type could only produce one grade (G1) for Grobogan (**Fig. 4a**), however there was two grades (G1 and G2) produced for Wilis (**Fig. 4b**). Material distribution patterns for Grobogan with spherical-hole screen type produced more at G1 (96.5%). Nevertheles, material distribution patterns largely distributed at G3 (73.6%) for Wilis, with average of seed diameter was 4.8 mm. This was caused by large number of medium-seeded size has been passing through the first screen of grader (hole size 6 mm).

b. For Oval-hole Screen Type

In contrast, seed sorting with oval-hole screen type produced more grades, Grobogan for instance, has produced two grades (G1 and G2) (**Fig. 5a**), meanwhile Wilis has produced three majority of grades (G1, G2 and G3) (**Fig. 5b**). Similarly, in terms of material distribution patterns, large number of seeds distributed at G1 (56.5%) for Grobogan and G3 (56.1%) for Wilis. In conclusion, oval-hole screen type could produce additional grades compare to spherical-hole screen type as G1 could be sorted back into two grades G1 and G2, which G1 was the superior quality of seed (**Fig. 5a**). Likewise for Wilis, the quality of seed at G2 could be sorted back into two grades G2 and G3 by using oval-hole screen type (**Fig. 5b**).

Table 10 Uniformity index of soybean seed Grobogan variety in comparison between oval-hole and spherical-hole screen type

Replication	Uniformity index, fraction (coarse : medium : fine)		Remark
	Oval-hole screen	Spherical-hole screen	
1	10 : 0 : 0	10 : 0 : 0	The example of calculation is provided in appendix 2.
2	10 : 0 : 0	10 : 0 : 0	
3	10 : 0 : 0	10 : 0 : 0	
4		10 : 0 : 0	

Table 11 Uniformity index of soybean seed Wilis variety in comparison between oval-hole and spherical-hole screen type

Replication	Uniformity index, fraction (coarse : medium : fine)	
	Oval-hole screen	Spherical-hole screen
1	10 : 0 : 0	10 : 0 : 0
2	10 : 0 : 0	10 : 0 : 0
3	10 : 0 : 0	10 : 0 : 0

Fig. 5a Material distribution pattern and averge of seed diameter of Grobogan variety using oval-hole screen type (G1 : seed diameter > 6 mm; G2 : seed diameter ≤ 6 mm and > 5mm; G3 : seed diameter ≤ 5 mm and > 4 mm; G4 : seed diameter ≤ 4 mm).

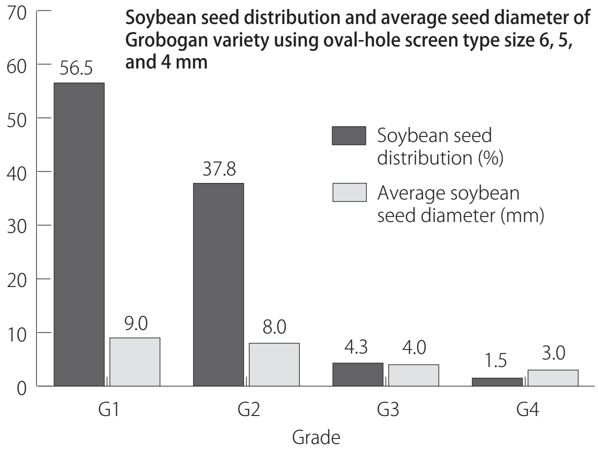
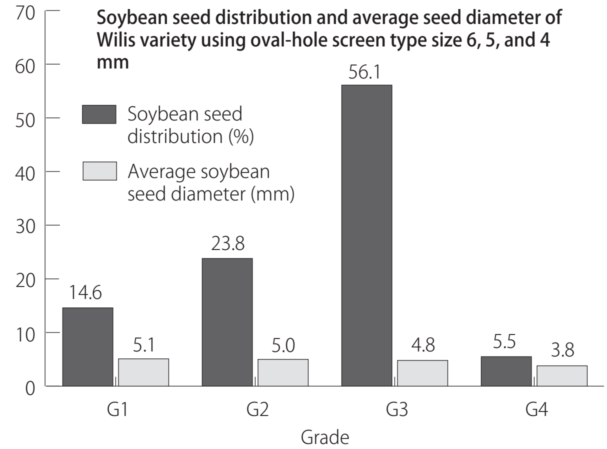


Fig. 5b Material distribution pattern and average of seed diameter of Wilis variety usingoval-hole screen type (G1 : seed diameter > 6 mm; G2 : seed diameter ≤ 6 mm and > 5mm; G3 : seed diameter ≤ 5 mm and > 4 mm; G4 : seed diameter ≤ 4 mm).



The average distribution of seed diameter for Wilis by using oval-hole screen type for grade G1, G2 and G3 was 5.1 mm, 5.0 mm and 4.8 mm respectiely. Hence the implication was seed quality at G1 and G2 could be combined into a grade as the average of diameter relatively not significant.

The observation of seed grades by calculating seed diameter (Henderson and Perry, 1976) found to be different with theoretically of seed classification according to hole size of screen. This was caused by the chance of seed to be sorted by oval-hole screen type could be releasing two to three seeds per hole, whereas there was only one seed per hole to be released by using spherical-hole screen type. Therefore, a grade from spherical-hole screen type (**Figs. 4a** and **4b**) could be separated into two to three grades when using oval-hole screen type (**Figs. 5a** and **5b**).

Verification Performance Test of ILETRI Soybean Seed Grader

Verification performance test was conducted in order to support data collection process in terms of grader capacity for determining financial feseability analysis. Soybean seed Argomulyo variety (large-seeded size) has been used in this test either for oval-hole or spherical-hole screen type. Besides that, uniformity index and seed quality has also observed.

Grader Capacity

The result showed that grader capacity was similar for both of screen types either for Grobogan or Argomulyo (**Figs. 12a** and **12b**). Similarly, grade capacity was not significant for Wilis and Argomulyo when screened by sperical-hole screen type (**Table 13a**). However, grader capacity was higher for Argomulyo compared to Wilis when screened by oval-hole screen type (**Table 13b**). This result showed similarity when seed grader was tested at functional performance test process with Grobogan and Wilis varieties. This was because Argomulyo and Grobogan grouped as large-seeded size, besides that oval-hole screen type could produce more grades compared to spherical-hole screen type.

Uniformity Index

Uniformity index at verification performance test also revealed similar result with previous test, in which uniformity index of soybean seed using both type of screens has reached 100% as all seeds grouped as one coarse fraction (**Table 14**).

Table 12a t-Student test of grader capacity in comparison between Grobogan and Agromulyo variety using spherical-hole screen type

Capacity (kg/h)		
Grobogan	Replication	Argomulyo
741.1	1	681.5
750.7	2	654.2
698.4	3	686.6
689.2	4	
4	n	3
719.9	X (mean)	674.1
4.2	CV (%)	2.6
t-counted	2.2	ns
t-Table (0.05; 5)	2.6	

ns = not significant at α 5%

Table 12b t-Student test of grader capacity in comparison between Grobogan and Agromulyo variety using oval-hole screen type

Capacity (kg/h)		
Grobogan	Replication	Argomulyo
668.6	1	580.1
692.9	2	668.3
606.0	3	786.7
3	n	3
656	X (mean)	678.3
6.8	CV (%)	15.3
t-counted	0.3	ns
t-Table (0.05;4)	2.8	

ns = not significant at α 5%

Fig. 6a Material distribution pattern and averge of seed diameter of Argomulyo variety using spherical-hole screen type (G1 : seed diameter > 6 mm; G2 : seed diameter ≤ 6 mm and > 5mm; G3 : seed diameter ≤ 5 mm and > 4 mm; G4 : seed diameter ≤ 4 mm).

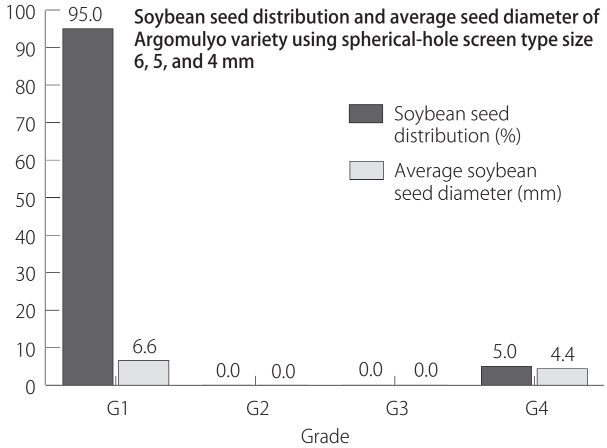
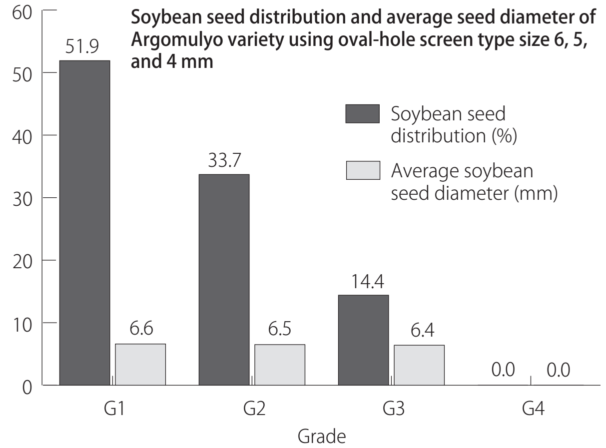


Fig. 6b Material distribution pattern and averge of seed diameter of Argomulyo variety using oval-hole screen type (G1 : seed diameter > 6 mm; G2 : seed diameter ≤ 6 mm and > 5mm; G3 : seed diameter ≤ 5 mm and > 4 mm; G4 : seed diameter ≤ 4 mm).



Sorting Quality

In general, seed sorting quality result at verification performance test was not significantly different with the result of functional performance test. Seed sorting with spherical-hole screen type could only produced one grade (G1) for Agromulyo (**Fig. 6a**). Material distribution pattern using this screen was also largely distributed at G1 (95.0%) with average seed diameter was 6.6 mm.

However, seed sorting with oval-hole screen type produced two grades (G1 and G2) (**Fig. 6b**), meanwhile its material distibution pattern was also largely distributed at G1 (51.9%). However, the average seed diameter was relatively similar for G1 (6.6 mm) and G2 (6.5 mm) and hence the grade at G1 and G2 could be combined as similar grade.

Likewise functional performance test, in this test also pointed out that by using oval-hole screen type there was diferrences between the observation of seed grades based on calculating of seed diameter (refers to method of Henderson and Perry (1976)) and theoretical clasification of seed grades according to hole size of screen. This was caused by the chance of seed to be sorted by oval-hole screen type could be releasing two to three seeds per hole, whereas there was only one seed per hole to be released by using spherical-hole screen type. Therefore, a grade from spherical-hole screen type (**Fig. 6a**) could be separated into two to three grades when using oval-hole screen type (**Fig. 6b**).

The Impact of Grader to Soybean Seed Quality

Seed viability and vigor has been tested using sand medium (ISTA, 2008) in order to find out the impact of grader to seed quality. The result showed that after sorting with ILETRI grader, soybean seed viability was 70% in which this result still met standard seed quality for extension seed class (Departemen Pertanian, 2007). In addition, t-Student test showed that seed viability was not significantly different (t-count = 1.154 < t-table $_{(0.05;6)}$ = 2.447) between oval-hole screen type and spherical-

Table 14 Uniformity index of soybean seed Argomulyo variety in comparison between oval-hole and spherical-hole screen type

Replication	Uniformity index	
	Oval-hole screen	Spherical-hole screen
1	10 : 0 : 0	10 : 0 : 0
2	10 : 0 : 0	10 : 0 : 0
3	10 : 0 : 0	10 : 0 : 0

Table 13a t-Student test of grader capacity in comparison between Wilis and Agromulyo variety using spherical-hole screen type

Capacity (kg/h)		
Wilis	Replication	Argomulyo
694.9	1	681.5
604.3	2	654.2
629.3	3	686.6
3	n	
642.8	X (mean)	674.1
7.3	CV (%)	2.6
t-counted	0.9	ns
t-Table (0.05; 4)	2.8	

ns = not significant at α 5%

Table 13b t-Student test of grader capacity in comparison between Wilis and Agromulyo variety using oval-hole screen type

Capacity (kg/h)		
Wilis	Replication	Argomulyo
466.7	1	580.1
435.3	2	668.3
409.0	3	786.7
3	n	3
437.0	X (mean)	678.3
6.6	CV (%)	15.3
t-counted	3.2	ns
t-Table (0.05; 4)	2.8	*

ns = not significant at α 5%

Fig. 7a The impact of ILETRI grader to soybean seed germination of Grobogan, Argomulyo and Wilis varieties (similar letter in a bar chart showed not significant different at α = 0.05).

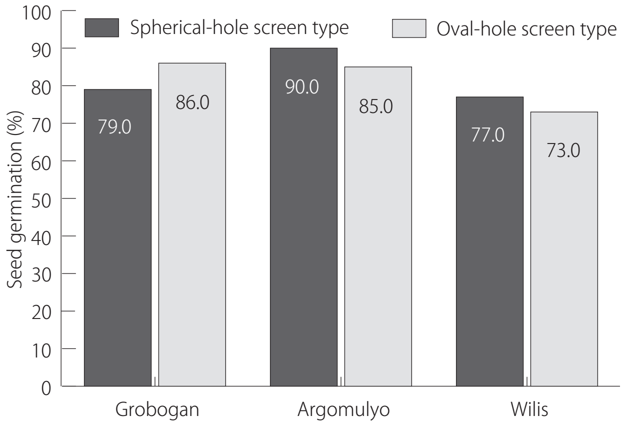
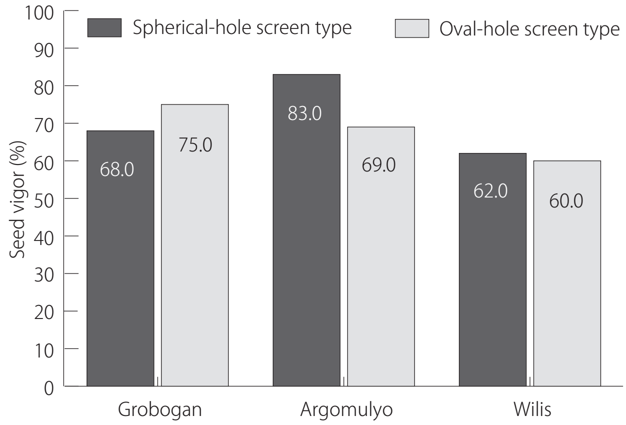


Fig. 7b The impact of ILETRI grader to soybean seed vigor of Grobogan, Argomulyo and Wilis varieties (similar letter in a bar chart showed not significant different at α = 0.05).



hole screen type for Grobogan variety. Similarly for Argomulyo (t-counted = 1.296 < t-Table $_{(0.05;6)}$ = 2.447) and Wilis (t-counted = 0.527 < t-table $_{(0.05;6)}$ = 2.447), the response of seed viability was similar for both type of screens (**Fig. 7a**). Meanwhile, the averge of seed germination for Grobogan, Argomulyo and Wilis was 82.5%, 87.1% and 74.6% respectively.

Furthermore, seed vigor of Grobogan, Argomulyo and Wilis was 71.4%, 76.0% and 60.9% respectively. The impact of grader to seed vigor of Grobogan variety was not significantly different between spherical-hole and oval-hole screen type (t-counted = 0.641 < t-table $_{(0.05;6)}$ = 2.447). Likewise, in case of Argomulyo (t-counted = 2.173 < t-table $_{(0.05;6)}$ = 2.447) and Wilis (t-counted = 0.198 < t-table $_{(0.05;6)}$ = 2.447), the result of t-student test showed also similar for both type of screen (**Fig. 7b**).

Financial Feasibility of the ILETRI Soybean Seed Grader

The price per unit of seed grader in farm level is one of essential item which can determine financial feasibility of seed grader. After several test (functional and verification tests) have been conducted, the price of ILETRI grader can be reached Rp 16 million/unit when it produced in a local workshop.

In addition, grader capacity is also another important item to determine financial feasibility of seed grader. On average, grader capacity for large-seeded size was 667 kg/h (**Table 12b**) however, for medium-seeded size was 427 kg/h (**Table 13b**). Therefore, the mean grader capacity was 552 kg/h and this is the capacity which can be used for analysis of financial feasibility.

Moreover, another several asumptions that can be used for determining analysis of fianancial feasibility is presented in **Appendix 3**. The cost for grading service is another important consideration for analysis of financial feasibility. The cost should be cheaper (Rp 100/kg) than the existing method (manual) (Rp 500/kg) and hence the grader is eligible to be operated in the farming service system. According to the data of grader capacity (552 kg/h), grader operation (operated by 2 people) and wage for 8 hour (Rp 75.000/operator) therefore, the cost of goods (CG) is Rp 52/kg; break even point (BEP) is 103 t/year; payback periode (PBP) is 6.0 month (**Appendix 3**); Net Present Value (NPV) for five years of economic life of grader is Rp 73.9 million; benefit-cost ratio (B/C) is 1.67 and Internal Rate of Return (IRR) is 199.8% (**Appendix 4**).

Although ILETRI grader is more expensive than Indonesian Center for Agricultural Research and Development (ICAERD) grader (Rp 6.5 million/unit) and local farming workshop grader (Rp 9 million/unit), its financial feasibility is higher than among the last two of grader (**Figs. 8a** and **8b**). This result pointed out that ILETRI grader feasible to be applied in soybean seed producer called Penangkar Benih.

Dissemination and Implication of the ILETRI Soybean Seed Grader

The ILETRI soybean seed Grader has been patented in Indonesia with

Appendix 1 Angle of repose measurement of Grobogan and Wilis at several moisture content levels of soybean seed

Replication	Angle of repose (°) for Grobogan at different moisture content (% bb)			Angle of repose (°) for Wilis at different moisture content (% bb)		
	10.64	13.68	17.28	10.64	13.68	17.28
1	22.52	26.84	29.65	15.79	19.21	19.71
2	22.09	30.16	29.02	15.64	17.82	**19.71**
3	23.15	23.30	27.18	15.25	18.72	18.25
Sum	67.76	80.29	85.85	46.68	55.75	57.67
Mean	22.59	26.76	28.62	15.56	18.58	19.22
SD	0.53	3.43	1.28	0.28	0.71	0.84
CV (%)	2.35	12.82	4.48	1.79	3.79	4.38

Fig. 8a The unit cost (BP), break even point (BEP), and payback period (PBP) in comparison between ILETRI, ICAERD and local workshop grader

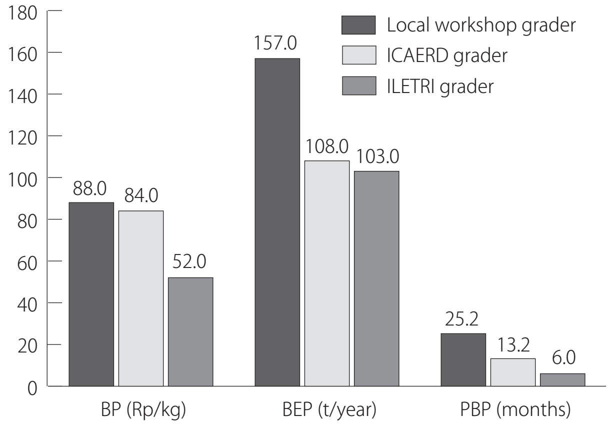
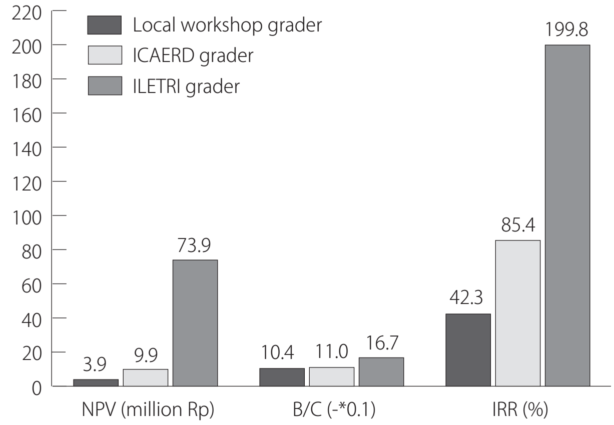


Fig. 8b The net present value (NPV), benefit-cost ratio (B/C), and internal rate of return (IRR) in comparison between ILETRI, ICAERD and local workshop grader



patent number: S00201200065. Since 2012 to 2016 the grader has been applied at soybean seed producer called Penangkar benih about 20 unit. The disemination of the grader mostly to the soybean centre production area suh as Java (Jawa Barat, Jawa Tengah, Jawa Timur) and West Nusa Tenggara (NTB) (**Fig. 9**).

The practical implication of the new type ILETRI grader is the oportunity to enhance value added of soybean seed in terms of price according to seed diameter. Therefore, it can be used to become a principal consideration to determine seed price in which has been established by government and dissemination of ILETRI grader in farm level (seed breeder) and seed production unit.

Appendix 2 The sample of calculation of uniformity index and seed diameter for Grobogan variety (Seed diameter > 6 mm) by using ILETRI grader with oval-hole screen type

Mesh	Retained material (%)	Material weight (g)	Total % divided by 10	Nearest Integers
Uniformity Index				
3/8	108.1	43.24		
4	141.3	56.52		
8	0.6	0.24		**Coarse**
Total	250	100		3
14	0	0		
28	0	0		**Medium**
Total	0	0		5
48	0	0		
100	0	0		
Pan	0	0		**Fine**
Total	0	0		2

Uniformity Index (fraction coarse : medium : fine) = 10 : 0 : 0

Calculation of seed diameter

Mesh	Hole size (mm)	Material retained (%)	Multipliers factor	The multiplication result
3/8	9.42	43.24	7	302.68
4	4.70	56.52	6	339.12
8	2.36	0.24	5	1.2
14	1.17	0	4	0
28	0.59	0	3	0
48	0.29	0	2	0
100	0.15	0	1	0
Pan		0	0	0
Total		100 (A)		643 (B)

Degree of fineness (DF) = B/A =6.43
Average of seed diameter (mm) = 0.10414 * (2) ^ DF =8.98

Conclusions

1. Functional and verification test of ILETRI grader showed that its capacity by using oval-hole screen type was 552 kg/h/2 operators (4 t/day/2 operators), and the uniformity index was 100%.
2. Eventhough a spring system has been applied in the grader, it has less impact on seed viability (70%). By using oval-hole screen type, on average, seed viability for large-seeded size (Grobogan and Argomulyo) was 85%, while for medium-seeded size (Wilis) was 73%.
3. Applying oval-hole screen type produced additional grades compare to spherical-hole screen type.
4. At the price of grader Rp 16 million/unit, financially ILETRI grader feasible to be applied in soybean seed producer; with BP is Rp 52/kg; BEP is 103 t/year; PBP is 6.0 month; NPV for five years of economic life is Rp 73.9 million;

B/C is 1.67 and IRR is 199.8%.

Acknowledgement

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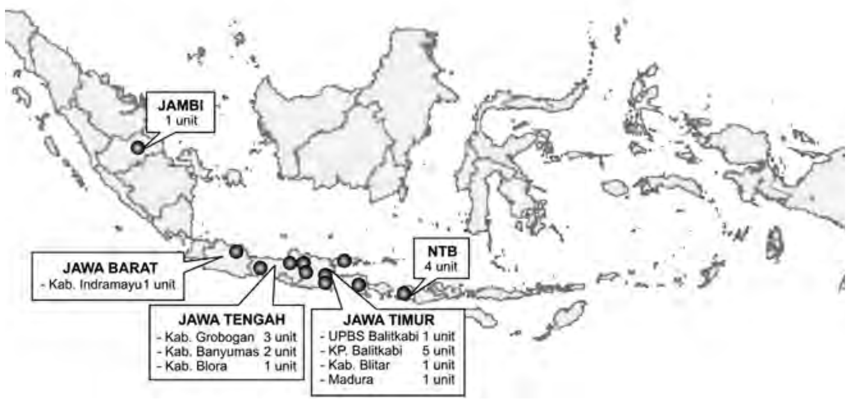
Fig. 9 Dissemination of the the ILETRI soybean seed grader since 2012-2016 in Idonesia



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Appendix 3 Analysis of Unit cost (BP), Break even point (BEP) and Payback period (PBP) of ILETRI grader

Remark	Year					
	0	1	2	3	4	5
A. Income:						
a. Grading fee (Rp)	-	66,240,000.00	66,240,000.00	66,240,000.00	66,240,000.00	66,240,000.00
b. Salvage value (SV) (Rp)	-	-	-	-	-	6,400,000.00
Annual benefit (Rp)	-	66,240,000.00	66,240,000.00	66,240,000.00	66,240,000.00	72,640,000.00
B. Cost:						
a. Investment cost (M) (Rp/unit)	16,000,000.00					
b. Variable cost (BTT):						
1. Operator cost (Rp/year)	-	22,500,000.00	22,500,000.00	22,500,000.00	22,500,000.00	22,500,000.00
2. Fuel cost (BBM) (Rp/year)		5,940,000.00	5,940,000.00	5,940,000.00	5,940,000.00	5,940,000.00
3. Oil cost (Rp/year)		4,444.44	4,444.44	4,444.44	4,444.44	4,444.44
Total BTT (Rp/year)		28,444,444.44	28,444,444.44	28,444,444.44	28,444,444.44	28,444,444.44
c. Fixed cost (BT)						
1. Depreciation (c1) (Rp/year)	-	1,920,000.00	1,920,000.00	1,920,000.00	1,920,000.00	1,920,000.00
2. Investment Interest (c2) (Rp/year)	-	2,016,000.00	2,016,000.00	2,016,000.00	2,016,000.00	2,016,000.00
3. Maintenance (c3) (Rp/year)	-	1,600,000.00	1,600,000.00	1,600,000.00	1,600,000.00	1,600,000.00
4. Tax & Assurance (c4) (Rp/year)	-	320,000.00	320,000.00	320,000.00	320,000.00	320,000.00
Total BT (Rp/year)		5,856,000.00	5,856,000.00	5,856,000.00	5,856,000.00	5,856,000.00
Annual Cost	16,000,000.00	34,300,444.44	34,300,444.44	34,300,444.44	34,300,444.44	34,300,444.44
C. Net benefit (KU) (Rp/year)	-16,000,000.00	31,939,555.56	31,939,555.56	31,939,555.56	31,939,555.56	38,339,555.56

Assumption:

1. Working day:	150	day/year	10. Depreciation c1 = (M-S)/N		
2. Working hour per day:	8	hour/day	11. Operator cost	150,000.00	Rp/day
3.Total working hour (X):	1,200	hour/year	12. Seed grading cost (OP)	100	Rp/kg
4. Interest rate (i):	18	%/year	13. Grading capacity (KE)	552	kg/hour
5. Maintenance (c3):	10	%*M	14. Fuel rate	0.20	l/hour/hp
6. Expected economic life (N):	5	year	15. Oil rate	0.07	l/200 hour
7. Tax & Assurance (c4):	2	%*M	16. Oil price	10,000.00	Rp/liter
8. Investment interest c2=i*(M+SV)/2			17. Fuel price	4,500.00	Rp/liter
9. Salvage value (SV) = 0.4*M			18. Power source	5.5	hp

Calculation:

1. Unit cost (BP) = (BTT + BT) / (X × KE) = 52 Rp/kg of soybean seed
2. Break even point (BEP) = BT / (OP – BTT / (X × KE)) = 103 t soybean seed / year
3. Payback period (PBP) = M / (KU) = 0.5 year

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Appendix 4 Analysis of Net present value (NPV), Benefit cost ratio (B / C) and Internal rate of return (IRR) of ILETRI grader

Year	Annual benefit (Rp)	Annual cost (Rp)	Net benefit (Rp)	Discount factor (24 %)	Discount benefit (1*4)
	(1)	(2)	(3)	(4)	(5)
0	0.00	16,000,000.00	-16,000,000.00	1.000	0.00
1	66,240,000.00	34,300,444.44	31,939,555.56	0.806	53,419,354.84
2	66,240,000.00	34,300,444.44	31,939,555.56	0.650	43,080,124.87
3	66,240,000.00	34,300,444.44	31,939,555.56	0.524	34,742,036.19
4	66,240,000.00	34,300,444.44	31,939,555.56	0.423	28,017,771.12
5	72,640,000.00	34,300,444.44	38,339,555.56	0.341	24,778,066.24
Total					184,037,353.26

Year	Discount cost (2*4)	Trial I		Trial II	
		DFP (24%)	NPV (3*7)	DFN (200%)	NPV (3*9)
	(6)	(7)	(8)	(9)	(10)
0	16000000.00	1.000	-16000000.00	1.0000	-16,000,000.00
1	27,661,648.75	0.806	25,757,706.09	0.3333	10,646,518.52
2	22,307,781.25	0.650	20,772,343.62	0.1111	3,548,839.51
3	17,990,146.17	0.524	16,751,890.02	0.0370	1,182,946.50
4	14,508,182.39	0.423	13,509,588.72	0.0123	394,315.50
5	11,700,147.09	0.341	13,077,919.15	0.0041	157,775.95
Total	110,167,905.64		73,869,447.61		- 69,604.02

Calculation:

1. et present value (NPV = PVP) = Rp 73,869,448
2. Benefit cost ratio (B / C) = 1.67
3. Internal rate of return (IRR) = DFP + (PVP × (DFN – DFP) / (PVP – PVN)) = 199.9%

where,
DFP: Interest rate produced PVP (%), DFN: Interest rate produced PVN (%)
PVP: Positive net present value (Rp), PVN: Negative net present value (Rp)

Yield and Economics Attributed Study of Direct Seeding and Transplanting Method on Beds for Onion (*Allium Cepa L.*) Cropwith Pneumatic Precision Multicrop Planter and Manual Transplanting Method Along With Rotary Tiller Cum Bed Former in Indian Conditions

by

Surinder Singh Thakur
Senior Engineer
Dept. of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Punjab Agricultural University (PAU), Ludhiana, INDIA
Corresponding authorl: ssthakur@pau.edu

Manjeet Singh
Sr. Research Engineer Cum Head
Dept. of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Punjab Agricultural University (PAU), Ludhiana, INDIA
manjeetsingh_03@pau.edu

Rupinder Chandel
Demonstrator (Agricultural Engineering)
Dept. of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Punjab Agricultural University (PAU), Ludhiana, INDIA
rupinder26@gmail.com

Abstract

Presently area under vegetable cropping in India is declining and is not even able to meet the demand due to lack of mechanization. The cost of labour involved in sowing and transplanting operations for vegetable crops is very high. Therefore, mechanization in sowing becomes crucial for increasing area under vegetable crops. In context to this, a precision multicrop planter was evaluated for onion crop and locally sown variety Punjab Naroyawas selected. The seed spacing was adjusted to 0.02 × 0.075 m in the laboratory. The rotary tiller cum bed former made beds with overall width of 1.25 m and its mean fuel consumption for tilled and untilled soil was 6.93 and 7.01 l.h^{-1} respectively. Four lines of onion were seeded on each bed with pneumatic planter. At an average speed of 3.36 km.h^{-1}, mean fuel consumption was 2.65 l.h^{-1}, mean RTR spacing was 20.42 cm, mean depth of seed was 2 cm, mean PTP spacing was 7.86 cm and mean field capacity was 0.17 ha.h^{-1}. The mean observed precision index (PI) of the planter was 4.52 %. The mean bulb weight and yield of onion sown with pneumatic precision multicrop planter were 57.45 g and 9,562 kg.acre^{-1} and 57.86 g and 10,515 kg.acre^{-1} for transplanting method. The saving in cost and time with pneumatic precision multicrop planter were 55.12% and 98.53% as compared with transplanting method. The benefit cost ratio for onion sown with pneumatic precision multicrop planter and manual transplanting method were 5.11:1 and 2.62:1, respectively.

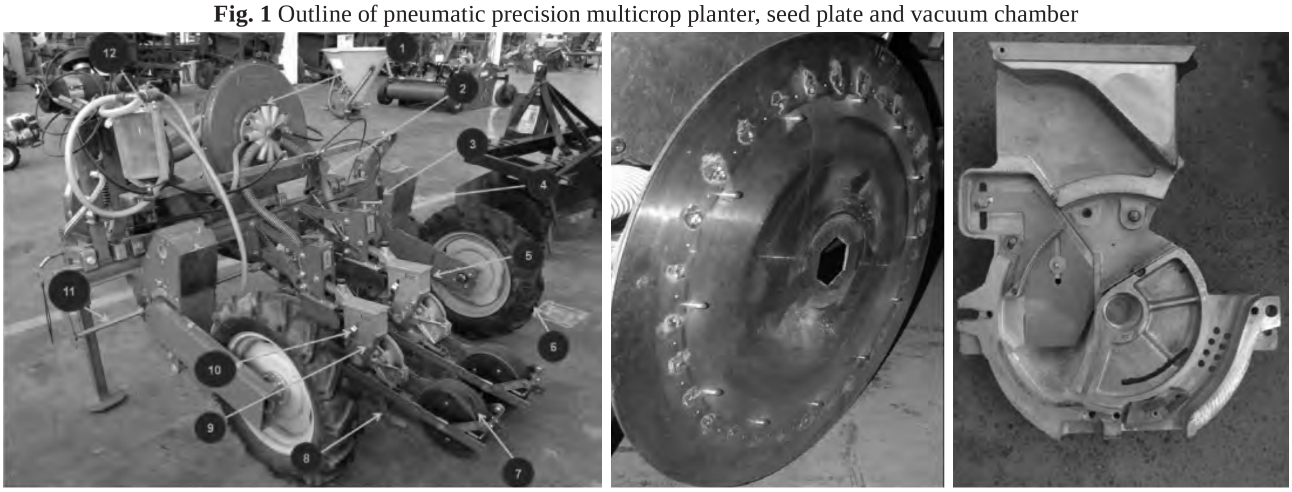
Keywords: Onion, precision planter, vegetable crop, field capacity

1. Introduction

Onion (*Allium cepa L.*) is one of the oldest cultivated species in use for more than 5000 years as an integralcomponent of various culinary preparations (Jones, 1983).India ranks second after China in the global production of onion with an annual production of 16 to 17 million tons which accounts for around 20% of global production. However, India onion yield is one of the lowest. The inherent lower productivity in subtropical countries like European counties, shortage and high prices of quality seeds, high incidence of pests and diseases prevailing under tropical conditions, moisture stress or excess rains during critical growth stages are factors constraining high yield. Wide price fluctuations make it a risky crop discouraging large scale adoption of input intensive production techniques and good management practices by farmers. In India, onion is grown in three crop seasons, namely kharif (harvested in October-November), late kharif (harvested in January-February)and rabi (harvested in April-May). Rabi season crop is the largest accounting for about 60 percent of annual production with kharif and late kharif accounting for about 20%. Major producing states are Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Bihar, Gujarat, Rajasthan and Haryana, which together accounts for 85% of total production (Anonymous, 2014). Mechanization of onion which is a vegetable crop is most important for its successful cultivation. Presently area under vegetables in Punjab State is 188,000 ha with a production of 3.645 million tons and an average productivity of 19.34 $t.ha^{-1}$. The areas under onion, potato and pea crops were 8.22, 83.57, and 19.66 thousand hectares, respectively. Likewise, the area under cauliflower and cabbage were 8.65 and 4.37 thousand hectares. Area under vegetables is not even able to meet current demand. Per capita availability is less than half in the state. To feed the present population of the state, the production of vegetables has to be doubled (Anonymous, 2011). Sowing of vegetables seed is mostly done manually which involves more labour cost and time. Therefore, there is need for mechanization of sowing operation of onion and other small seeds vegetable crops and direct seeding and accurate placement of small seeds in the soil. This has the advantages of time saving, cost saving and higher area coverage over manual method. Cost of vegetables seed like onion is very high where its sowing and transplanting operations are done manually in almost every part of India. In manual method, 5-6 persons sows onion nursery for one acre per day. Onion seed germinates in around 10-15 days and then transplanting the same seedlings into an area of 1 acre is done in a day by 15 people. Thus 1 acre area is completed in around 10-15 days which makes it very labour intensive, costly and time consuming operation. Similarly, this is the case for other small seed vegetable crops. Therefore, there is the need of a precision multicrop planter for the direct sowing of onion and other small seed vegetable crops. A study was conducted in which onion was precision planted at three spacing 3.5, 4.125, 4.5 inches using a pneumatic precision double row planter. Narrow plant spacing resulted in higher yields. Total onions greater than 3-inch diameter was not affected by the spacing but more colossal onion was produced at larger spacing (Shock and Barlow, 1986). A study was done to develop and evaluate a tractor drawn pneumatic precision planter to precisely plant rape seed, mustard, sorghum, soybean, pigeon pea, maize, radish, onion seed, pea, wheat, sunflower and okra etc. The machine could plant on an average of 0.5-0.6 $ha.h^{-1}$ (Yadav and Yadav, 1987). In a study carried out by Bracy et al. (1991[a]), two precision belt seeders were compared in laboratory tests using seeds from vegetable crops (cabbage, cucumber, onion and spinach). There were no significant differences in seed placement uniformity with onion seed. Each vacuum seeder was compared independently with the precision belt seeder in replicated field tests of vegetable crops. In the field, there were few differences in stand or yield. Bracy et al. (1991[b]) conducted an experiment on broccoli, cabbage, mustard and spinach to evaluate production of these crops on single and multiple row configurations on narrow (1 m) and wide (2 m) beds. The precision cultural system was assessed to be an excellent method for production of small seeded crops that were tested. Yield was highest for cabbage, mustard and spinach planted in six rows on 2 m beds compared with four, two or one row beds. According to Far et al. (1994), a hydro-pneumatic planter was developed and evaluated with primed vegetable seeds. The performance tests indicated that the planter worked well on paved surface. The field performance of this planter was at least as good as that of regular air planter. Primed seeds germinated faster than raw seeds. A study was carried out by Kachman and Smith (1995) to evaluate a planter using a single seed metering mechanism, the ability to place seeds at a given distance apart in a row was an important factor in evaluating the planter's performance. The results showed that when the planter was operated at 3.2 $km.h^{-1}$, it gave a multiple index value of 2.23%, miss index value of 34.7%, quality of feed index value of 63% and precision value of 13.4% of the theoretical spacing. Another study determined the optimum pressure of a precision vacuum seeder and to develop mathematical models by using some physical properties of seeds such as one thousand kernel mass, projected area, sphericity and kernel density. Maize, cotton, soya bean, watermelon, cucumber, sugar beet and onion seeds were used in laboratory tests. One thousand kernel mass, projected area, sphericity and kernel density of seeds varied from 4.3 to 372.5 g, 5 to 77 mm^2, 38.4 to 85.8% and 440 to 1,310 $kg.m^{-3}$, respectively. The optimum vacuum pressure was determined as 4.0 kPa for maize 3.0 kPa for cotton, soya bean and watermelon, 2.5 kPa for cucumber, 2.0 kPa for sugar beets and 1.5 kPa for onion seeds (Karayel et al., 2004). A study was conducted to develop, construct and test a vacuum precision seeder prototype suitable for onion seeds. The developed prototype was fabricated from local materials using Stainless Steel 304. It was designed to plant two rows at 70 mm apart instead of one row as the most onion vacuum seeders in the market. Tests were conducted using an indoor soil bin facility under different operational parameters. These parameters were three levels of seed plates having different hole diameters (0.8, 1.0 and 1.2 mm), four levels of disc speeds in terms of the peripheral velocity of seed plate (0.08 (7.3), 0.14 (12.5), 0.21 (18.7) and 0.28 $m.s^{-1}$ (24.4 rpm)), four levels of blower speeds (4,000, 4,500, 5,000 and 5,500rpm) and three level of forward speeds (2.7, 3.6 and 5.3 km/h). Measurements were taken for the actual seed spacing, seed miss index, seed multiple index, quality of feed index, precision in spacing and the vacuum pressure in the hole. Results indicated that the optimum values of the actual seed spacing (5.93 mm), seed miss index (8.1%), seed multiple index (8.12%), quality of feed index (83.7%), precision in spacing (23.4%) and the vacuum pressure in the hole (4.75 kPa.) were obtained with the seed plate of 1.0 mm hole diameter. Results of statistical analysis showed that the most desirable conditions in terms of operating developed prototype were obtained with the seed plate hole of 1.0 mm diameter at 0.21 $m.s^{-1}$ (18.7 rpm) disc speed, 4500 rpm blower speed and 3.6 km/h forward speed. It also indicated that there was no appreciable difference between the two rows of the developed prototype under different operational conditions (Shaaban et al., 2009). A cone seed planter has been developed for planting experimental plots in the onion research program at Gatton Research Station. A four row Stanhay model S870 precision planter, with the seed boxes and planting feet removed, was used as the basic frame. Four Hege belt driven seed cones (manufactured in Germany) were mounted on a frame above the planting feet. The seed cones work on the principle of a measured quantity of seed being released from a seed chamber and distributed evenly around a belt driven revolving cone, which in turn drops the seed over a pre-determined row length. The cones are driven by the Stanhay master land wheel to the main shaft, with a chain drive between the main shaft and cone to minimize soil disturbance and enable planting into moister soil conditions, the planting feet were modified by attaching a narrow Janke planting point to the depth adjustment of the Stanhay planter (Schrodter, 1988).The objective of this study was to determine spatial variability in a dry onion field and to produce a management strategy which is based on spatial variability of yield and soil components. The onion field properties were determined and given in maps. Soil samples were taken to determine properties of soil such as pH, salt, humidity, $CaCO_3$, organic matter, total N, Zn, Fe, P_2O_5, Ca+Mg, K, texture. Longitudinal slope was also measured. Results were used to produce maps. Most percentage of the field soils was determined as clay-loam. Small part of the field was loam. Yield of dry onion decreased by increasing Organic Matter, Total Nitrogen, Iron, and Zinc in the field according to the related maps. Relationship between yield and phosphorous, $CaCO_3$, Ca+Mg and salt was positive according to the related maps (Akdemir et al., 2005). The seeding performances were investigated and evaluated based on the seed distribution accuracy by sticky belt sand tests in laboratory conditions. The experiments were conducted at forward speeds of 1.0, 1.5 and 2.0 ms^{-1} and seed spacing of 25 and 50 mm for each seed. The vacuum plate of precision metering unit with 90 holes of 0.8 mm diameter was used. The seed distribution accuracy was determined according to the factor of variation (V_f) and goodness criteria (λ) which represents the compatibility to the Poisson distribution. The factors of variation were found in the range of 0.74-0.89 for carrot and 0.52-0.55 for onion. These values indicated that carrot and onion seeds can be planted in the character of precision seeding by the vacuum type vegetable planter. According to the results of the experimental tests, it was found that seed distribution accuracy of machine was in very good quality for carrot (λ = %78.42 – %93.16) and onion (λ = %88.95 – %94.11) seeds also (Yazgi et al., 2013).It was reported that in order to obtain optimize performance, planters should be designed to release seed such that the relative velocity between the seed and soil surface is as close to zero as possible and with a consistent trajectory. Five planter configurations were tested in the field at four travel speeds ranging from 1.0 to 2.5 mph. The mid-level drop height planter had significantly better seed placement precision and fewer closely spaced seed spacing as compared to the unmodified vacuum planter. No differences in planter performance were found between the two belt planter configurations tested. Vacuum and belt planters both provided acceptable levels of performance at speeds below 1.5 mph, but at higher speeds, seed placement accuracy declined rapidly. Belt planter performance was significantly better than that of the vacuum planter. Additional planter performance studies are needed to confirm that belt planters provide superior seed placement accuracy as compared to vacuum planters as the opposite is commonly believed to be true (Siemens and Gayler, 2015). Karayel and Ozmerzi (2002) stated that the best sowing uniformity, the most uniform sowing depth, and maximum emergence percentage occurred when a precision seeder was used after preparing the soil with a moldboard plow, disc harrow, and roller. Different tilling conditions had no effect on the multiple index, the miss index, and the quality of feed index. Although vegetable seeds are typically sown with precision planters, seed placement uniformity is surprisingly poor. Research studies with various crops have shown that typically only about two-third of the seeds planted with precision planters are placed within 1.5 inches of the target spacing (Bracy et al., 1999; Parish and Bracy, 1998; Kachman and Smith, 1995). Wanjura and Hudspeth (1969) evaluated a vacuum planter with cotton seed at differentspeeds and vacuum pressures. They found that a 3 inch drop height consistently resulted in a better seedpattern than a 6 inch drop height. They concluded that seed release height should be as low as practical and seed should fall freely to the seed furrow for optimum performance. Koller et al. (2014) reported that exit location of seed leaving a vacuum planter after falling 10 inches varied by as much as 1 inch for some planters. Bracy and Parish (1998) evaluated a belt and two vacuum type planters for seeding uniformity with five vegetable crops. It was concluded that the belt planter provided more uniform and precise metering than the vacuum planter. Bracy et al. (1999) who found that the percentage of quality spacing, defined as spacing within ± 1.4 inches of target spacing, was over 90% with a Stan hay belt planter and less than 41% with a precision vacuum planter designed for vegetable seeds. In a study, a travel speed of 1.5 mph and cabbage seed was used. Spacing distribution patterns are visually similar for belt planter at 2.0 mph and Vacuum planter at 1.0 mph. This result was significant and implied that belt planters can be operated at twice the speed of vacuum planters with similar seed spacing accuracy. They reported that the direction seed is released from the vacuum planter is much more variable than that of the belt planter. In order to obtain optimize performance, plantersshould be designed to release seed such that the relative velocity between the seed and soil surface is asclose to zero as possible and with a consistent trajectory (Bracy et al., 1999). India is projected to have a population of 1.7 billion by 2050, and there is no possibility of increase in cultivable land. To cater for the requirement of this ever increasing population, considering per capita consumption, export, processing and losses at existing rate (consumption i.e. 7.83 kg/person/year, export 9%, processing 6.75% andlosses 30%; base year 2010-2011), we will require 24.62 million tons of onion in 2050 against 19.29 million tons in 2013 and 2014. This demands an increase in average productivity from 15.85 to 22.7 t/ha, which is 42.9% higher than that of 2013and 2014. Efforts can be made to reduce losses up to 20%, increase export up to 25% and processing up to 15% by 2050. With these targeted numbers the production has to increase from 19.29 million tons to 33.39 million tons with productivity of 30.72 t/ha. Thus there is need to explore the innovative measures to improve productivity and stabilize production in India (Gopal, 2015). The mechanization of sowing operation using precision planter can be helpful to improve onion productivity and prospects of onion cultivation in India.

The precise planting of vegetable and other small seed crops is required for better crop stand and saving of time, labour and efficient use of various inputs like seed, water, labour, fuel etc. Lack of mechanization leads to increased cost of cultivation of vegetable crops. Also the water requirement of vegetable crops is low and these give best results if raised on beds especially with sprinkler and drip irrigation methods. Therefore, in the light of need of sustainable mechanization in sowing operation of small seed vegetable crops, the present study was conducted to evaluate performance of pneumatic precision multicrop planter and rotary tiller cum bed former for direct seeding of onion seed on beds and compare its performance with manual transplanting method.

Fig. 1 Outline of pneumatic precision multicrop planter, seed plate and vacuum chamber



1. Air intake of suction fan, 2. 35 mm suction pipe, 3. Crank to adjust seed depth, 4. Gear box, 5. Seed hopper, 6. Drive wheel, 7. Press whee, l 8. Flapper, 9. Inner singulator, 10. Outer singulator, 11. Transmission hexagon, 12. Seed recovery container

2. Materials and Methods

Accurate placement of seeds is necessary for achieving good stand of the crop. Therefore, a tractor operated pneumatic precision multi-crop planter (**Fig. 1**) was evaluated in the field for direct sowing of onion crop. The onion variety used for this study was Punjab Naroya.

2.1 Sphericity

The sphericity (Φ) is defined as the ratio of the surface area of the sphere having the same volume as that of the grain to the surface area of the grain. Sphericity was calculated using the formula given by Mohsenin (1986) as:

$$\Phi = (LWT)^{1/3} / L \qquad ...(1)$$

where,

L = Length of seed (mm)

W = Width of seed (mm)

T = Thickness of seed (mm)

2.2 Angle of Repose

The angle of repose (θ) is the angle between the base and the slope of the cone formed on a free vertical fall of the mass to a horizontal plane. The filling or static angle of repose is the angle with the horizontal at which the kernels will form a heap when piled. This was determined using a topless and bottomless cylinder which was placed at the centre of a raised circular plate. The plate was filled with maize kernels. The cylinder was raised slowly until it formed a heap on a circular plate. The height of the cone was measured and the filling angle of repose (θ_f) was calculated using the following relationship given by (Ozguven and Vursavus, 2005; Galedar et al., 2008) as:

$$\theta_f = Tan^{-1} (2H / D) \qquad ...(2)$$

where,

H = height of cone (cm)

D = diameter of cone (cm)

2.3 1,000 Kernel Weight

One thousand (1,000) kernel weight was used in handling the processing of grains. In earlier day's 1,000 kernel weight were used in determining the density of kernels. To determine 1,000 kernel weight, one hundred maize kernels were counted manually and the kernels weight were weighed by means of an electronic weighing balance having an accuracy of 0.01 g and extrapolating the value obtained to give the mass for 1,000 kernels.

Table 1 presents the results obtained for the physical properties of onion seed under the given field condition. The physical properties of onion seed such as sphericity and angle of response as contained in **Table 1** were determined using the expression given in **Equations 1** and **2** under subsections 2.1, and 2.2, respectively. The weight of 1,000 kernels was obtained using the procedure presented under subsection 2.3.

The main components of precision multicrop planter were metering plate, vacuum chamber, gearbox, gear and chain sprocket drive, furrow opener, spring loaded soil covering flaps and steel wheels. This machine consisted of two seed planters which had provision for spacing adjustment for the various vegetable crops. The spacing between rows is also adjustable depending upon type of crop.

2.4 Detail of Pneumatic Precision Multicrop Planter

2.4.1 Suction Fan

A suction fan with a capacity to develop suction pressure of about 1,000 mm of water column (0.1 kg.cm^{-2}) was provided to provide necessary suction pressure to pick up seeds at the metering plate. It was connected to the vacuum chamber through a 35 mm flexible suction pipe and fitting which included valves for pressure regulation. A pressure gauge was used to measure the suction pressure at the outlet of the vacuum chamber. The pressure gauge has two zones: a green zone that indicates the suction from 200 to 400 (suitable for small seeds, up to onion seeds) and a red zone 500 to 700 (suitable for larger seeds).

2.4.2 Compressor Fan

A compressor fan with a capacity to develop a pressure up to 85 psi (5.98 kg.cm^{-2}) was provided to disconnect seed from the seed plates. It provided necessary pressure to release the seed at the bottom of plate. Both the compressor fan and suction fan were operated by belt drive which is powered by the tractor's PTO.

2.4.3 Seed Metering Unit

The most important requirement of pneumatic precision multicrop planter is to pick single seed for each hill and drop it at specified distance. The seed metering unit was provided to pick up single seed with negative pressure (vacuum). It consisted of an integrated assembly of vacuum housing, seed metering plate and seed hopper. The metering plate as shown in (**Fig. 1**) of section 2, mounted within seed housing and vacuum chamber, had holes of appropriate size along and inside its periphery. One face of the metering plate was exposed to the vacuum, while other to seeds. The suction pressure applied on one side of the plate caused sucking of air through

Table 1 Physical properties of onion seed (*Punjab Naroya variety*) and field parameters

Parameters	Range/value
Equivalent diameter (mm)	2.96-3.10
Sphericity (%)	71.30-81.25
One thousand (1,000) kernel weight (g)	2.90-3.10
Angle of repose (°)	24.12
Soil type	Sandy loam
Longitude	75º49'09.082''E
Latitude	30º54'39.286''N

the holes which made the seeds to stick and be held on the holes while the plate rotated. The seeds were released at a pre-determined location by cutting off the suction pressure against the plate holes. Seed metering plate rotates in between the vacuum chamber and seed hopper to pick up seeds from the seed hopper and then release at a pre-determined location. The thickness of the seed metering plate should be kept minimum possible with adequate flexural strength to ensure its smooth rotation. The seed metering plate was made from stainless steel plate of 1.0 mm thickness (**Table 2**). Holes were drilled at a specified pitch circle diameter so that the holes should be in line with the middle of the cavity in the vacuum chamber. A small countersunk was made on one end of each hole to facilitate more suction of air through it. The plate was fitted on the shaft so that the countersunk side of the holes was exposed to the vacuum chamber. The seed plate had on one side a series of brass pins for seed agitation. However, for different size of seeds the seed plates with different number and size of holes can be used.

Table 2 Specifications of pneumatic precision multicrop planter

Specifications of Pneumatic precision multicrop planter	
Make	Agricola Italiana
Overall dimensions, (L × B × H), mm	2030 × 1700 × 1300
Tractor HP required	≥ 22.38 kW
Type	PTO operated
Vacuum range	0-1000 mm of H_2O (0-0.1 $kg.cm^{-2}$)
Releasing pressure, bar	0-6 (0-85 psi or 0-5.98 $kg.cm^{-2}$)
Vacuum range during field operation, mm of H_2O	200-400 mm of H_2O
No. of seed planters	2
Spacing between planters, mm	140-900 (adjustable for different crops)
Metering plate dimensions	
Diameter of inner most circumscribed circle, mm (having brass pins)	175
Size of brass pin, mm	2 × 3 (diameter 3 mm)
Spacing between consecutive brass pins, mm	43.0
No. of brass pins on plate	12
Outer diameter of metering plate, mm	235
Pitch circle diameter, mm (for holes)	190
Spacing between consecutive holes, mm	10
No. of holes in plate	60
Diameter of each hole, mm	1.0
Side of hexagonal slot in centre of metering plate, mm	14.0
Cross section of hexagon, mm	28 × 24
Press wheels	
Pressing wheel	One in front and one at the rear of each furrow opener
Size of press wheel (diameter × width), mm	235 × 80
Specifications of container (for collection of left over seed)	
Height, mm	200
Top diameter, mm	160
Bottom diameter, mm	150
Hexagonal shape Central driving shaft (with 6 bearings)	
Length of each side of hexagon, mm	10
Length of shaft, mm	2030
Driving tyre diameter	620
Rim diameter, mm	410
Tyre width, mm	130
Centre spacing between tyre to tyre, mm	1,270 (adjustable)
Flapper spacing, mm	70
Flapper height, mm	20

2.4.4 Vacuum Chamber

The vacuum chamber made by aluminum casting, was machined and fitted to the frame. The housing was provided with an annular cavity which was divided in two parts to create and release vacuum. First part, covering 310° annular spaces was acting as a vacuum chamber which was connected to the aspirator by means of a flexible rubber pipe. The second part covering remaining annular space 50° was provided with a hole of 10 mm diameter for maintaining atmospheric pressure (vacuum cut-off), so that the seeds stuck on the holes could be released. A nylon ring was provided in the vacuum chamber, which provided an effective vacuum seal as the seed metering plate rotated and also reduced wear and friction on the seed metering plate. The drive shaft was of hexagonal section so that the seed metering plate could be mounted and dismantled conveniently.

2.4.5 Seed Hopper

The seed hopper was made by aluminum casting and machined to fit properly on the vacuum chamber. The upper part of the hopper was rectangular in shape with a smooth curved surface towards the end. This ensured easy flow of seeds to the seed metering plate by gravity. Two openings were provided, one at the bottom and the other at the upper side. The lower opening was for seed delivery while that at the upper was for visual inspection of seed picked up. A plate was also fitted near the seed outlet to guide the seed to the furrow opening. The furrow opener was directly attached to the vacuum chamber to minimize the seed dropping height. The seed selectors are provided to minimize double seeds.

2.4.6 Frame

The frame of the seed metering unit was made of 5 mm mild sheet (MS) sheet on which all the accessories were attached. This frame was mounted on the main bar which was provided with a screw type depth adjustment. Adjustable spring loaded parallelogram linkage was used for applying upward or downward pressure on shoe opener. The seed metering unit and gear drive were fitted on this frame.

2.4.7 Furrow Opener

The furrow opener consisted of two parts, one was MS sheet metal bracket and the other was the shoe opener made of cast iron. The bracket also acted as a seed tube through which the seeds were dropped into the furrow. The shoe openers were attached to the bottom of the bracket. The depth of planting was regulated by lowering the shoe opener through a screw type depth adjusting mechanism fitted on the frame.

2.4.8 Soil Covering Bars and Press Wheel

Adjustable spring-loaded steel soil covering bars were provided to put the correct amount of soil over the seed. The front wheel which is made of steel controls the seed depth and the rear wheel which is made of rubber slightly compacts the soil over the seeds. Metallic scrapers were provided to remove soil stuck on the wheel.

2.4.9 Drive System

The drive system as shown in **Fig. 2** rotates the seed metering plate at specified speeds which isachieved through the combination of drive wheels, chain-sprockets and gears. A Norton gear system provides simple and fast gear change to vary seed spacing. An intermediate shaft of hexa-section was provided along the main bar to transfer drive from the ground wheels. A multi-speed gear-box was provided in between the ground wheels and intermediate hexagonal shaft and the seed metering plate. Chain-sprocket system was used to drive hexagonal shaft and the seed metering plate rotation. It was necessary to minimize the velocity of the dropped seeds relative to forward speed of multicrop planter to minimize bounce and to ensure proper placement of seed. Therefore, a series of transmission gears was provided between hexagonal transmission shaft and seed plate. This gear transmission was used to rotate the metering plate in the opposite direction with respect to the forward travel of the planter.

2.5 Precision (C)

Precision is a measure of the variability in spacing after accounting for variability due to both multiples and skips. The degree of variation is the coefficient of variation of the spacing that are classified as singles, and expressed as:

$$C = S \times 100 / X_{th} \quad ...(3)$$

where,

S = Sample standard deviation of the n observations, cm

X_{th} = theoretical spacing, cm

The rotary tiller cum bed former-as shown in **Fig. 3** was used to make beds prior to sowing by pneumatic precision planter having working width of 1.3 m (**Table 3**).

2.6 Forward Speed

The operational speed of machine was calculatedusing a stop watch to determine the time taken to cover a

Table 3 Specifications of tractor operated rotary tiller cum bed former

Specifications of Pneumatic precision multicrop planter	
Make	FORIGO douplex
Overall dimensions (L x B x H), mm	2100 × 1950 × 1350
HP required	≥ 44.76 kW
Power Transmission	Cardan shaft with shear bolt torque limiter SB
Universal 3 Points linkage	2nd category
Gear box one speed	P.T.O. 540 rpm
Metal front seal in oil bath on rotors.	--
Couple of front disk adjustable in width and bath	Ø 460 mm
Couple of rear wheels	adjustable in width and height
Height of hitch, mm	1,320
Working width, mm	1,300
Hub diameter, mm	70
No. of flanges on hub	13
No. of blades on each flange and pattern	4, staggered
Length of each blade, mm	280
Spacing between flange to flange, mm	110
Diameter of middle drum (excluding lugs), mm	280
Dimensions of each lug on middle drum, (L × B × H), mm	40 × 37 × 27
Pattern and horizontal and vertical spacing between lugs, mm	Staggered, 50 and 40
No. of lugs on consecutive rows	14 and 13
Diameter of shaping drum, mm	320
Tyre width, mm	140
Tyre diameter, mm	380
Rim diameter, mm	230
Disc coulter diameter, mm	460
Height of bed formed (adjustable), mm	150

Fig. 2 Norton Gear system

Fig. 3 Front view of rotary tiller cum bed former

measured distance in the field. This can be expressed mathematically as:

$v = S / T$ ...(4)

where,

V = operational speed (m/s)

S = distance covered (m)

T = time taken (s)

2.7 Estimation of Field Capacity

Theeffective field capacity of planter was calculated using the formula given by Kepner et al. (1978) as:

$C = SW / 10 \times E_f / 100$ ...(5)

where,

C = effective field capacity (ha.h^{-1})

S = speed of travel (km.h^{-1})

W = rated width of implement (m)

E_f = Field efficiency (%)

where, $E_f = 100\ T_o / T_e + T_h + T_a$,

T_o = theoretical time per hectare (per acre), T_e – effective operating time = $T_o \times 100 / K$

K = percent of implement width actually utilized

T_h = time lost per acre due to interruptions that are not proportional to area

At least part of T_h usually tends to be proportional to T_e

T_a = time lost per acre due to interruptions that tend to be proportional to area

2.8 Estimation of Fuel Consumption

In order to obtain the fuel consumed during the sowing, a fuel consumption meter was attached to the tractor. The fuel consumption reading at the start and end point of the field experiment were observed and the fuel consumption value was measured as:

$F = 3.6 \times L / T$ ...(6)

where,

F = fuel consumption (l.h^{-1})

L = fuel consumption meter readings difference i.e. $L_f - L_i$ (ml)

T = time for particular length (s)

L_f = Fuel consumption meter readings at start of experiment (ml)

L_i = Fuel consumption meter readings at finish of experiment (ml)

3. Evaluation of Pneumatic Precision Multicrop Planter in the Field

The field was prepared and beds with top width of 1.25 m were prepared through a tractor operated rotary tiller cum bed former (**Figs. 4** and **5**) at the departmental research farm in years 2014 and 2015. The treated and weighed onion seed were put in two hoppers provided above the metering mechanism of the machine. The machine was operated in the field to observe the machine's forward speed, fuel consumption and plant to plant (intra-row) spacing. The Punjab Naroya onion seed variety was used for the field study with a two-row tractor operated precision planter. The onion seed rate for 0.20 × 0.075 m plant spacing was 5.00 kg.ha^{-1} with precision multicrop planter whereas the onion seed rate in the transplanting method was 12.50 kg.ha^{-1} (recommended).

The performance evaluation of the pneumatic precision multicrop planter was carried out for sowing singulated seeds of onion in the field at a spacing of 0.20 × 0.075 m (**Fig. 6**). It was operated in the field for direct sowing of four rows of onion seed on beds and parameters like forward speed, fuel consumption, field capacity, depth of seed placement and plant to plant spacing were recorded. The transplanting method spacing was kept at 0.17 × 0.065 m on beds. The software CPCSI was used for conducting statistical analysis.

4. Results and Discussions

The rotary tiller cum bed former made beds with overall width of 1.25 m for tilled as well as untilled soil. The other specifications of bed are shown in **Table 4**. Its mean fuel consumption (FC) for tilled and untilled soil was 6.93 and 7.01 L.h^{-1}, respec-

Fig. 4 Line diagram of bed formed in tilled soil by rotary tiller cum bed former

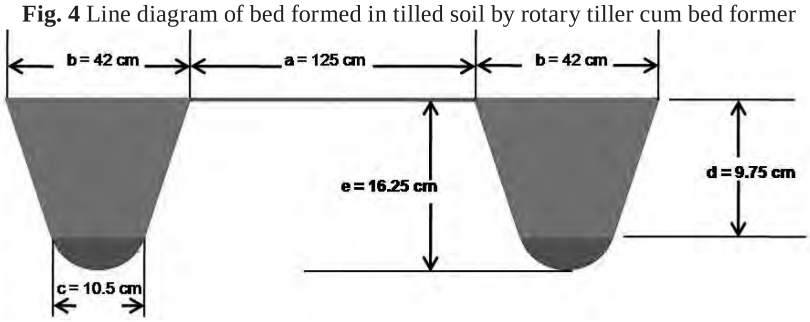


Fig. 5 Rotary tiller cum bed former in operation

tively and mean field capacity was 0.30 ha.h^{-1}. The pneumatic planter was operated on beds of width 1.25 m made by rotary tiller cum bed former in tilled soil. The tilled soil was selected for sowing owing to small size of onion seed and for facilitating better soil condition for its germination. Different parameters of both machines such as forward speed, fuel consumption, depth of seed placement, bed width, depth etc. were measured (**Table 4**). Operating at an average speed of 3.36 km.h^{-1}, the planter placed the onion seeds at desired spacing of 0.20 m, average plant to plant spacing of 0.075 m and average depth of 0.02 m. With a mean effective field capacity of 0.17 ha.h^{-1}, the pneumatic planter's fuel consumption was 2.65 L.h^{-1}.

The effect of tilled and untilled soil on depth of bed and channel was statistically found to be non-significant and its effect was significant for width of water channel at the top and was non-significant for width of water channel at bottom. The average saving time using the precision multicrop planter as compared to manual method was 98.53%. It provided accurate placement of seeds with minimum of skips and doubles. The seed metering plate rotates in the opposite direction of machine travel, which reduced the relative velocity with respect to the ground. This minimized "bounce" of the seed leading to much more accurate placement. In comparison with the precision planter, the onion seedlings were also sown using the traditional manual transplanting method on beds. In manual transplanting method onion nursery was transplanted at spacing of 0.15 × 0.075 m. After the germination of onion crop parameters like number of plants per 5 meter length, plant to plant and row to row spacing were measured (**Table 5**).

The average number of plants per 5 meter length were 59, average plant to plant (intra-row) spacing was 7.96 cm and average row to row spacing was 20.42 cm. The variation observed in plant to plant spacing in field is shown in **Fig. 7**. It

Fig. 6 Direct sowing of onion seed on beds

is clear from **Table 5** that the mean plant to plant spacing and row to row spacing for pneumatic precision multicrop planter were 7.86 cm and 20.42 cm, respectively. The observed mean precision index of machine was 4.52%. At maturity stage of onion crop, the onion crop were harvested and test parameters like number, weight of bulbs per m^2 were recorded as shown in **Table 6**. This was done for both pneumatic precision multicrop planter sown and manually transplanted fields. Other measured test parameters aside the earlier ones mentioned where also presented in **Table 6**. These measured test parameters

Table 4 Field evaluation of rotary tiller cum bed former and Pneumatic precision multicrop planter

Rotary tiller cum bed former

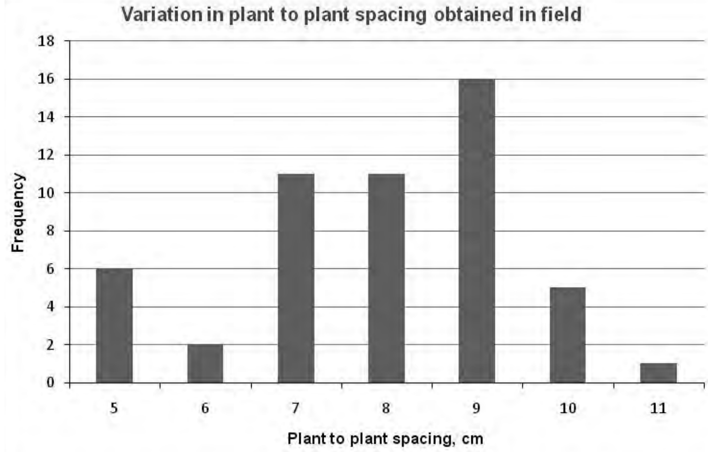
S. No.	Forward speed^{ns} km.h^{-1}		Fuel consumption^{ns} L.h^{-1}		W_b^{ns} a, cm		Depth of channel, cm UT^{ns}		Depth of channel, cm TD^{ns}		WWC_t b, cm		WWC_b^{ns} c, cm	
	T	UT	T	UT	T	UT	T	UT	T	UT	T	UT	T	UT
1	2.50	2.2	7.04	7.00	125	125	10	9	17	15	40	42	10	10
2	2.00	2.5	6.35	6.80	125	125	10	9	15	19	40	42	11	11
3	3.00	2.4	7.41	7.20	125	125	10	11	18	16	40	42	10	10
4	2.79	2.3	6.91	7.05	125	125	10	10	19	15	40	42	11	10
Mean ± SE	2.57 ± 0.08	2.35 ± 0.03	6.93 ± 0.07	7.01 ± 0.03	125 ± 0.00	125 ± 0.00	10 ± 0.00	9.75 ± 1.92	17.25 ± 0.31	16.25 ± 3.21	40 ± 0.00	42 ± 0.00	10.5 ± 0.13	10.25 ± 0.09
$LSD_{0.05}$	--	--	--	--	--	--	--	--	--	--	0.223420E-05		--	--

Pneumatic precision multicrop planter

S. No.	Forward speed km.h^{-1}	Fuel consumption L.h^{-1}	Depth of seed cm	Effective field capacity, ha.h^{-1}	Manual transpl. capacity (including nursery raising), ha.h^{-1}	Saving in time with precision multicrop planter as compared to manual method, %
1	3.36	2.70	2.00	0.17	0.0025	98.53
2	3.42	2.88	1.90	0.18	0.0026	98.55
3	3.30	2.36	2.00	0.16	0.0024	98.50
Mean ± SE	3.36 ± 0.01	2.65 ± 0.06	2.00 ± 0.14	0.17 ± 0.00	0.0025 ± 0.00	98.53 ± 1.80

Keynote: W_b -top width of bed, UT- depth of upper trapezoidal section of channel, TD- total depth of channel, WWC_t- width of water channel at top, WWC_b-width of water channel at bottom, T: tilled soil, UT: untilled soil with paddy residue (in manual harvested field, height of cut close to ground) ns: non-significant

Fig. 7 The variation observed in plant to plant spacing in field



include weight of bulbs, number of bulbs and weight of leaves per m^2.

The mean numbers of bulbs per m^2 were 60.5 and 68 for pneumatic precision multicrop planter sown and manual transplanted onion. The weight of bulbs per m^2 for pneumatic precision multicrop planter and manual method were 2.39 and 3.93 kg, respectively.

The mean bulb weight and yield for pneumatic precision multicrop planter and manual transplanting were 57.45 g and 9,562 kg.acre^{-1} and 57.86 g and 10,515 kg.acre^{-1}, respectively. The effect of two onion sowing techniques was found to be significant for mean bulb yield at 5 % level of significance.

4.1 Economics Analysis

Table 7 presents the economic analysis involved with the use of pneumatic precision multicrop planter and manual transplanting method. The cost of field operation, seed cost, fertilizer and weedicides cost, labour cost etc. were included in this study. The cost of diesel, labour and tractor operator were Rs. 52 per liter, Rs. 31.25.h^{-1} and Rs. 40.h^{-1}, respectively. Total man hours involved in manual method were 160 h or 20 man days. In manual method seed rate is higher and 5-6 person sows onion nursery for 1 ha in around 20 h. The onion seed germinates around 7-10 days and then transplanting the same seedlings in an area of one hectare is done in 20 hours by 15 people. Thus one hectare area is completed in around 15 days whereas the machine had a field capacity of 0.17 ha.h^{-1}.

There was an overall saving of Rs. 1974.11/ha with pneumatic precision multicrop planter as compared to manual transplanting method.

In India, the shortage of labour at the crucial time and increasing labour cost make onion mechanization inevitable. This intervention is mainly solicited in labour intensive works, that is., sowing, transplating, harvesting etc. Direct seed sowing with the use of local and pneumatic seed drill machine were compared with the manual direct seed sowing (broadcasting) and seedling transplanting methods (DOGR, 2013). Among various direct sowing methods, bigger bulbs, more percent of A grade bulbs and less number of double bulbs were observed in sowing done through the use of pneumatic seed drill. However, transplanting method of onion production re-

Table 5 Germination data for onion crop for pneumatic multicrop planter

S. No.	No. of plants / 5 m length				Row to row spacing, cm	SD[a], cm	Plant to plant spacing, cm	Precision index, (PI) %
	1st row	2nd row	3rd row	4th row				
1	62	58	60	61	20.00	0.42	7.33	5.59
2	57	61	62	55	20.33	0.29	8.00	3.84
3	63	55	54	56	21.00	0.36	8.00	4.81
4	56	60	58	59	20.33	0.29	8.10	3.84
Mean ± SE[b]	59 ± 0.60				20.42 ± 0.03	0.34 ± 0.00	7.86 ± 0.08	4.52 ± 0.00

[a]: standard deviation plant to plant spacing, [b]: standard error

Table 6 Yield data for pneumatic precision multicrop planter and transplanting method

Source	df	No. of bulbs per m^2	Wt. of bulbs kg per m^2	Wt. of leaves kg per m^2	Mean Bulb weight, g	Mean bulb yield kg per acre
Pneumatic precision planter						
Treatments	1	59	3.13	0.38	53.05	9,562
Error	6	58	3.34	0.37	57.58	
Total	7	64	3.85	0.50	60.16	
		61	3.60	0.56	59.02	
Mean		60.5	3.48	0.48	57.45	
Manual transplanting method						
Treatments	1	78	4.46	0.74	57.18	10,515
Error	6	64	3.76	0.62	58.75	
Total	7	61	3.59	0.45	58.85	
		69	3.91	0.70	56.67	
Mean		68.0	3.93	0.62	57.86	
F-ratio		3.61^{ns}	3.38^{ns}	4.88^{ns}	0.06^{ns}	367.36
$LSD_{0.05}$		--	--	--	--	120.33*
CV		8.69	9.34	20.75	4.06	0.69

^{ns}: non-significant, * significant at 5 % level.

corded the highest marketable yield, which was significantly higher over the direct sowing that involved the use of pneumatic seed drill. But low seed rate, easy sowing, saving in time and early maturity of onion were observed in sowing with pneumatic seed drill. The lowest marketable yield was observed in Poona seed drill followed by manual sowing (broadcasting) method.

This study also focused on the pneumatic precision multicrop planter for the different types of seeds in which by changing the metering plate and the suction pressure the sowing of different seeds can be done precisely which amounts to saving of time and labour. Besides, this machine is suitable for custom hiring purpose in respect to small land holdings in India.

5. Conclusions

The rotary tiller cum bed former made beds with an overall width of 1.25 m recorded mean fuel consumption values of 6.93 and 7.01 $l.h^{-1}$ for tilled and untilled soil conditions, respectively. The bed top width was same as 125 cm for both tilled and untilled conditions. The width of water channel at top was 40 cm and 42 cm for tilled and untilled soil, respectively. The mean precision index of pneumatic precision multicrop planter as observed during field operation was 4.52 %. The mean numbers of bulbs per m^2 were 60.5 and 68.0 for pneumatic precision multicrop planter sown and manually transplanted onion, respectively. The weight of bulbs per m^2 for pneumatic precision multicrop planter and manual method were 3.48 and 3.93 kg, respectively. The mean bulb weight and yield were 57.45 g and 9,562 $kg.acre^{-1}$ for pneumatic precision multicrop planter and 57.86 g and 10,515 $kg.acre^{-1}$, respectively for transplanting method. The higher yield in manual transplanting method can be attributed to the fact that in transplanting method the seed germination count factor was minimized and plant population was complete, whereas in direct sowing with pneumatic precision planter, the seed germination count factor affects plant population and thereby the mean bulb yield. However, onion seed with higher germination count will enhance the performance of pneumatic precision planter. The saving in cost and time with pneumatic precision multicrop planter were 55.12% and 98.53%, respectively, when compared with the transplanting method. The net returns from onion sown by pneumatic precision multicrop planter and transplanting method were Rs. 192,248.94 and 190,274.83 per ha, respectively. The B:C ratio for pneumatic precision multicrop planter and transplanting method were 5.11:1 and 2.62:1, respectively. Thus with precision multicrop planter we can save seed, time as well as labour cost. With precision planter, we can increase area under different vegetables as by changing only metering plate it can also be used for sowing of other small seed crops like car-

Table 7 Economic analysis of pneumatic precision multicrop planter and transplanting method

Parameters	Pneumatic precision multicrop planter	Transplanting method
Cost of bed making with tractor operated rotary tiller cum bed former (fixed and variable), $Rs.ha^{-1}$	1,733.93	1,733.93
Seed required, $kg.ha^{-1}$	5.00	12.50
Seed cost, $Rs.ha^{-1}$ [@Rs. 2000 per kg]	10,000.00	25,000.00
Seed treatment cost, $Rs.ha^{-1}$	10.00	10.00
Machine cost (fixed and variable), $Rs.ha^{-1}$	4,825.89	--
Labour cost of manual nursery and transplanting, $Rs.ha^{-1}$	----	15,625
Cost of fertilizer, $Rs.ha^{-1}$ [1.5 qtl SSP + 1 qtl urea + MOP 40 kg per acre]	5,911.25	5,911.25
Cost of weedicide [Goal (1 spray after 1 week) and Fungicide M-45 (2 sprays intermediate) per acre] along with cost of engine operated knapsack sprayer and labour , $Rs.ha^{-1}$	4,856.58	4,856.58
Cost of manual weeding with labour, $Rs.ha^{-1}$	6,250.00	6,250.00
Irrigation and application cost, $Rs.ha^{-1}$ [15 irrigations per acre]	5,890.62	5,890.62
Harvesting cost, $Rs.ha-^{1}$ [Tractor operated digger + manual picking with 4 persons @ Rs. 31.25 h^{-1}]	7,322.79	7,322.79
Grand cost, $Rs.ha^{-1}$	46,801.06	72,600.17
Saving in operational cost, %	55.12	-----
Mean yield, $kg.ha^{-1}$	23,905.00	26,287.50
Income, $Rs.ha^{-1}$ [@ Rs. kg^{-1} 10.00]	239,050.00	262,875.00
Net returns, $Rs.ha^{-1}$	192,248.94	190,274.83
(USD* . ha^{-1})	*2,902.31*	*2,872.51*
B:C	5.11:1	2.62:1

1 USD = 66.24 Indian rupees, SSP- Single super phosphate, MOP- Muriate of potash

rot, cauliflower. Cabbage, broccoli, cucumber, coriander, fennel, asparagus, lettuce, tomato, sunflower etc. and it is feasible for custom hiring operation under Indian conditions.

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■■

ABSTRACTS

The ABSTRACTS pages is to introduce the abstracts of the article which cannot be published in whole contents owing to the limited publication space and so many contributions to AMA. The readers who wish to know the contents of the article more in detail are kindly requested to contact the authors.

1703

Positioning of Agricultural Equipment Maintenance and Repair Service Centers Using Reilly's Center of Gravity Models: B. Psiroukis, A. Natsis

The purpose of this research is to identify a method that allows agricultural equipment service companies to define the ideal location for the establishment of a new repair and maintenance service center, based on the total annual workload of the currently existing centers in the nearby regions, using the corporate headquarters' location as a reference point. The positioning of the currently existing service centers also defines whether a customer from a certain region will show interest in visiting one of these service centers, and in this case, which one would he choose. The results of this research and the methods introduced may help agricultural equipment service companies reduce excessive costs, improve service quality and consult their customers about which one of their service centers is the most suitable for them to visit. ■■

1713

Status of Farm Mechanization in Bhopal Region of India Using Artificial Neural Network: Manoj Kumar, C. R. Mehta, V. Bhushana Babu, Anurag K. Dubey

Farm mechanization is one of the most important input in agricultural production system for timely completion of agricultural operations to increase productivity and to maintain sustainability on the farm. Considering the importance of agricultural mechanization, a study was carried out to quantify agricultural mechanization status in Bhopal region (Bhopal and Sehore districts) of Madhya Pradesh in India. The primary data were collected using developed questionnaire. The objective of the study was to find out relationship between mechanization index (MI) and other input variables. The inputs for the study were net cultivated area, net irrigated area, area under soybean crop, area under wheat crop, average holding size, cropping intensity and irrigation intensity and output variable was mechanization index (MI). The Artificial Neural Network (ANN) architectures based on Multi-layered Perceptron (MLP) were used in modelling mechanization index. The best model was selected on the basis of Mean Absolute Percentage Error (MAPE). An ANN architecture having 1 hidden layer and 5 neurons was found to be the best to predict mechanization index in Bhopal region. It was also observed that the mechanization index was highly sensitive to net cultivated area and followed by net irrigated area and area under wheat crop in the region. ■■

1724

Effect of Microwave Radiation on Reduction of Potato of Tubers Storage Losses – Evaluation of Suitability: Tomasz Jakubowski

The goal of the paper is to evaluate the suitability of the 2.45 GHz microwave radiation in reducing the potato tubers (*Solanum tuberosum L.*) storage losses. The experiment was conducted between 2011 and 2014 for three consecutive storage seasons on six edible potato varieties: Lord, Owacja, Vineta, Ditta, Finezja and Tajfun. It was determined that reaction of potato tubers to microwave radiation defined by processes taking place during the storage has a varietal character. Some microwave-irradiated combinations showed tendencies for increased germination. One potato variety responded to microwave radiation with significantly lower degree of infection by black scurf (Rhizoctonia solani). The calculated percentage values of total losses, natural losses, and germination losses do not indicate that the physical method based on the action of 2.45 GHz microwaves and exposure time of 10 s can be qualified as a way to reduce the potato storage losses. From the agricultural practice point of view, the amount of storage losses caused by pathogens is also important. In four potato varieties irradiated in the experiment the amount of disease losses was lower in relation to the control group. ■■

1727

Agricultural Mechanization-An Alternative to Rural Development in the State of Gujarat, India: Surya Nath, Abhinab Mishra, Vipal Mansuriya, Bhalchandra Vibhute, Hina Bhatu

India is basically an agrarian country and almost 60% of the population is engaged in Agriculture. The rate of population growth is still on high side and to cater the need of growing population is a real challenge to planners and implementers. The state of Gujarat situated on the western coast of India, is in unique situation to produce, process and distribute the agro-based produce to the majority of the nation's state. The arid and semi arid regions can be exploited to produce variety of Agricultural products solving food problems. Keeping some of the criteria like land availability, manufacturing hubs of many products and suitable infrastructures, agricultural mechanization in Gujarat have been covered in the write up. The soil and the climate, area under crop production, prospects and constraints of agricultural mechanization, future energy requirements, role of fruits and vegetables in economic development have been discussed. Suggestions have been put forward for the development strategy of agriculture and allied industry for the state of Gujarat. It is hoped that the development planners shall look into such suggestions. ■■

1744

Effect of Spike Spacing and Cylinder Speed on Spike Tooth Cylinder Performance for Threshing of Cumin Crop: Sachin Pathak, Abhay Kumar Mehta

The performance for cumin threshing by spike tooth cylinder was evaluated based on three spike spacings and four cylinder speeds with constant concave clearance and grate spacing. Test results indicated that threshing efficiency was maximum at 50 mm spike spacing and 17.19 m/s cylinder speed. The values obtained for selected dependent variables were different from one another at each cylinder speed and spike spacing therefore, overall threshing loss was also considered as an important criteria for finalization of parameters. At the combination of 65 mm spike spacing and 14.51 m/s cylinder speed, the optimum threshing efficiency was observed with minimum overall threshing losses. The obtain results can effectively be used for the development of cumin thresher. ■■

1745

Energy Analysis of Jatropha Curcas Plantation in Indian Context: V. B. Shambhu, T. K. Bhattacharya, S. K. Chaudhary

Agriculture requires two major resources land and energy and agricultural productivity could be linked directly to the energy inputs. Jatropha curcas is a multipurpose, drought resistant, perennial plant with many attributes and considerable potential. The energy requirement for raising nursery and establishment of the crop Jatropha plant during first year has been estimated as about 428.2 and 11,553.6 MJ/ha respectively. The total energy requirement for cultivation of crop during second year amounts to 5,442.4 MJ/ha. The energy requirement from third year onwards till the economic life of cultivation would be estimated as 8,757.1 MJ/ha /year. Field preparation is the most energy consuming operation which amount to 4,223.9 MJ/ha of the total energy input during initial period but after plant establishment fertilizer application becomes the highest energy consuming operation requiring about 39.66% of total operational energy input followed by oil expelling (19.10%), harvesting of fruits (15.20%). Source-wise energy requirement for 35 years economical life of Jatropha crop cultivation through seed, diesel, human, FYM, fertilizer, chemicals, machinery and electricity would be 0.8, 3.94, 68.73, 27.3, 120.45, 4.48, 62.11 and 19.32 GJ/ha respectively. It has been found that total energy requirement for 35 years cultivation of Jatropha curcas L. crop would be 306.41 GJ/ha. ■■

1747

Status of Farm Power and Mechanization in Punjab Agriculture: Shiv Kumar Lohan, Naresh Kumar Chhuneja, Ravinder Singh Chhina, Ajaib Singh, Gagan Jyot Kaur, Vicky Singh, Hardeep Singh Sabhikhi

To estimate the power availability and machines in Punjab agriculture, data were collected from 200 selected villages of 5 districts of the state. The surveyed villages have 91,600 ha of net cultivated area out of which 83,114 ha was irrigated by tubewell. The density per thousand hectare of net sown area of the sample villages were about 933 agricultural workers, 16 bullock pairs, 262 electric motors, 106 diesel engines, 154 tractors and 8 self propelled combine harvesters. On the basis of surveyed villages, it is estimated for Punjab state that there are about 38,72,304 agricultural workers as human power, 67,008 bullock pairs as animal power, 10,88,975 electric motors for irrigation pump-sets and 4,41,416 diesel engines, 6,37,637 tractors and 34,206 self propelled combine harvesters. The power availability of the state was found to be 7.79 kW per hectare of net cultivated area of Punjab state. Out of the total available power, the major contribution is from mechanical power (84%) and electrical power (15%). An estimate was also made for various manual operated, animal operated and tractor /power operated agricultural machines and implements. ■■


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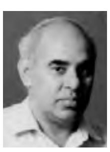
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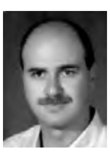
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MOROOKA Co., Ltd.
358, Shoubeeshindenmachi, Ryugasaki city, Ibaraki Prefecture, 301-0031, Japan
TEL : +81-297-66-2111 FAX : +81-297-66-3110 E-mail : info@morooka.co.jp
URL : www.morooka.co.jp (Japanese) www.morooka.com (English)