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EDITORIAL

The world's population continues to grow. According to the UNFPA's World Population White Paper 2023, the world population in 2023 was 8.045 billion, an increase of 76 million over the previous year.

This is the first time that the world population has surpassed 8 billion. India overtook China as the world's most populous country, which had previously topped the list, with the population of 1.4286 billion, followed by China with 1.4257 billion, and the United States with 340 million in third place.

In Africa, Nigeria has the largest population, having already surpassed the 200 million mark with 223.8 million people. Japan has 123.3 million. The amount of farmland per capita is decreasing every year: in 2020, the world's farmland per capita was about 0.177 hectares; assuming little change in the amount of farmland, divided by the population in 2023, the amount of farmland per capita in 2023 will be 0.1724 hectares, a 2.5% decrease. This rate means that in about 80 years, the amount of farmland per capita will be less than half. What will it take to cope with this phenomenon? The most important thing is to increase yield per unit area. Land productivity must be increased. What is needed is precise and timely work. New agricultural mechanization is indeed needed to do that.

Agricultural mechanization has been more advanced, i.e., larger in size and power. However, with agricultural machinery robot technology, we are now entering an era in which small agricultural machinery robots, rather than large agricultural machinery, will play an active role. Since there will be no human on the farm machinery robots that do the work unattended, it will be okay if they take a lot of time.

A new era of agricultural mechanization, or robotization of agricultural machinery, is about to arrive not only in developed countries but also in developing countries. It is of utmost importance for agricultural machinery manufacturers to develop and produce new agricultural machinery that is compatible with this new era.

Yoshisuke Kishida
Chief Editor
December, 2023

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Development of Gin Trash Handling System to Prevent Dissemination of Pink Bollworm from Cotton Ginneries

by

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Abstract

Cotton ginneries are observed as one of the source for reintroduction of pink bollworm (PBW); as during ginning operations alive PBW gets escaped through gin trash and get disseminated in neighborhood cotton fields. Pink bollworm is a dreaded pest that adversely affects cotton yield, fibre quality and thus income of farmers and ginners. Hence it is must to break down life cycle of PBW and prevent damage to cotton crop in subsequent season. A gin trash handling system comprising of centrifugal trash fan, cyclone and compactor was developed with a capacity of 2.5 tons of trash per hour with an aim to crush and treat gin trash in such a way that all PBW are destroyed. Performance of trash handling system in terms of mortality rate of PBW was assessed by using trashes viz. cyclone fly waste, lint cleaner waste and pre-cleaner waste. The PBW culture i.e. larva and pupae were multiplied in the laboratory and mixed artificially in trash samples during experimentation. Experiments were conducted by preparing samples with different configurations of gin trash and PBW culture. Performance testing of trash handling system shown that the system had successfully attained the intended function of destroying PBW. The mortality rate of larva and pupae was found to be 100%. Ginning performance of pink bollworm infected cotton on DR gin showed 17%, 14% and 11% reduction in ginning percentage, fibre length and tenacity respectively along with significant deterioration in colour grade of cotton. Gin trash handling system found suitable to destroy and prevent dissemination of PBW to neighbourhood of cotton ginneries.

Keywords: cotton, ginnery, trash, pink bollworm, destroy

Introduction

Since 2011-12 nearly 90-92% of the total cultivable area under cotton was occupied by Bt cotton in India. Cotton is known to harbour several pests. Among them American bollworm and Pink bollworm (PBW) are of serious concern. The pink bollworm is a dreaded pest. After the introduction of Bt cotton in 2002, there was an excellent response to curtail incidence of all bollworms because the Bt gene provided inbuilt protection against them. Since 2015, the outbreak of pink bollworm (PBW) is seen greatly because of development of resistance to PBW in Bt cotton. During 2015 to 2018, there was sporadic occurrence of PBW in the states of Maharashtra, Andhra Pradesh, Gujrat and Telangana. Cotton growing season of 2017-18 saw an unusual outbreak of PBW in most of the cotton growing districts of Maharashtra. The rough estimates of incidence varied from 20-60% resulting into an estimated loss of yield to the tune of 10-30% in quantity but much more in quality impairment (Mayee et al., 2018). Lukefar et al through experiments conducted at Brownsville, Texas reported 34% reduction in cotton crop value when seasonal infestation counts averaged at least 60% of the bolls infested by pink bollworm. Losses were about equally distributed between reductions in yield and quality of lint and seed. (Lukefar et al., 1963).

The stages in the life cycle of PBW are eggs, larvae, pupae and adult. Pink bollworm is a monophagpous pest, which can multiply only on cotton and no other host crop. PBW has unique ability to diapause as a larvae when climate is unfavourable and become active during favourable conditions. PBW larva can survive in uprooted cotton stalks stored by farmers for fuel purpose and feed and multiply on seed cotton stored in cotton gins. Longer the storage, higher the propensity to multiply. The pupae enter into diapause phase of life cycle of the pest in the absence of cotton crop through cotton crop residues and gin trash. However, if the cotton crop is available beyond this period the pest does not go to resting stage and continue to survive in fruiting parts resulting in early incidence and higher PBW damage (Vennila et al., 2007). Therefore, timely termination of Bt cotton crop is a must to break down the life cycle of PBW resulting in very low carryover of PBW population and low PBW damage in the following season.

The young larva enter cotton bolls and remain inside boll and damages seed and fibre forming tissues. Pink bollworm also causes shedding of immature bolls or staining of the fibres and affect the ginning percentage and spinning quality in case of mature bolls. Besides this, the cottonseed oil, also gets lost to the tune of 5-10%. Pink bollworm significantly affects the yield and quality of cotton fibre and thus adversely affects income of cotton farmers (Mayee et al., 2019).

There is concern that cotton gins may serve as site for reintroduction of PBW. Cotton ginneries are one of the important single factors in disseminating the pest in regions where the cotton fields are located nearby. It is virtually necessary that all PBW entering the gin in the seed cotton should be removed. Where cotton fields are located at considerable distance from the gins, transportation of seed cotton from infested area or the gin leads to the fast spread of PBW in the neighbourhood locality where cotton is ginned. During ginning operations, PBW find its place in the lint and cottonseed. Those not killed by the seed cotton cleaning and ginning machinery reach alive into the trash fractions (Huges et al., 1994).

Level of infestation affects the ginning performance and quality of lint and seed. Reductions in staple length, strength, and fineness or immaturity of fibre are directly related to pink bollworm infestation levels. There is potential for PBW to survive and pass through pre-cleaning and ginning machinery in the gin. Survival potential of PBW passing through the gin stand and segregating into the cottonseed, lint fractions and trash needs to be assessed. From the survival potentials of PBW in cotton gin one can calculate the risk of a live PBW spreading the nearby locality (Huges et al., 1994).

Earlier, experiments were conducted in the USA to determine the survival of larvae in lint cotton and lint cleaner waste, and to understand the effect of arrangements of trash fan inlet piping on kill potential of PBW. The study reported that nearly all the larvae were killed from the lint by the time it reached the lint cleaner. Further the results showed that all larvae passing through the saw types of lint cleaners were killed, but there was some survival when the pneumatic lint cleaner was used (Robertson et al., 1963).

It is important to determine whether or not it is possible to prevent the dissemination of the pest through the gins. It is most likely that live PBW find its way into trash fraction and immature & unopened bolls. It is necessary to kill those PBW in trash fractions and infected bolls before they are disposed of. Presently in ginneries, trash is found scattered in the gin premises. From this place PBW disseminate to neighbouring areas. Therefore it is essential to crush all trashes obtained during ginning with certain device. After that has been done it would be immaterial whether the debris are scattered around gin premises or disseminated to the neighbouring areas. Hence the trash therefrom needs to be treated in such a way as to cause destruction of PBW. A device or system needs to be developed for removing and destroying PBW.

Robertson et al. (1963) conducted test with gin trash fed into a 23-in. trash fan. The use of a 141/2-in. inlet pipe with a 90° elbow connected directly to the fan housing gave mortality similar to that in tests reported previously [*R.A.E.*, A 49 353], in which the inlet pipe was 11 in. in diameter with at least 58 in. of straight pipe between any elbow and the fan housing (Robertson el al., 1963).

Sappington et al. (2004) experimentally determined survival potential of boll weevils passing through various sub processes of the gin, from which the risk of a live boll weevil reaching any point in the process can be ascertained. Reports showed that there is virtually no chance of a boll weevil being segregated alive into the cottonseed or of one surviving in the lint to approach the bale press. Therefore, quarantine or fumigation of cottonseed and cotton bales to guard against boll weevil introductions is unnecessary.

Flat-blade centrifugal fan to process gin trash for killing PBW larvae has been an accepted method of control. Studies conducted on flat-blade centrifugal fan to kill pink bollworm by indicated that fan tip speeds above 3,962 m/min (13,000 ft/min) resulted in 100% mortality of pink bollworm larvae contained in green bolls regardless of fan wheel diameter. Specifications for the operation of pink bollworm fans from 48.3 to 82.6 cm diameter forms part of USDA, APHIS regulations (Huges et al., 1995).

The pink bollworm is a public nuisance and a menace to the cotton industry, and its eradication is a public necessity. Ginneries are equally responsible for dissemination of the PBW which has not been realized generally. If it is possible to control the pest at gins, it will retard its rate of spreading. Unless measures are taken to control and eradicate PBW in gins, the menace of PBW will continue. Therefore the present work has been undertaken with an aim to evaluate effect of pink bollworm infestation of ginning performance and to develop and evaluate trash handling system for eradication of PBW from cotton gin trash in ginneries.

Material and Methods

Design and Fabrication

A gin trash handling system was designed with an aim to crush gin trash obtained in cotton ginnery during ginning process. In this system, trash is treated in a way that all BW are destroyed. Thus, the developed system prevents the dissemination of PBW through ginneries. The system is designed and fabricated with a capacity of 2.5 tons of trash per hour. On an average a cotton ginnery with 24 DR gin processes around 20,000 bales (170 kg bale weight) during ginning season. Ginnery processing manually picked cotton contains a maximum of 5% gin trash by weight of lint which comprises of pre-cleaner waste, lint cleaner waste, cyclone fly waste and other trashes. Based on this assumption, every day around 1.25 tons of gin trash was expected to be generated. Considering factor safety of 2, the trash handling system was designed to handle 2.5 tones gin trash per hour. While designing capacity, it was planned that whatever the quantity of gin trash was generated every day in the ginnery will be treated in one hour prior to its disposal to prevent dissemination or spread of PBW in neighborhood areas of ginnery. The developed trash handling system essentially comprises of centrifugal trash fan, ducting, cyclone and compactor. The design features and constructional details of each component are discussed below.

Centrifugal Trash Fan

Centrifugal fan treatment method is mostly used to treat gin trash prior to disposal. If gin trash is passed through impeller of a trash fan operating according to pink bollworm quarantine regulations laid down by USDA, the action of the fan kills pink bollworm in the trash. Centrifugal trash fan was designed as per recommendations of Federal Pink bollworm quarantine requirements (USDA) for wheel diameter, inlet size, and speed of single fans for treating gin trash. The design considerations kept in minds while designing trash fan includes; trash fan impeller should have minimum of 6 straight, forward, reverse or curved tip blades with diameter not less than 482.6 mm, minimum fan tip speed of 4,192 m/min, impeller must be laterally centered to have equal clearance in the front and back and trash must enter at 90° angle to the fan impeller (Ginners Handbook, 1994).

With above design considerations; a centrifugal trash fan (**Fig. 2**) was fabricated with six number of straight type blades having fan impeller (**Fig. 1**) diameter 490 mm and tip speed of 4,615 m/min. The power requirement was worked out to be 20 hp for an air volume requirement of 4,800 m^3/h with 363 mm wgp pressure to handle 2.5 tons of trash per hour. The rotational speed of was maintained at 3,000 rpm. The minimum air velocity was expected to be around 17 m/s. Fan inlet diameter was kept as 280 mm and outlet

Fig. 1 Schematic diagram of fan impeller

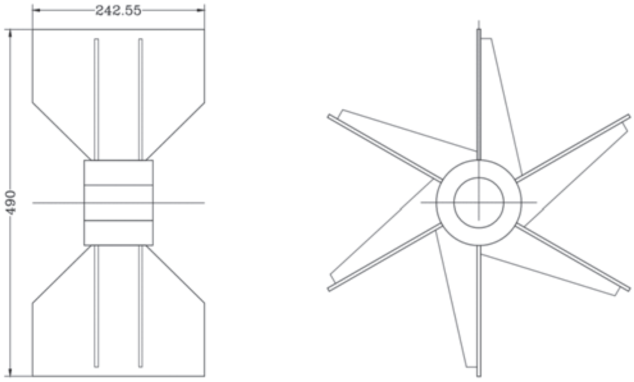
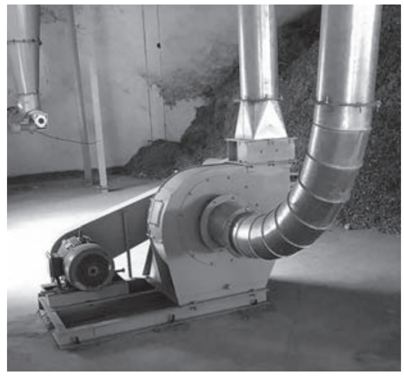


Fig. 2 Pictorial view of centrifugal trash fan

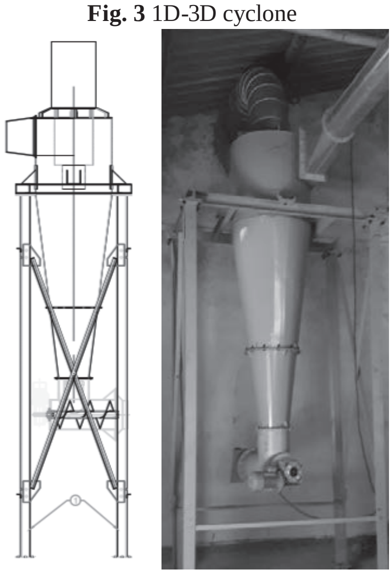


size was 268 × 268 mm and was fabricated out of mild steel. Fan impeller and casing was fabricated out of E350 grade steel material. The shaft and hub were fabricated out of EN8 material.

Cyclone

Cyclones are the most widely used air pollution abatement system in cotton gins. Cyclones are used on high pressure centrifugal fan discharges, to separate air and to collect the waste. Prominent among the cyclone design are 1D - 3D cyclone, which has a cylinder length equal to the length of cylinder diameter and has a cone that is three times the length of the cylinder diameter. Cyclone size depends upon volume of air to be handled, entrance and exit air velocities, pressure drop across the cyclone and air density are the important factors to consider while designing cyclone. Velocity varies with air density hence standard air density was assumed. The 1D-3D cyclone was designed for pressure drop of 140 mm across cyclone with corresponding air velocity of about 19 m/sec and to handle air volume of 4,800 m^3/h. The 1D-3D cyclone (**Fig. 3**) with diameter of 815 mm and height of 2,445 mm was fabricated with mid steel plates of 10 mm and 8 mm thickness. Other cyclone design parameters were calculated as per design given in Ginners handbook (1994). The steel support structure was provided to rest the cyclone. The compactor was fitted as the bottom of cyclone.

Fig. 3 1D-3D cyclone



(a) Schematic diagram (b) Pictorial view

Compactor

The primary function of compactor is volume reduction of gin trash after treatment. The compaction enable cost effective disposal of treated gin trash. Gin trash compactor (**Fig. 4**) with 1hp, 1,500 rpm electric motor was developed. It was attached with reduction gear box of 20:1 to drive screw conveyor at a speed of 72 rpm. Screw conveyor was fabricated with screw length of 715 mm, screw pitch of 320 mm, outside diameter of 320 mm and inside dimeter 80 mm. Screw conveyor was provided with hinged door attached with counter weight. Screw conveyor was housed in a metal body of made from 3 mm thick MS sheet. Feeding to screw conveyor was done through an inlet pipe of 320 mm diameter made out of 3 mm thick MS sheet. The schematic diagram of compactor is shown in **Fig. 5**.

Ducting

The ducting convey gin trash from the point of feeding through the trash fan and form outlet of the fan to the inlet of the cyclone. Various kinds' of bends and reducers as per the design and layout of the system were fabricated. The ducting of 254 mm in diameter was provided at the inlet of blower and at the outlet with suitable bends and reducers for conveying trash from feeding point to blower and from blower to cyclone.

Assembly of Trash Handling System

Various sub-assemblies of trash handling system viz. trash fan, cyclone, compactor and ducting, were assembled and were installed at Ginning Training Centre of ICAR-Central Institute for Research on Cotton Technology, Nagpur. **Fig. 6** depicts assembled pictorial view and **Fig. 7** depicts schematic layout of developed trash handling system.

Ginning Performance of Pink Bollworm (PBW) Infested Cotton

Ginning performance of pink bollworm infested cotton on double

Fig. 4 Pictorial view of compactor

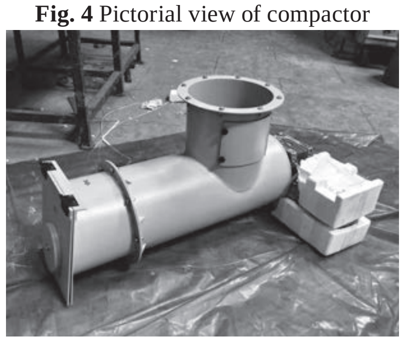
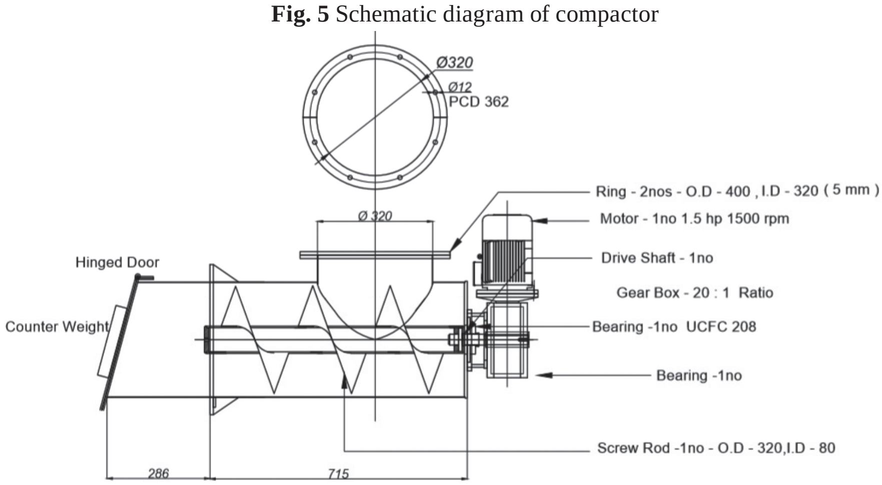


Fig. 5 Schematic diagram of compactor



roller gin (DR) in terms of effect on ginning percentage and fibre quality was studied at ICAR-CIRCOT laboratory at Nagpur. The ginning trials were conducted on Bajaj make Jumbo model DR gin with roller length of 1,360 mm. Ginning was performed on pink bollworm infested and un-infested cottons. The performance of PBW infested cotton was assessed in terms of percentage change in ginning output, ginning percentage and fibre quality as compared to un-infested cotton. The fibre quality parameters viz. fibre length, micronaire, uniformity index, tenacity, elongation, short fibre content (SFC), degree of reflectance (Rd), degree of yellowness (+b) and colour grade were measured by suing High Volume Instrument (HVI) in HVI mode. The colour grades were assigned to each sample following the USDA HVI colour chart for American upland cotton. The first two digits in the colour grade indicates the colour grade and last digit after hyphen indicates the leaf grade for that cotton. The ginning percentage was measured by weighing the lint weight after ginning 100 gm pink bollworm infested seed cotton.

Fig. 6 A View of gin trash handling system

Performance Testing of Trash Handling System

The developed gin trash handling system was tested for its functionality and to find out mortality rate or kill potential of pink bollworm (PBW) in gin trash. The performance was assessed by using gin trashes viz. cyclone fly waste, lint cleaner waste and pre-cleaner waste. The larva and pupae of pink bollworm was used as culture during experimentation.

Sampling of Gin trashes

Two tons of gin trash consisting of cyclone fly waste, lint cleaner waste and pre-cleaner waste was procured from cotton ginning factory. Two kilogram of gin trash sample was taken for each experimental trial. It was presumed that there is no pink bollworm infestation in the selected trash samples

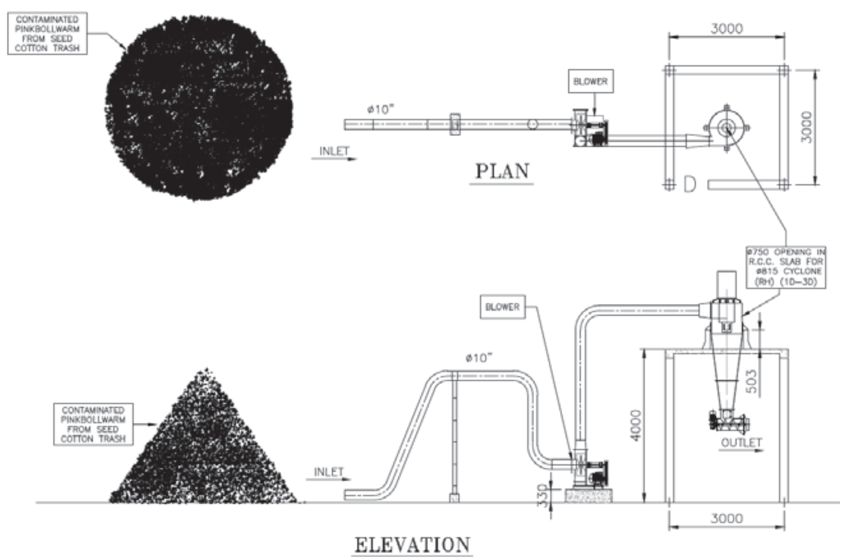
Multiplication Pink Bollworm Culture

The culture of pink bollworm i.e. larva and pupa were grown and multiplied in entomology laboratory of ICAR-Central Institute for Cotton Research at Nagpur by using the standard procedure. This PBW culture in predetermined numbers as per the experimental plan were mixed artificially in gin trash sam-

Table 1 Configuration of experimental trials conducted on gin trash handling system with different combinations of gin trashes and PBW culture

Cotton gin trash	Experiment		
	E1	E2	E3
T1	LPR1 LPR2 LPR3	LR1 LR2 LR3	PR1 PR2 PR3
Control	T1C	T1C	T1C
T2	LPR1 LPR2 LPR3	LR1 LR2 LR3	PR1 PR2 PR3
Control	T2C	T2C	T2C
T3	LPR1 LPR2 LPR3	LR1 LR2 LR3	PR1 PR2 PR3
Control	T3C	T3C	T3C

Fig. 7 Schematic layout of gin trash handling system



ples.

Experimental Methodology

Experimental trials were conducted by preparing samples with different configurations of gin trash (Cyclone fly waste – T1, Lint cleaner waste – T2, Pre-cleaner waste – T3,) and PBW culture i.e. Larva (L) and Pupae (P). The experimental plan is depicted in **Table 1**. Three sets of experiment viz. Experiment 1 (E1), Experiment 2 (E2), and Experiment 3 (E3) were carried out with three replications for each experiment. In E1, fifteen number of larva and fifteen number of pupae were mixed artificially in each set of trash sample. The control samples were prepared without mixing PBW culture. In E2, 40 number of larva were mixed artificially in each set of trash sample. In E3, 40 number of pupae were mixed artificially in each set of trash sample. For each treatment and experiment a control sample was prepared and processed through trash handling system.

Experiments were conducted on the assumptions that there was no alive PBW in larva and pupae in trash samples before artificially adding the PBW culture into each sample. Sample of each configuration was passed through inlet of trash handling system and collected at outlet of the system. Samples were collected and packed in cotton nags and tied up at the top. All samples were manually checked one day after treatment and thirteen days after treatment for presence of live PBW larva and pupae. Number of live larva and pupae in each sample was counted. Data was analyzed to find mortality rate or kill potential of pink bollworm after passing through the gin trash handling system.

Results and Discussion

Effect on Pink Bollworm Infestation of Ginning Performance

Effect of pink bollworm infestation on ginning performance showed deterioration in ginning percentage and fibre quality in comparison to uninfected cotton (**Table 2**). Fibre quality deteriorated in terms of reduction in parameters viz. fibre length (13.9%), micronaire (25%), uniformity index (4.8%), tenacity (11.5%) and degree of reflectance (16.3%) whereas short fibre content and degree of yellowness increased by 67.3% and 42.4% respectively which is undesirable. The ginning percentage found to decrease by 17.1% in PBW infested cotton. Negative sign (-) against each parameter denotes the adverse effect on PBW infestation on cotton fibre quality. Colour grade of PBW infested cotton observed to deteriorate from middling (31-1) to strict low middling (41-1) as per HVI colour grade chart for American Upland cotton (USDA). The deterioration in ginning percentage and fibre quality has significant impact on the economic value of cotton thus affects cotton producers and processors.

Table 2 Ginning performance of pink bollworm infested cotton

Parameter	Un-infested cotton	Pink bollworm infested cotton	Change (%)
Ginning Percentage (%)	35	29	(-) 17.1
Fibre length (mm)	31.0	26.7	(-) 13.9
Uniformity Index (%)	83	79	(-) 4.8
Fineness (mic)	4.0	3.0	(-) 25.0
Tenacity (g/tex)	29.5	26.1	(-) 11.5
Elongation (%)	5.6	5.3	(-) 5.4
SFC (%)	5.2	8.7	(-) 67.3
Rd (%)	76.8	64.3	(-) 16.3
+b (%)	8.5	12.1	(-) 42.4
Colour grade	31-1	41-1	-

Table 3 Survival potential of PBW after passing through trash handling system

Cotton gin trash	Experiment 1		Experiment 2		Experiment 3	
	One day after treatment (L/N)	Thirteen days after treatment (L/N)	One day after treatment (L/N)	Thirteen days after treatment (L/N)	One day after treatment (L/N)	Thirteen days after treatment (L/N)
T1	0/30 (15+15)	0/30 (15+15)	0/40	0/40	0/40	0/40
	0/30 (15+15)	0/30 (15+15)	0/40	0/40	0/40	0/40
	0/30 (15+15)	0/30 (15+15)	0/40	0/40	0/40	0/40
Control	0/0	0/0	0/0	0/0	0/0	0/0
T2	0/30 (15+15)	0/30 (15+15)	0/40	0/40	0/40	0/40
	0/30 (15+15)	0/30 (15+15)	0/40	0/40	0/40	0/40
	0/30 (15+15)	0/30 (15+15)	0/40	0/40	0/40	0/40
Control	0/0	0/0	0/0	0/0	0/0	0/0
T3	0/30 (15+15)	0/30 (15+15)	0/40	0/40	0/40	0/40
	0/30 (15+15)	0/30 (15+15)	0/40	0/40	0/40	0/40
	0/30 (15+15)	0/30 (15+15)	0/40	0/40	0/40	0/40
Control	0/0	0/0	0/0	0/0	0/0	0/0

L = Alive PBW, N = Total PBW

Performance Evaluation of Gin Trash Handling System

The cyclone fly waste, lint cleaner waste and pre-cleaner waste samples treated with PBW culture were manually inspected and checked for count of alive PBW larva and pupae one day and thirteen days after treatment for finding out mortality rate or kill potential W for each set of experiment. **Table 3** depicts results all three experiments E1, E2 and E3. Results indicated that no single larvae or pupae survived after passing through developed system. Mortality rate of larvae and pupae at one day after treatment was noted to be 100%. Even thirteen days after treatment no growth of any adult was noticed in any set of experimental sample. It indicated that the mortality rate of PBW was 100% even after thirteen days of treatment.

Performance testing revealed that developed system has successfully attained intended design functions of destroying PBW's from the gin trashes in cotton ginneries. Results in the present study are found in conformity with those obtained by Huges et al. (1995) with flat blade centrifugal fan to process gin trash to kill 100% PBW larvae with fan tip speeds above 3,962 m/min.

Conclusions

Cotton gin trash handling system was developed with an aim to crush and treat gin trash in such a way that all PBW in gins trash are destroyed which further enables to break down life cycle of PBW and prevent its dissemination from ginneries to neighborhood area and prevent damage to cotton crop in subsequent season. The system comprises of centrifugal trash fan, cyclone, compactor and ducting and has a capacity of 2.5 tons of trash per hour. Performance results indicated that system has successfully attained the intended function of destroying PBW in gin trash and the mortality rate of larva and pupae was 100%. Developed system is recommended to be employed in cotton ginneries to destroy and prevent dissemination of pink bollworm. Successful elimination of pink bollworm would help cotton producers to grow cotton profitably by increasing yields and reducing chemical inputs and preserving fibre quality.

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Equilibrium Sorption Isotherms of Damask (*Rosa Damascena* Mill.) Rose Flowers

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Abstract

Products from Rosa Damascena Mill. (Damask rose) have a very wide use in medicine, food, cosmetics, skin care, aroma therapy, and beverage fields. In recent years, the international demand for "dried damask rose petals or whole flower petals" is increasing. Optimum drying air temperature and relative humidity should be determined to ensure proper storage conditions for Damask rose. The equilibrium moisture content of Damask rose whole flower petals or "Damask rose" was determined by static gravimetric method at 25, 30, 35, and 40 °C. Five different mathematical models including Oswin, Peleg, Henderson, Iglesias-Chirife, and Smith describing the sorption isotherms of Damask rose were used to predict the experimental data. The results showed that at the same water activity, equilibrium moisture content increased with a decrease in temperature. On the other side, at the same temperature, the equilibrium moisture content increased with an increase in water activity. Hysteresis effect was dominant for the Damask rose obtained at 25 °C at water activity ranging from 0.2 and 0.8. The highest predictive performance was acquired by the Peleg model for the experimentally obtained desorption and adsorption isotherms of Damask rose.

Keywords: Dried damask rose whole flower petals; Equilibrium moisture contents; Rosa Damascena Mill .; Sorption isotherms

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Introduction

Damask rose (*Rosa damascena* Mill.) is a natural hybrid of *Rosagallica* L. and *Rosa phoenicia* Boiss. species of naturally grown in Turkey. Among the other fragrant roses that are cultured around the world, it is characterized by its distinctive sharp and intense scent, which has the highest economic value for perfume, cosmetics, pharmaceuticals, and food industry (Baydar and Kazaz, 2013). Turkey is one of the two biggest producers of rose oil in the world. The world rose oil demand is met from Turkey (50%), Bulgaria (40%), and Iran, India, Morocco, and Afghanistan (10%) (Gular, 2015). Damask rose takes a long time to bloom all the buds because there are a large number of flower buds in different developmental periods. In Turkey, flowering time lasts about 2 months starting from the beginning of May until the beginning of July depending on the altitude (between 800-1500 m) (Baydar et al., 2008). Rose oil, rose water, rose concrete and rose absolute are the main products obtained from Damask rose flowers. As these products have high odor spreading odors, they are the main ingredients of many perfumes and can be easily mixed with other fragrances (Khosh-Khui, 2014). Damask rose is well known as medicinal herbal. In addition to its perfume feature, in traditional medicine, several pharmacological effects of Damask rose, such as a therapeutic effect on premenstrual breast tenderness and reduction of inflammation, especially of the neck, were reported (Basim and Basim, 2003).

Nowadays, increasing international interest has been recorded for "dried damask rose petals" (Abduljabbar, 2018). Studies conducted on the drying of Damask rose whole flower petals or "Damask rose" are very limited. It is known that product quality is deteriorated due to rapid moisture absorption during drying, dusting, and attractiveness for insects and microorganisms. Moisture absorption, mold and moth growth, and loss in color are experienced in a short time depending on storage conditions after drying and the product has to be discarded before it is marketed. In order to maintain appropriate storage conditions for damask rose, the optimum drying air temperature and relative humidity should be investigated. The moisture sorption isotherm depicts the variation of equilibrium moisture content changing with the water activity at constant surrounding environment pressure and temperature (Kaymak-Ertekin and Gedik, 2004). The nature of the sorption isotherms is unique for every foodstuff. In order to improve the drying process while reducing the cost of drying, the relationship between water activity and moisture content should be determined for the moisture sorption isotherms (Soysal and Oztekin, 1999). Although numerous studies on sorption isotherms of medicinal and aromatics plant have been extensively studied (Soysal and Oztekin, 2001), sorption isotherms data of Damask rose have not been reported yet.

A wide range of drying models describing sorption isotherms for various agricultural products including aromatic and medicinal plants have been reported (Ait Mohamed et al., 2005; Belghit et al., 2000; Park et al., 2002). Furthermore, it was noted that no single equations describing precisely the sorption isotherms of all products at different humidity and temperature ranges existed. Therefore, it is necessary to determine the optimum isotherm equation for a given biological material and relative humidity and temperature ranges (Bahloul et al., 2008).

This study aimed to (1) assess the desorption and adsorption isotherms of Damask rose at different relative humidity (from 11% to 93%) and temperature from 25 to 40 °C; and (2) to evaluate the predictability of different drying models describing sorption isotherm of Damask rose and to determine the most suitable model for the experimental data for the examined temperature ranges.

Material and Methods

The Damask fresh rose harvested between May and July 2017 was used in this study. After harvesting, the static gravimetric method at 25, 30, 35, and 40°C was performed to determine equilibrium moisture content (Xe) of Damask rose. The similar temperature ranges were applied for drying of medicinal and aromatic plants (Bahloul et al., 2008). In this method, the mass transfer between material and the surrounding air was ensured by the natural diffusion of water vapor, and the water activity of the material is equal to the relative humidity of the surrounding air in equilibration. Nine saturated salt solutions (LiCl, CH_3COOK, $MgCl_2$, K_2CO_3, $Mg(NO_3)_2$, NaBr, NaCl, KCl, and $BaCl_2$) were used to provide relative humidities ranging from 11 to 93% in the desiccator (Arslan and Togrul, 2006). The salts were dissolved in distilled water at each temperature. **Table 1** presents the amount of salt and water used to maintain a fixed relative humidity (RH) corresponding to a fixed water activity (aw) for the nine selected salt solutions at four temperatures. aw ranges from 0.11 to 0.93. Five rose flower petal samples (approximately total in 5 g) of Damask rose for adsorption and desorption experiments were weighted and transferred into the desiccator. The whole rose flower petals were placed on the plate on top of tripod located inside of desiccator. The desiccator was then transferred into the temperature-controlled cabin (incubator) set at 25, 30, 35, and 40 °C for equilibrium. The whole rose flower petals were tarred at least every day using a balance with an accuracy of ±0.001 g. Xe was determined when three sequential measurements showed a difference of less than 0.001 g (after 10-14 days). The moisture con-

Table 1 Water activities (a_w) of the saturated salt solutions at different temperatures (Bertuzzi et al., 2007; Durmus, 2008)

Salt	Water (ml)	Water (ml)	a_w			
			25 ºC	30 ºC	35 ºC	40 ºC
LiCl	42.5	75	0.113	0.113	0.108	0.112
CH_3COOK	37.5	100	0.237	0.216	0.216	0.201
$MgCl_2$	12.5	100	0.329	0.324	0.318	0.316
K_2CO_3	45	100	0.443	0.432	0.436	0.423
$Mg(NO_3)_2$	15	100	0.536	0.514	0.516	0.484
NaBr	35	100	0.653	0.560	0.638	0.532
NaCl	30	100	0.762	0.751	0.743	0.747
KCl	40	100	0.900	0.836	0.855	0.823
$BaCl_2$	35	125	0.934	0.898	0.881	0.891

tent of the equilibrated whole rose flower petals was determined using the procedure outlined by (AOAC, 2000).

Five mathematical equations (the models of Oswin, Peleg, Henderson, Iglesias-Chirife, and Smith) were fitted to experimentally measured Xe as a function of aw for desorption and adsorption isotherms of Damask rose in the temperature ranged from 25 to 40°C as presented in **Table 2**.

The predictive performance of the model in terms of Xe as a function of aw was determined by five error functions: R^2: The coefficient of determination, MAE: Mean absolute error, MSE: Mean squared error, RMSE: Root mean squared error, MAPE: Mean absolute percentage error by using the following equations:

$$MAE = \frac{100}{N} \sum = \frac{M_{exp} - M_{exp}}{M_{pre}} \quad [1]$$

$$RMSE = \sqrt{\left(\frac{\sum(M_{exp} - M_{pre})}{df}\right)} \quad [2]$$

$$MSE = \frac{100}{N} \sum_{i=1}^{N} (\hat{x}_i - x_i)^2 \quad [3]$$

$$MAPE = \frac{100}{N} \sum_{i=1}^{N} \frac{|x_i - \hat{x}_i|}{x_i} \quad [4]$$

Where;

M_{exp} and M_{pre} are the experimental and estimated moisture content values, respectively, N is the number of experimental data and df is the degree of freedom. x_i is the real observations time series, $\hat{x}_i$ is the approximated time series and N is the number of non-missing data points.

Results and Discussion

The experimentally obtained data of Xe as a function of aw for sorption isotherms performed at 25, 30, 35, and 40 °C are given in **Figs. 1a** and **b**. It can be said that the shape of the isotherms is similar to the sigmoid shape of the type II pattern in the Brunauer's classification (Brunauer, 1943) which is commonly determined for agricultural products (Blahovec, 2004; Mathlouthi and Rogé, 2003). As shown in the sorption curves of Damask rose, a substantial temperature impact was detected on sorption isotherms. It can be observed that sorption isotherms are temperature dependent. At constant aw, higher Xe values were obtained at lower temperatures. As the temperature increased in constant aw, the amount of water absorbed by the product decreased. At higher temperatures, the distance between the water molecules increases and the attractive force between them decreases thereby decreasing water sorption rate at constant aw at increasing temperatures (Bejar et al., 2012). At the other side, at the fixed temperature, Xe increased with the increment in aw (**Figs. 1a** and **b**). This may be due to the fact that as the moisture content

Table 2 Mathematical models used to describe the sorption isotherms of Damask rose

Model	Equation	References
Oswin	$X_e = A\left[\frac{a_w}{1 - a_w}\right]^B$	Barbosa-Canovas et al., 2007
Peleg	$X_e = Aa_w^C + Ba_w^D$	Timmermann et al., 2001
Henderson	$X_e = c\left[-\frac{\ln(1 - a_w)}{A}\right]^{1/B}$	Bell and Labuza, 2000
Iglesias and Chirife	$X_e = Aa_w + B$	Arslan and Togrul, 2006
Smith	$X_e = A + B\ \ln(1 - a_w)$	Al-Muhtaseb et al., 2002

* A, B, C, and D are the equation constants.

Fig. 1 Xe as a function of aw for (a) desorption; (b) adsorption isotherms Damask rose at 25, 30, 35 and 40 °C

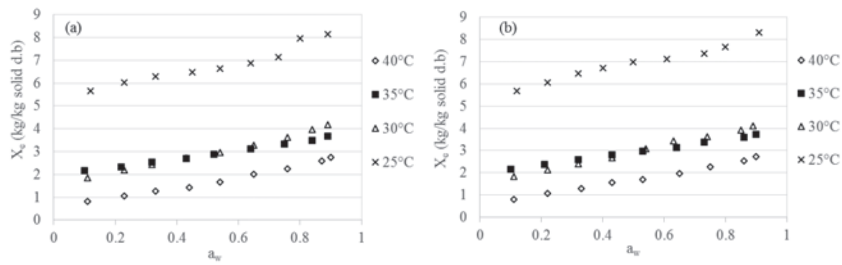
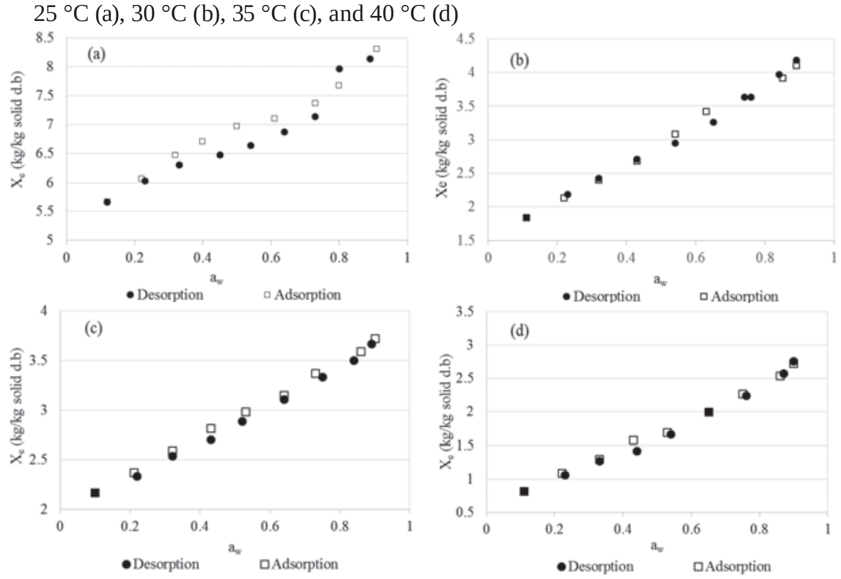


Fig. 2 Sorption data (desorption and adsorption) for the Damask rose determined at 25 °C (a), 30 °C (b), 35 °C (c), and 40 °C (d)



decreases, the product tends to show lower vapor pressure in the water. With the change of atmospheric humidity, the vapor pressure in the environment causes the characteristic sigmoid shape of moisture sorption isotherms (Caurie, 1970).

The hysteresis effect observed for Damask rose obtained at 25, 30, 35, and 40 °C is given in **Fig. 2**. The different Xe observed in the same aw constitute the hysteresis cycle between adsorption and desorption processes. Higher hysteresis was detected between adsorption and desorption for the Damask rose obtained at 25 °C at aw between 0.2 and 0.8. Further, the hysteresis effects at higher temperatures were not clear especially at 35 and 40 °C (**Figure 2c** and **d**) since structural changes of the pores and surface characteristic modifications at higher temperatures are supported (Moreira et al., 2005). However, Bahloul et al. (2008) reported that higher Xe values at a particular aw for desorption than for adsorption. In the current study, Xe value for adsorption was usually higher than that of desorption. This could be due to the fact that the magnitude of hysteresis effects is dependent on the structure and condition of the biological material (Al-Muhtaseb et al., 2002). The behavior of the sorption hysteresis curve at 40 °C is similar to that reported for Lemon Balm at 40 °C (Andrade, 2011).

The predictive performance of the model with the estimated constants using nonlinear regression analysis for fitting models to experimental data with R^2, MAE, MSE, RMSE, and MAPE for desorption and adsorption for the studied temperature are given in **Table 3** and **Table 4**, respectively. Results showed that the predictive performance of the Peleg model to the experimentally obtained data of both desorption and adsorption isotherms of Damask rose for the range of aw from 0.11 to 0.93 for the given temperatures. Furthermore, the Peleg model resulted in the highest R^2 values ranging from 0.9726 to 0.9985 with the lowest MAE, MSE, RMSE, and MAPE varying from 0.9726 to 0.9985, from 0.0137 to 0.0317, from 0.0003 to 0.0168, from 0.017 to 0.1296, and from 0.4658 to 1.2446 for desorption and adsorption isotherms for the studied temperatures, respectively. It could be said that predictive performance of all the models for desorption and adsorption isotherms at 25 °C was usually lower for those at the 30, 35, and 40 °C.

Figs. 3 and **4** show comparison of the predictive performance of models with experimental data for

Fig. 3 Comparison of predictive performance of models with experimental data for desorption isotherm of the Damask rose obtained at 25 °C (a), 30 °C (b), 35 °C (c), and 40 °C (d)

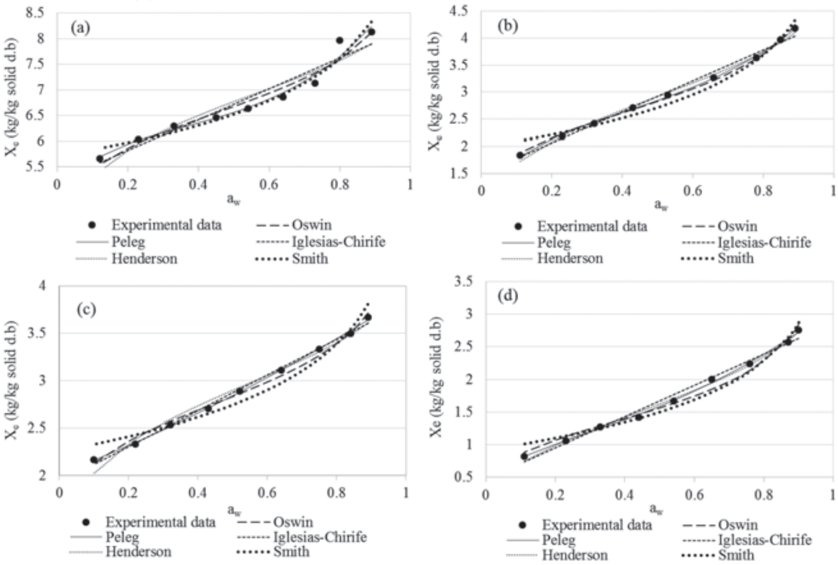
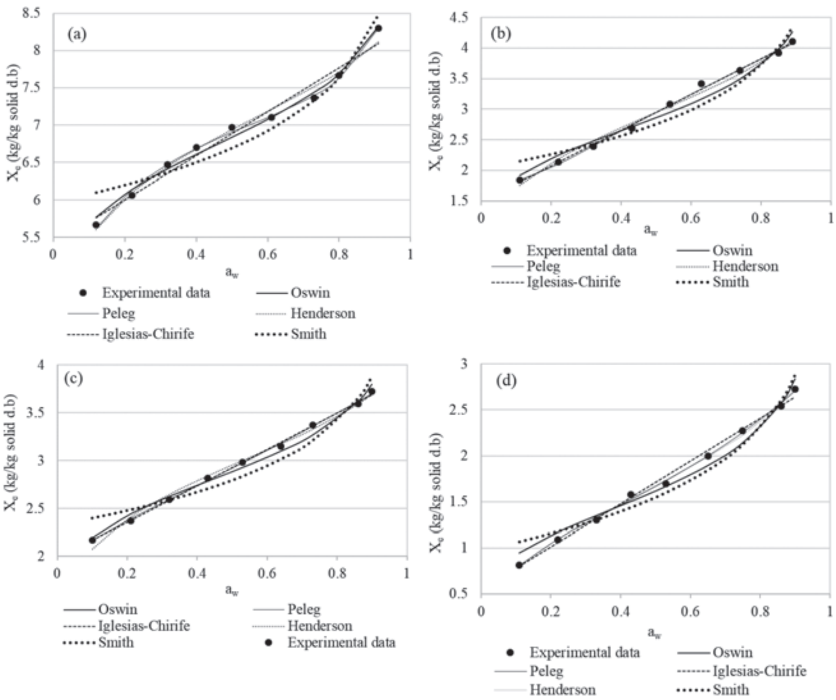


Fig. 4 Comparison of predictive performance of models with experimental data for adsorption isotherm of the Damask rose obtained at 25 °C (a), 30 °C (b), 35 °C (c), and 40 °C (d)



desorption and adsorption data for Damask rose obtained at 25 °C, 30 °C, 35 °C, and 40 °C. Even though predictive performances of all the models were high, the Peleg model has been found to be the most suitable model for experimental data. The predictive performance of the Peleg model also was found to be successful for garden mint leaves (Park et al., 2002).

Conclusions

This study focused on the moisture desorption and adsorption isotherms of Damask rose whole flower petals at water activity ranged from 0.113 to 0.934 at the studied temperature of 25, 30, 35, and 40°C using by the static gravimetric method. Mathematical models (Oswin, Peleg, Henderson, Iglesias-Chirife, and Smith) were used for prediction of experimentally determined sorption isotherms of Damask rose. The predictive performance of the model was determined based on error functions and coefficient of determination. The results revealed that the equilibrium moisture content increased with a decrease in temperature at a constant water activity. At constant temperature, the equilibrium moisture content increased with increasing water activity. The results showed that higher hysteresis was determined between adsorption and desorption for the Damask rose obtained at 25 °C at water activity ranging from 0.2 to 0.8. Furthermore, the hysteresis effects at higher temperatures were not clear especially at 35 and 40 °C. The Peleg model was the model that best matches the experimental data of both desorption and adsorption isotherms of Damask rose at the water activity of 0.11-0.93 for the studied temperatures.

Table 3 Predictive performance parameters and constants of five different models to experimental desorption data for Damask rose

Model	Error functions and constants	Temperature			
		25 °C	30 °C	35 °C	40 °C
Oswin	R^2	0.9538	0.9971	0.9913	0.9853
	MAE	0.1362	0.0370	0.0423	0.0673
	MSE	0.0283	0.0017	0.0021	0.0060
	RMSE	0.1683	0.0408	0.0462	0.0775
	MAPE	1.9638	1.3265	1.4993	4.2201
	A	6.6794	2.8265	2.8325	1.5647
	B	0.0931	0.1948	0.1299	0.2706
Peleg	R^2	0.9726	0.9988	0.9988	0.9978
	MAE	0.0910	0.0231	0.0137	0.0248
	MSE	0.0168	0.0007	0.0003	0.0009
	RMSE	0.1296	0.0265	0.0170	0.0298
	MAPE	1.2446	0.8777	0.4658	1.3238
	A	2.4113	1.5108	1.6522	1.5757
	B	6.8012	3.3126	2.2348	1.5243
	C	4.0469	3.8897	1.3454	0.3015
	D	0.0836	0.2726	0.0295	2.3017
Henderson	R^2	0.9101	0.9939	0.9829	0.9954
	MAE	0.2093	0.0510	0.0517	0.0346
	MSE	0.0551	0.0035	0.0042	0.0019
	RMSE	0.2347	0.0595	0.0648	0.0434
	MAPE	3.0238	1.8606	2.0027	2.4772
	A	0.0000	0.0185	0.0026	0.2275
	B	7.5488	3.3825	5.2377	2.2977
Iglesias-Chirife	R^2	0.9248	0.9900	0.9961	0.9867
	MAE	0.1953	0.0627	0.0250	0.0622
	MSE	0.0461	0.0058	0.0010	0.0054
	RMSE	0.2146	0.0763	0.0310	0.0738
	MAPE	2.7878	1.9585	0.8812	4.0733
	A	3.0208	2.8665	1.8816	2.3951
	B	5.2124	1.4887	1.9309	0.4722
Smith	R^2	0.9579	0.9693	0.9579	0.9670
	MAE	0.1231	0.1121	0.1231	0.1004
	MSE	0.0258	0.0179	0.0258	0.0135
	RMSE	0.1606	0.1337	0.1606	0.1163
	MAPE	1.7502	4.2959	1.7502	6.7596
	A	5.7038	1.9790	5.7038	0.9069
	B	-1.1870	-1.0649	-1.1870	-0.8550

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Table 4 Predictive performance parameters and constants of five different models applied to experimental adsorption data for Damask rose

Model	Error functions and constants	Temperature			
		25 °C	30 °C	35 °C	40 °C
Oswin	R^2	0.9902	0.9700	0.9869	0.9862
	MAE	0.0639	0.1172	0.0521	0.0712
	MSE	0.0057	0.0174	0.0034	0.0067
	RMSE	0.0757	0.1318	0.0580	0.0819
	MAPE	0.9690	3.9442	1.7486	5.5417
	A	6.8346	2.8641	2.8852	1.5851
	B	0.0851	0.1902	0.1252	0.2900
Peleg	R^2	0.9975	0.9973	0.9985	0.9982
	MAE	0.0317	0.0316	0.0171	0.0211
	MSE	0.0015	0.0016	0.0004	0.0007
	RMSE	0.0382	0.0398	0.0198	0.0259
	MAPE	0.4790	1.0155	0.5611	1.2294
	A	1.7827	0.4070	1.3964	1.0134
	B	7.6208	3.9700	2.5121	2.0512
	C	8.6929	-0.4252	1.3783	2.9195
	D	0.1430	0.7221	0.0773	0.4205
Henderson	R^2	0.9853	0.9897	0.9925	0.9978
	MAE	0.0737	0.0688	0.0360	0.0251
	MSE	0.0086	0.0060	0.0019	0.0008
	RMSE	0.0926	0.0773	0.0438	0.0288
	MAPE	1.0222	2.5441	1.3706	1.5153
	A	0.0000	0.0171	0.0022	0.1966
	B	7.9196	3.4202	5.3250	2.4434
Iglesias-Chirife	R^2	0.9724	0.9967	0.9982	0.9941
	MAE	0.1137	0.0348	0.0158	0.0378
	MSE	0.0161	0.0019	0.0005	0.0023
	RMSE	0.1268	0.0438	0.0215	0.0476
	MAPE	1.6016	1.1679	0.4950	2.2164
	A	2.9489	2.9109	1.9024	2.3313
	B	5.4117	1.4935	1.9755	0.5429
Smith	R^2	0.9246	0.9220	0.9260	0.9497
	MAE	0.1722	0.1870	0.1242	0.1219
	MSE	0.0440	0.0451	0.0191	0.0193
	RMSE	0.2097	0.2125	0.1380	0.1389
	MAPE	2.6338	6.6036	4.3774	8.3806
	A	5.9640	2.0239	2.3262	0.9688
	B	-1.0474	-1.0539	-0.6738	-0.8320

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Development of a Double-pan Roasting Machine for Chinese Green Tea

by
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Abstract

A Double-pan Roasting Machine was designed and developed, and its performance was evaluated for Chinese green tea. The major parts of the Double-pan Roasting Machine included main frame, reduction motor, roasting pan, and electric heater. The transmission comprised crank rocker mechanism. The orthogonal experiment of 7 factors 3 levels was adapted to optimum structural parameters. The result revealed the key dimensions as: crank length was 200 mm, connecting rod length was 360 mm, rocker length was 330 mm, body frame rod length was 320 mm, horizontal inclination angle of roasting pan was 35, fry speed was 75 r/min, and electric heating power was 10 kW. Under this configuration, the broken tea rate was 5.4%. The reported results would help in providing a reference for the design of the double-pan roasting machine.

Keywords: Double-pan roasting machine, parameter optimization, orthogonal test

Introduction

China is known as the hometown of tea since it introduced tea to the world and made tea into a beverage. In 2020, the national output of crudely tea leaves was 2.9860 million tons, an increase of 192,600 tons over the previous year. In 2020, affected by the global epidemic, China's tea export was 348,800 tons, it has declined for the first time since 2014. The process of gunpower production included fixation, twisting, first-step roasting, second-step roasting and final roasting. Traditional manual processing of tea is time-consuming and laborious. Nonetheless, there is a high rate of getting broken tea during processing, which lacks standardization. Double-pan Roasting Machine has a great influence on the appearance and taste of gunpower. Compared with the traditional equipment, the design of Double-pan Roasting Machine has greatly improved the processing quality, which plays an important role in the process performance, production efficiency and tea quality.

Over the years, the research on Double-pan Roasting Machine has focused on the development of computer simulation and optimization. Wang et al. (2013) used Pro/E 3D software to virtual assembly design. Zhao et al.(2018) used numerical calculation and simulation to define and study the work efficiency of Double-pan Roasting Machine. Li et al. (2019) used discrete element method (DEM) to establish the tea particle model of geometric and contact mechanics and obtained the kinematics and dynamics curves of gunpowder tea particles in the shaping process. Li et al. (2019) used ant colony algorithm to set up the mathematical model and obtained optimal parameters.

Currently, there are few studies about the distribution of the tea on the Double-pan Roasting Machine. At the same time, the unreasonable parameters of the Double-pan Roasting Machine result in a high broken rate and low forming rate. To date, there have been difficulties in designing a Double-pan Roasting Machine with an increased forming rate and reduced broken rate.

The aim of this study was to determine the tea mechanism of the Double-pan Roasting Machine and obtain the appropriate parameters of the Double-pan Roasting Machine to promote tea processing mechanization.

Machine Development

Power transmission is realized by means of a pulley driven by a reduction motor. The power source of the reciprocating movement of the arc frying plate is a crank rocker mechanism. The belt drive drives the driven pulley, and drives the crank to rotate at a constant speed. Through the crank rocker mechanism, the arc frying plate swings to promote the tea to stir fry in the roasting pan. Under the extrusion effect of the roasting pan arm and the arc frying plate, the tea gradually curls into a ball. The tea in the was roasting pan heated and was rubbed, roasted.

The developed Double-pan Roasting Machine is photographed in **Fig. 1** and illustrated schematically in **Fig. 2**. 3D model design on double-pan roasting machine using of SolidWorks (**Fig. 3**).It consisted of following main parts.

Main Frame

The overall size of the whole machine is 2110 mm × 900 mm × 1180 mm, the power of the driving motor is 0.5 kW, and the belt is b-belt. First drive was one-stage belt mechanism, Second drive was Crank rocker mechanism, which was designed to convert rotary motion to swing motion.

Pushing Fry Institution

The material selected is steel. The pushing fry institution is composed of a frying pan, an arc frying plate and a crankshaft. The connecting crankshaft is attached to the arc frying plate at one end and to the crank rocker mechanism at the other end. The position of the roasting pan should ensure that the gunpower cannot fall out and can be maximum heating. When heating, the gunpower should not fall from the gap between the roasting pan and the arc frying plate. The frying width and speed of the pushing fry institution was the key parameters. There was a far infrared metal heating tube of power 10 kW under frying pan. Quality of tea was influenced by the parameters shape of roasting pan and the crank rocker mechanism.

Crank Rocker Mechanism

The Double-pan Roasting Machine adopts type I crank rocker mechanism, the best position of optimum transmission angle is the position when the crank and the frame are collinear. The stir frying plate is driven by the crank rocker mechanism to move back and forth. The main parameters of the crank rocker mechanism were crank length, rocker length, connecting rod length and crank speed, which would influence the quality of the tea.

Analysis of Movement and Stress of Tea

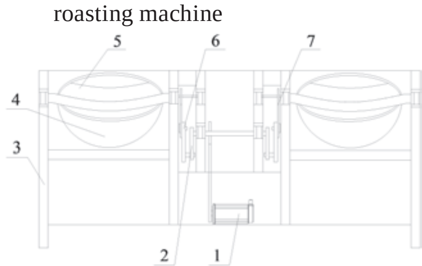
During the working process of the Double-pan Roasting Machine, the frying plate swings back and forth under the action of the crank rocker mechanism, to drive the tea to move inside the frying pan. The forces on the tea in the frying pan mainly include: the friction between the tea and the pot wall, the gravity of the tea itself, the reaction force of the pot wall and the thrust of the frying plate. The analysis of the specific stress is shown in **Fig. 4**.

Combined literature (Zhao et al., 2018) ,Movement and force of tea leaves in frying pan. G is the gravity of the spherical tea particles (G = mg), F is the force exerted by the frying plate on the tea particles, F_X is the centripetal force exerted by the spherical tea particles ($F_X = M_V^2 / R$), F_N is the reaction force exerted by the pot body on the spherical tea particles, and F_f is the friction force between the spherical tea particles and the wall of the fryer (Ren, 2018).

The motion of tea in the frying pan mainly includes the following three types: under the joint action

Fig. 1 Prototype Double-pan Roasting Machine

Fig. 2 Schematic view double-pan roasting machine



1.reduction motor; 2.crank; 3.body frame; 4. roasting pan; 5. fry plate; 6.connecting rod; 7.rocker

Fig. 3 Structure diagram of double-pan roasting machine

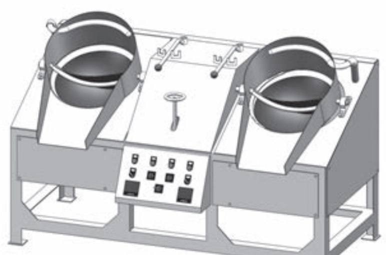


Fig. 4 Stress diagram of tea

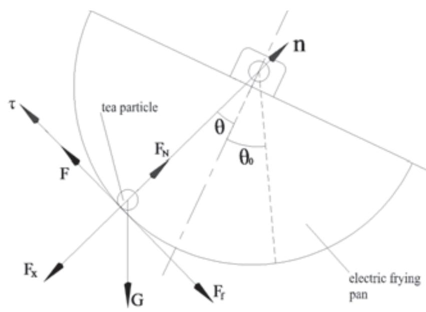
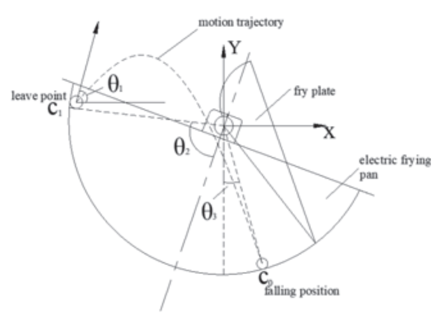


Fig. 5 Motion diagram of tea



of friction between tea and pot wall, self-gravity, pot wall reaction force and the thrust of frying plate, tea moves along the pot wall, and tea particles move internally under their mutual extrusion pressure and friction; When the tea leaves the inner wall of the frying pan, it does the projectile motion. The analysis of motion is shown in **Fig. 5**.

Material and Methods

The orthogonal experiment of 7 factors 3 levels was adapted to optimum structural parameters. Factors influencing the broken tea rate were crank length, connecting rod length, rocker length, body frame rod length, horizontal inclination angle of roasting pan, fry speed, electric heating power. The 3 levels of 7 the independent variables are given in **Table 1**.

The broken tea rate was calculated as follows.

$$V = m / M \quad [1]$$

where,

V = broken tea rate, %

m = mass of the broken tea, g

M = mass of the sample taken ,g

Table 1 Factors and levels of the orthogonal design

A	B	C	D	E	F	G
190	300	300	310	30	75	9
200	330	315	320	35	85	10
210	360	330	330	40	95	11

A: Crank Length; mm
B: Connecting rod Length; mm
C: Rocker Length; mm
D: Body frame rod Length; mm
E: Horizontal inclination angle of roasting pan; degree
F: Fry speed; rpm
G: Electric heating power; kW

Table 2 The orthogonal experimental plan for Double-pan Roasting Machine

Expt. number	A	B	C	D	E	F	G	broken tea rate, %
1	1	1	1	1	1	1	1	11.7
2	1	2	2	2	2	2	2	10.9
3	1	3	3	3	3	3	3	9.7
4	2	1	1	2	2	3	3	9.8
5	2	2	2	3	3	1	1	10.3
6	2	3	3	1	1	2	2	9.4
7	3	1	2	1	3	2	3	12.8
8	3	2	3	2	1	3	1	8.9
9	3	3	1	3	2	1	2	7.2
10	1	1	3	3	2	2	1	12.1
11	1	2	1	1	3	3	2	10.6
12	1	3	2	2	1	1	3	9.4
13	2	1	2	3	1	3	2	7.5
14	2	2	3	1	2	1	3	8.4
15	2	3	1	2	3	2	1	9.1
16	3	1	3	2	3	1	2	6.8
17	3	2	1	3	1	2	3	11.4
18	3	3	2	1	2	3	1	7.8
K1	10.73	10.12	9.97	10.12	9.72	8.97	9.98	
K2	9.08	10.08	9.78	9.15	9.38	10.95	8.73	
K3	9.15	8.77	9.22	9.7	9.88	9.05	10.25	
R	1.65	1.35	0.75	0.97	0.52	1.98	1.52	

Order: F > A > G > B > D > C > E
Optimum combination: A2 B3 C3 D2 E2 F1 G2

Results and Discussion

The Double-pan Roasting Machine was designed, developed and its performance was evaluated. The major parts of the Double-pan Roasting Machine were main frame, reduction motor, roasting pan, electric heater. The orthogonal experimental data of Double-pan Roasting Machine are shown in **Table 2**. The seven factors of the machine influencing the broken tea rate were studied. The result showed that the order of the seven factors was crank length, connecting rod length, rocker length, body frame rod length, horizontal inclination angle of roasting pan, fry speed, electric heating power. The most effective combination for the broken tea rate was under the following conditions: crank length was 200 mm, connecting rod length was 360 mm, rocker length was 330 mm, body frame rod length was 320 mm, horizontal inclination angle of roasting pan was 35 degrees, fry speed was 75 rpm, electric heating power was 10 kW. The experiment showed the broken tea rate was 5.4% under this condition.

In summary, the above orthogonal experiment optimization results, which greatly improves the performance of the Double-pan Roasting Machine. The parameters obtained in this study can be used for the kinematic simulation analysis of the tea roasting process, and provide basic data for the further development and optimization of the Double-pan Roasting Machine. However, in addition to the above factors, there are other influencing factors, such as temperature, swing amplitude, etc., which will be studied from other factors.

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Super Straw Management System - An Innovative and Complementing Mechanised Solution for In-Situ Recycling of Rice Residue in Rice-Wheat System of South Asia

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Abstract

Rice-wheat (RW) system is highly productive and important for food security in South Asia practiced on an area of 13.5 million ha. Huge quantities of crop residues are generated by the RW system. Rice straw is considered as waste, whose disposal or utilization is very difficult. Thus, open-field burning of rice residue is still the most convenient option for the farmers due to the lack of user-friendly, cost- and time-effective options. Constraints to adoption of recently developed Turbo Happy Seeder (THS) machine for direct seeding wheat into heavy loads of residue include low field capacity due to its inability to operate in wet straw, and uneven distribution of rice straw due to lack of straw spreaders on the current combine harvesters, which causes poor crop establishment. To address these concerns, efforts were made to develop and evaluate a straw management system (SMS) as an attachment to combine harvesters to chop and uniformly spread rice straw in the field to improve the efficiency of the THS machine. Three types of prototypes of SMS were developed culminating in the development of the most efficient Super SMS version 3. The coefficient of variation for uniformity of straw spread varied from 13 to 18% and 116-130% for operating combine harvester with super SMS attachment and traditional harvester, respectively. The weighted mean chop size of rice straw with super SMS was reduced to 14.9 cm compared with 28.6 cm for the traditional harvester. The field capacity of exiting THS machine was increased by 18.4% in the rice fields harvested with combine having super SMS attachment compared to that without SMS. The attachment of newly developed Super SMS on combine harvesters will accelerate the large-scale adoption of THS for direct seeding of wheat

in rice fields to curb straw burning.

Keywords: Combine harvester, Conservation agriculture, Rice residue management, Rice straw, Straw management system, Turbo happy seeder

Introduction

Rice-wheat (RW) system is practiced on around 13.5 million ha across the Indo-Gangetic alluvial plains (IGP) of South Asia (Ladha et al., 2009). RW system is highly productive and important for the food security and livelihood of thousands of millions of resource-poor families in South Asia. RW system also generates large quantities of crop residues wherein wheat residues are used as animal fodder but rice residues are generally considered as waste due to its non-economical uses outside the farm. In the RW system, management of rice residues is a serious problem, because there is very little turn-around time between rice harvest and wheat sowing and it has no economic use and thus remains unutilized due to its high silica content. Unlike rice straw, 75-80% of the wheat straw is collected from the fields for feeding to the cattle. After combine-harvesting, rice residue remains scattered in the field and is difficult to collect, and impedes seedbed preparation for subsequent wheat. In-situ incorporation of rice residue is energy/cost-intensive and it requires 2-3 extra tillage operations in addition to the use of a chopper to reduce the size of residue. Furthermore, extra time (20-25 days) needed for in-situ decomposition of rice residue is a major limitation because it delays the timely sowing of wheat, which adversely affects crop productivity. In north-western India, open-field burning of about 23 million tons of rice residue every year, is still the most convenient option for the farmers due to the lack of user-friendly, cost- and time-effective alternative options to clear the fields for sowing of the next wheat crop (NAAS, 2017). The burning of residues contributes to atmospheric pollution that has serious human and animal health implications due to the release of large amounts of air pollutants, and the loss of soil organic matter and plant nutrients during burning adversely affect soil health and sustainability of the RW system (Singh et al., 2014). However, crop residue is not a waste but rather a useful natural resource. In-field retention of crop residues as surface mulch can play an important role in replenishing soil nutrient stocks and improving soil health, contributing to sustainable RW production systems (Singh et al., 2010). Cost-effective management of crop residues is thus both a major challenge and a big opportunity for increasing the sustainability of the intensive RW systems of South Asia.

There are problems with direct drilling of wheat into combine-harvested rice fields using the conventional zero till seed drill due to: (1) straw accumulation in the seed drill furrow openers, (2) poor traction of the seed metering drive wheel due to the presence of loose straw, and (3) the need for frequent lifting of the implement under heavy residue conditions, resulting in uneven seed depth and thus crop establishment. To avoid rice straw burning, an innovative machine known as 'Turbo Happy Seeder' (THS) was developed, which can direct drill wheat into heavy loads of residue (Sidhu et al., 2007). Zero till wheat sowing with THS is a perfect climatic adaptation and mitigation strategy because it reduces the greenhouse gases emissions, enables early sowing of wheat, reduces fuel consumption and crop lodging, saves irrigation water, and increases the crop yields, particularly during high rainfall and/or years with terminal heat stress (NAAS, 2017). However, challenges in sowing wheat using THS have been chopping and uniform spread of loose residue across the harvested area because the current combine harvesters result in the uneven spread of the straw behind the combine (**Fig. 1**) and lower seeding capacity (0.3 ha h^{-1}) of the machine compared with 0.5 ha h^{-1} with conventional seed drills (Sidhu et al., 2015). Problems associated with concentrated windrows or piles of heavy residue include inherent uneven distribution of nutrients and soil moisture; difficulties in the following tillage and drilling; straw "tucking" or hair pinning in the seed row which affects poor seed-to-soil contact, resulting in poor and uneven emergence; non-uniform depth of seed placement due to the presence of loose straw; and emergence under residue mats, which can stunt early crop growth (Siemens and Wilkins, 2006; Schillinger et al., 2008; Botta et al., 2015). Uniform distribution of loose straw is a critical component of reduced or zero-till farming systems. The evenly spread of loose residues in the field is a prerequisite for the smooth operation of THS, while manual spreading of loose residue is costly and compounded by the acute shortage of labor (Sidhu et al., 2015). Therefore, a crop residue treating device, such as a straw chopper, straw spreader, or similar device as an attachment to the straw discharge hood of a combine is needed for treating the residue material before the discharge of the same over the ground (Detlev, 1986). The

Fig. 1 Rice field having uneven distribution of residue after using traditional combine harvester

current combine harvesters in South Asia have no straw management system (SMS) for managing heavy loads of rice residues. Therefore, the present study was undertaken to develop and evaluate an efficient mechanized straw management system (SMS) as an attachment to the combine harvesters, which could help in chopping and uniformly spreading the rice residue as a part of the process of harvesting rice. The objectives of the present study were to (1) design and evaluate the performance of indigenous SMS attachment with a possibility of straw chopping for combine harvesters for uniform spread loose rice straw in the fields, and (2) evaluate the effect of the SMS on the performance efficiency of the combine harvester and turbo happy seeder under RW system. We hypothesized that SMS with a straw chopping facility will improve the performance and field capacity of Turbo Happy Seeder for direct seeding of wheat into heavy loads of rice residue.

Development of Straw Management System for Combine Harvester

The development of different prototypes of straw managing system (SMS) was made in the workshop of the Department of Farm Machinery and Power Engineering, Punjab Agricultural University (PAU), Ludhiana, India. Field testing of the performance of the SMS and turbo happy seeder was conducted at the research farm of the PAU Ludhiana, Borlaug Institute for South Asia-CIMMYT at Ladhowal, Ludhiana, PAU Seed Farm, Ladhowal, Ludhiana, and on farmers' fields at different locations in Punjab India during 2006-2016 including testing of Super SMS (Version 3) at CIMMYT-CCAFS Climate-Smart Villages (CSVs) at Ludhiana.

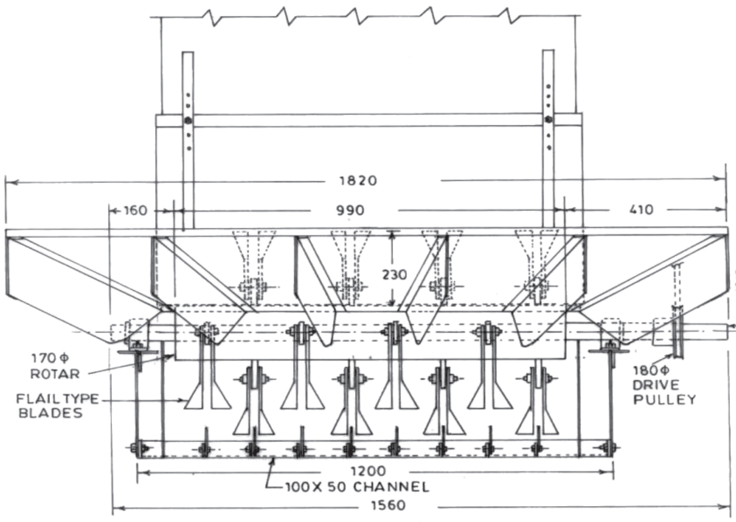
Shredder and Blower Type Straw Management System (Version 1)

The first version (V.1) of the tractor-operated combine-mounted straw managing system (SMS) was developed in 2006-07 (**Fig. 2**). The SMS consisted of a hub/rotor mounted for rotation in the horizontal plane. Four pairs of flails in a row were mounted on the hub and each of the four equally spaced rows along the entire periphery of the hub (**Table 1**). Each pair of flail during rotation passed over the fixed serrated blades which cut the straw into small pieces when it fell from the straw walker and chaffer sieves. The flail was designed by flapping its edge to create a blower action. This blower action was used to blow off the chopped material tangentially with the increased discharge velocity. At the end of the housing, an adjustable deflector was used, which was provided with hanging louvers/flaps for a uniform spread of residues. The chopped material passing through the deflector flaps was distributed uniformly on the already harvested field. There was provision for adjusting the deflector angle to the ground so that the chopped material could be evenly spread across the ground up to the width equal to the swath from which the crop was cut. The drive to the rotor of the SMS was obtained from the PTO of the same tractor (55 hp) with a dual-clutch mounted over the chassis of the combine harvester. The blower action of the flails created suction in the straw walker section of the combine harvester. This reduced the separation time of material on the straw walkers thereby, increasing the straw walker losses. In addition, blower action had a high power requirement. This initiated the development of low powered spreader type SMS as the power requirement for chopping and blowing the straw was high.

Spreader Type Straw Management System (Version 2)

Due to the high power requirement for chopping and its straw walker losses, the system for chopping of straw and generation of air current was abandoned. The future work was aimed at developing the spreaders using spinner discs (without size reduction). The spreader-type SMS included straw spreader discs placed below straw walkers and behind the chaffer sieves. It consisted of two counter-rotating spinner discs made from MS sheets. Three vertical vanes are riveted on each spinner disc at an angle of 120° and these divide the discs into 3 sections (**Fig. 3**). The counter-rotating discs spin at 500 rpm and evenly distribute the loose residues discharged from straw walkers in the cutter bar width of the harvester.

Fig. 2 Front view of straw managing system (V.1)



The SMS included stationery housing for easy attachment/detachment to the rear of the combine.

Chopper Type Straw Management System (Version 3)

The size reduction of rice residues improves the performance of machinery for in-situ management of residue due to the increased rate of its drying. Generally, rice residues contain 40-50% moisture content at the time of harvesting and the drying will reduce its load to be handled by the residue management machines, like turbo happy seeder. Therefore, work on the development of low-energy flails for the SMS rotor was undertaken. Chopper type SMS (V.3) hereafter named as 'Super SMS' consisted of stationary housing for attachment to the rear of the combine harvester. The straw coming out of the straw walkers of the combine harvester is fed to the unit from one side and is discharged from the outlet of the housing. Inside the housing, a rotor is mounted having six lugs in a row and four equally spaced rows along the entire periphery of the rotor. The rotor operates at speed in a range of 1600-1800 rpm, driven through V-belt and pulley arrangement. There are 24 stationary serrated blades fixed on the concave portion of the rotor housing for a combine harvester having 130 cm thresher drum width (**Fig. 4**). Each pair of flail during rotation passes over the stationary serrated blades and cuts the straw into pieces. This chopped straw is blown off tangentially and uniform spread is achieved with the help of a deflector attached at its outlet. The deflector spreads the chopped straw into the full width of the combine harvester. The brief specifications of the different versions of SMS are listed in **Table 1**.

Material and Methods

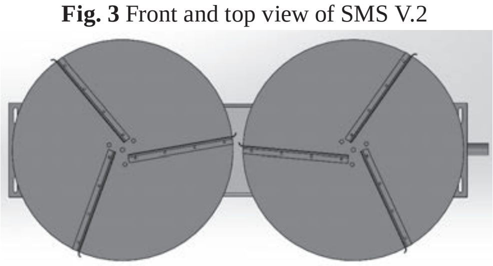
Field Evaluation of Straw Management Systems

On-farm and farmer participatory trials were conducted in different parts of Punjab, India, to evaluate the performance of the three versions of the SMS (V.1, V.2, and super SMS). The performance of different versions was compared based on uniformity of spread of rice residue and its size reduction, and fuel consumption and field capacity of combine harvester.

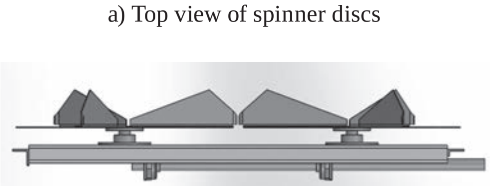
Evaluation of Straw Management System (V.1)

The first version of tractor-operated combine-mounted SMS (V.1) was tested for harvesting rice (variety PR-118) having an average plant height of 105.2 cm and the average height of cut by the combine was 37.6 cm from the ground. The combine was operated over the full width of the cut. The three variables selected for evaluation of the SMS in terms of the uniformity of straw spread were; the number of rows of fixed serrated blades, rotor speed index, and deflector angle. Fixed serrated blades and rotor speed index had three levels, whereas two deflector angles (200 and 300) were included in the study. Each treatment combination was replicated thrice. The combine was operated at PAU Seed Farm, Ladhowal, Ludhiana for harvesting rice having a straw load of 8.2 t ha^{-1}. The rotor speeds of 2120, 1820, and 1590 rpm were varied by using different V-belts pulleys, to create rotor speed index of 40, 35, and 30, respectively. Based on the preliminary testing, two deflector angles (20° and 30° with horizontal) were selected for the study which threw the straw within the desired swath width. The performance of SMS (V.1) was measured in terms of uniformity of straw spread by attaching the unit with a combine harvester having a 3 m width of cut. The harvester width of cut was divided into three equal grids (left, middle, and right) and loose straw mass was collected from each quadrant of 1 m^2 each.

Fig. 3 Front and top view of SMS V.2

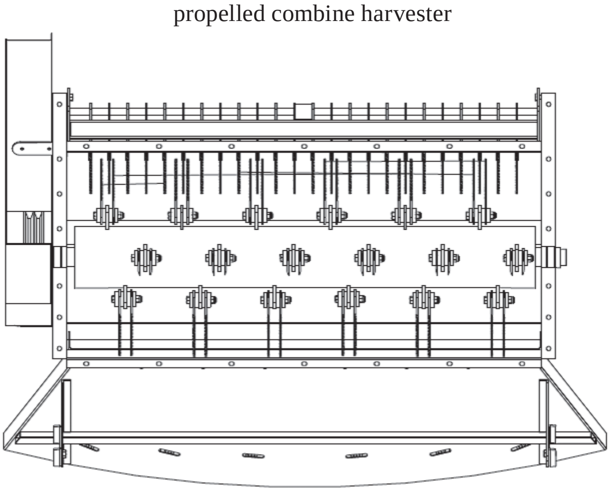


a) Top view of spinner discs



b) Front view of spinner discs

Fig. 4 Top view of PAU Super SMS attachment for the self-propelled combine harvester



Evaluation of Straw Management System (V.2)

Field experiments were conducted to check the uniformity of spread of rice residue by attaching SMS (V.2) in the rear of combine harvester in 2008 at the research farm of PAU, Ludhiana, India. The uniformity of residue spread was measured in terms of the coefficient of variation (CV). Version 2 (V.2) was attached behind the tractor-operated combine harvester of the Department of Farm Machinery and Power Engineering of PAU, Ludhiana with a 3 m cutter bar width. Combine harvester with SMS attachment at the rear was operated in a paddy field with an average straw load of 8.84 t ha^{-1}. The spinner discs of SMS attachment were operated at three different rpm (180-200, 480-500, and 780-800 rpm). The uniformity of residue spread was measured by dividing the width of the cut into three equal sections (left, middle and right) of 1 m each. After the harvesting operation, the loose residue dropped in the three sections of one-meter length of travel was collected for both with (V.2) and without SMS. The CV of residue spread of combine harvester was compared.

Evaluation of Super SMS

The uniformity of spread and size reduction was measured and the weighted mean of straw chop size was recorded. The Super SMS was attached behind the self-propelled combine harvester with a 4.27 m cutter bar width. Combine harvester with Super SMS attachment at the rear was operated in paddy field with an average straw load of 6.67 t ha^{-1}. The Super SMS attachment was operated at 1,700 rpm. The uniformity of residue spread was measured by dividing the width of the cut into four equal sections (left, middle left, middle right, and right) of 1.06 m each. After the harvester operation, the loose residue dropped in these sections for a one-meter length of travel was collected to determine the CV. The size reduction of straw was measured by segregating the collected samples after operation of combine harvester with and without Super SMS into various size ranges such as < 2.5, 2.5 to 7.5, 7.5 to 12.5, 12.5 to 20, > 20 cm to calculate the weighted mean of chop size. Performance evaluation of combine harvester in terms of cleaning efficiency, straw walker losses, sieve losses, fuel consumption, etc. was carried out with and without SMS operation. The samples of grain and straw from various outlets of the harvester were collected at selected forward speed, the width of cut, the height of cut, and engine rpm for a specified duration. A fuel flow meter (Aqua metro make, AM02025) with the least count of 1 ml was installed in the diesel line of combine harvester to measure the fuel consumption. The uniformity of spread of rice residues by attaching SMS in the rear of combine harvester was recorded in the year 2015 and 2016 at PAU seed farm, Ladhowal, Ludhiana, and research farm of Borlaug Institute for South Asia (BISA)-CIMMYT, Ladhowal

Table 1 Specifications of three versions of straw management system (SMS)

Description	Shredder & blower type SMS (V.1)	Spreader type SMS (V.2)	Chopper type Super SMS (V.3)
Combine harvester	Tractor operated	Tractor operated	Self-propelled
Power Required, hp	15-20	1-2	10-15
Power transmission	V-belt Pulleys	V-belt Pulleys	V-belt Pulleys
Mounting type	Detachable	Detachable	Detachable
Option for on/off switch	No	No	Yes
Harvester width, m	3.0	3.0	4.27
Speed of operation, km h^{-1}	1.4	1.7	3.4
Working capacity, ha h^{-1}	0.29	0.36	1.16
Fuel consumption, l ha^{-1}	4.0	0.89	3.06
Size reduction unit	Rotor with flails having flapped edge	-	Rotor with straight flails
Rotor diameter, mm	170	-	165
No. of lugs on rotor in a row	4	-	6
No. of rows of flails in periphery	4	-	4
Length of pivotal blade/flail, mm	230	-	172
Width of flail, mm	40 (top)	-	50
Thickness of flail, mm	8	-	4
No. of flails in one unit	2	-	2
Spacing between flails of one unit, mm	30-35	-	35
Distance between adjacent flail units, mm	248	-	202
No. of rows/bars of fixed serrated blades	3	-	1
No. of serrated blades in a row	8	-	24
Spacing between serrated blades, mm	124	-	50
Clearance between pivotal blade and concave, mm	15	-	10
Overlapping of pivotal blade on serrated blade	Fixed	-	Adjustable
Speed of rotor, rpm	1500-2100	480-500	1600-1800
Spreader unit type	Deflector type	Spinning discs	Deflector type
Number of flaps	6	-	8
Spreader angle with horizontal	Adjustable	0º	Adjustable
Spreader RPM	-	450-500	-
CV of spread, %	< 20	< 10	< 20
Size reduction	Yes	No	Yes

(Ludhiana), Punjab. The SMS was tested on 100 ha land planted with PR-121 and PUSA 1121 rice varieties having a straw load of 8.5 and 7.9 t ha^{-1}, respectively.

The rotor of the Super SMS unit operates at 1,600-1,800 rpm for chopping and spreading of rice residues in the entire width of combine header. Moreover, the Super SMS unit is attached below the combine harvester straw walkers and vibrations occur on the straw walkers for segregation of grains from the residue. To measure the effect of dynamic balancing on the machine rotor, acceleration was measured on the 9 locations marked on the super SMS and combine harvester (**Fig. 5**). The acceleration for super SMS was measured for a manually balanced and dynamic balanced rotor by operating the combine harvester at rated engine rpm. The acceleration was also measured by operating the combine harvester at rated engine rpm without engaging the Super SMS rotor. The vibration meter (VB-8201HA, aqua metro) having a least count of 0.1 ms^{-2} was used to measure acceleration at all the locations.

Performance of Turbo Happy Seeder in Rice Fields Harvested with Combine with SMS Attachment

The field trials were conducted in 2017 to check the effect of loose straw chopping on the operation of Turbo Happy Seeder in terms of residue clogging and field capacity at BISA farm, Ladhowal, Ludhiana, India.

Economic Evaluation of Straw Management Systems

The fuel consumption and time taken for harvesting rice were recorded for individual plots for combine harvester fitted with SMS V.2, Super SMS, and without SMS. A tractor operated and self-propelled combine harvester was used for performance evaluation of SMS V.2 and Super SMS, respectively. The combine harvester required two operators to operate the machine in the field and the hiring charges were taken as Indian Rs. 62.5 h^{-1}. The annual cost of tractor operated and self-propelled combine harvester was calculated using the straight-line deprecation method for the total life of 10 years and annual usage of 750 and 350 hours, respectively. The initial cost of tractor operated and self-propelled combine harvester was taken as Indian Rs. 800,000/- and Rs. 1,900,000/-, respectively. The total cost of tractor operated and self-propelled combine harvesters with SMS attachment V.2 and super SMS was taken as Rs. 830,000/- and 2,020,000/- respectively. The total variable cost was calculated by considering the fuel, lubricants, and repair and maintenance charges. The manual spreading of loose straw takes around 10 man-h ha^{-1} for spreading of loose straw and labour hiring charges were taken as Rs 37.5 h^{-1}. The total cost was calculated as the sum of hourly fixed and variable costs for the different harvester combinations.

Statistical Analysis

Data collected for different dependent variables were subjected to analysis of variance in a completely randomized design using SAS 9.3 software package. The differences between the two treatment means were considered significant at $P \leq 0.05$. Student's T-test using SAS 9.2 software package was performed for comparing grain yield between SMS versions (V.1, V.2, and super SMS) versus traditional combine harvester without SMS unit. Before statistical analysis of data, Levene's test was performed to test the homogeneity of variances using the Proc GLM procedure with the HOVTEST option in the MEANS statement. Differences between treatment means were compared using an LSD test at $P < 0.05$ (Gomez and Gomez, 1984).

Results and Discussion

Uniformity of Rice Residue Spread for Different Straw Management Systems

SMS V.1

The rotor speed index and fixed

Fig. 5 Spots for measurement of vibration data of SMS unit

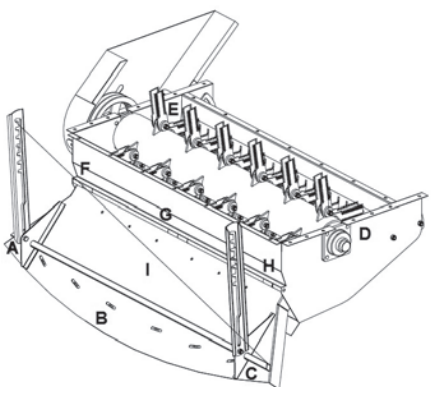


Table 2 Average value of coefficient of variation (CV) indicating uniformity of straw mass thrown at different number of fixed serrated blade rows (FSB), rotor speed index (RSI) and deflector angle (DA) for SMS V.1

Treatment	Treatment level			p-value
RSI	30	35	40	-
CV (%)	24.6a*	20.6b	16.8c	< .0001
FSB	One	Two	Three	-
CV (%)	27.2a	21.8b	12.9c	< .0001
DA, angle	20º	30º	-	-
CV (%)	20.8a	20.6a	-	0.86
RSI × FSB	-	-	-	0.27
FSB × DA	-	-	-	0.75
RSI × DA	-	-	-	0.88
RSI × FSB × DA	-	-	-	0.30

*Values followed by the different letter differ significantly at p < 0.05

serrated blade rows had a significant positive effect on the uniformity of straw spread (measured as coefficient of variation, CV) by the SMS V.1 (**Table 2**). The CV was significantly decreased with the increase in rotor speed index and the rows of fixed serrated blades on the concave. The deflector angle and different interactions among the three variables had no significant effect on the uniformity of spread (**Table 2**). The rotor speed index increases the tip speed of flails whereas fixed serrated blade rows increase the interference among stationary blades and rotor flails. This increases the amount of straw chopping and tangential velocity of straw from the SMS attachment. The high tangential velocity of straw residues and small chop size results in uniform spreading of straw.

SMS V.2

The CV among three sections of harvester width (left, middle, and right) was significantly lower compared to both 200 and 800 rpm (7.1%) for 480-500 rpm of spinner disc (**Table 3**). The CV of combine harvested rice residues without SMS attachment varied from 74.7 to 92.9% and was significantly more compared to combine operation with spinner disc attachment.

Fig. 6 Rice field showing uniformly spread of loose rice residues after using combine harvester with Super SMS attachment

Super SMS (V.3)

The CV for four sections of harvester width (left, middle left, middle right, and right) varied from 13.0 to 18.3% and 116 to 130% with and without super SMS attachment, respectively (**Table 4** and **Fig. 6**). The values of CV for combine harvested rice straw without SMS attachment was significantly more (122%) compared to combine operated with Super SMS attachment (15.7%). The CV was 7.6, 7.1, and 15.7% for straw management systems V.1, V.2, and Super SMS, respectively. The CV was higher for the Super SMS version as the combine harvester width was 4.27 m compared to 3.0 m for SMS versions V.1 and V.2.

Table 3 Coefficient of variation (%) for uniformity of rice residue spread at different revolutions (rpm) of spinner disc using combine harvester with and without SMS V.2

Parameter	Treatment	RPM of spinner discs		
		200	500	800
Coefficient of variation (%)	SMS V.2	37.6c* ±2.8	7.1a ±0.8	18.5b ±1.8
	Control (no SMS)	96.5a ±5.2		

± Standard error
*Values followed by the different letter differ significantly at $p < 0.05$

Table 4 Coefficient of variation (%) of rice residue spread with and without straw management system attachment on harvester

SMS Version	Without SMS attachment	With SMS attachment	P-value
V.1	96.5a* ±5.2	7.6b ±0.8	< .0001
V.2	85.5a ±3.9	7.1b ±0.8	< .0001
V.3	121.5a ±3.4	15.7b ±1.1	< .0001

± Standard error
*Values followed by the different letter differ significantly at $p < 0.05$

Table 5 Performance parameters of combine harvester with and without Super SMS attachment (V.3)

Parameters	SMS V.1		SMS V.2		Super SMS	
	Yes	No	Yes	No	Yes	No
Speed of operation, km h^{-1}	1.60	1.70	1.70	1.70	3.40	3.64
Width, m	3.00	3.00	3.00	3.00	4.27	4.27
Field capacity, ha h^{-1}	0.34	0.36	0.36	0.36	1.16	1.24
Fuel consumption, l h^{-1} (No load)	-	-	-	-	6.96	6.45
Fuel consumption, l h^{-1} (Full load)	8.44	6.50	6.77	6.45	13.67	11.08
Fuel consumption, l ha^{-1}	25.12	18.21	18.96	18.07	11.98	8.92
Straw walker loss, %	5.10	0.52	-	-	0.69	0.26
Sieve loss, %	0.20	0.40	-	-	0.18	0.23

Performance of Combine Harvester with and without Super SMS Attachment

The fuel consumption and field capacity were 13.7 l ha^{-1} and 1.16 ha h^{-1} for the combine harvester with super SMS and 11.08 l ha^{-1} and 1.24 ha h^{-1} for without SMS attachments, respectively (**Table 5**). The fuel consumption at 26 cm height of cut was 23.4% higher for combine with Super SMS attachment compared with a conventional combine harvester. The Super SMS attached with different makes of self-propelled combine harvesters was also evaluated in paddy fields having a straw load of 8.83 to 10.0 t ha^{-1}. The straw walker and sieve losses were in the range of 0.36 to 3.42% and 0.27 to 1.41%, respectively, for combine harvester with Super SMS attachment. The total losses of the combine harvester varied from 1.66 to 4.83% (**Table 6**). The chopping size of straw ranging from 2.5 to 20 cm was 211% smaller for combine harvester with Super SMS compared with combine harvester without SMS attachment (**Table 7**). The chop size was > 20 cm, which was 64% lesser for combine harvester with Super SMS compared with combine harvester without SMS attachment (**Fig. 7**). The weighted mean chop size was 48% smaller for Super SMS attachment compared with traditional combine harvester (28.6 cm).

Fine Tuning of Super SMS

The average acceleration was increased from 14.3 m s^{-2} without SMS to 31.6 m s^{-2} for static balanced SMS but it was decreased to 17.0 m s^{-2} for combine harvester with dynamically balanced SMS rotor while operating at rated engine speed (**Table 8**). The increase in acceleration was 121 and 18.9% for static balanced super SMS and dynamically balanced super SMS rotor over combine harvester without super SMS. The average reduction in vibration was 45.5% for the dynamically balanced super SMS rotor over the static balanced rotor.

Economic Evaluation of Straw Management Systems (V.2 and Super SMS) and Turbo Happy Seeder

The total cost of rice harvesting using tractor operated combine harvester was Indian Rs. 1,778 and Rs. 1,845 ha^{-1} for without and with SMS V.2 attachment, respectively (**Table 9**). Similarly, the total cost of harvesting rice using tractor operated self-propelled harvester was Indian Rs. 1,822 and Rs. 2,193 ha^{-1} for without and with Super SMS attachment, respectively. Thus additional cost involved was Rs. 86.2 and Rs. 371 ha^{-1} for operating the SMS V.2 and Super SMS, respectively. The custom operators are, however, charging Rs. 250 and Rs. 875 ha^{-1} more for operating the SMS V.2 and Super SMS, respectively. The cost of manual spreading of loose straw is Rs. 375 ha^{-1}, which can be saved when using SMS with a combine. The custom hiring cost of stubble shaver used by the farmers for cutting and spreading of the rice residues before burning is around Rs. 750 to Rs. 875 ha^{-1}. The Super SMS also chop the rice residue along with uniform spreading.

Effect of Super SMS on Performance of Turbo Happy Seeder

There was no straw accumulation when THS was operated in the rice fields harvested using combine fitted with SMS V.2. The attachment of Super SMS on combine increased the field capacity of THS by 18% over the THS used for seeding wheat in fields harvested with combine without SMS attachment (0.38 ha h^{-1}). The fuel consumption was 2.5% lower and the speed of operation was 29.3% higher for THS used for sowing wheat in rice fields harvested using combine fitted with Super SMS compared with no attachment of SMS (**Table 10**).

Present Status of the Technology

Currently, there are 4,455 and 7,613 units of tractor-operated and self-propelled combine harvesters available in the Punjab state of India (Anon., 2016). Super SMS has been installed on 1,360 and 4,722 self-propelled combine harvesters during 2016-2017. The Super SMS have covered about 54,400 and 180,000 ha of area respectively, during 2017-18 and 2018-19 (Source: Department of Farm Machinery and Power Engineering, PAU, Ludhiana, India). The government of Punjab (India) has made the installation of Super SMS mandatory on all self-propelled combine harvesters for harvesting rice crops from the year 2018-19 under the Air Quality Act-

Fig. 7 Different chop sizes of rice residues after operation of combine harvester with Super SMS attachment

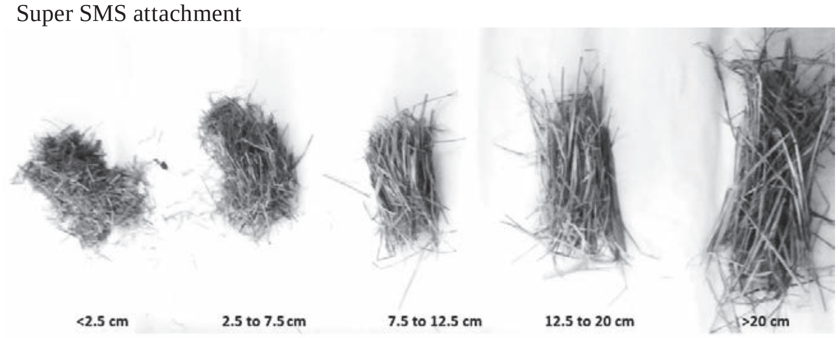


Table 6 Performance parameters of combine harvester with Super SMS

Combine harvester with SMS V.3	Rice straw load (t ha^{-1})	Straw walker loss (%)	Sieve loss (%)	Total loss (%)
Make 1	8.83	1.66	0.27	1.93
Make 2	9.50	0.36	1.30	1.66
Make 3	6.23	3.42	1.41	4.83
Make 4	10.0	1.46	0.54	2.00

Table 7 Percent distribution of chop size (cm) of residue for rice harvested by combine with and without Super SMS attachment

Range in chop size (cm)	Average size (cm)	Percent distribution	
		Without SMS	With Super SMS
< 2.5	1.25	10.6 ±2.2	28.1 ±10.4
2.5 to 7.5	5	2.5 ±1.9	11.5 ±1.7
7.5 to 12.5	10	3.1 ±1.1	15 ±1.5
12.5 to 20	16.25	7.1 ±2.3	18 ±3.1
> 20	35	76.8 ±4.9	27.3 ±4.3
Weighted mean size (cm)	-	28.6a ±1.2	14.9b ±2.1

± Standard error
*Values followed by the different letter differ significantly at $p < 0.05$

1981. Accordingly, over 4,000 combine harvesters have already been equipped with Super SMS. Presently, there are more than 150 combine manufacturing companies in Punjab state of India having manufacturing capacity of 15-20 units year^{-1} to 400-500 units year^{-1}. The super SMS system has increased the adoption rate and acceptability of THS among the farmers of the state. With the adoption of Super SMS technology, the number of units of THS sold has increased significantly from 980 units in 2017 to 8,902 units during 2018. Therefore, Super SMS is a precursor for the large-scale adoption of Turbo Happy Seeder. Super SMS attachment for the self-propelled combine harvesters will play a key role in tackling the problem of residue burning in the North-Western states of India and the other parts of South Asia thereby reducing environmental pollution and improving soil health.

Table 8 Comparative vibrations for combine harvester with and without Super SMS (V.3)

Mark on harvester	Acceleration, m s^{-2}			% decrease in vibration over static balance
	No SMS	Super SMS, static balanced	Super SMS, dynamic balanced	
A	12.7	29.7	16.0	46.1
B	21.5	43.1	26.3	39.0
C	16.3	39.8	17.8	55.3
D	6.5	25.2	7.9	68.7
E	7.5	21.3	12.3	42.3
F	14.3	23.6	14.4	39.0
G	19.6	24.2	19.7	18.6
H	9.4	21.6	11.0	49.1
I	20.7	56.0	27.2	51.4
Average	14.3	31.6	17.0	45.5

Table 9 Comparative economics of SMS V.2 and Super SMS for harvesting paddy residues

Item	Tractor-operated combine harvester		Self-propelled combine harvester	
	Without SMS V.2	with SMS V.2	Without Super SMS	With Super SMS
Machine cost*, Rs.	800,000	830,000	1,900,000	2,020,000
Total fixed costs (Rs. year^{-1})	145,200	150,645	344,850	366,630
Total fixed costs (Rs. h^{-1})	207.4	215.2	985.3	1,047.5
Total variable cost (Rs. h^{-1})	732.6	768.8	1,274.0	1,496.2
Total cost (fixed + variable) (Rs. h^{-1})	940.0	984.0	2,259.3	2,543.8
Cost (Rs. ha^{-1})	1,843.2	1,912.3	1,822.0	2,192.9
Additional cost due to SMS attachment (Rs. ha^{-1})	-	86.2	-	370.9
Custom hiring rate (Rs. ha^{-1})	3,000	3,250	3,000	3,875
Additional hiring charge due to SMS attachment (Rs. ha^{-1})	-	250		875
Cost of manual spreading (Rs. ha^{-1})	375	-	-	-

* The cost calculations were done in Indian currency and 1 Rs. = 0.015 USD

Table 10 Fuel consumption and field capacity of turbo happy seeder for sowing wheat after operating combine harvester with and without Super SMS (V.3)

Turbo Happy Seeder Operation	Fuel (l h^{-1})	Fuel (l ha^{-1})	Forward Speed (km h^{-1})	Field capacity (ha h^{-1})
After no SMS	8.04 ±0.38	21.27 ±0.74	1.91 ±0.04	0.38 ±0.005
After SMS	11.11 ±0.23	20.74 ±0.53	2.47 ±0.05	0.45 ±0.01
% change over no SMS	38.2	-2.5	29.3	18.4

± Standard error

Conclusions

1. The total rice grain losses from the straw walker of the combine harvester with SMS V.1 attachment were 5.1%, as the flails of the SMS were generating the air current to create suction. This reduced the separation time of the material (straw and grains) over the straw walkers and increased the straw walker losses. Moreover, the fuel consumption of the SMS V.1 was 29.9% higher compared with the combine harvester without SMS attachment.
2. SMS V.2 with counter-rotating spinner disc type arrangement only spreads/deflects the loose residue without size reduction.
3. Super SMS, having modified flails with serrated-straight edge blades, resulted in grain loss from straw walker and sieves of combine harvester as 0.69 and 0.18%, respectively however, the losses were under the permissible limit of 2.5% as per IS 8122 (1994). Super SMS operation does not affect the cleaning efficiency of the combine harvester.
4. Dynamic balancing of the rotor with pivoted flails on Super SMS is mandatory due to large vibrations on the straw walkers during the segregation of rice grains from straw.
5. There is a saving in cost by 33% with Super SMS over manual spreading. Super SMS also chop the rice residue along with uniform spreading. Therefore, the farmers need not incur extra costs for chopping and spreading rice residues by hiring a stubble shaver machine.
6. Due to chopping and uniform

spreading of the rice residue, there is an increase in field capacity of THS by 18.4%, enabling a custom operator to cover 0.5 ha day^{-1} more than THS without the Super SMS operation. This increases the return of custom operators by Rs. 1,875 day^{-1}.

7. Super SMS attachment for the self-propelled combine harvesters can play a key role in tackling the problem of rice residue burning thereby reducing environmental pollution and improving soil health.

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Design, Development and Evaluation of a Swinging Lance Sprayer

by

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Abstract

Application of pesticide in recommended dose not only reduces the input cost of chemical but also reduces the ill effects due to excess application. The spray swath of conventional tractor mounted gun type sprayer depends on the movement of the spray gun by the operator, resulted in uneven distribution. A tractor operated swinging lance sprayer was developed with automation of spray gun operation by eliminating manual operation of spray guns. The developed sprayer consists of piston type pump, power transmission system, chemical tank, crank-rocker type swinging mechanism, worm gear DC motors, power terminals. The developed swinging lance sprayer resulted in uniformity distribution of spray chemical over crop canopy. The theoretical field capacity, effective field capacity and field efficiency of developed sprayer was 3.6 ha/h, 2.56 ha/h, 71.1%, respectively at forward speed of 0.75 m/s. The bio-efficiency of sprayer was 68.5% and 91% at 3DAS and 5DAS, respectively. The operating cost per hectare was USD 3.32. The developed sprayer performed better in terms of spray deposition, low application cost, saving of manpower, elimination of chemical exposure to the spray gun operators over conventional tractor mounted gun-type sprayer.

Introduction

The world is facing challenges of food, water, energy and environmental pollution, leading to a serious climate change risk. Optimum use of resources to meet the food demand of the burgeoning population is a major issue before researchers. Food grain production in India increased from 52 million MT in 1951-52 to 303.34 million MT in 2020-21. The critical role played by plant protection practices is well recognized. Direct yield losses range between 20 and 40% of global agricultural productivity due to pathogens, animals, and weeds (Oerke, 2006). The production loss due to pests estimated in India is USD 42.66 million annually (Devi et al., 2017). The increased damage to crops due to pests and subsequent losses results in serious threat to food security. A 40-50% reduction in pesticide consumption reduces the protection cost from USD50/ha to less than USD30/ha (Kumar et al., 2020). Tractor mounted gun type sprayer with hose pipe length 60-300 m, was popular in many parts of India due to its high field capacity, low application cost and versatility for multi crop usage. However, a tractor mounted gun-type sprayer required four persons, out of which two are for operating spray guns, one for handling hose pipes and one for operating tractor (Narang et al., 2015). Though this method gives satisfactory pest control, it consumes a large volume of liquid per hectare. The spray swath depends on the movement of the spray gun by the operator. Uneven distribution was a significant drawback from conventional spraying due to varying swing speed and distance by the operator (Hermosilla et al., 2011). On the other hand, the operators were exposed to the chemical spraying in front of his way. The dermal exposure with a manually operated gun sprayer is very high; a human-driven vehicle with fixed boom and constant spray volume can reduce dermal exposure by 60-fold compared with manual gun spraying (Nuyttens et al., 2007). Automation of swinging of spray guns could improve spraying efficiency in terms of uniform application, and reduction in chemical losses. Hence, a tractor operated swinging lance sprayer was developed with automation of spray gun operation by eliminating manual operation of spray guns. The present study focused on objectives of (1). Design and fabrication of various components of swinging lance sprayer (2). Performance evaluation of developed swinging lance sprayer in green gram crop.

Material and Methods

Design of Components for Swinging Lance Sprayer

To design swinging lance sprayer, some of the components were selected based on the requirement from the commercially available products. The other components were designed analytically and fabricated based on the requirement. The critical components of swinging lance sprayer, their selection and design procedure explained in details in following sections.

Selection of Spray Guns for Swinging Lance Sprayer

In order to ensure the application of recommended chemical, it was essential to estimate the required discharge rate of spray guns. The maximum time required to cover one hectare of field was 27 min at forward speed of 0.75m/s, swath width of 8 m. The recommended application rate of field crops was 500 l/ha. The required discharge rate of sprayer was 18.5 l/min. In developed swinging lance sprayer, there were two spray guns. Hence, the required discharge rate of each spray gun was 9.25 l/min.

Selection of Pump for Swinging Lance Sprayer

The required discharge rate of spray guns was 18.5 l/min. A capacity of 25% higher than the requirement needs to consider for the design. Usually, 5-10% of pump discharge required for hydraulic agitation of sprayer (Sharma and Mukesh, 2019). The sprayer demands a continuous supply of chemical of 25 l/min. Piston type pumps were most suitable for high pressure applications up to 40 kg/cm^2 (Manian et al., 2002). A commercially available piston type pump was with maximum discharge rate of 36 l/min with operating rpm of 950, maximum pressure of 28 kg/cm^2 was selected.

Design of Chemical Tank for Swinging Lance Sprayer

The tank acts as a reservoir for the supply of chemical solution during the spray. The application rate for field crops was 500 l/ha. The majority of farmers in the selected area were marginal and small group with the average field size of one acre. Hence, a capacity of 400 liters was selected to avoid frequent refilling. The material of tank was polyvinyl chloride chosen due to its low expensive and highly resistant to most of the agrochemicals used.

Design of Power Transmission System for Swinging Lance Sprayer

The sprayer pumps, driven by tractor PTO shaft were widely acceptable due to its mounting versatility and ease of operation and maintenance (Wolf et al., 2004). The rotary power to drive the hydraulic pump of the sprayer was taken from the tractor PTO shaft. Adjustable telescopic universal propeller shaft was used to transmit the tractor P.T.O shaft power. The rotary power of tractor PTO transmitted to piston type pump through pulley and V-belt drive. The design criteria to determine size of the pulley and V-belt was given below

Design of pulley

The selected pump was fitted with pulley of 101 mm size (D_1). The size of the pulley for universal propeller shaft was calculated based on following criteria.

Available speed at tractor P.T.O shaft = 540 ± 10 rpm

Required speed at pump shaft = 950 rpm

Velocity ratio = Speed of the pump, rpm / Speed of PTO, rpm [1]

Velocity ratio = 950 / 540 = 1.76

Size of universal PTO shaft pulley (D_2) = Velocity ratio × D_1 = 1.76 × 101 = 177.76 ≈ 178 mm

Hence, a pulley of 178 mm size was selected for universal PTO shaft.

Selection of V-belt

Velocity of belt is calculated by using Formula 2.

$V = (\pi \times D \times N) / 60$ [2]

$V = (3.14 \times 0.178 \times 540) / 60$

$V = 5.03$ m/s

When the belt continuously runs over the pulley, centrifugal forces were caused to increase the tension on both the tight side as well as slack sides. At lower belt speed (< 10 m/s), centrifugal tension is very small. The designed speed of the belt is 5.03 m/s; hence its centrifugal tensions was neglected.

The distance between pump pulley and PTO pulley was 830 mm. The length of V-belt was calculated by using Formula 3 (Sharma and Mukesh, 2019).

$L = (\pi/2) \times (d_2 + d_1) + (2x) + [(d_2 - d_1)^2 / 4x]$ [3]

$L = (3.14/2) \times (178 + 101) + (2 \times 830) + [(178 - 101)^2 / 4 \times 830]$

$L = 2057$ mm

The total length of belt was 2057 mm, hence A81 inch V-belt was selected for the power transmission system of developed swinging lance sprayer.

Design of Frame for Swinging Lance Sprayer

The rectangular frame was fabricated using a hallow square MS pipe of with 50 × 50 × 5 mm. The MS flat of size 50 × 10 mm was fabricated on the sides of the rectangular frame with of size 3200 × 920 × 1550 mm (L × W × H). The inner section of the frame accommodate 400 liters chemical tank. The front of the frame fixed with a three-point linkage. The rear end of the frame has provision to adjust the spacing between spray guns, height of the spray gun and swing angle of the spray gun. The boom has telescopic extension. The spacing between spray guns was 2 m; there was provision to 30 cm and 60 cm either sides of the boom. If extension was 30 cm in both the sides, the spacing between spray guns was 2.6 m; if the extension was 60 cm in both the sides, the spacing between spray guns was 3.2 m.

Design of Swinging Mechanism of Spray Guns

The mechanism considered for the design of swinging of spray guns was four-bar linkage mechanism. A four-bar linkage mechanism consists of four rigid links connected end to end and forms a closed loop. The fours links were: fixed link, crank, coupler and rocker. The fixed link was a stationary link, the crank was input link, and rocker was output link. The rotary motion of crank was converted to oscillating motion of rocker by means of coupler link (**Fig. 1**).

(a) Degree of freedom

The degree of freedom can be defined as the number of actuators needed to operate the mechanism. The degree of freedom of a mechanism can be calculated by using the Formula 4 (Esmail et al., 2018).

$$DOF = 3L - 2J - 3 \quad [4]$$

Where,

L = number of links

J = number of joints

There are four links and four joints in selected linkage mechanism.

$$DOF = 3(4) - 2(4) - 3 = 1$$

The degree of freedom of selected four bar linkage was one, hence it can be operated by a single motor.

(b) Grashof's Criteria

Let the length of links of four-bar mechanism be as following:

a = shortest link,

b = longest link,

c = one of the intermediate links,

d = other intermediate link.

For swinging operation of spray guns, oscillating motion was required, hence crank- rocker type four bar linkage considered. For the crank-rocker type mechanism, the shortest link should be at side as per four-bar linkage classification (**Table 1**). Hence, the crank was considered as shortest link and fixed as side link, the rocker was longest link, the other two links were coupler and frame.

The dimension of shortest link (crank) was 8.5 cm, longest link (rocker) was 42 cm, coupler was (38-42 cm), fixed link was 40 cm.

Grashof's criteria: $(a + b) < (c + d)$

$(8.5 + 42) < (40 + 42)$

$50.5 < 82$

The positions of the mechanism when the rocker is at a limit position are called the dead-center positions of the four-bar mechanism. The oscillation angle of the rocker between the dead-center positions and measured from the extended dead-center to the folded dead-center position was called the swing angle (Θ), (**Fig. 2**). The swing angle was always corresponding with crank angle. The maximum swing angle between dead center positions was 120°, (**Fig. 3**).

The swinging mechanism of developed sprayer required one rotary motion. There were two such swinging mechanisms in the developed sprayer; hence two motors are required. The torque required by the motor was calculated, Formula 5.

$$T = F \times \mu \times f_s \times f_l \times l \times (\omega a/\omega m) \times (1/e) \quad [5]$$

Where,

T = Torque of wiper motor, N-m;

F = Force required by swinging rocker, N;

μ = maximum dry coefficient of friction, 2.5;

f_s = multiplier for joint friction, 1.15;

f_l = tolerance factor, 1.12;

l = length of swinging rocker, m;

ωa = max. angular velocity of rocker, rad/s;

ωm = mean angular velocity of motor, rad/s;

e = efficiency of motor gear unit, 0.8.

Table 1 Classifications of four bar linkage (Esmail et al., 2018)

Classification	Conditions	
	Criteria	Smallest link
Double Crank	(a + b) < (c + d)	Frame
Crank-Rocker	(a + b) < (c + d)	Side
Double -Rocker	(a + b) < (c + d)	Coupler
Change Point	(a + b) = (c + d)	Any link

Fig. 1 Line diagram showing various links of four-bar linkage

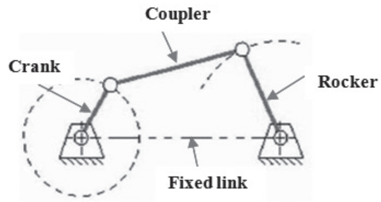


Fig. 2 Line diagram of crank-rocker mechanism

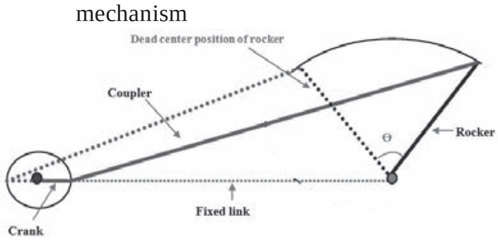
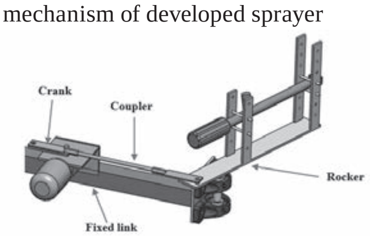


Fig. 3 Schematic diagram of swinging mechanism of developed sprayer



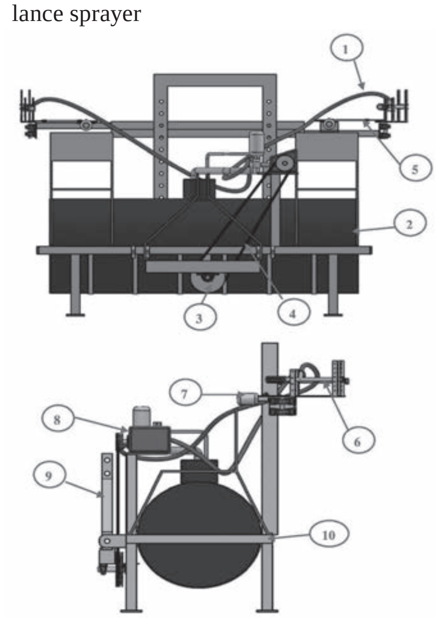
The force required to operate swinging mechanism was 17.95 N, maximum angular velocity of rocker was 4.68 rad/s, mean angular velocity of motor was 4.68 rad/s. By substituting the values in the equation 3.6, the torque required for swinging operation was 26 N-m, hence commercially available worm gear DC motor of 30 N-m torque, 12 V DC, 50 W was selected for design.

Performance Evaluation of Developed Precision Swinging Lance Sprayer

Measurement of Application Rate

A distance of 100 m length was marked in the field. The sprayer was operated and covered 100 m distance at three forward speeds, i.e., 0.75 m/s, 1.0 m/s, 1.25 m/s. The waster consumed to spray 100 m was measured with top-up method. The actual discharge rate of sprayer was calculated from volume of water consumed and time taken to cover 100 m distance. The application rate was calculated by using following Formula 6.

Fig. 4 Schematic diagram of swinging lance sprayer



1. Hose pipe, 2. Chemical tank, 3. PTO-pulley, 4. V-belt, 5. Swinging mechanism. 6. Spray gun, 7. Worm gear DC-motor, 8. Pump, 9.3-point linkage, 10. Frame

Application rate (l/ha) = (D × 600) / (S × W)   [6]

Where,
D = discharge rate, l/min;
S = speed of tractor, km/h;
W = swath width, m.

Measurement of Spray Droplet Deposition

Five plants were randomly selected in each run, and kromekote papers (5 × 2 cm) were placed on the upper side of the top and bottom portion of the plants (**Fig. 6b**). Methylene blue MS dye mixed @5 g/l was mixed with spray solution. After spraying kromekote papers were allowed to try and collected for droplet analysis. In first step, the deposit collected paper was scanned by using scanner. In second step, convert the image type from RGB to 8-bit gray image. Select the portion of image that need to analyze by using tool bar. Finally, gets the results window showing droplet size at DV0.1, DV0.5 and DV0.9, density, percent cover, volume of spray. The time required to process and get the results is less than 30 seconds (Zhu et al., 2011) (**Fig. 5**).

Measurement of Field Performance Parameters

The field performance parameters such as theoretical filed capacity (ha/h), effective field capacity (ha/h) and field efficiency (%) were measured with standard procedure. The theoretical field capacity was calculated by considering speed and swath width. The actual field capacity was calculated by measuring actual time taken to cover one-hectare area. The field efficiency was the ration of effective field capacity to theoretical field capacity.

Measurement of Bio-efficiency

The field experiment conducted in green gram field after 60DAS to control pod bug (Riptortus Pedestris). Thiamethoxam 25% WG @100g/ha, spray liquid volume of 500 l/ha sprayed on the crop. Before spraying activity, number of pod bugs in m^2 area counted randomly. After spraying activity, the number of pod bugs at 3DAS (days after spraying) and 5DAS (days after spraying) also counted and compared with control. The bio-efficiency was calculated using Formula 7 (Ordaz et al., 2016).

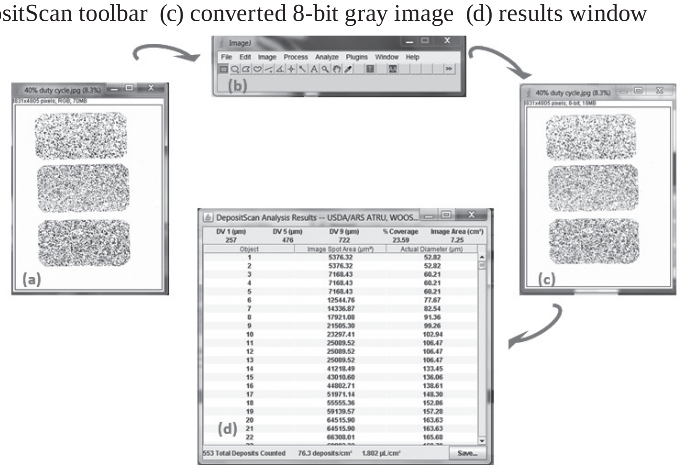
Percent pod bug reduction = 1 − (number of pod bugs after treatment / number of pod bugs in control) × 100   [7]

Results and Discussion

Application Rate (l/ha)

The application rate of the developed swinging lance sprayer was calculated at forwarding speeds of 0.75m/s, 1.0 m/s and 1.25 m/s. The application rate of 773 l/ha,580l/ha and 464l/ha observed for forward-

Fig. 5 Droplet analysis steps using DepositScan (a) original scanned color image (b) DepositScan toolbar (c) converted 8-bit gray image (d) results window



ing speeds of 0.75m/s, 1.0m/s and 1.25 m/s, respectively.

Spray Droplet Deposition

The CV in droplet size was 3.9 and 5.78 for top leaves and bottom leaves, respectively. The mean droplet size of 427.5 m and 342. m for the top leaves and bottom leaves, respectively. The droplet size was not significantly influenced by the forward speed of the tractor (Pankaj et al., 2011). The CV in droplet density was 9.91 and 8.41 for top leaves and bottom leaves, respectively. The mean droplet density of 114.8 drops/cm^2 and 110.13 drops/cm^2 for the top leaves and bottom leaves, respectively. In comparison, the droplet density was more on top leaves than bottom leaves. The top leaves invariably receive more droplet density due to direct exposure (Narang et al., 2015; Sirohi et al., 2008) crop canopy influence the spray deposition on bottom leaves. At the same time, droplet density decreased with an increase in speed for top and bottom leaves. The forward speed of sprayer determines the exposure time of target to the spray. Lower operating speeds resulted in more spray per unit area of plant canopy, thereby, increase in droplet density (Jassowal et al., 2016; Pankaj et al., 2011). The CV in percent cover was 6.21 and 9.35 for top leaves and bottom leaves, respectively. The mean percent cover of 21.47% and 19.36% for top leaves and bottom leaves, respectively. The same time, the percentage cover decreased with an increase in speed for top and bottom leaves .The CV in volume of spray was 3.7 and 3.44 for top leaves and bottom leaves, respectively. The mean volume of spray of 1.47 L/cm^2 and 1.21 L/cm^2 for the top leaves and bottom leaves, respectively. The volume of spray increased with increase in speed for both the systems for top and bottom leaves. The CV in uniformity coefficient was 5.15 and 4.04 for top leaves and bottom leaves, respectively. The mean uniformity coefficient of 1.66 and 1.52 for the top leaves and bottom leaves, respectively. The Uniformity coefficient increased with an increase in speed for top leaves, whereas the uniformity coefficient decreased for bottom leaves. The uniformity coefficient nearer to one is desirable; the forward speed should be such that the canopy receives adequate spray.

Fig. 6 (a) Field evaluation of swinging lance sprayer (b) Placement of kromekote papers on crop canopy


(a)


(b)

Field Parameters

The theoretical field capacity of the developed swinging lance sprayer at forward speeds of 0.75 m/s, 1.0 m/s and 1.25 m/s, were 3.6 ha/h, 4.8 ha/h and 6.0 ha/h, respectively. The effective field capacity of the developed swinging lance sprayer, at forward speeds of 0.75 m/s, 1.0 m/s and 1.25 m/s, was 2.56 ha/h, 3.33 ha/h and 4.16 ha/h, respectively. The field efficiency capacity of the developed swinging lance sprayer, at forward speeds of 0.75 m/s, 1.0 m/s and 1.25 m/s, was 71.1%, 69.3% and 71.7%, respectively.

Bio-efficiency (%)

The percentage reduction in pod bugs was considered to identify bio-efficiency of developed swinging lance sprayer. The bio-efficiency of developed sprayer in control of pod bug at 3DAS and 5DAS was 68.5% and 91.0% , respectively.

Cost Economics

The operating cost of the tractor was USD 7.10 /h, the operating cost of swinging lance sprayer was USD 1.41 /h. Total operating cost of swinging lance sprayer was INR. 641 /h. The operating cost per hectare was USD 3.32. The break-even point was 127 h/year or 325 ha/year.

Conclusions

The developed swinging lance sprayer with automation of spray gun operations resulted in uniformity distribution of spray chemical over crop canopy. The theoretical field capacity, effective field capacity and field efficiency of developed

Table 2 Spray droplet deposition parameters

Parameter	Top leaves				Bottom leaves			
	Range	Mean	SD	CV	Range	Mean	SD	CV
Droplet size (µm)	405.1-465	427.52	16.7	3.9	310.1-378.7	342.9	19.82	5.78
Droplet density (drops/cm^2)	103.4-137	114.87	11.39	9.91	96.8-124.2	109.98	9.25	8.41
Percent cover (%)	19.07-23.73	21.42	1.33	6.21	17.67-21.8	19.36	1.22	9.35
Volume of spray (µl/cm^2)	1.4-1.59	1.49	0.05	3.7	1.13-1.27	1.21	0.04	3.44
UC	1.53-1.81	1.66	0.08	5.15	1.43-1.62	1.52	0.06	4.04

sprayer was 3.6 ha/h, 2.56 ha/h, 71.1%, respectively at forward speed of 0.75 m/s. The bio-efficiency of sprayer was 68.5% and 91% at 3DAS and 5DAS, respectively. The operating cost per hectare was USD 3.32. The developed swinging lance sprayer can be used for multiple crops like green gram, black gram, soya bean, chilli, cotton, tobacco. The developed sprayer performed better in terms of spray deposition, low application cost, saving of labor, elimination of chemical exposure to the spray gun operators over conventional tractor mounted gun-type sprayer.

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An Overview of the Cotton Value Chain and Perspectives in the Republic of Mozambique

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Abstract

Cotton, is one of the main cash crops of Mozambique, contributes significantly to the country's economy and foreign exchanges earnings. In Mozambique, cotton production is predominantly household farming, with around 220000 household farmers in the rural areas, benefiting approximately 1.2 million people directly. The sale of raw cotton's seed is the main source of household family's income. Production is mainly concentrated in the Northern and Central regions of the country, with around 180000 hectares. Sowing is usually carried out between October and December and harvesting takes place from April to June. The importance of cotton in Mozambique goes beyond its weight in the trade balance and in the generation of jobs in the countryside. Throughout its production chain, it generates between 15 and 20 thousand jobs, between seasonal and permanent. This paper presents information and analysis regarding current situation and perspectives developments in the value chain of cotton economy of the Republic of Mozambique.

Keywords: Cotton, Mozambique, Value Chain, Market, Production

Introduction

Cotton is one of the most important cash crops in Sub Saharan Africa (SSA) and has had an important role in job creation, poverty reduction and foreign exchange generation. With coffee, it is the most important export cash crop (before sugar cane, oil seeds, nuts, tea, and spices). It is an essential cash crop in more than one third of SSA countries and one upon which millions of small holder farmers and rural households depend for their livelihood. Hence, developments in the cotton sector play a crucial role in poverty reduction. SSA countries dependent on the export of one or few cash crops face particularly three interconnected challenges, first, how to increase yields and quality and hence achieve higher incomes in the context of small holder farming those accounts for most of the agriculture economy in SSA, second, how to deal with volatile international prices and hence external vulnerability, third, how to increase value addition through local processing and or input provision. These issues are connected. In the context of high price instability farmers try to manage risk and maximize their income by switching between different cash and food crops or varying the use of inputs with important implications on production volumes, yields and quality as well as on the sustainability of processing and input provision activities (Staritz and Troster, 2015).

Cotton is one of the major sources of income for the rural households in the central and northern Mozambique. The cotton sector is generally characterized by low yields and low returns and has a high dependency on weather and climate conditions due to its heavy reliance on rain fed system of production (IAOM, 2012).

Mozambique is a small cotton exporter, characterized by being a price receiving country, therefore, events that affect market and price conditions are carefully observed at the cotton subsector and state level (IAOM, 2011). In the country, this is the only crop whose marketing price is approved annually by the government, which diverges from the free market macroeconomic policy adopted by the Mozambican state (MozSAKSS, 2011).

Cotton cultivation in Mozambique was introduced in the 19th century, going through different production models. Currently, cotton production is based on the system of concessions of areas to cotton ginning companies, responsible for the promotion and rural extension of this crop, which is practiced mainly by small farmers. The cotton subsector is an important source of income in rural Mozambique. The importance of cotton is also reflected in its weight in the trade balance, as it is one of the most exported agricultural products in the last decade. This study aims to describe the current situation regarding to production and marketing structure of this commodity, moreover, to characterize the different aspects of the cotton subsector in Mozambique over the period between 2015 to 2021 and identify the main factors of competitiveness, as well as the major constrains.

Material and Methods

The data were obtained from the Institute of Cotton and Oilseeds of the Republic of Mozambique, while writing up updated information was given by stakeholders involved in whole value chain of this commodity across the country. These stakeholders include private sector actors, government staff engaged in the planning, monitoring, and evaluation of the cotton subsector. Moreover, secondary data from various sources were consulted, such as, lecture reviews, including, official publications, published articles journals as well as documents from the internet. Analysis of the data were processed by using excel software program.

Results and Discussion

Cotton Production

Cotton production in Mozambique is mostly carried out by small farmers (household farmers) since its introduction in the early 19th century. In regional terms, cotton production is carried out mostly in the northern and central regions of the country (Bruna, 2014). The Southern region comprises the smallest cotton cultivated area. Because, in this region, cotton is just cultivated in some regions of the provinces of Inhambane and Gaza. Inhambane province has recorded the largest cotton cultivated areas. The cultivated area and evolution of production in Mozambique in last seven cropping seasons is shown in the **Fig. 1**. Cotton production sharply decreased over the period of our analysis from 45,824 tons in 2015 cropping year to 35,832 tons in 2017 cropping year, it reached its maximum production of 65,653 tons in 2018 cropping year, which is very low compared to historic production of 144,061 tons achieved when Mozambique was under Portuguese rule. From the **Fig. 1**, it is possible to verify that the cotton cultivated area tends to decrease over the years under analysis. In the cropping year 2016, the cotton cultivated area reached its minimum in the period of our analysis, having registered 101,404 hectares. From 2017 to 2019, this variable registered an increase from 114,068 to 196,274 hectares. After this increase, it showed almost similar cultivated areas in 2020 and 2021, thus reaching its maximum in 2021, when there was a cultivated area for cotton of 134,586 hectares. The production of lump cotton comes mainly from the northern region of the country (Nampula, Niassa and Cabo Delgado Provinces) from the provinces shown in the **Fig. 2**. Nampula province produced the largest volume of cotton in year

Fig. 1 Area and lump cotton production in Mozambique, from 2014/2015 to 2020/2021 cropping season
(Source: IAOM, 2022)

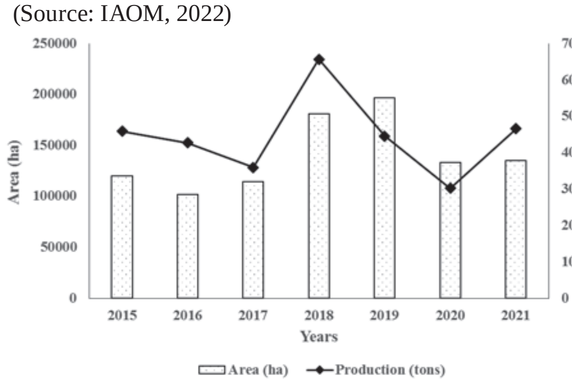
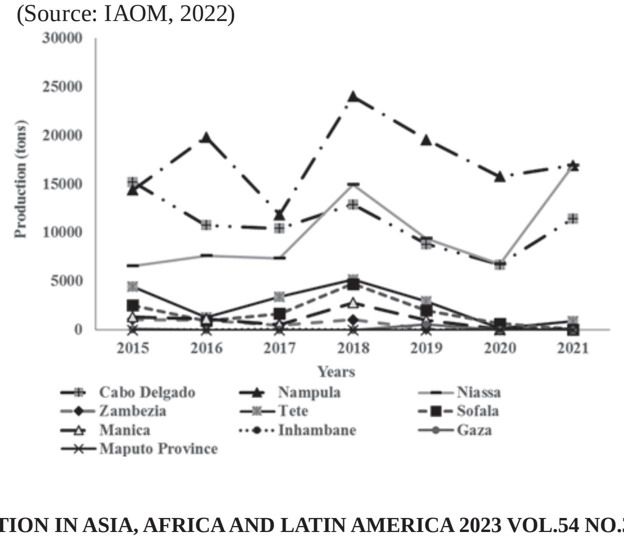


Fig. 2 Evolution of lump cotton production by provinces, from 2014/2015 to 2020/2021 cropping season
(Source: IAOM, 2022)



2018. It is noted that, in the period of our analysis the production, referring to all the provinces, present many variations throughout their series, however, with a tendency to decrease. Nampula has been considered the main source of cotton in recent years in the country. Regarding the central region, the second largest cotton producer in the country, the following scenery can be seen (**Fig. 2**), it is possible to verify that the province of Tete produced the largest amounts of lump cotton in the central region, in the period between 2015 and 2021. As of this last year, the lump cotton production, from this province, registered decreases and produced around 930 tons. The production of lump cotton, referring to the province of Sofala, shows an increasing trend until 2018, the year in which it reached its maximum production of 4,725 tons over the period of our analysis. In the following years, the cotton production, in this province, registered significant decreases, since in 2019 to 2021, there were produced only 2,713 tons of lump cotton in Sofala. The production of lump cotton from the provinces of Manica and Zambezia is considered the smallest of the remaining provinces under review. Regarding the southern region, which registers the lowest levels of lump cotton production, the following evolution is presented, the **Fig. 2** shows that, in Maputo Province cotton is not grown. In the period of our analysis, it is shown that, Maputo and Inhambane Provinces did not Produce lump cotton. In the case of the province of Gaza, it is noted that, in the last seven cropping years analyzed, just produced 570 tons in 2019.

Mozambique's Response for Organic Cotton Production

The cotton organic production in Mozambique is emerging but will be a wise bet to boast this sector. The cotton agenda is part of the development policy of the agricultural sector, and it constitutes one of the challenges for the government. The Institute of Cotton and Oilseeds is aware that the transition or the exploration of this organic cotton market has challenges related to adequate technology, best research practices, technological packages, technical assistance to farmers, cultural changes, and access to financial aid. But as Mozambique is committed to the Sustainable Development Goals (SDGs) that are outlined in the 2030 agenda, the production of organic cotton is an assumed fact and from 30th June to 1st July, Mozambique hosted the XV session of the Southern and Eastern Africa Cotton Forum (SEACF) which took place under the theme of "Prospects for Organic Cotton in Africa", the aim of this conference was to exchange experiences and identify answers about the steps that the regions of Southern and Eastern Africa should follow to introduce and massify the production of organic cotton and to take advantage of the opportunities that this emerging market offers to the so-called "white gold". The Institute of Cotton and Oilseeds of Mozambique (IAOM) is aware that, organic cotton production by household sector farmers is an opportunity to increase income and improve their quality of life (IAOM, 2022).

Agricultural Yield of Lump Cotton and Industrial Yield of Fiber Cotton

According to Mahalambe (2012), cotton fiber in Mozambique has one of the lowest levels of yield in Africa and in the world. This fact may indicate that the cotton sector in Mozambique has low levels of competitiveness. The **Fig. 5** shows the evolution of lump cotton agricultural yield and fiber cotton industrial yield, in the period between 2015 and 2021. In the period of our analysis, the lowest yields of lump cotton were verified in the cropping

Fig. 5 Agricultural yield of cotton lump and industrial yield of cotton fiber, from 2014/2015 to 2020/2021 cropping season (Source: IAOM, 2022)

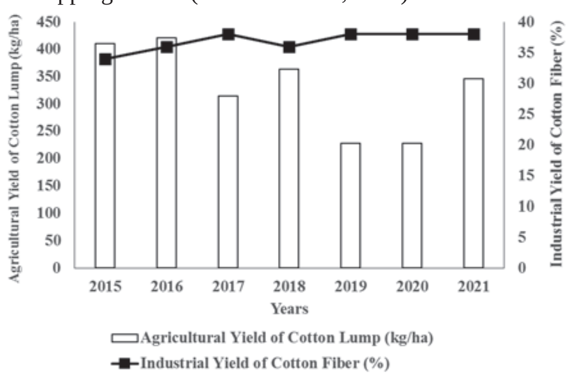


Fig. 3 Cotton field in Manica province (Source: IAOM, 2022)

Fig. 4 Cotton research field in Niassa province (Source: IAOM, 2022)

years of 2019 and 2020, in those years approximately 230 kg of lump cotton were produced per hectare. However, in the same period of our analysis, the lump cotton reached its maximum of 421 kg/ha in the cropping year of 2016. Regarding cotton-fiber, it appears that it shows less marked variations in comparison with lump cotton, throughout the analyzed series. On average, the industrial fiber yield was about 37%. Fiber cotton had its maximum industrial yield of 38% in the years of 2017, 2019, 2020 and 2021.

Number of Cotton Farmers in Mozambique

The number of cotton farmers in Mozambique has shown the following evolution since year 2015 to 2021. Different literatures, such as IAOM, indicate that by 2005 there were more than 300,000 cotton farmers in the country. In the **Fig. 6** below for the years analyzed, it is possible to verify that, over the seven years analyzed, the number of cotton farmers in Mozambique shows a downward trend, despite it reached its maximum in the year 2018, having 228,133 farmers. It can be said that, on average, there were approximately 174,525 cotton farmers over the period under review.

Process of Cotton Commercialization in Mozambique

The cotton marketing process in Mozambique follows two stages namely, the marketing of seed, cotton carried out between farmers and companies where the price applied is in Mozambican currency (Metical) and calculated through the pricing mechanism agreed at subsector level and the export of fiber to the international market, commercialization that takes place between the concessionaires and the textiles whose prices are applied in USD according to the international price practiced (IAOM, 2011).

Marketing of Lump Cotton in Mozambique

The lump cotton marketing process takes place annually in a period between the months of June and September, obeys the minimum price stipulated by the government and is remunerated or paid according to the classification assigned by the marketing agents (IAOM, 2008). Lump cotton trading points both inside and outside the areas under contract promotion and commercialization of cotton, are installed in places and dates agreed with the farmers and approved by the Institute of Cotton and Oilseeds Delegations in the respective geographical areas, heard community authorities and District Governments. These points of sale are in distance of less than five (5) km from the farmer's areas of residence or from the storage of the respective lump cotton by farmers, as applicable (IAOM, 2008). Cotton companies draw up a calendar for the marketing of lump cotton, indicating the locations, dates and itinerary of the markets and submit them to Institute of Cotton and Oilseeds of Mozambique for analysis and approval, are also obliged to form lump cotton purchase brigades and to supply, to the farmers and in return, up to fifteen (15) days before the date set for the markets, bags for packing lump cotton, in a good condition and in quantity sufficient, complying with the criteria established by the Institute of Cotton and Oilseeds of Mozambique (IAOM, 2008). **Fig. 7** shows the trend of price as well as the revenue at the farmer's level, from this figure it's possible to see that, in the cropping years of 2015 and 2016 the price of seed cotton was the lowest of 0.2 USD/Kg and it reached its maximum of 0.4 USD/Kg in the cropping years of 2017, 2018, 2019 and 2021. On the other hand, the revenue to the farmer's level showed almost similar tendency as compared to the price, reaching its minimum of 8,469,787 US dollars in cropping year of 2017 and the maximum revenue of 24,754,409 UD dollars was verified in the cropping year of 2018.

Fiber Cotton Marketing

According to (IAOM, 2008), after cotton ginning, the fiber obtained is

Fig. 6 Number of farmers, quantity of cotton lump and cotton fiber produced, from 2014/2015 to 2020/2021 cropping season (Source: IAOM, 2022)

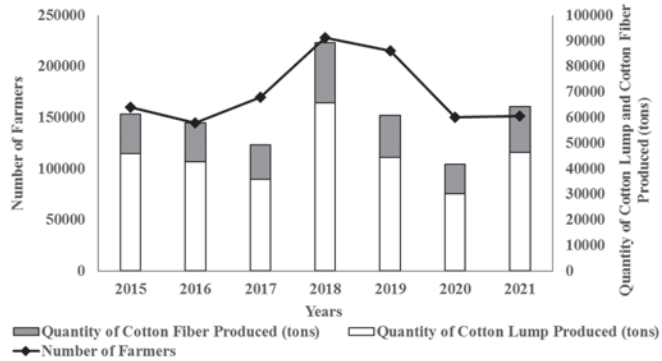


Fig. 7 Price and revenue of cotton lump to the farmer, from 2014/2015 to 2020/2021 cropping season (Source: IAOM, 2022)

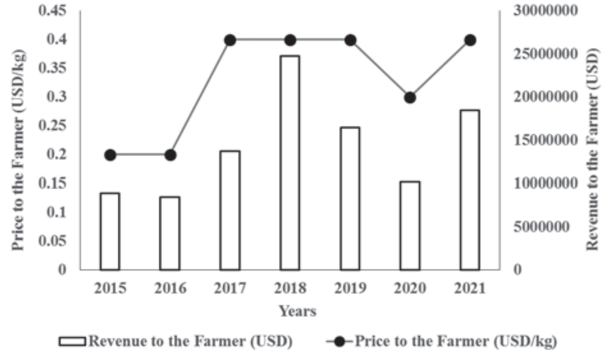
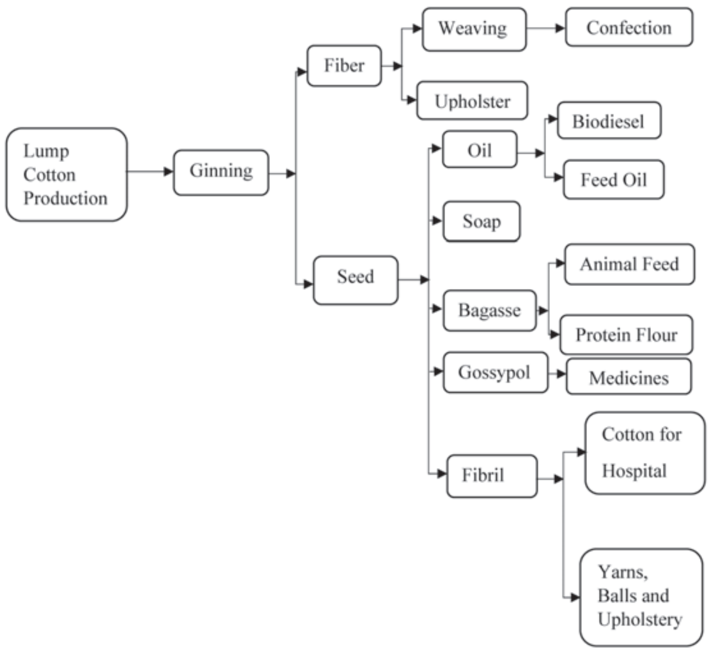


Fig. 9 Value chain scheme of cotton in Mozambique (Source: IAOM, 2022)



pressed and packed in bales. These bales are covered with cotton fabric or plastic first use, being prohibited the packaging of the fiber by different material to avoid the risks of Contamination. The commercialization of fiber takes place throughout the year and is carried out according to the demand of the international buyers. The fiber commercialization is made up of bales of uniform graded fiber. The fiber classification is done by the Institute of Cotton and Oilseeds of Mozambique (IAOM), which assigns a classification certificate. According to the Mozambican fiber classification standard, the fibers have seven grades of extra qualities, first, second, third, fourth, fifth and sixth. Depending on the classification assigned to the fiber, during the process of export to the international market, it can receive bonuses if it is classified between the extra and second or receive penalties/discounts if classified between classes fourth and sixth (IAOM, 2008). From the **Fig. 8**, it is possible to verify that the seed cotton production decreased from 30,248 to 21,518 tons between 2015 and 2017, however the seed cotton production reached its maximum of 39,422 tons in 2018. Moreover, in the last tree cropping seasons it decreased and reached its minimum of 16,266 tons in 2021. Therefore, in the same period of analysis in figure below, can be seen the average international price of seed cotton in USD which shows the constant Prices of 120 US dollars/ton except for the 2018 cropping year when it reached its maximum of 140 US dollars/ton.

Value Chain of Cotton in Mozambique

The value chain concept was introduced by Porter, within his theory of competitiveness. According to this author, the value chain represents the set of activities carried out by a company, from the projection of its product to its consumption, (Porter, 1989). GDS states that, "the competitiveness of the private sector depends on how well the market is doing, organized and how productivity is maximized throughout the activity chain, from the inputs of raw materials for the commercialization of final goods" (GDS, 2005). It also mentions that the analysis of the value chain aims to achieve the following objectives, (1) identify inefficiencies throughout the activities, (two) identify and prioritize constraints along the value chain, (3) get a comparative international basis and, (4) allow recommendations to improve competitiveness. In the case of the cotton subsector, the value chain should illustrate its different activities, from cotton production to export. The analysis of the value chain will allow to understand

Fig. 8 Quantity of cotton fiber and international average prices, from 2014/2015 to 2020/2021 cropping season (Source: IAOM, 2022)

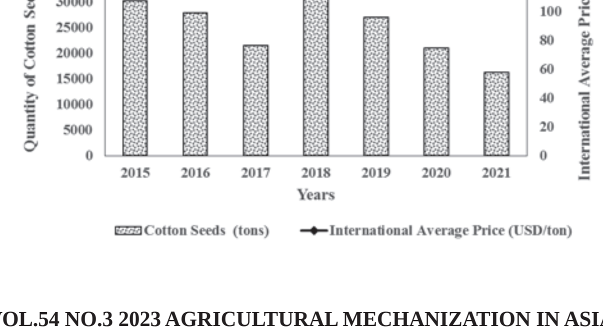
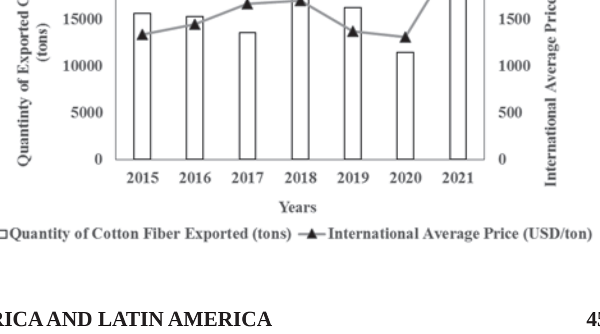


Fig. 10 Quantity of exported cotton fiber and international average prices, from 2014/2015 to 2020/2021 cropping season (Source: IAOM, 2022)



the level of competitiveness existing in this subsector. To analyze the value chain of the cotton subsector in Mozambique, first, it is necessary to understand its structure, which is summarized in the figure below. As already mentioned, it is up to the concessionaires to provide farmers with agricultural inputs needed for cotton production. These also grant credit and are responsible for extension. Through the **Fig. 9**, it is possible to understand that, after ginning, the fiber is exported (by the companies) and the seed is used internally for the manufacture of oil and bagasse. According to Santos (2012), the cotton value chain consists of five main phases, (I) agricultural production, (II) seed cotton processing, (III) wiring, (IV) weaving, and (V) making clothing.

Cotton Export in Mozambique

Cotton subsector accounts for approximately 3.51% of Mozambique's total exports, and the 98% of total textile material exports. The revenue obtained from exports of the product reached around 60 million dollars in 2012 (IAOM, 2013). International market and the existing possibility of eliminating market distortions and barriers for exports, opens the possibility of greater cotton demand for countries in the process of development, such as Mozambique, with the potential for a positive impact on revenues exporting to more remunerative markets (UNCTAD, 2012). Arlindo and Keyser (2007) state that "as an export product, cotton-fiber in Mozambique has a long history of accessing important international markets such as Europe and Asia. Despite presenting low rates of return, there is a dynamic in this Mozambican cotton sector, characterized by the entry of new concessionary companies and investments in areas outside the traditional cotton belt in Nampula and Cabo Delgado Provinces". Mozambique's cotton-fiber exports are mainly destined for the Asian continent which absorbs 63% of the total fiber export, distributed as follows, Bangladesh 24%, Malaysia 19%, Singapore 11%, China 7%, and India 2%. The remaining 37% is distributed as follows, 17% is exported to South Africa, 17% to Mauritius, 1% to Portugal and 2% is for domestic consumption. According to Mahalambe (2012), this fact is due to the change of the textile industry from Europe to Asia, where it is most competitive. From 2017 to 2019, the export quantity of fiber cotton showed a sharp decrease of 15,653 to 13,564 tons. Moreover, the international average price increased in the same period due to appreciation of US dollar, the lowest quantity of cotton fiber exported was verified in 2020 cropping year with an amount of 11,459 tons, while in the period of our study the cotton fiber export reached its maximum of 23,718 tons in the cropping year of 2018 while, the maximum average international price of 2230 USD/ton was reached in the cropping year of 2021 (**Fig. 10**).

Specific Measures Being Taken by the Mozambican Government and Stakeholders to Boast Cotton Subsector

There are several factors that influence the current stage of the cotton subsector in Mozambique. First, there is an issue of price, which depends on the international tendency, but also the low productivity is witnessed. The production per hectare in Mozambique is one of the lowest in the world, which means that farmers are not able to earn large revenues. Mozambique does not have a significant weight in the world scenario. We are talking about an industry that moves billions of dollars annually, and Mozambique has a very small share of 0.12% of world exports, which is very low. Cotton is basically produced by the household farmers within the country, and the government understands that there is a need to increase the capacity of these farmers, through the transfer of technologies to the farmers. It is necessary to create market access facilities, through a logistical base that allows production to leave the fields for the industries, and from there to the national and international market. On the other hand, for Mozambique to be able to compete with other countries that produce 7, 8 or even 9 tons per hectare, and to counter the current situation of 350 to 500 kg per hectare, the government of Mozambique is willing to invest in the production of organic cotton, which is less subject to international competition. Moreover, to enhance the productivity of cotton the Institute of Cotton and Oilseeds (IAOM) in collaboration with the Institute of Agricultural Research of Mozambique (IIAM), train extension workers in cotton production technologies to disseminate to the farmers. There are ongoing projects such as, Shire - Zambeze, between Mozambique and Malawi, this project is carried out by Brazilian Cooperation Agency (ABC), and is technically supported by the Brazilian Agricultural Research Corporation (EMBRAPA), in partnership with the Institute of Cotton and Oilseeds of Mozambique (IAOM) through the Regional Center for the Transfer

Fig. 11 Regional center for the transfer of cotton technologies in Manica Province – Guro district (Source: IAOM, 2022)

of Cotton Technologies (CRETTA), Makoka Agricultural Research Station of Malawi, Brazilian Cotton Institute (IBA) and the United Nations Development Program (UNDP), this project supports the production of certified seeds, and has contributed to resumption of natural fiber production in African countries. There are 15 young people from Manica Province, Guro District where the Regional Center for the Transfer of Cotton Technologies (CRETTA) is located who learn cotton technologies to improve the production and productivity of cotton to disseminate to their communities (IAOM, 2022).

Conclusions

Although Mozambique has great potential in the cotton subsector and accessing important international markets, the low yields recorded by this crop make the exports related to cotton below the largest cotton exporters in the world. Mozambique has one of the lowest revenues in the countries cotton producers, however, the quality it presents is significant, since the fiber has a length of approximately 2.86 cm, while many African countries produce fiber that reaches less than 2.6 cm. This study considers the fiber produced in Mozambique to be relatively competitive. In addition to the cotton fiber produced in Mozambique presenting a relatively high quality higher, its production costs per hectare are lower in Mozambique compared to with other cotton producers in the world. The long-term negative trend in the price of cotton, forces Mozambique to organize itself to increase the productivity and quality of its cotton, indispensably passing through a better quality of extension and technical assistance. The international price of cotton was identified as the main determinant in setting the national price for the consumer which in turn influences the volume of production. The system of fixing the national price to the cotton farmer can be out of step when there are important exchange rate variations. The value chain of this subsector is not fully located in the country (for instance, the Textile industry), thus reducing the potential for added value of this commodity. The production trends over the past a few years decreased because, there are not enough cotton promotion industries, the farmers that basically rely on agriculture, abandoned production of cotton, and opted in other crops that could give them revenues. The authors view, it is important for the government to place industries in these locations and the results may emerge.

Acknowledgements

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An Assessment of Production and Market Structure of Soybean in the Republic of Mozambique

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Abstract

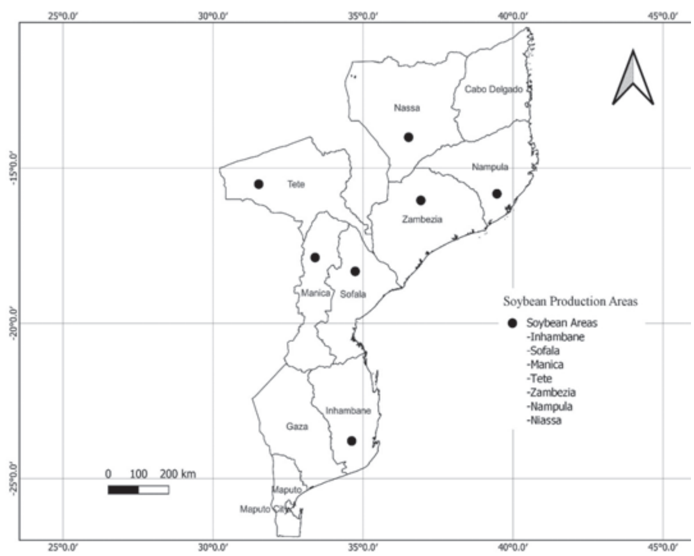
This article presents both methodology and results of an outlook for value chain of soybean production, and market structure in the Republic of Mozambique. Soybean is an attractive crop for many economic, social, and environmental reasons, and the sector has a promising future in Mozambique. For instance, it improves soils, provide a value-added processing activity, and offer an alternative crop to be produced by both smallholders and commercial farmers. Recently soybean has been the driving force behind Mozambique's recent agricultural development specially in the Central and Northern areas, due to higher demand in the poultry farming, with significant economic and social impact. To move forward, Mozambique needs to introduce efficient technology to increase the production and productivity in the designated agroecological zones which have potential for this commodity. Availability of arable lands and entrepreneurial farmers must be secure. The global demand for soybean and the associated market prices will determine how much Mozambican soybean production will grow in each cropping season.

Keywords: market, Mozambique, soybean, value chain

Introduction

The cultivation of soybeans began in the 1980s when the country's socialist regime looked to develop state farms throughout the country. The Centre of soybeans production was in the administrative post of Lioma, within the district of Gurue, on the Zambezia plateau. the state farm, Agricultural Complex of Lioma (CAPEL), planted, among other crops, between 400 and 500 non-irrigated hectares of soybean, with technical assistance from Brazil-

Fig. 1 Map of Mozambique showing the soybean production areas (Source: MADER, 2022)



ian development cooperation. This project failed when the widespread armed clashes of the Civil War reached Lioma. The Civil War ended in 1992, but soybean production in Mozambique would not resume until the early 2000s. In 1997, Mozambique passed a new Land Law, declaring all land as public land and that should be used for the benefits of local communities. At the same time, failed state farms such as CAPEL were being re-occupied by small and medium sized farmers, and development NGOs were highly active in their involvement to promote food and nutrition security. In the early 2000s, the international NGO, World Vision, introduced soybean production in the region as part of a project to enhance nutrition and food security for children (Di Mateeo et al., 2016). Soybean is a nutritious but not traditionally consumed crop in Mozambique. It is profitable for small and medium scale "emerging commercial" farmers with gross margins averaging from 306 to 371 USD (Payongayong, 2012). Additionally, women have been successfully increasing their involvement in distinct levels of the soybean value chain. The domestic market for soybean is estimated to be growing at about 60% per year, and about 60% of Mozambique's domestic demand for soybean is currently met through imports. There is a limited geographic area suitable for soybean production, this area is limited to highlands in central and northern Mozambique, with only 5 to 10 districts perceived to have "high potential" for suitable and profitable production given current and anticipated world prices that mediate local competitiveness (Walker and Cunguara, 2016). Several current and recent donors funded initiatives offer rich examples of promising interventions and opportunities to develop the supply base and expand the competitiveness of the value chain. This paper review intends to present and discuss the beginnings of soybean growing demand in Mozambique, the challenge in the soybean market structure. It also addresses the importance of Mozambican soybean sector to supply the industries for processing feed for poultry farming as well as the status of soybean research in Mozambique.

Material and Methods

The assessment of production and market structure of soybean analysis considered from production, processing to the market of this commodity. We assessed production by year as well as the total area. The researchers got relevant information from the key authors for soybean production within the country. We mapped the main provinces for production of this commodity as well as the percentage of farmers involved to enhance the production and productivity in the country. Additionally, while writing up this article we got updated information from various sources of the Ministry of Agriculture and Rural Development (MADER).

Results and Discussion

Soybean Production in Mozambique

Soybean production has grown rapidly in Mozambique, with most of that growth being credited to donor interventions as well as the impetus provided by a rapidly expanding market. In 2019/2020 crop season (**Figs. 2** and **3**), more than 50,000 tons were produced on 65,834 hectares of land (Integrated Agrarian Survey, 2020). Soybean is nontraditional crop in Mozambique, and its production is overwhelmingly oriented to the market rather than consumption. Zambezia, particularly Alta Zambezia, is responsible for just over 60% of annual soybean production (with 50% of total production from just one district, Gurue). Tete accounts for approximately 24% of national Production and the remaining 16% is distributed among, Inhambane, Manica, Sofala, Nampula and Niassa Province (**Fig. 1**).

Fig. 2 Area and production of soybean in Mozambique by years, from 2017 to 2020 (Source: Integrated Agricultural Survey, 2020)

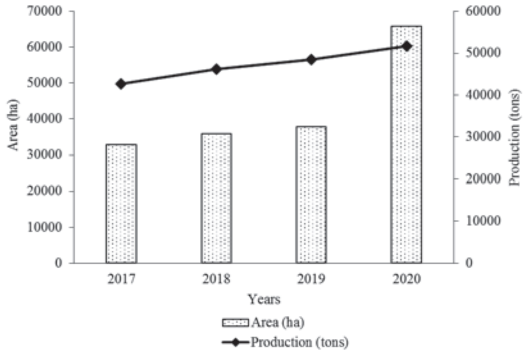
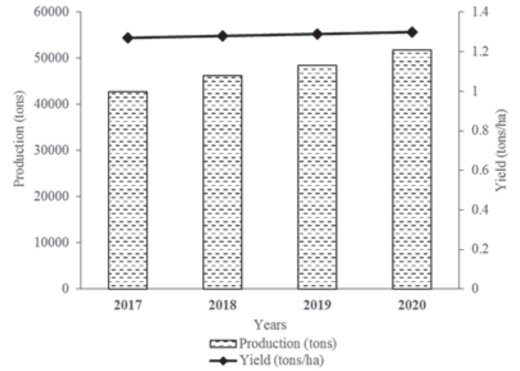


Fig. 3 Production and yield of soybean in Mozambique by years, from 2017 to 2020 (Source: Integrated Agricultural Survey, 2020)



Soybean Cropping Calendar in Mozambique

Table 1 Cropping calendar of the main soybean varieties in Mozambique (Source: IITA, 2011)

Activities	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Tillage preparation	←→						
Fertilizer application		←→					
Sowing		←→					
Pest control				←———	———→		
Harvest						←→	
Dry and storage						←→	
Transportation							←→
Commercialzation							←→

The sowing period is a key factor affecting soybean yield. Soybeans are photosensitive and bloom only when the day length is shorter than the critical period. Thus, the sowing period influences the number of days for flowering, the duration for vegetative growth, and the development of the plant. It also influences the amount of water, nutrients and light that will be available to the soybean plant during its development. The ideal sowing period for all varieties in Mozambique is between the first week of December until the end of December (**Table 1**). Yield decreases drastically when sowing is done late after December. Sowing in November is very risky because the rain is unreliable and normally not well distributed for good establishment of young plants. Irrigation will be good option for sowing in November, but it will not be economically sustainable (IITA, 2011).

Soybean Value Chain in Mozambique

Soybean, a newly introduced cash crop to Mozambique, had not been valued at the same level of importance as common bean in terms of household food security in South Saharan Africa. To some extent soybean was regarded as woman's crop and played a key role of gender equity (Rusike et al., 2013). Soybean production is driven by soybean cake demand from the poultry

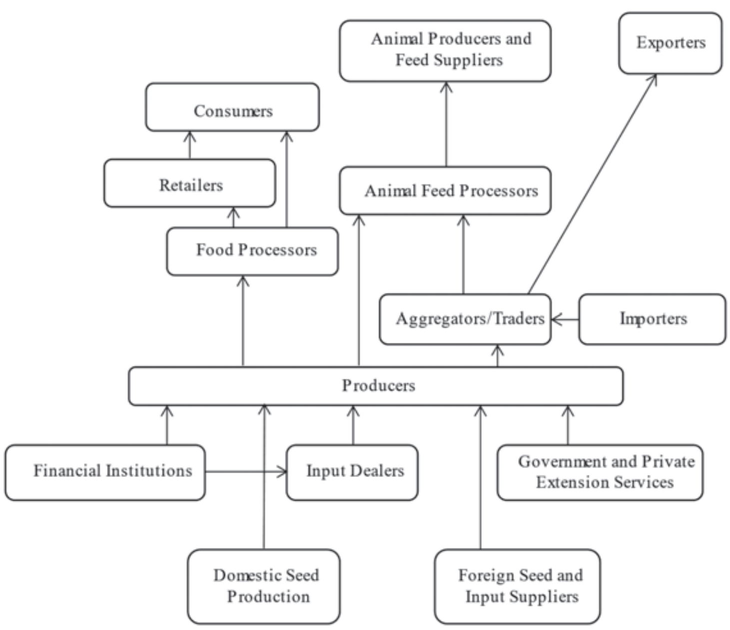
Fig. 4 Soybean fields in Niassa province (Source: MADER, 2022)

Fig. 5 Soybean harvest and threshing in Zambezia province (Source: MADER, 2022)

Fig. 6 Packing soybeans into bags after harvesting in Niassa province (Source: MADER, 2022)

industry (TechnoServe, 2011). There has been a considerable gab between production and consumption of soybeans in Mozambique since 2009. This shortage gap is estimated at about 30,000 tons of soybeans. In fact, the demand for soybeans in 2018 was projected at 120,000 tons against 85,000 tons. This gap is expected to be filled by imports (SPEED, 2015). Walker and Cunguara (2016) argue that soybean production has taken off in Mozambique spite of years of stagnation characterized by the doubt that soybean would become smallholder's crop any time soon. A rapid expansion of soybean cultivation in Mozambique can, however, be attributed to the role of the international donor community, soybean's potential for transformative structural change in the Mozambican economy, as well as high market demands. The soybean value chain in Mozambique has had 10 years of significant international donor community investment, which has accelerated growth but also brought market distortions (USAID FTF Inova, 2017). The soybean value chain includes various links ranging from input suppliers to small holder farmers, medium and large –scale farmers, traders/aggregators, soybean processors, and users (**Fig. 7**). In Mozambique, the soybean production practices are poor, with exception of commercial farmers, with low input use, limited irrigation systems, and poor agronomic practices (Opperman and Varia, 2011).

Fig. 7 Soybean value chain in Mozambique (Source: ACDI/VOCA, 2016)



Soybean Agroindustry and Market in Mozambique

From the farm, soybean typically moves through structured supply chains to processing plants where it is converted to animal feed, with soybean oil as a byproduct. Often producer associations serve as intermediaries and may support producers with provision of seed, mechanical services, post-harvest handling, and in-kind finance for inputs. Large-scale buyers buy directly from farmers or farmer associations under contracts of varying intensity; **Fig. 8** shows the percentage of farmers involved in the soybean sector for five cropping seasons by Provinces. Donor-funded projects such as AgriFUTURO and non-government organizations (NGOs) such as TechnoServe and NCBA CLUSA typically play a key role in the creation and maintenance of these buyer-supplier relationships, providing technical assistance and training and other forms of assistance to help ensure the success of the relationship, in particular adherence of both parties to agreed-upon contract terms. While there is demand for soybean (for animal feed) in southern Mozambique (Maputo area), transport from the central and northern, where it is produced is prohibitively expensive, and southern buyers most commonly import from South Africa, Brazil, or other countries in Latin America. **Fig. 10** shows the quantity of exports, imports, and domestic prices for soybean in Mozambique for five cropping seasons. These sources also offer consistent quality, which is important for efficient processing. In the central and northern of the country, the growing market for animal, particularly poultry feed translates to an expanding market for soybean. The quality of soybean meal that is used for animal feed is determined in large part by its protein content, which is an outcome of the variety 3 and/or processing method. There are only four plants in Mozambique that have the solvent-based extraction capability required to produce top-quality (Grade A1) soybean cake with 47% protein. Other plants use less-expensive expresser extraction processes, which lead to a lower-protein soybean cake with a higher oil content (Grade A2 and below) (TechnoServe, 2009). Only two of these plants, Abilio Antunes in Manica, and Alif Quimica in Nampula are currently working with soybean. The largest poultry producers tend to have their own feed production facilities and constitute an important end market for domestic soybean production. On 18th August of 2022 His Excellence President of the Republic of Mozambique inaugurated the new plant for soybean oil processing in the Niassa Province Budgeted at 4,687,500 US Dollars, part of which comes from the

Ministry of Agriculture and Rural Development program "SUSTENTA", that factory has the capacity to extract 7,500 tons of crude oil and refining 3,000 tons per year, being the first industry of this size to be built in the Province from Niassa. The project will significantly reduce the import of cooking oil, expanding the country's financial autonomy. It also constitutes an opportunity to increase the value chain in the province, streamlining coordination and reducing unemployment rates, especially in the youth people, who makes up most of the workforce, said the Mozambican Head of State, Filipe Jacinto Nyusi. He also called attention to the farmers to increase the cultivation fields, since there is a guaranteed market to absorb several products that constitute raw material for the full operation of the factory, such as cotton and soybeans. His Excellence President Filipe Nyusi expressed his satisfaction, a factor allied to the agroecological conditions that Niassa has, which puts the province in a favorable position in terms of production and productivity. It should be noted that the construction of the cooking oil extraction and refining factory in the City of Cuamba in Niassa Province is part of the "Industrialize Mozambique" initiative, which the Mozambican government and partners have conducted to stimulate the growth of the industrial sector within the country (MADER, 2022).

State of Soybean Research in Mozambique

Soybean research in Mozambique started in the early 1980s, in northern highlands of Zambezia Province. This research activity was part of the overall program of the state commercial farm CAPEL (Lioma Agro-Industrial Enterprise). However, the seventeen-year civil war stopped the program and the varieties grown at that time disappeared. These varieties were brought into the country from elsewhere notably Brazil. In the late 1990s. The Agricultural Research Institute of Mozambique (IIAM) reintroduced some varieties from Institute of Tropical Agriculture (IITA) for evaluation. During the cropping season 2002/03 some promising lines from neighboring countries like Malawi, Zambia and Zimbabwe were introduced for both on-station and on-farm evaluation, in different agroecological zones. The varieties used were, TGx 1740-2F, TGx 1485-1D and TGx 1448-2E. In **Table 2** we can find some characteristics of some new and improved varieties already realized in Mozambique. Farmers who began growing soybean in the late 1990s used the varieties Santa Rosa, Solitaire, and Storm, which were introduced from neighboring countries (Zambia, Malawi, and Zimbabwe). As a result of the combined effort of IITA and IIAM, the first varieties were released, and farmers have more va-

Fig. 9 Soybean oil plant inauguration by his excellency president of the Republic of Mozambique in Niassa province (Source: MADER, 2022)

Fig. 8 Percentage of farmers that grew soybean in Mozambique by provinces, from 2012 to 2020 (Source: Integrated Agricultural Survey, 2020)

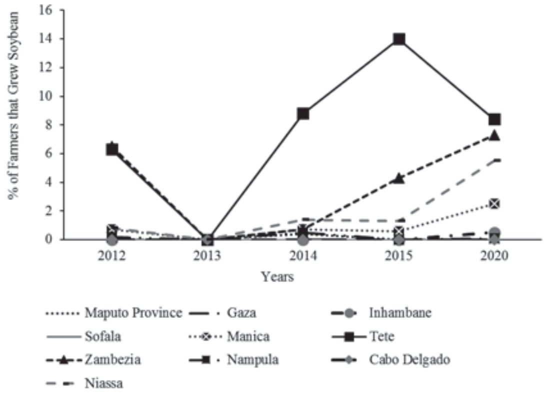
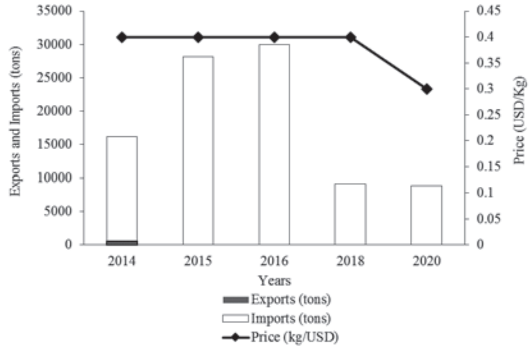


Fig. 10 Exports, imports and prices of soybeans in Mozambique by years, from 2014 to 2020 (Source: Integrated Agricultural Survey, 2020)



riety options. The released varieties are: Wamini (TGx 1740-2F), Sana (TGx 1485-1D), Zamboane (TGx 1904-6F), Wima (TGx 1908-8F), Olima (TGx 1937-1F), Ocepara-4, H7, H17 and 427/5/7 (IIAM, 2014). All introduced varieties in Mozambique are just improved ones, not genetically modified.

Opportunities for Investment in Soybean Subsector in Mozambique

Mozambique is located at strategic point of maritime transportation. If Mozambique can take advantage of this and become a soybean exporting country, would be able to supply Asian market in countries such as, China and Japan to stop relying only in the United States, India, Brazil, and Russia Far East markets for soybean supply. To realize this goal, the Mozambican government and importing countries must invest appropriately to ensure stable large – scale production of soybean oil and soybean meal, as well as higher – order processing such as, soy lecithin, will be effective in developing high value – added agricultural business. However, government support measures, such as introduction and increase of production of already realized and new varieties of soybean with high potential through the Mozambique Agricultural Institute Research (IIAM) for sustainable agricultural production are necessary not only for commercial farmers but for smallholders as well. The poultry and livestock industries in Mozambique demand more than 100,000 tons of soybean for feed every year. The gap between current production and domestic demand is largely met by imports from Argentina and Brazil. Good climatic conditions for soybean production coupled with available land for expansion. The major interest and support from donors to improve income and food security and enhance livelihoods of smallholder farmers through research and dissemination of technological packages to boost crop yields. The presence of Institute of Tropical Agriculture (IITA) and the collaboration with Agricultural Research Institute of Mozambique (IIAM) on all aspects of soybean research. The current government policy is favorable to soybean production. There is shortage of edible oil, and the government is looking for local production and processing. In this regard, the government is encouraging the production of oilseed crops. There is significant market for edible oil and the annual industrial production is estimated to be as high as 110,000 tons (Monyo and Gowda, 2014).

Conclusions

The soybean industry in Mozambique is characterized by minimal use of mechanization and wide use of household labor. In addition, only a few small farmers are currently emerging as commercial increasing production areas as well as profits. Soybean production levels were at 42,700 tons in 2016/2017, 46,200 tons in 2017/2018, and 51759 tons in 2019/2020 cropping season. This fact reveals that the production of soybean has increased within the country despite is nontraditional crop. The lack of the specific government programs to enhance the production of this crop is linked to the small numbers of farmers who are involved to produce this commodity. However, it can be stated that the current mechanization programs subsidized by the government through the Ministry of Agriculture and Rural Development (MADER) is contributing to an increase in soybean production mainly in the Nacala and Niassa - Pemba Corridors. Due to higher demand to this commodity the government must increase the support of small commercial farmers through intensification of multiplication of improved seed varieties. Define soybean production zones, including preferred farming systems. The domestic soybean demand is based on growth of feed industry for poultry production, Mozambique still not self-sufficient in this commodity to supply the industries, therefore, it is expected to expand the areas of production in the next coming cropping seasons. Mozambique needs large commercial farms to achieve economies of scale, and to increase availability of technologies. More investment in agribusiness is needed for this commodity to promote the competitiveness among the small commercial farmers and increase the availability of this product in the market.

Acknowledgments

The research work was financially supported by Japan International Cooperation Agency (JICA), we also thank colleagues from the Ministry of Agriculture and Rural Development (MADER) who provided

Table 2 Characteristics of selected improved varieties of soybeans released and introduced in Mozambique (Source: IIAM, 2014)

Name of Varieties (g)	Breeder	Breeder	Protein (%)	Oil (%)	Weight of 100 Seeds
Sana (TGx 1485 – 1D)	IITA & IIAM	Early Maturing	35.7	19.4	15
Zamboane (TGx 1904 – 6F)	IITA & IIAM	Medium Maturing	35.4	19.6	15
Olima (TGx 1937 – 1F)	IITA & IIAM	Late Maturing	36.1	17.4	14
Wamini (TGx 1740 – 2F)	IITA & IIAM	Early Maturing	35.6	19.3	15
Wima (TGx 1908 – 8F)	IITA & IIAM	Medium Maturing	38.1	17.6	15
TGx (1835 – 10E)	IITA & Ibadan	Early Maturing	34.4	17.3	15

expertise that greatly assisted this research.

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■■

Current Situation of Cashew Nuts and Macadamias Value Chain in the Republic of Mozambique

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Abstract

Most cashew production in Africa is undertaken by smallholders, with individual trees standing amongst annual crops. It makes it difficult to compare yields with those achieved in plantations devoted exclusively to cashew. This reflects the age of few trees, and the extensive approach to cultivation adopted by smallholders who manage their cashew trees as one of several crops, that are integrated into a mixed farming system. About two million smallholders are involved in cashew production in Africa, and nearly three-quarters of them are poor. On the other hand, Mozambique used to be one of the world's biggest producer of raw cashew nuts and exporter of processed kernels. However, since the mid-1970s various problems have meant that production and quality have declined, with rapid liberalization in the 1990s resulting in the collapse of the processing sector. Mozambique is now a small world player, competition has increased and countries like India, Brazil and Vietnam dominate the world market. This article intends to describe the current situation of the cashew nuts and macadamias value chain in the Republic of Mozambique. For methodological purposes, it has used the consultation of bibliographic material, interviews with the staff of the Ministry of Agriculture and Rural Development (MADER) and the Institute of Almonds of Mozambique (IAM), the data obtained were statistically analyzed using the excel package. Analysis of the data shows that there are internal factors that contribute to the reduction of the supply of these commodities, such as the weak financial capacity for the supply of raw materials, unfair competition in marketing, the unavailability of raw materials and the delay in refunding value added tax (VAT).

Keywords: Almonds; Cashew Nuts; Macadamias; Mozambique

Introduction

The cashew tree is a native to Brazil. It was introduced in Mozambique as in many other tropical countries by the Portuguese explorers during the 16th century. For several centuries it was a small agricultural commodity, mainly cultivated for its fruits and used in the forestry sector for its fast-growing properties, for reforestation and timber production (INCAJU, 2020). With the establishment of colonial power in the country, cashew cultivation became mandatory in the country for the indigenous population; initially, the colonial government required Mozambican families to produce nuts to satisfy the interests of India. Later in the early 1950s, cashew nuts began to be processed in Mozambique, reaching a processing capacity equal to 150 million kilograms. Since the second decade of the 20th century, the population of cashew trees has risen dramatically, reaching 30 million trees 40 years later (Pereira Leite, 2009). Cashew nuts were before 1970s, one of the main exports cash crops in Mozambique, where production reached 200 million kilograms per year. However, pests, diseases and the aging of cashew trees led to a decline in production, reaching 64 million kilograms in 2012. In the meantime, reforms introduced since 2000 are reviving the crop. In the colonial period, cashew nuts were one of the export bases, with north region playing an import role. Until 1970s, Mozambique was on the side of great powers such as India, having reached the historic record of 200 million kilograms. Then there was a deep crisis in the sector, with the nationalizations that led to the closure of many processing plants, the increasing shortage of raw materials due to the aging of the cashew trees, as well as the diseases and pests that attacked the orchards, had a negative effect and the country disappeared from the international map for years. The cashew sector employs a lot of population, many small and medium producers benefit from the sale of raw nuts to processing companies and in the international market. Revitalizing the sector was the watchword in the government of Mozambique and the first action was to create a specific sector in the Ministry of Agriculture and Rural Development, thus the Institute of Cashew Nuts Promotion was established in 1997. Three years later, in 2000, the massive chemical treatment program or simply spraying begins. However, the most important step begins in 2009 with the approval, by the council of Ministers, of the program to intensify the production and distribution of seedlings to repopulate the fields (IAM, 2020). The main goal of this research paper is to describe the status of cashew nuts and macadamias production, agro- industry as well as international market of almonds in the Republic of Mozambique.

Material and Methods

To analyze the value chain of cashew nuts and macadamia in Mozambique, we collected data from various sources including key informants from public and private sector, information collected from the agricultural survey of Ministry of Agriculture and Rural Development (MADER) and through Institute of Almonds of Mozambique (IAM). Secondary data were obtained from official publications, and documents available on the internet, such as, FAOSTAT. The analysis of these commodities was made by the excel package.

Results and Discussion

Production of Cashew Nuts in Mozambique

In Mozambique, cashew production was introduced and maintained by the Portuguese during the colonial period and declined after the country's independence. Agricultural statistics for 2005 indicate the existence of 32 million cashew trees. Several reasons contributed to this decline, namely internal conflict during the 1980s, changes in political of exports, the failure of the liberalization attempts in the sector processing, the general difficulties linked to the intensification of production systems based on small farms cashew nuts across the country, as well as the rapid expansion of production in competing countries. In 2007, according to FAO statistics information, Vietnam, West Africa, and India contributed, respectively, with 30%, 29% and 19% of global cashew

Fig. 1 Selection of the chestnut seed for sowing in the nursery in Maputo province, Manhica district (Source: IAM, 2022)

Fig. 2 Nursery Preparation for Vegetative Multiplication in Maputo Province, Manhica District (Source: IAM, 2022)

Fig. 3 Tractor carrying seedlings to the fields in Maputo province, Manhica district (Source: IAM, 2022)

Fig. 4 Planting seedlings to establish a clonal garden in Maputo province, Manhica district (Source: IAM, 2022)

production. Today, Mozambique is developing efforts to revitalize the sector and recover a greater share of the expanding market for the benefit of local producers. Based on the existence of about 32 million cashew trees and a production of 80 million kilograms, an average yield around 2.5 kg/tree, assuming that the production is underestimated by 20%, the average yield is between 2 and 4 kg per cashew tree. In view of the above, it is estimated that the average yield is 3 kg/tree. This value is low when compared to the potential yield of 8 to 10 kg/cashew tree that can realistically be obtained under the conditions prevailing in the country and with an appropriate management of trees, including spraying (African Cashew Initiative, 2010).

Production and Distribution of Seedlings

Cashew nuts are mainly produced in the household sector using the direct sowing process, however in recent years new production technologies based on vegetative multiplication have been introduced. This vegetative production makes the new cashew trees produce two years earlier than the normal trees that produce five years later and are tolerant to pests and diseases. Despite all these advantages most farmers do not buy seedlings unless they are offered by the Institute of Almonds of Mozambique through their provincial delegations, farmers claim lack of money despite knowing that these trees produce earlier than normal (IAM, 2002).

Fig. 5 Cutting cashew trees for pruning to replace the crown in Maputo province, Manhica district (Source: IAM, 2022)

Fig. 6 Pest control of cashew trees in Zambezia and Maputo province (Source: IAM, 2022)

Fig. 7 Cashew nuts commercialization in Manhica district (Source: IAM, 2022)

Evolution of the Commercialization of Cashew Nuts in the Period from 2016 to 2021

The seedling, production and distribution subcomponent using improved vegetative material, constitutes the main pillar for the recovery of the production indices of cashew nuts to medium and long term, having been established annually about 2 million new plants, of which 60% by the public sector and 40% by the private sector and farmer's associations. In this period, an average of 134 million kilograms were traded, the average annual rate of growth stood at 8%, being pointed out as the causes of the increase in proportions reduced in marketed production, the following factors: (I) climate change characterized by irregular distribution of rain, (II) sometimes excessive and sometimes deficient rainfall for the hydric requirements of the crop, (III) periods of severe drought limit performance of cashew trees, even inducing the total dryness of young plants and promoting the occurrence of emerging pests, (IV) the departure from the fruiting phase to later periods, coincides with the period of chestnut harvest with the beginning of the rain season, significantly harming the quality of the same by accumulation of excessive moisture and subsequent rotting, (V) almost frequent occurrences of cyclonic winds, namely, Eloise, Idai, Keneth, associated to rainfall that, in addition to breaking the fruiting branches, causes root waterlogging, gradual death of cashew trees, consequently low production, and quality of the nut. In a way cyclical, these phenomena occur in areas that were previously not prone, especially in the provinces of Sofala, Manica, Gaza and Inhambane. **Fig. 8** illustrates the evolution of cashew nut marketing in the period of 2016 to 2022.

Macadamias Production

Macadamia is a crop produced in the country by the private sector. A total of 32 companies are involved in the macadamia production, distributed throughout the provinces of Maputo, Gaza, Inhambane, Manica, Zambezia and Niassa. To boost the macadamia subsector, it was held on the 17th of June 2022 a consultation meeting with macadamia producers, guided by His Excellency the Minister of Agriculture and Rural Development, in which it was recommended to the Institute of Almonds of Mozambique (IAM) that in its strategies to increase the production and productivity of macadamia must integrate the household farmers. This philosophy consists of each company producing macadamia integrating 10 small farmers with 5 hectares each. Macadamia nuts are produced by the private sector in a total of 32 companies, 6 of them in the Niassa Province, 2 in Zambezia Province, 12 in Manica Province, 5 in Inhambane Province, 2 in Gaza Province and 5 in Maputo Province, employing a total of 2,927 workers. It should be noted that the companies with orchards in the productive phase are in the Provinces of Niassa, Zambezia, Manica and Maputo (**Fig. 9**) (IAM, 2022).

Table 1 Main cashew nut plants in Mozambique (Source: IAM, 2022)

Cashew Plant Name	Province Located	Capacity (kg)
Caju Ilha	Nampula	5,000,000
Caju Ilha	Nampula	5,000,000
MOCAJU, LTD	Nampula	2,000,000
Korosho	Nampula	5,100,000
Sunny Moz. Intern.	Nampula	2,100,000
Indo Africa	Nampula	3,000,000
CN CAJU	Nampula	10,000,000
Korosho	Cabo Delgado	5,000,000
Condor Anacardium	Gaza	5,000,000

Agroindustry of Cashew Nuts

The cashew industry has been facing a troubled phase in the last 3 years, given the current macroeconomic environment. The increase in the tax on imports of cashew kernels, introduced by the Indian Government on 2nd July 2019, rising from 45% to 70%, had a negative impact on the processing industry in Mozambique. As an example, the category of split almonds, which represents 40% of the number of almonds produced and had the preferential destination to India, was held in warehouses due to lack of market for its placement, affecting agro − processing plants revenues. In the 2020/21 cropping season, the industry achieved 70% performance with the supply of 36 million kilograms of raw material, corresponding to a decline of 21%, when compared to 45 million and 500 thousand kilograms processed in the 2019/2020 cropping season. The number of raw cashews purchased by the industrial plants (**Table 1**) represented 25% of commercialized production (IAM, 2022).

Cashew Nuts Quality Test

Traditionally, cashew nuts are sun dried (Ajith et al., 2015) and then stored before they are industrially and manually processed. Raw cashew nuts are dried to reduce deteriorating moisture at harvest, from 25% to 7% (Adeigbe et al., 2015), and this is achieved by exposure to direct sunlight. However, heat and light from the sun in association with oxygen lead to loss of sensitive nutrients, for example flavonoids (Ali et al., 2016), and depending on the intensity and duration, a change in the quality characteristics of cashew kernels is observed (Bai et al., 2017). The key objective of industrial processing is to remove the kernel from the shell and separate the testa from the endocarp (Sunday and Abdulkarim, 2017). However, in this process, kernels can be broken, over-steamed or damaged resulting in a series of

Fig. 8 Evolution of cashew nuts marketing in the period of 2016 to 2021 (Source: IAM, 2022)

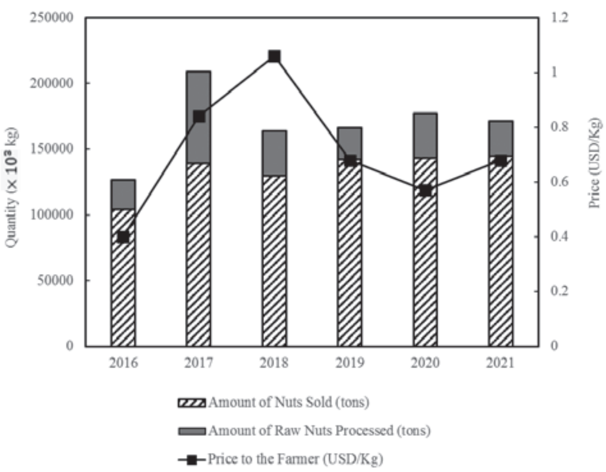


Fig. 9 Area, production and exported production of macadamias by provinces in the cropping year of 2021 (Source: IAM, 2022)

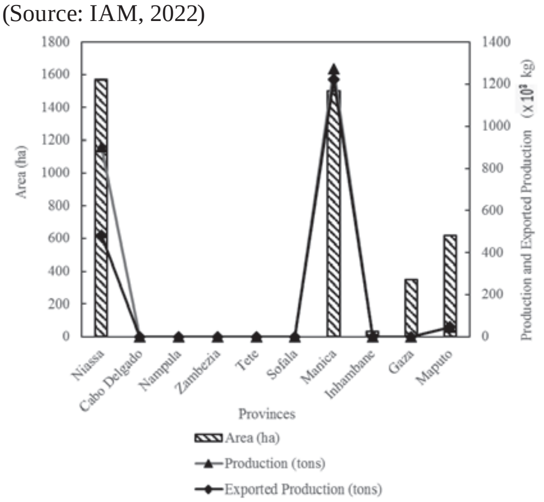


Table 2 Parameters of the cashew nuts quality classification in the Republic of Mozambique (Source: Bulletin of the republic of Mozambique, 2003)

Category	(Out-turn) (kg)	Moisture Content (%)	Flat and Immature (%)	Impurities (%)	Number of Units (Units)
Extra	> 21.6	≤ 10	≤ 10	≤ 1	< 168
Type 1	20.7 to 21.6	≤ 10	≤ 10	≤ 1	< 168
Type 2	19.4 to 20.3	≤ 12	≤ 10	≤ 1	168 to 200
Type 3	< 18.9	≤ 12	≤ 13	≤ 1.5	> 200

different kernel grades based on their color, size, quality, and integrity.

According to the Bulletin of the Republic of Mozambique (2003), cashew nut marketing is classified into two levels, the primary one based on physical characteristics, large type nut which has several units lower than 168 per kilogram, medium type nut has a unit number between 168 and 200 units per kilogram, small type chestnut has a number greater than 200 units per kilogram. The second classification is based on the yield test (outturn), the moisture content, flat and immature nuts, level of impurities, and the number of units. The granulation and the count of nuts per kilogram, is obtained by dividing the number of nuts counted in the sample by the weight of the same sample. This data informs the average size of the nuts, the higher the number obtained, the greater the number of nuts in a 1 kilogram bag and the smaller the size of the nuts.

Degree of Defect

The degree of defect of the kernels is obtained by the following equation (Technical Manual, 2022).

$$D_d = (P_{rjc} + P_{rj}) / P_t \times 100 \qquad [1]$$

Where,

D_d = Degree of Defect, %;

P_{rjc} = Weight of nuts rejected at 100%, kg;

P_{rj} = Weight of nuts rejected at 50%, kg; and

P_t = Weight of nut sample, kg.

Production of Nuts

The yield is obtained by the following equation (Technical Manual, 2022).

$$R_a = (A_s + A_c/2) / P_t \times 100 \qquad [2]$$

Where,

R_a = Production of nuts, kg;

A_s = Total weight plus pellicular of healthy nuts, kg;

A_c = Total weight plus Pellicular of rejected nuts at 50%, kg; and

P_t = Total weight of the nut sample, kg.

In the industry, the commercialization of the nuts is done based on 80 kg bags (expressed in pounds Ib), so the production Ra becomes Outturn, performing conversion using the equation 3, in general the values of outturn from 40 to 50 Ib/80kg are consider lots with excellent quality (Technical Manual, 2022).

$$\text{Outturn} = [R_a/100 \times 80] \times 1/\,0.453559 \qquad [3]$$

Cashew Nuts Quality Test Results for Cropping Year 2021

Quality control in the marketing circuit plays a crucial role, therefore in 2021 cropping year samples were collected at national level recognition of the importance of this step, appreciation of cashew nuts quality was made, whose results indicated the average Outturn of 20.9 kg (**Table 3**). Except for Sofala Province, where chestnut size was classified as small type, the remaining provinces presented medium and large type chestnuts. Due to climate events (cyclones and floods), that devastated the provinces of Manica, Sofala, Inhambane and Gaza, the low chestnut quality was influenced

Fig. 10 Nut size sorting machine and an oven to cook chestnuts at Condor Caju Agro processing factory in Gaza province (Source: IAM, 2022)

Fig. 11 Chestnuts opening machine and separation of the husk process and almond at Condor Caju Agro processing factory in Gaza province (Source: IAM, 2022)

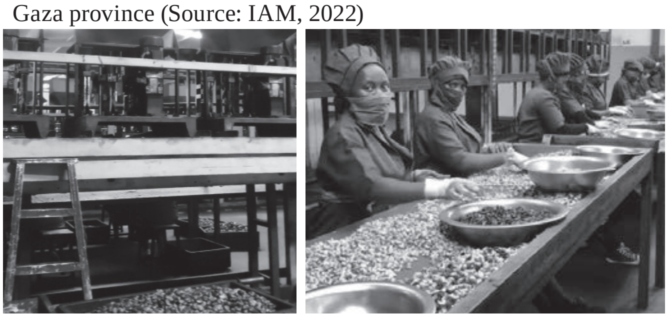
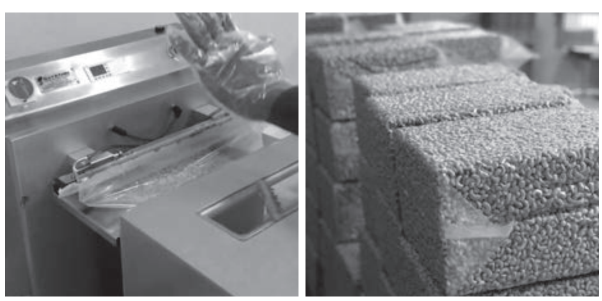


Fig. 12 Vacuum packaging process at Condor Caju Agro Processing factory in Gaza province (Source: IAM, 2022)



by high humidity levels between 11 and 13%.

Export of Raw Cashews

With the entry into force of the regulation for the production, promotion and marketing, cashew processing and exporting, cashew nuts can be exported raw and under almond shape by actors registered with Institute of Almonds of Mozambique (IAM). Chestnut export volumes crude must be determined annually based on total production surpluses national level relative to the existing processing capacity. The capacity projection installed, and the total national production is made until September 15th of each year, determine the quantity of raw nuts destined for export. In the 2019/2020 cropping season, the process of exporting raw cashew nuts began on the 8th of January 2020, having been exported until the month of July 2020, around 33 million and 251 thousand kilograms of raw cashews, which resulted in gross revenue of about 39,879 million US Dollars, India being the biggest destination.

Evolution of Farmers and Export Prices from 2016 to 2021

As Mozambique is a price-taking country, the worsening of prices in the international market, has a direct impact on the national market. The positive correlation of the prices of almonds in relation to producer and export prices of raw nuts are evidenced in the last 6 years. It should be noted that the rising trend in prices, recorded in the cropping season of 2017/18, was induced by the increase in almonds demand internationally. Nonetheless, from the 2018/19 cropping season, due to surplus production and the effect of the pandemic, the dynamics of the global cashew market, declined substantially, which exacerbated the gap in Brazil nut purchase prices from the producer in the order of 44%. **Fig. 13** shows the evolution of the farmers and export prices in the period between 2015/16 to 2020/21 (IAM, 2022).

Table 3 Cashew nuts quality test results for 2021 cropping year (Source: IAM, 2022)

Provinces	Outturn (kg)	Nut Count (Unit)	Moisture Content (%)
Cabo Delgado	21.6	171	10
Nampula	20.7	189	8
Zambezia	20.7	164	8
Sofala	20.3	203	12
Manica	21.6	190	11
Inhambane	20.7	185	13
Gaza	20.7	168	13
Maputo	21.2	173	12

Export of Cashew Almonds

The experience accumulated in the nut processing sector gives a competitive advantage to the country in conquering international markets, whose key factors established by importers/traders, include compliance with agreements, supply of good quality of the almonds considering the size, color, and flavor, guided by the observance of the norms of good manufacturing practices and food safety, to respond to consumer preferences. In 2020, around 9,200 thousand kilograms of almonds were exported, which resulted in the inflow of 44 million of US dollars, made up of 3 segments to be highlighted, (I) raw almonds (6 million and 550 thousand kilograms), (II) almond with skin (2 million and 730 thousand kilograms) and (III) almond ready

Fig. 13 Evolution of cashew nuts marketing in the period of 2016 to 2021 (Source: IAM, 2022)

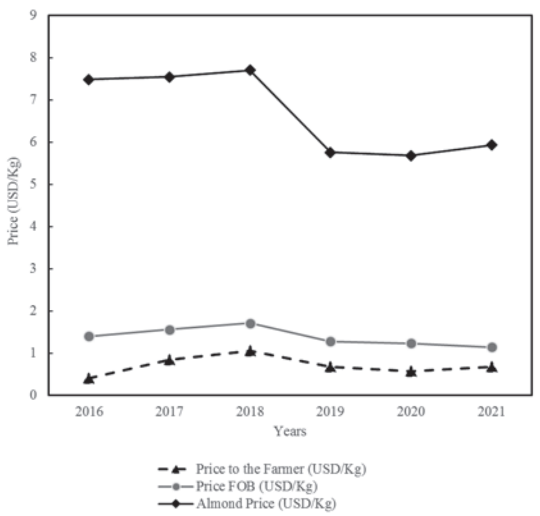
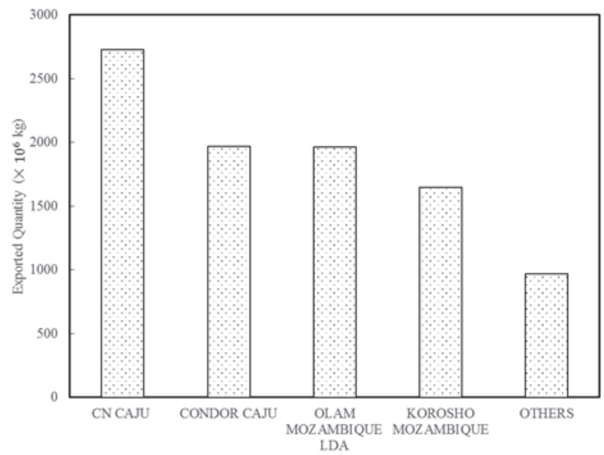


Fig. 14 Quantity of almonds exported by industries in 2021 (Source: IAM, 2022)



for consumption (85 thousand kilograms). It is estimated that during the first quarter of 2021, the revenues reached 12 million dollars by exporting 2 million and 700 thousand kilograms of cashew kernels. Regarding the preferred destinations for almonds produced in the country, in the last 2 years the first position was occupied by Vietnam (40%), followed by the USA (16%), Europe (15%), South Africa (12%), Canada (6%), United Arab Emirates (4%), Lebanon (3%) and others (4%). There is a growing trend in the export volumes of almonds with film, mainly by the companies CN Caju and Korosho that have contracts signed with the Vietnamese market. This Asian country leads the world ranking in the processing and import of this almond category, called "Borma Kernels". In contrast, almond segments primary and secondary are more consumed in the European, American, and South African market. **Fig. 14** shows the quantity of exported almonds by industries in 2021 cropping year.

Conclusions

Regarding internal factors, the cashew nuts industry struggles with the weak financial capacity for the raw material supply. Unfair competition in marketing, delay in reimbursement of value added tax (VAT). Unavailability of raw material in quantity and quality. This research work demonstrated the need to strengthen the quality control mechanism for the cashew produced along the value chain to increase the competitiveness of the cashew sector within the country. The issue of quality must be addressed along the chain, it must be addressed as a whole, from the nut farmers, traders, retailers, processors, and exporters. The low quality of the chestnut makes the trader suffer the imposition of the buyer in the fixing of the price, this imposition of the buyer is due to the fact that they are the only ones willing to buy our product, this action causes the revenues in the chain to be low and the farmers diversifies crops as a way to expand the source of income, failing to pay more attention to cashew production and, further lowering the quality will be observed. Paying a high price for nuts because of their quality may provide an incentive for the farmers to increase their investment in the plantation, but this is not enough. It is necessary to adopt mechanisms that increase the interest of farmers in cashew sector, not only based on price. One of the things to consider is to understand the characteristics and profile of the farmers, as well as their abilities, and to assist and aid each one of them according to their needs.

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Development of a Make-shift Integrated Free Flow Manual Grain Bagging (IFFMGB) System for Small Holder Farmers in Developing Countries

by
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Abstract

This article presents the development and evaluation of a make shift grain bagging equipment known as Integrated Free Flow Manual Grain Bagging System (IFFMBS). The equipment was mainly developed to fill the void created by the absence exorbitant conventional grain bagging plant/equipment used in the packaging of grains/paddy crops for middle level storage, smallholder farmers and cottage industries in developing countries. IFFMGB equipment is basically made of a long, 0.24 m size diameter and 4 mm gauge galvanized steel pipe (chute), which uses confined flow for bagging of grains when attached vertically to a bulk loading bin or grain storage tank. The actual length of the pipe needed to be used depends on the distance between the ground level and the bagging hopper. The pipe is cut into three desired sections and joined together with a manually constructed wide clamp joints. The upper end is made of a short piece, and also a slide gate welded together with a flat steel plate for attachment to the bagging hopper/grain storage tank. While the mid-section remains bare, the lower end is made of a long piece of pipe with a simple manual slide gate at one end, while the hose/bag used for the metering of the grain will be attached at the other end. The discharged grain is to be metered on top of a standing weighing scale provided for easy monitoring of weight. Whenever a bag is filled to the required weight, it will be carried out of the weighing scale and sewed immediately using a hand held stitching machine. The result of the evaluation of IFFMGBS in the bagging of maize, showed that the throughput capacity of the system was 10 bags of 50 kg, 0.50 MT (metric tonnes) of maize per minute in a continuous flow while for complete handling process (bagging and stitching) inclusive, 5 bags of 50 kg (0.25 MT) per minute was recorded against 7-10 bags of 50 kg (0.35-0.5 MT) for most conventional industrial mechanized grain bagging equipment. Though the make shift bagging system, is labour intensive, portable, affordable, versatile, maintenance free, easy to fabricate and needs no technical skills to operate.

Keywords: Manual, grain bagging equipment, affordability, gravitational/free flow.

Introduction

Post harvest handling operations of grains in developing countries are labour intensive and time consuming, majority of the operations are still done manually, especially in Nigeria and other developing countries. The mechanization of the process will not only add value to the process and product, but will also minimize the handling time. Nevertheless the gains, the demands and cost of mechanization have always been an impediment to agricultural development in the developing countries where farmers' finances are relatively low compared with developed economies (Okolo et al., 2020).

Grain bagging is an important and integral part of grain production, storage and distribution value chain, which simply entails packaging in bags of harvested, stored or processed grains for purpose of storage, marketing and immediate consumption (Okolo et al., 2017). Grain bagging consists of two major operations namely metering/discharge of the grains into packaging bags and stitching of the packaged grains. In modern conventional grain bagging systems, where mechanized material handling equipment are used, the instrumentation (metering and discharge of grains) is achieved through a mechatronic digital system made up of sensors, fuses, valves, timing relays and converters linked together to form a circuit. The digital system also controls the pneumatic system comprising of an air compressor and a couple of air filters, electrical sensors, pneumatic hoses, valves and iso-cylinders responsible for clamping, discharging and release of packaged bags of grains. The other component is the stitching of the packaged bags. Though manual hand held stitching machines could be used, most conventional industrial bagging system operate with automated industrial stitching and thread cutting machines using about 0.45 kg of industrial sewing machine thread to sew 600 bags of grains. Generally, all grain bagging systems are normally fed from a reservoir of the commodity to be bagged. In most bagging mechanism, bagged commodities are stored overhead. Gravity discharge is used, either via confined flow i.e. by chute or spout or unconfined flow i.e.by open drop, such as filling a silo, bin or container (Kurt and Evers, 2018; GRDC, 2012; FAO, 1995). Since grains are discrete solids, in a confined flow it is expected that there will be reduction in speed due to friction, especially at contact points between grain and metal housing as well as grain to grain giving rise to abrasions. In confined flow, the higher the diameter of the pipe the faster the grain speed and throughput capacity (Zdzislav et al., 2015).

The greatest challenge of this bagging equipment lies in instrumentation such as the manual measuring of the accurate quantity of grains before stitching, which the conventional bagging systems are better off. Presently a unit of modern grain bagging system costs a minimum of US$ 700, depending on capacity, type and brand. Owing to the fact that modern conventional bagging system are not easily affordable, and needs a bit of technical know-how to manage and operate, most small holder farmers, middlemen grain merchant, and cottage industries especially in developing countries can hardly afford it. The difficulty of precise and convenient bagging and weighing has left many farmers with no other choice than packaging their grains manually, indiscriminately on assumption resulting to non-weighing, non-uniformity and standardization of weight of grains sold in open markets in most developing countries especially Nigeria. It has further made all post harvest packaging processes to be manually oriented with hardly potential interest for improvement. The above challenge in the post harvest management of harvested grains highly justifies the need for a cheap and affordable alternative in the packaging of grains and paddy crops, which can add value to the entire value chain. With the development of the make shift bagging system, most cottage industries, small holder farmers and middlemen grain merchants who store or produces grain in bulk could easily have a cost effective and efficient way of metering and packaging their grains and paddy crops.

Material and Methods

A 0.24 m diameter size and 4mm gauge galvanised steel pipe was cut into three desired lengths joined with 2 units 0.30 m wide pipe clamp joint with slide gates at both ends. The pipe was designed to be attached at one end, to the lower end/body of overhead bulk grain loading bin or bagging hopper, and bolts and nuts couplings were constructed for its firm attachment. A groove was carefully created in the bulk loader or hopper to match the chute to facilitate confined free gravitational flow of grain into the grain chute from the hopper. The incoming grains were controlled by gates, but metered into the packaging bags with a flexible hand controlled sewn polypropylene bag or hose, fixed/clipped at the lower end of the chute. The entire steel pipe was finally braced into two places with a movable jointed angle iron to limit vibration during operations. The packaging/metering of grains was done on top of a weighing scale for easy metering and measurement of weight. As soon as the desired weight is metered, the filled bags are carried out of the weighing scale platform and sewn with a manual hand held sewing machine.

2.1 Development Process

The distance between the ground (floor) level and the hopper of a bulk loading bin was measured and it was 16 m, though could be varied depending on design. A 16 m length, 0.18 m diameter size and 4 mm gauge thick galvanized steel pipe, a 100 kg capacity standing monitor weighing scale, a manual hand held stitching machine, 50 units of 50 kg empty weaved propylene bags, 2 units of a wide locally constructed pipe clamp joints, and 0.12 m^2 of 3 mm diameter galvanised steel flat plate was purchased from a local market in Minna for the purpose of fabrication. The length of the intended packaging bag was also measured along with the weighing scale and it was 2 m. A total length of 3 m was deducted from the total measured length of the equipment including 1 m tolerance for activity and length of flexible filling hose/ polypropylene. The actual length of the equipment obtained was 13 m.

The chute was divided into three lengths in ratio of 1:2:6, translating to 1.62 m, 3.25 m and 9.75 m as sections A, B and C, respectively as presented in **Fig. 1**. All the sections were attached to each other with the aid of a locally fabricated heavy duty long pipe clamp joints. The gaps in between the sections/ joints were not tightly closed during clamping to allow for escape of dust from the grains in flight during operations to enhance further cleaning. A small bend was introduced at mid-section of A at 135° for the purpose of easy attachment to the bulk loading bin and as grain speed breakers. The section was further attached to a slide gate and a flat plate with 4 unit bolts and nuts for attachment to the body of the loading hopper or storage tank, and a groove was created in the bagging hopper for easy confined flowing of grains into Section A. Section B was further attached to section A and section C to section B respectively. The second and last slide gate was attached few meters to the end of section C, creating a long flange of galvanized steel chute from the bottom of the hopper to the ground. A flexible polypropylene bag or hose was further attached to the pipe using hose clip for the manual metering of the grain as presented in **Fig. 1**. The final stage of the design involves the bracing of the pipe with two different clamp joints, with a strong bolted moveable angle iron to forestall the effect of vibration during operation.

The design considerations and choice of 0.24 m diameter size and 4 mm gauge galvanised steel pipe was based on its ability to withstand corrosion and abrasive forces of grains in flight and to allow for enough and easy flow of grains. Others are working cost and ergonomic considerations, efficiency of the gates, metering and measuring system, tensile strength of the clamp joints, strength of bracing/joint and the ability of the attachment to the hopper to withstand different types of forces/vibrations as stated above. (Andrze, 2010; Slocum, 1992).

2.2 Experimental Procedure

Before the evaluation of the efficiency and throughput of IFFMGBS, a 50 Metric Tonnes (MT) capacity bagging hopper was fully loaded with maize procured from Mariga grain markets in Niger State, by Federal Government Licence buyers Agents. The grains were cleaned, and loaded into the bulk loading via a chute in a grain storage facility. At the beginning of the evaluation, an empty packaging bag was placed on top of the weighing scale. The weighing scale was zeroed and the slice gates were opened for flow of grains into the bag. The grains flow was controlled as desired by spontaneously squeezing and releasing the flexible bag held manually till the desired weight is attained. The duty of the operator was to monitor the weight as it discharges and stop the flow when the desired weight is attained. As soon as the weight is attained a worker carried it away to another standby worker who sewed the bag with a hand held bag stitching machine. The throughput capacity and number of bags produced by this manual bagging system was timed for 9 trial runs. The average values obtained were recorded and used as the tentative value. The cost benefit analysis was equally carried out to evaluate its economics.

Results and Discussion

The result of the evaluation showed that the throughput capacity of the IFFMGB system was 10 bags of 50 kg (0.5 MT) of maize per minute in a continuous flow situation. However in terms of the actual handling (bagging and stitch-

Fig. 1 (i) IFFMGBS, (ii) IFFMGBS used for bagging of grains, (iii) IFFMGBS illustrative diagram

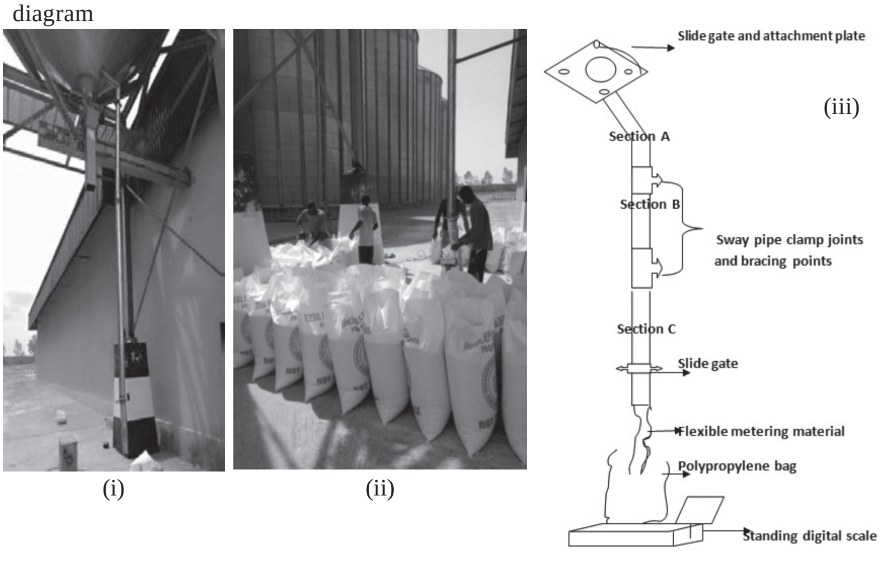


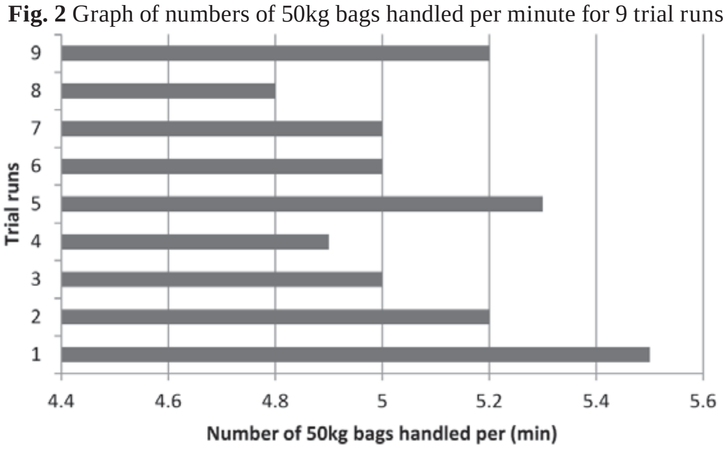
Table 1 Cost Analysis (CA) for purchase of materials and fabrication of IFFMGB system

S/ No	DESCRIPTION	QTY	Unit Cost (N)	Amount (N:k)
1	0.24 m diameter size 5 m length aluminium galvanized pipe	3	5,000	15,000.00
2	Welding electrode	20	150	3,000.00
3	0.5 diameter hose clip	2	200	400.00
4	0.5 m flat iron plate with 4 bolts and nuts	1	5,000	5,000.00
5	5 m length 10 mm angle iron with 4 bolts and nuts for brazing	1	5,000	5,000.00
6	Digital standing weighing scale	1	50,000	50,000.00
7	Labour for fabrication	1	10,000	10,000.00
8	0.5 diameter size 1 m long short flexible hose	1	2,000	2,000.00
	TOTAL			N90,500.00k

ing time), a total of approximately 5 bags of 50 kg (0.25 MT) of maize was bagged per minute as presented in **Fig. 2** as against 7-10 bags of 50 kg for most conventional industrial mechanized grain bagging systems. It takes 5 seconds to fill a 50 kg bag using IFFMGB system, while the time to stop the discharge to change the bag accounts for the difference between the throughput and the actual handling time. The thread consumption/requirement of IFFMGB system is 290 units of 50 kg bags sewed per 0.10 kg of thread using a manual hand held stitching machine against 240 units of 50 kg bags per 0.10 kg for conventional modern bagging equipment. The difference is accounted by long extension of thread needed before trimming, and inability of the thread cutters to function as expected in automatic/conventional bagging plants, which is inexistence in IFFMGB due to its manually system.

The labour requirements for the IFFMGB system are three individuals. The first person meters the grain on top of a standing weighing scale, the second person picks the empty packaging bag, opens it and hands over to the first person before carrying the filled bag to the third person that will sew the bag with a hand held stitching machine as presented in **Fig. 1**. Worthy to note is that bagging operations using IFFMGBS could be done in the absence of electricity, whereby as small as 1.5 kVA generating set could be used to power the hand held bag stitching machine. The system can also be operated 100% manual whereby the stitching could be done manually, in dire situations or where a small number of bags are handled. IFFMGBS offers a wide range of options at middle level grain processing and storage especially the cottage industries as far as packaging/bagging of grains are concerned. Any cottage industry that could not afford modern bagging equipment can make do with it as an alternative, or can use IFFMGBS as a support bagging equipment to complement modern conventional bagging equipment. Presented in **Fig. 2**, is the graph of handling time for 50 kg bags for 9 trial runs using IFFMGBS.

Fig. 2 Graph of numbers of 50kg bags handled per minute for 9 trial runs



Presented in **Table 1** is the cost analysis (CA) for purchase of materials and fabrication of IFFMGB system as at March, 2021 in Nigeria.

The summary of the cost analysis shows the total sum of Ninety Thousand Five Hundred Naira only (N 90, 500.00 k) approximately (US$ 221.00) at official exchange rate of N 410 per US Dollar as at April, 2021 can provide a complete IFFMGB system.

Advantages of the IFFMGBS over the conventional grain bagging system are as follows:

i. It is generally a cost effective grain bagging system

ii. Thread consumption is reduced using IFFMGBS due to use of hand held stitching machine

iii. Fuel consumption is reduced with the use of IFFMGBS in the absence of electricity where small internal combustion 1.5 kVA generator could be used to power the hand held sewing machine.

iv. It is maintenance free equipment and not prone to technical challenges in course of use.

v. Provides opportunity for extra cleaning of the bagged grains through the deliberate openings created at clamp pipe joints along the chute, especially if the system is used in an open air operation.

vi. Not prone to periodic breakdowns like the normal conventional bagging plant.

vii. Creates employment for low skilled workers and requires less technical skill to use.

viii. It affords an extra opportunity for observation of the physical state of the grains before bagging.

ix. It is portable and hence could be easily dismantled and transferred to another place for use.

Conclusion

IFFMGB system has become imperative considering seemingly non availability of affordable alternatives to high cost of conventional modern bagging equipment and several technical challenges associated with the use of this system in developing economies. Though ergonomics considerations are not at its best with this system, it is relatively cheap, easy to use and maintenance free. Its ability to compete with the modern bagging equipment in terms of rate of handling time further buttresses the fact that it is an important equipment, that can be used both in absence of the modern bagging equipment or in a complimentary role, to solve the problem of bagging and metering of grains for middle level storage and cottage industries in developing economies.

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Feasibility and Economic Sustainability of Mechanization in Sugarcane Planting Under Western Plain Zone of Uttar Pradesh India

by

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Abstract

The mechanization status under sugarcane cultivations in western plain zone of Uttar Pradesh were assessed through both quantitative and qualitative data collection by the sugarcane growers' farmers. The feasibility and its economic viability of 2-row sugarcane automatic cutter planter were studied at farmers' field. The labour intensive and time exhaustive operation are common problems associated to conventional sowing of sugarcane. Tractor drawn commercially available ICAR-Indian Institute for Sugarcane Research, Lucknow designed and manufactured two - row sugarcane automatic cutter planter was tested and evaluated. The field trials were conducted for sugarcane sowing of different three farmers' field. The performance indicators of the planter viz., field capacity, efficiency and machine index were calculated by using the observed data in the field. An average field capacity of 0.18 ha/h was obtained for continuous operation of planter with average speed of 1.62 km/h. The field efficiency varied from 63.49 to 70.81 percent in different field conditions. The machine index was estimated 44.38 percent. The planter was operated a tractor of engine 1000 to 1200 rpm with second low gear so that planter able to achieve the theoretical travel speed of 0.50 m/sec. The cutting sett length was found on average 33.75 cm with 2 to 3 bud eyes of each sett and planted with overlapping 34.44 mm which is recommended range of 30 to 50 mm. The average depth of placement of setts in 10 observations of each farmer's field was measured 116.0 mm. The operating cost of planter was found to be Rs. 906/h and Rs. 4,975/ha, however, in conventional method of sugarcane sowing (rider and furrower followed by dropping of setts in furrow manually), the cost was analyzed to be Rs. 4,049/h and Rs. 10,172/ha. The cost benefits in machine planting was calculated Rs. 5,197/ha over the conventional method. As per survey data, the mechanization in planting of sugarcane crop is adopted half mechanized system i.e. setts cutting and placing in furrow is being done by manually which is very tedious and cumbersome job and only furrow making is being done by tractor operated ridger/furrower. Extent of adoptability and suitability of machine in the region, it has very cost effectiveness, timeliness operation, good quality of work & safety of work, reduction in drudgery etc.

Keywords: Mechanization, Machine index, Field capacity, Field efficiency, Cost benefit

Introduction

The mechanization is critical need of farmers due to non-availability of labours at the peak period of agricultural activities caused not to accomplish work timely with accurate inputs which saved resources, time and cost as well as it is required for achieving sustainable higher production crops and environmental benefits. In the present era of labour shortage and unavailability of animal to do farm operations, there is an urgent need to mechanize sugarcane planting for reducing the cost as well as human drudgery involved. The most of activities in sugarcane cultivations are done by locally made or indigenous manufactured tools & equipment's for performing different operations like land preparation, planting, irrigation, interculture, earthing, plant protection, harvesting, transportation and ratoon management. These operations are labour intensive and hence it is a crucial need to shift over to mechanization of cultural practices to increase overall productivity (Kumar et al., 2012). The labour consumption in cultivation of sugarcane is more and mechanization is less and also the energy consumption in sugarcane production is more as compared to other crops like paddy, wheat, potato, maize, etc. Since the cost of labour in country is increasing rapidly and the price of local sugar is uncompetitive with the product from mechanized international producers, India needs to change its sugarcane production methods from manual work to mechanization in order to catch up with international trends in this global industry. Use of mechanization helps in labour saving, timeliness of operations, human drudgery reduction, reduces cost of operation, helps in improving quality of work and ensures effective utilization of resources (Kishore et al., 2017). The highest labour (i.e. 375 man-days/ha) required in sugarcane crop as compared to any other crop for different operations. Considering the present trend of availability of labour for sugarcane production, it has been experienced that use of modern machinery is inevitable (Singh et al., 2016). The sugarcane (*Saccharum hybrids* L.) is the important cash crop of India and its operations are arduous, energy, labour and drudgery intensive. It is main source of sugar, gur and khandsari in the country. The 5.3 million ha area under sugarcane is grown in India with an average production of 75 tonnes/ha and an annual production of about 366 million tonnes (Anon., 2016). Traditionally sugarcane has always planted manually in flat method. Mechanization in planting of sugarcane is urgently essential to reduce the cost of planting, time saving, drudgery and proper placement of seed & fertilizer etc. Planting of sugarcane is highly labour and time intensive operation. It involves sett cutting for preparing seed material, furrow opening in field, placing seed-setts in furrows, mixing of fertilizer, application of insecticide and then coverage of setts with soil. The substantial saving (about 11 times) in labour requirement was observed in mechanical planting (25 man-h per ha) as compared to conventional method (280 man-h per ha) (Singh and Singh, 2016). It has also been reported by Bhal et al. 2001 that reduction in labour requirement from 130-150 man-h per ha by conventional method to 35-40 man-h per ha by machine planting. Proper placement of seeds or setts of sugarcane crop creates favorable environments for foundation of any crop and plays an important role in its growth and yield. For sugarcane planting, manually operated hand tools and power operated sett-cutting machines are used to cut the setts and it is planted in the form of cut setts with 2-3 buds. Tractor operated rotavator, cultivator and ridger & furrower are the main farm equipments, used for tillage and ridge forming operations in sugarcane cultivation. In conventional method, the sugarcane sett cutting process is a pre planting practice, while in mechanized system setts cutting is done simultaneously by the planter. This ultimately reduces time, labour and moisture loss in setts of sugarcane and helps in higher germination percentage (Kumar et al., 2012). Conventionally, opening of furrow using tractor operated ridgers are only mechanized operation and rest of the sugarcane planting operations are done manually. In addition to this, the bud damage due to excessive handling of seed cane, desiccation of setts and loss of soil moisture could hardly be checked. The various types of sugarcane planting machineries have already been developed in different Institutions as per location wise and method of planting. These machines are basically of two types, widely known as drop planters and cutter planters. In drop planters, pre cut sugarcane setts of desired length are fed in to the machine (Singh et al., 2011). The setts may be cut manually or mechanically. These planters' consist of two vertical rotating drums with 12 circular vertical seed compartments in each drum. The rotating drum is powered by ground wheel through central shaft. In the cutter planter, whole cane is fed. It is provided with the cutting unit, which cuts the fed cane to a predetermined length and carries it to the furrow. Presently most common design of planter is the cutter planter which performs the job of sett cutting, furrow opening, fungicidal and anti-termite treatment of setts, and placement of the fertilizer in bands or either side of setts, covering and pressing the setts. Whole cane is fed through the chute manually from the sugarcane hopper. Designs of two and three row cutter planters are commercially available. There are about 10 to 15 manufacturers of sugarcane planters in the country who manufacture different models. These models are tested and evaluated at different research stations in the country. In Northern India is flat planted, but where sugarcane lodging takes place, trench planting is adopted. Different row spacing ranging from 60-70 to 90-150 cm is maintained at different places in India (Sharma et al., 1995). The recommended row spacing is 90 cm for autumn planting and 75 cm for spring planting (Patil et al., 2004; Singh and Singh, 2016). There was a need for development of a planting device for mechanizing sugarcane planting to facilitate furrow planting and have provision for adjustment of row spacing of 75 or 90 cm. Therefore to reduce drudgery and cost of planting, efficient utilization of seed and fertilizer, use of planters is advocated.

In under western plain zone Uttar Pradesh have major area under sugarcane out of which 90 percent of area is sown manually by making furrow through tractor operated ridger and sett dropping through manually. The objectives of this study is to test feasibility and economic option of sugarcane automatic cutter planter in western plane zone of Uttar Pradesh to increase the mechanization level of sugarcane planting and timeliness operation with performing all unit operations involved in sugarcane planting simultaneously in its single pass.

Material and Methods

Constructional Details of Sugar Cane Planter

The planter consists of frame, row wise separate fertilizer box, fertilizer metering units, MB type furrow opener, sett cutting, power transmission, insecticide solution application and soil covering units. The sturdy mild steel (MS) frame works are provided to mount all the units. Two furrow openers, one for each row, were made for adjustment of row spacing between two furrow openers either at 75 or 90 cm. Each furrow opener consisted of two mould board plough bottoms (mould board, share bar, share, landside) joined together. Sett cutting unit consisted of two blades mounted on a rotating disc and apair of guiding ring for each row. Whole canes are fed up to the depth of furrow bottom manually through the guiding ring to the rotating blades. Designed sett cutting blades were curved to provide sharp cut with minimum force. A safety cover was provided over the blades for avoiding any accident. Planter was designed to provide the desired overlapping of 50-100 mm of seed-setts at a tractor operating speed of 0.50 ms^{-1}. Seed box was designed to accommodate 100 kg of whole seed cane. Fertilizer metering unit consisted of MS fertilizer box, PVC casings, PVC edge cell circular rotors and PVC pipe to guide them entered fertilizer to the desired location in furrow bottom. Rate of fertilizer was regulated by adjusting the clearance gap between the casing and rotor within allowable range. For further variation of rate of fertilizer different size rotors could be selected. The capacity of each fertilizer box was 20 kg. Sett cutting and fertilizer metering units were powered through tractor power take off (PTO) shaft. Power from output shaft of reduction gear box was transmitted to fertilizer metering rollers through chain and sprockets. PVC pipe of 200 mm diameter and 1,150 mm length was attached with the main frame for insecticide solution. Liquid solution was applied over setts in furrow through PVC pipe under gravity force. The capacity of the insecticide solution storing pipe was 35 liter. Sett covering unit consisted of covering tynes with reversible shovels and a tamping roller for each row on a ‘U’ frame. While sett covering was provided with the help of shovels, the tamping roller was used to press the blanket of soil lightly for conserving the soil moisture. The equipment was provided with two seats for feeding the seed canes.

Famers Field Experimental Techniques

The field experiments were conducted at two villages − Pahardpur (block- Mawana) and Pawersa (Block- Sardhana), farmers field (29 6 50.92° N, 77 50 32.71° E and 237 m above mean sea level) of Meerut district, Uttar Pradesh, India. The Climate of the area is semi-arid, with an average rainfall of 800 mm (75-80 % of which is received during July to September) minimum temperature of 0-4.8 °C in January, maximum temperature of 41-45 °C in June, and relative humidity of 67-83% throughout the year. The experimental soil (0-15 cm) was silt loam in texture, with an average bulk density of 1.40 mg m^3.

Field Evaluation

The field experiments on performance evaluation of the tractor operated sugarcane automatic cutter planter were conducted in the farmers’ fields in the Meerut district. The planter was attached with tractor by three-point linkage system and powered by PTO. Tractor was operated in second low gear at 1,000-1,200 engine rpm. The procedure for testing the performance of planter was adopted from RNAM test codes. The field was prepared into fine tilt by twice harrowing followed by rotavetor for operation of planter. The operation provided the friable condition with minimum clod and tillage depth up to 10-15 cm. The plot area of 2,300, 2,400 and 6,500 m^2 were taken for evaluating field performance of the implement at three farmers’ field at the three locations. The experiment was divided to accommodate in three replications with Randomized Block Design. The following variables independent (operating speed) and dependent parameters (machine parameters and soil parameter) were recorded.

The soil samples were taken up to a depth of 15 cm to measure the moisture content of the field. The soil samples of known weight were kept in the oven for 24 h at 105 °C. Thereafter, the weight of oven dried samples was taken by triple beam balance having 0.01 g least count. The soil samples were collected randomly from each sub plot of the experimental field with the help of core sampler having height (12.5 cm) and diameter (9.0 cm) to determine the bulk density of field. The core sampler was inserted into field by hammering up to full height and then dug out along with soil by using a spade and khurpi. The total weight of core sampler along with soil was determined and kept in oven at 105 °C for 24 h. Thereafter, the dry samples were taken out, cooled and weighed for their dry weight. The bulk density of soil was calculated using Black equation. A standard cone penetrometer (model BL, 250 EC, Baker Mercer type C10, LC = 0.002 mm), having 26.18 mm cone diameter and 200 cone angle was used to measure the cone index of field. While inserting penetrometer into the soil with uniform speed, for every 2.5 cm depth dial gauge readings were recorded. The calibration of penetrometer of applied load with gauge deflection was done. A relationship was established between the parameters.

The forward speed of operation was determined by recording the time required to travel 15 m distance by the planter with the help of a stop watch. The speed was calculated in km/h. The amount of fuel consumed during field operation was determined by filling the fuel tank up to its brim at the beginning of each field operation and after covering the test plot. The fuel required to refill the tank to its previous level gave the actual fuel consumed and calculated as litre per hour. The parameters were calculated from the equations given below.

Moisture content (% db)

$MC = [(W_1 - W_2) / W_2] \times 100$

where,

W_1 = weight of wet soil sample, g

W_2 = weight of oven dry soil, g

Bulk density

BD = [(Dry weight of soil, g) / (Volume of cone sampler, cm^3)] × 100

where,

Volume of core sampler = $(\pi/4) D^2H$

D = Diameter of core sampler, cm

H = height of core sampler, cm

Cone index

$CI = 0.025Y + 0.099$

where,

CI = Cone Index, kg/cm^2

Y = gauge deflection, subdivisions

Travel speed

$S = 3.6 L/t$

where,

S = travel speed, km/h

L = travel distance, m

t = time second, sec.

In order to evaluation of sugarcane planter and data recording, the both sugarcane hoppers were filled with whole sugarcane. The fertilizer was filled and adjusted with recommended dose of fertilizer. The insecticide was filled with solution of water in tank and opens the nob. The planter was operated in straight line. The operation was replicated. The observation regarding time taken to cover the area, fuel consumption of coved area, the actual travel speed of planter, time losses in turn of turning, filling/loading of sugarcane were recorded. The performance indicators of planter viz., field capacity, efficiency and machine index were calculated using observation data in the field. The theoretical field capacity is the rate of field coverage that would be obtained if planter was operating continuously without interruptions like turning, loading of sugarcane seed, others like break down, clogging of machine etc. The effective field capacity is the actual average rate of coverage including the time lost in loading of sugarcane seed in hopper, turning loss at end of rows and others. Field efficiency is the ratio of the effective field capacity to theoretical field capacity as shown below. Time utilisation study (Singh and Mani, 2006) was conducted for recording the time utilised in different activities of sugarcane planting i.e. time lost in turning of planter at head land, filling of seed, fertiliser, insecticide solution and miscellaneous activities. The machine index was calculated by using the following formula, which indicates the influence of field geometry on working capacity of the machine. Performance of the planter was compared with conventional method of planting i.e. furrow opening by tractor drawn ridger and rest of the operations including sett cutting manually.

$FMI = [T_o / (T_p + T_r)] \times 100$

where,

FMI = Field machine index

T_o = Theoretical field time, min./plot

T_p = Total productive time, min./plot

Table 1 Specification of sugar cane planter

S/No	Particulars	Specification
1	Type	Mounted type - 3 point linkage system
2	Make of machine	ICAR - IISR, Lucknow
3	Agency designed	ICAR - IISR, Lucknow
4	Source of Power	45 HP tractor
5	Overall dimensions (mm)	1900 (L) × 1500 (W) × 2000 (H)
6	No. of Furrow opener & type	2 & two mould board plough bottoms (mould board, share bar, share, landside) joined together
7	Sett cutting unit	PTO operated rotating blades
8	Seed tray	100 kg of whole seed cane stalks
9	Fertilizer metering unit	Box capacity – 20 kg & PVC casing and edge cell PVC rotors
10	Power transmission	Suitable speed reduction of PTO operated sett cutting (reduction ratio 8.3:1) and fertilizer metering units (reduction ratio 4.15:1)
11	Insecticide solution application	Volume of container – 35.1 litre & Flows under gravity regulated by gate valve
12	Soil covering	Reversible shovel attached with adjustable tyne at both ends of furrow for soil covering and rotary mild steel rollers for compressing soil cover

T_r = Total turning time, min./plot

TFC = (W × S) / 10

where,

TFC = Theoretical field capacity, ha/h

W = Width of coverage, m

S = Speed of operation, km/h

EFC = Actual area covered in unit time, ha/h

FE = (EFC / TFC) × 100

where,

FE = Field efficiency (%)

EFC = Effective field capacity, ha/h)

TFC = Theoretical field capacity, ha/h

Performance Results of Field Trials

The field trials were conducted for planting at farmers' field. The information farmers, his cultivation practice and conventional equipment's used were also recorded. Details are given in **Table 2**. The trials were conducted at village- Pahadpur (Mawan), Distt.- Meerut on farmer's field over an area of 0.47 ha & 0.64 ha in village – Pawersa, Distt.- Meerut for planting of sugarcane. The granular fertilizer i.e. DAP was drilled simultaneously. Planter performance parameters like average length of setts, average number of buds per setts, depth of planted sett, number of setts per meter furrow length, overlapping of setts were recorded to observe the sugarcane sett cutting and placing pattern of planter. The planter was run in the field for 60 meters length to measure the overlap/gap of the setts placed in the furrow (Daffa and Humiedia 1991). All setts dropped were collected and number of setts and length of each sett was measured and average was taken. Out of collected setts, 100 setts were selected randomly and number of buds damaged and nature of cut was also observed and recorded. Depth of placement of setts in the furrows was evaluated and measured at five different places and average was calculated. Depth of placement of setts was controlled by the hydraulic system of the tractor.

Average overlap = {[(Total length of setts) – (Distance for 60 m)] / (Total no. of setts)} × 100

Average gap = {[(Distance for 60 m) – (Total length of setts)] / (Total no. of setts)} × 100

Cost Economics

Total cost of planting operation was determined and analysed based on fixed cost and variable cost (IS: 1964-1979) of the tractor and planter. The fixed cost and variable cost was considered in determining the cost of operation of the planter. Fixed cost includes depreciation, interest, insurance and taxes and shelter, where as variable cost includes repair and maintenance cost, fuel consumption and labor cost etc. Total cost of operation was determined as the sum of the fixed and variable cost. The total cost of operation per hour of machine was computed. The cost of operation of the tractor was also calculated following the same procedure. The cost of fuel, lubrication and operator was added to the variable cost. The total cost of operation of the planter was determined by adding the hourly cost of operation of the planter and tractor and expressed in Rupees per hour. It was converted into area basis by multiplying it with the effective field capacity of the machine and expressed in Rupees per hectare.

The cost of manual planting was calculated by taking into account the cost of man-hour required for cutting the setts and placing/planting of the setts in furrow. The man-hour requirement for planting of sugarcane setts was recorded in the test plot. The manual planting was performed by farm labor. The cost of operation of tractor and fixed and variables cost furrower were determined as same procedure done in case of sugarcane cutter planter. The total cost of manual planting was determined by adding total man-hour cost and operation of furrower and tractor and expressed in Rupees per hectare. The detail of cost analysis is presented in **Table 6**.

Utility and Efficacy of the Sugarcane Cutter planter in Comparison to Conventional Method (Manual Planting)

Feasibility test of sugarcane cutter planter was undertaken at the farmers field an area of 10 ha. The information regarding for achieving timeliness, improvement in quality of work, reduction in drudgery and cost effectiveness of planter were recorded. The germination duration of sugarcane buds decreased and greater percentage of germination was observed in sugarcane cutter planter in comparison to conventional method of planting. The utility and efficacy of the sugarcane cutter planter in comparison to conventional method were also recorded. The details of the same are

Table 2 Information regarding farmers, his cultivation practice and conventional equipment's used

Name of farmers	Mr. Sanser Pal	Mr. Om Pal	Mr. Om Veer
Village	Pahardpur	Pahardpur	Pawarsa
District	Meerut	Meerut	Meerut
Land holding (total) (ha)	1.5	1.25	2.5
Irrigated upland/lowland (ha)	2.0	3.5	3.0
Rain-fed upland/lowland (ha)	Nil	Nil	Nil
Cropping pattern	Sugarcane-wheat	Sugarcane-wheat	Sugarcane-wheat
Next crop to sown	Wheat	Wheat	Wheat
Conventional equipment used	Disc harrow, Rotavetor	Rotavetor, cultivator	Rotavetor, cultivator
Stubbles of previous crop grown	Sugarcane	Sugarcane	Sugarcane

listed in the **Table 3**.

Results and Discussion

Study on Feasibility of Mechanization in Sugarcane Planting

The mechanization in planting of sugarcane crop in western Uttar Pradesh was analyzed on the basis of economic viability and feasibility with 2- row mounted type sugarcane cutter planter at the different farmers' field. The field was prepared with twice harrowing followed by rotavetor to get fine tilth (depth of tillage up to 15-20 cm) with minimum clod for operation of planter. The unit operation of sugarcane cutter planter is enhanced the quality and safety of work such as furrow making, sett cutting & dropping in furrow followed by insecticides and fertilizer application along with covering of furrow simultaneously. The planter accepted whole cane thereafter setts were cut and placed in furrows synchronously.

Field Capacity and Field Efficiency

The effective field capacity were observed to be 0.18, 0.17 and 0.19 ha/h (Mandal et al., 2008) in the field of Mr. Sanser Pal, Mr. Om Pal in vill. - Pahadpur and Mr. Om Veer in vill.- Pawarsa, however, the theoretical field capacity is 0.27 ha/h (**Table 4**). The lower effective field capacity was due the different field size, wheel slip losses and time losses in turning and filling of inputs like seed, fertilizer and pesticides etc. The field efficiency varied from 63.49 to 70.81 percent (Singh and Singh, 2016).

Field Performance Test

Field performance test were carried at the three different farmers field (**Fig. 1**). The performance related data of sugarcane planter were generated and presented in **Table 4**. The soil parameters like cone index (16-18), soil moisture content (14-18%), bulk density (1.23 to 1.45) was found to suitable for sugarcane sowing. The tractor (FARMTRAC-50, size 50 HP) was used for the sowing of the sugarcane. An average field capacity ranged 0.17 to 0.19 ha/h was obtained with an average speed ranged 1.59 to 1.65 km/h. The field efficiency was ranged 63.49 to 70.81 percent which are at par with Singh and Singh 2016. The major losses in efficiency due to frequent filling of sugarcane seed in hopper; it has been reported 36 times required to fill by sugarcane seed and 8 times for fertilizer boxes for planting of one hectare. Results revealed that about 52 percent of total time planting was lost in different activities such as seed filling in hopper, turning, other losses as break down, clogging etc. The major time loss in filling of seed in hopper of machine

Table 3 Specification of sugar cane planter

Extent of achieving timeliness of operation and contribution of the equipment in enhancing productivity through timeliness of operation	Saving in time
Improvement in quality of work	Proper placement of sugarcane setts in furrow with recommended overlapping setts.
Reduction in drudgery of work	Complete work performed by planter in single pass as proper making of furrow with setts cutting from whole cane and planting in furrow followed by insecticides and fertilizer application along with coving with soil in furrow.
Improvement in safety	Yes
Cost effectiveness	Sufficient saving in cost and inputs
Suitability of equipment to the region from the following aspects	
Crop grown	Sugarcane
Problems existing in conventional practice	Higher labor requirement, improper sugarcane setts planting
Prevalent farm sources	Tractor power
Labor scarcity in the peak period	Yes
Initial cost of machine	Rs. 100,000.0
Operational skills required	Training of operator
Repair and maintenance facilities	Available

Fig. 1 Sugarcane planting in the farmer's field by sugarcane cutter planter

Fig. 2 Sugarcane set as planted in the field by sugarcane cutter planter

was about 38 percent of total planting time. The machine index was observed to be at an average 44.38 percent. It was observed in the rectangular plot size with head land width varied 23 to 64 m. The lower machine index was noticed due to higher time lost in filling of sugarcane seed in machine hopper and other losses. The sugarcane seed rate was varied from 8.89 to 9.12 t/ha and depth of sowing was 110 to 120 mm. The length of sugarcane sett was noticed within 33 to 34 cm with on average of 2.82 eyes in each sett. The overlapping between two successive setts was 34 to 35 mm which was well acceptable and within the desirable overlapping range (**Fig. 2**).

Table 4 Field performance sugarcane cutter planter at farmers' field

S/No	Particulars	Parameters		
A. General Information				
1	Testing at each farmers field	Mr. Sanser Pal	Mr. Om Pal	Mr. Om Veer
2	Crop (variety)	Sugarcane (CO-238)	Sugarcane (CO-238)	Sugarcane (CO-238)
3	Date of sowing	5/5/2017	24-03-2017	20-04-2018
4	Training to operator (h)	1	1	1
5	Type of soil	Sandy loam	Sandy loam	Sandy loam
6	Cone index (before testing)	16	18	18
7	Soil moisture (% db) (before testing)	14.23	15.5	18.0
8	Bulk density (g/cm2) (before testing)	1.23	1.40	1.45
9	Type of fertilizer	DAP	DAP	DAP
10	Fertilizer rate (kg/ha)	>300	>300	>300
B. Calibration of Sugarcane Cutter Planter				
1	Seed rate (t/ha)	9.23	8.95	8.89
2	Length of sugarcane set (cm)	34.14	34.01	33.12
3	No. of setts per meter	3 to 4	3 to 4	3 to 4
4	No of eyes /sett	2.67	3.00	2.80
5	Overlapping of sett (mm)	34.00	35.00	34.33
6	Depth of furrow (mm)	120	118	110
7	Depth of ploughing (mm)	120 to 150	120 to 150	120 to 150
C. Performance Evaluation of Sugarcane Cutter Planter				
1	Sown area (ha)	0.23	0.24	0.65
2	Width of head land (m)	23.00	24.00	65.00
3	Effective working width (mm)	1500	1500	1500
4	Row spacing (mm)	750	750	750
5	Actual operating speed (km/h)	1.59	1.62	1.65
6	PTO /engine RPM	1000-1200	1000-1200	1000-1200
7	Time of planting (h/ha)	5.43	5.83	5.23
8	Total time losses (h/ha)	2.17	3.13	3.36
	i. Time losses turning (h/ha)	0.36	0.42	0.38
	ii. Time losses due to filling of hopper (h/ha)	1.45	2.22	2.56
	iii. Time losses due to repair/ breakdown (h/ha)	0.36	0.49	0.41
9	Machine Index (%)	48.68	41.34	43.12
10	Theoretical field capacity (ha/h)	0.27	0.27	0.27
11	Effective field capacity (ha/h)	0.18	0.17	0.19
12	Field efficiency (%)	68.15	63.49	70.81
13	Fuel consumption (l/ha)	23.91	25.00	23.08
14	Fuel consumption (l/h)	4.40	4.29	4.41
15	Labor requirement (man-h/ha)	27	29	28

The technical training of tractor driver as well as the farmers were conducted about 50 min to 1.25 hour to enhance the skill of the farmers and smooth operation of planter. The tractor driver understood tractor engine rpm should run between 1,000 to 1,200 rpm and travel speed of sugarcane planter (0.50 m/sec) which is achievable in second low gear. When forward speed of the tractor increased speed ratio of sett cutting blade and tractor decreased resulting in decreased overlapping between planted setts. This is very important for proper cutting of sugarcane setts as well as seed rate, as we know that optimum PTO speed is necessary for correct seed rate, and over lapping sugarcane setts for good plant populations. With the increase in tractor wheel slippage overlapping between planted setts increased due to increased speed ratio of sett cutting blade and tractor.

The suitability of the planter to the region is due to cropping pattern as major area under sugarcane crop and problems existing conventional methods i.e. labour scarcity during peak period of sowing, quality of work, less time requirement etc. (**Table 3**). The prevalent power sources tractor is easily available. Socio economic aspects like purchasing capacity of farmers, initial cost of machine, desired operational skills and repair and maintenance were also found substantial. Extent of achieving timeliness of operation and contribution of planter or equipments enhancing the productivity is significant due to huge saving of man hour's requirement. The cost of planting was quite substantial and justified the use of planter. The improvement in quality of work, reduction in drudgery and improvement in safety was also enhanced as compared to conventional method of sowing of sugarcane.

Cost Analysis

The cost of sugar cane planter was worked out (**Table 5**) to be Rs.

100,000.0 (1,538.0 USD) and hourly cost of operation planter only was computed to be Rs. 890.0 (13.69 USD). The man-hour requirement for planting one hectare of land through planter was observed to be 28.0. Only 28 man-h per ha was required for planting using the developed sugarcane planter (planter effective field capacity 0.18 ha/h) which is about 10 times less than the man requirement in conventional planting (280 man-h per ha). Result is agreement as reported by Singh and Sharma, 2008, reduction in cost of planting by machine about 60 percent as compared to conventional planting. The cost of planting by sugarcane planter was observed Rs. 4,975.0 (76.53 USD) per hectare as against 10,172.0 (156.49 USD) required for conventional method of sowing for sugarcane. The cost of manual planting (conventional method planting) was observed to be 104 percent higher than the machine planting and required 252.0 man-hours per ha more than machine planting. However, the planter reduces the human drudgery involved in sugarcane planting operations.

Conclusions

The mechanization status in sugarcane crop in western plain zone of Uttar Pradesh is very low. As per survey data, only tillage operation is mechanized about 95-100 percent and rest of other operations are being done tradionally. However, the mechanization planting of sugarcane crop is adopted half mechanized system i.e. setts cutting and placing in furrow is being done by manually which is very tedious and cumbersome job and only furrow making is being done by tractor operated ridger/furrower. The field evaluation of 2-row sugarcane cutter planter has performed at farmers' field and field capacity was observed to be 0.18 ha/h at average speed of 1.62 km/h and the field efficiency varied 63.49 to 70.81 percent. The machine index was estimated 44.38 percent. The sugarcane seed rate obtained was 9.03 t/ha. The length of cutting sett was recorded 33.75 cm and planting was performed about 110-120 mm depth in furrow with overlapping of 34.44 mm and having 2 to 3 eyes in each sett. The planter can be operated by 35 to 50 HP tractor. The utility and efficacy of tractor mounted sugarcane cutter planter in comparison to conventional method was found better for sugarcane sowing. Extent of achieving timeliness of operation and contribution of planter or equipments enhancing the productivity is significant due to huge saving of man hour's requirement. The cost of planting was quite substantial and justified the use of planter. The improvement in quality of work, reduction in drudgery and improvement in safety was also enhanced as compared to conventional

Table 5 Analysis of operation cost for planting by sugarcane cutter planter and manually with conventional ridger

S/ No	Particulars	Tractor	Attachment Implements	
			Sugarcane cutter planter	Conventional ridger
1	Initial cost (Rs)	600,000	100,000	20,000
2	Salvage value (Rs.)	60,000	10,000	2,000
3	Service life (years)	10	6	6
4	Annual uses (h)	1,000	300	300
5	Interest rate (%)	16	16	16
6	Effective field capacity (ha/h)	-	0.18	0.4
7	Field capacity, (h/ha)	-	5.49	2.5
8	Fuel price (Rs./ lit)	65	65	65
9	Machinery labor rate (Rs./day) for 8 hour	500	350	250
10	Labour requirement (man-h/ha)	-	28	280
11	Fuel consumption (l/ha)	-	24.00	9.98
A. Fixed Cost (Rs./year)				
1	Annual Depreciation = (Initial cost − Salvage cost) /Machine life (yr)	54,000	15,000	3,000
2	Interest on average investment = (Initial cost + Salvage value) / 2 × Bank interest	52,800	8,800	1,760
3	Repair and maintenance (5% of IC)	30,000	5,000	1,000
4	Tax and insurance (2% of IC)	12,000	2,000	400
5	Total fixed cost (Rs./h) = Fixed cost (Rs./yr)/ annual uses (h)	148.8	103	21
B. Variable Cost (Rs./h)				
1	Labour cost (Rs./ha)	62.5	1,225	8,750
2	Fuel cost (Rs./ha)	-	1,560	649
3	Oil cost (@ 30% of fuel cost) (Rs./ha)	-	468	195
4	Total variable cost (Rs./ha)	-	3,253	9,593
5	Total variable cost (Rs./h)	-	593	3,837
6	Total operating cost/hour = (Fixed cost (Rs./h) + Variable cost (Rs./h))	211	695	3,858
7	Total cost for tractor and implement combined (Rs./h)	-	906	4,069
8	Fuel consumption (l/h)	-	4,975	10,172
9	Labor requirement (man-h/ha)	27	29	28
C. Total operating cost (Rs./ha) = Total operating cost (Rs./ha) × field capacity (h/ha		-	4,975	10,172
	Benefits (Rs./ha)			5,197

method of sugarcane sowing.

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Fig. 3 Sugarcane crop germination planted by sugarcane cutter planter

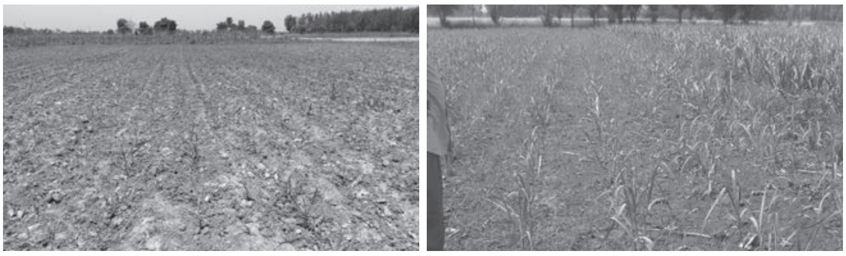

Fig. 4 Sugarcane crop as planted by sugarcane cutter planter

Effect of Mechanization on Economic Profitability and Productivity of Wheat Established Under Different Resource Conservation Machinery in Indo-Gangatic Plains

by

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Abstract

The field experiment was carried out at research farm of ICAR-IIFSR, Modipuram, Meerut during 2012-2019 for wheat establishment through different conservation techniques as machinery used viz., zero till drill (ZT), happy turbo seeder (HT), raised bed planter (BP), rotary tiller (RT) and conventional tilled practice (CS). The objective of this research was to analyze farm machinery performance, assess economic probability and productivity under different conservation tillage. The highest field capacity was observed in ZT (0.37 ha h^{-1}) and HT (0.36 ha h^{-1}) over other treatments RT (0.31 ha h^{-1}), BP (0.29 ha h^{-1}). The time taken for sowing and tillage operation was recorded as 2.70, 2.80, 3.25, 12.65 and 14.40 h ha^{-1} in ZT, HT, RT, BP and CS, respectively. The field efficiency was observed as 49, 55, 50 and 43% in ZT, HT, BP and RT, respectively. Significantly lower fuel requirement for seeding was observed as 8.0 and 9.0 l ha^{-1} in ZT and HT. However, fuel requirement was found highest in RT (16 l ha^{-1}) followed by BP (12 l ha^{-1}). The fuel consumption in conventional tillage system (CS) was about 47.10 l ha^{-1} which is more than 5 times to zero tillage systems. Significantly higher cost of cultivation was noticed in conventional tillage practice (CS, Rs. 47,199 ha^{-1}) than other treatments as RT (Rs. 37,702 ha^{-1}), HT (Rs 37,007 ha^{-1}) and ZT (Rs. 36,211 ha^{-1}) and at par with BP (Rs. 38,078 ha^{-1}). But the output cost was observed higher in HT (Rs. 121,570 ha^{-1}) and at with ZT (Rs. 120,970 ha^{-1}) than BP (Rs. 118,010 ha^{-1}), RT (Rs 118,230 ha^{-1}) and CS (Rs. 118,420 ha^{-1}). The benefit and cost ratio (B:C ratio) was also revealed higher in ZT (2.34) and HT (2.29) than RT (2.14), BP (2.10) and CS (1.51). The yield attributes were having no significant difference among the treatments. The grain yield was also observed significantly higher in HT (5.68 t ha^{-1}), ZT (5.63 t ha^{-1}) than CS (5.47 t ha^{-1}), RT (5.53 t ha^{-1}), BP (5.58 t ha^{-1}).

Keywords: Mechanization, Conservation agriculture, Economic, Productivity.

Introduction

Wheat (*Triticum aestivum* L.) is one of the important staples of nearly 2.5 billion of world population and the third largest leading cereal crop (after maize *Zea mays*, and rice *Oryza sativa*) grown in about 217 million hectares area with a production of 731 million tonnes grain (FAOSTAT, 2013; USDA, 2018). India occupies second place in the world in wheat production with 13.64% of world production from 14% area after China. Wheat is one of the main cereal crops of India with production of about 99.70 million tonnes from 30 million hectares with an average productivity of 3,371 kg ha^{-1} (MoA & FW, 2018). Conservation agriculture (CA) has been proposed as a management strategy to improve the sustainability and profitability of the farming system (Sayre and Hobbs, 2004). CA systems are based on three principles: (1) minimal soil movement, (2) the retention of rational amounts of residue mulch as a soil cover, (3) economically viable crop rotations, which together should lead to reductions in management costs and increased profitability (Hobbs et al. 2008 and Bhadu et al., 2018). The techniques to apply the principles of CA will vary with biophysical and system management conditions and farmer circumstances (Verhulst et al. 2010). Conservation agriculture (CA) can serve to mitigate greenhouse gas (GHG) emissions from agriculture by enhancing soil C sequestration, improving soil quality, N-use efficiency and water use efficiencies, and reducing fuel consumption. Understanding GHG mitigation benefits, however, requires adapting conservation agriculture principles within unique constraints (and opportunities) of working farms in varying climatic situations. The adoption of CA has significant environmental benefits (Kassam et al., 2012). The accumulation of soil organic carbon (SOC), i.e., due to the sequestration of carbon in the soil, is certainly one of the major benefits, making CA systems be considered as being effective in helping to mitigate the increase in atmospheric CO_2 concentration in annual, perennial and mixed cropping systems (Marquez-Garcia et al., 2013). At the same time, NT systems are acknowledged for being more profitable for farmers (Gonzalez-Sanchez et al., 2015). The crops managed under CA could capture between 0.1 and 1 tonne of carbon per hectare annually depending on the climate characteristics of the area; the lower figure applicable for dry areas and the higher for humid areas (Figueroa et al., 2007). These studies suggest that under different tillage and soil management practices, a range of interactions between the crop and soil quality clearly has an influence on CO_2 emissions, and that these relations are even more complex under the influence of climate change (González-Sánchez et al., 2012 and Aguilera et al., 2013). The technologies of CA provide opportunities to reduce the cost of production, save water and nutrients, increase yields, increase crop diversification, improve efficient use of resources, and benefit the environment (Bhadu et al., 2018). Research reports have identified several benefits of conservation tillage over conventional tillage (CT) with respect to soil physical, chemical and biological properties as well as crop yields. Processes of climate change mitigation and adaptation found zero tillage (ZT) to be the most environmental friendly among different tillage techniques (Mutiu Abolanle Busari et al., 2015).

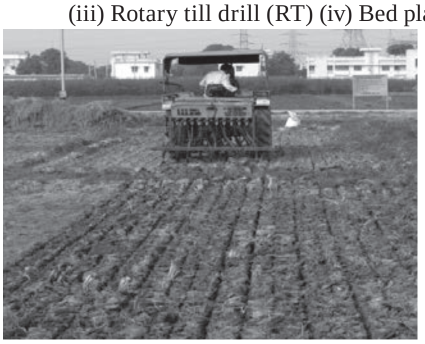
In this study, we hypothesized that wheat cultivation under different conservation tillage to reduce the cost of cultivation and higher productivity which impact on farmers profitability and livelihood. The objective of this study was to identify a suitable wheat cultivation method adopted under conservation tillage practice in the Indo-genetic Plain that had maximum productivity and low cost of cultivation and more profitable.

Method and Material

2.1. Study Site

The field experiment was conducted at the experimental farm of ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut (UP), India, (29°4' N latitude and 77°46' E longitude, 237 m above mean sea level), located at Indo-Gangetic Plain during 2012-2019. It is semi-arid subtropical with extreme summers and severe cold winters. The average monthly minimum and maximum temperatures in January (the coolest month) were 7.2 and 20.1 °C, respectively. The corresponding temperatures in May (the hottest month) were 24.2 and 39.8

Fig. 1 Sowing of wheat crop with (i) zero till drill (ZT) (ii) happy turbo seeder (HT) (iii) Rotary till drill (RT) (iv) Bed planting (iv) Conventional sowing (CS)



(i) zero till drill (ZT)

(ii) happy turbo seeder (HT)

(iii) Rotary till drill (RT)

(iv) Bed planting

(v) Conventional sowing (CS)

°C, respectively. The average annual rainfall of the region is 823 mm, of which around 75% of the rainfall is received through north-west monsoon during July-September.

2.2. Treatments and Crops Management

The five treatments were used for sowing of wheat crop by resource conservation machineries as zero till drill (ZT), happy turbo seeder, (HT), bed planting (BP), Rotary tiller (RT) and conventional sowing method (CS) with completely randomized block design (RBD) and three replications (**Fig. 1**). The experimental plots size was in 48 × 5 m. The details of different farm equipment used in land preparation and sowing operation in experiment are given in **Table 1**. In ZT and HT, sowing of wheat crop was performed in zero-tilled fields without residues and with residues (6 t ha^{-1}), respectively. In CS, land was prepared with two passes of harrow followed by two passes of tiller and one passes of rotavator, and sowing was done by using zero-till drill. In BP, methods, plots were tilled with two pass of harrow, followed by single pass of tiller and rotavator in dry field for first year after that reshaping followed by sowing of seed on bed was performed by bed planter. Whereas, in RT, rotary tiller was performed for shallow tilling in 2 t ha^{-1} of rice residue and sowing of the crops in single operation. The treatments were designed based on tillage intensities as follows: **Table A**.

The wheat (PBW-343) was sown as per recommended package and practices with seed rate 80 kg ha^{-1} in all treatment except in conventional sowing i.e. 100 kg ha^{-1} and line spacing was 22 cm except in bed planting where row spacing was 15 cm on bed. All the crops received a recommended fertilizer dose of 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied through above fertilizers. About 50% of the recommended nitrogen (N), entire phosphorous (P) and potassium (K) were applied as basal and the remaining 50% N was top-dressed in two split doses, at tillering and milking stages. The chemical weed control was applied using Sulfosulfuron @ 25 g active ingredient ha^{-1} + Metsulfuran methyl @ 4.00 g active ingredient ha^{-1} at 30 DAS followed by spot manual weeding at 35-45 DAS. Moreover, no tilled wheat sown plot had rarely problem after application of herbicides such as Glyphosate (*N*-(phosphonomethyl)-glycine) at the rate 1.5 kg active ingredient ha^{-1} as post emergence non-selective herbicide before seeding 25-30 days in addition to above post emergence herbicides.

The wheat crop was grown under assured irrigated conditions performed by electric operated submersible pump with varied 4 to 5 number of irrigations in different depth of irrigation as per treatments. Wheat was harvested in the third week of April in each year. The crops were grown under assured irrigated conditions. The grain and biomass yields were recorded at 12% moisture content in all treatments.

2.3. Fuel Consumption and Fuel Energy

The tillage operation was per-

Table A

Treatment	Machinery used	Details
ZT	Zero till drill	No tilled field sowing by zero till drill
HT	Happy turbo seeder	No-till with 6 t ha^{-1} rice residue as on surface mulching
BP	Bed planter	The fine seed bed was prepared with tillage operation of twice harrowing + once tiller + once rotavetor in I[st] year to make the bed and subsequent year reshaping of bed followed by sowing of 3 row of wheat on bed
RT	Rotary tiller	Reduced tillage with 2 t ha^{-1} rice residue incorporating by shallow tilling of rotary tiller followed by sowing in single operation
CS	Conventional tillage sowing	Conventional sowing practice adopted by farmers (2×Harrow + 2×Tiller + 1×Rotavetor followed by sowing by zero till drill)

Table 1 Technical specifications of implements used in different conservation practices adopted in wheat cultivation

S. No.	Implements	Specifications	Working width (cm)	Working depth (cm)	Weight (kg)	Economic life (h)
1	Zero till drill	Inverted – T type 9 tyne under no-till sowing	1,980	3-4	300	3,000
2	Happy turbo seeder	Inverted – T type tyne under no-till sowing with 6 t ha^{-1} rice residue mulching	2,000	2-3	400	2,400
3	Bed planter	Reshaping of bed followed by sowing of 3 lines on bed of 37 cm on top	1,500	3-4	300	2,500
4	Rotary tiller	Tilling of PTO operated rotary blade followed by sowing in tilled plot in single operation	1,980	8-10	400	3,000
5	Cultivator	9 shovel type tyne spring loaded cultivator	2,000	10-12	220	3,000
6	Harrow (14 disc)	Disc harrow with 14 discs	1,850	12-15	250	3,000
7	Rotavator	PTO operated rotovator with 42 L-shaped blades	1,500	8-10	500	4,000
8	Tractor	45 HP	-	-	1,650	10,000

formed in conventional sowing (CS) treatment. The diesel quantity was measured in each operation of different farm machineries by using of 45 HP 2-wheel drive tractor for land preparation and sowing as in ZT, HT, BP, RT and CS. The fuel tank of tractor was filled up to brim with diesel to measure fuel quantity before start of any operation as tilling or seeding. After finishing of each operation as per treatment, the diesel quantity used was recorded by refilling the fuel tank which was measured by 1000 ml graduated cylinder. Time spent for each operation as per treatment was documented. Fuel consumption per hectare-hour and time spent was calculated using following formula by Akbarnia et al., (2014). Values were then converted into liter ha^{-1} and hour ha^{-1} respectively. Fuel consumption of different tillage and sowing implements was measured in three replications.

Fuel consumption (FC) = Fu / A [1]

Where,

Fc is fuel consumption (l ha^{-1}),

Fu is fuel used per unit area [l],

A is Area of plot (ha).

2.4 Field Evaluation

Theoretical field capacity, effective field capacity, operation speed, field efficiency was calculated as given equations by RNAM (1995) in below.

Operation Speed

S = 3.6 L/t

Where,

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

L = travel distance (m)

T = time second (sec.)

TFC = (W × S) / 10

Theoretical Field Capacity

TFC = (W × S) / 10

Where,

TFC = theoretical field capacity (ha h^{-1})

W = width of coverage (m)

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

Effective Field Capacity

EFC = Actual area covered in unit time (ha h^{-1})

Field Efficiency

FE = (EFC / TFC) × 100

Where,

FE = field efficiency (%)

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

TFC = theoretical field capacity (ha h^{-1})

2.5 Economic Analysis

All fixed and variable costs were considered in the economic analysis (IS: 1964-1979). The variable costs (including land rent) comprised of labor cost; costs of other inputs such as tillage, planting, seed, fertilizer, pesticide, irrigation, harvesting, threshing, etc.; and costs involved in transporting grains to the market. Fixed costs consisted of the depreciation of farm machinery and taxes and interest on working capital as land revenue, farm buildings etc. The cost of human labor used for tillage, seeding, irrigation, fertilizer and pesticide application, weeding, and harvesting of crops was based on man-days ha^{-1}. The time (h) required to complete each field operation in as treatment wise was also recorded and expressed as man-days ha^{-1}, which considering 8 h to be equivalent to 1 man-day (standard working hours as per the labor law of the Indian government). The cost of labor was calculated using the minimum wage rate as per the labor law (Minimum Wage Act, 1948). Similarly, the time (h) required by a tractor-drawn machine/implement to complete a field operation such as tillage, seeding, and harvesting was recorded and expressed as h ha^{-1}. For irrigation costs, the depreciation cost of pump, electric motor and charges fixed by the electricity board of the UP Government (INR 5.30 per kW h of electricity) were used plus the cost of labor used for irrigation application. The total cost of cultivation (TC) for wheat crop established through different conservation machinery as ZT, HT, BP, RT and CS were calculated by adding all cost fixed and variable cost involved in cultivation.

Gross returns (GR) were calculated by multiplying the grain yield of each crop by the minimum support price offered by the Government of India (Economic Survey of India, various years), while straw value was calculated using current local market rates. Net returns (NR) were calculated as the difference between GR and total cost (TC) (NR = GR − TC). The benefit: cost ratio (B:C ratio) was calculated by dividing gross income by TC (B:C ratio= GR / TC).

2.6 Farmers Perception

The data of farmers perception about conservation agriculture viz., zero tilled drill and happy turbo seeder were also recorded about adopted 60 farmers randomly in Western Uttar Pradesh to make the impact study in the region. Quantitative data was collected by using pre-tested structured questionnaire with the farmers.

2.7 Statistical Analysis

The experiment was laid in randomised block design (RBD) with three replications. The data on energy input and output, carbon foot print were subjected to analysis of variance as per the procedure Little et al., 1991 and treatment means were compared using least significant difference (LSD) at 5%.

Result and Discussion

3.1. Field Capacity, Field Efficiency and Operating Speed

Tractor drawn conservation machineries were assessed for seeding of wheat crop in different tillage condition and machine parameters were presented in **Table 2**. The highest field capacity was observed in ZT (0.37 ha h^{-1}) and HT (0.36 ha h^{-1}) over other treatments. This was due to sowing of wheat without any tillage condition which requires less time. However, field capacity was recorded 0.31 ha h^{-1} in RT which was due to shallow tilling by PTO operated rotary blade attached in front of seeding unit. The field capacity of combine operation (i.e. tillage and sowing) (0.088 ha h^{-1}) of conventional wheat sowing practices (CS) was very low, it was due to use of different tillage farm equipment such as harrow (0.45 ha h^{-1}) for two pass and tilling by cultivator (0.44 ha h^{-1}) of one pass followed by rotavetor (0.40 ha h^{-1}) one pass that requires more time to accomplish all operation. The time taken for sowing and tillage operation was recorded as 2.70, 2.80, 3.25, 12.65 and 14.40 h ha^{-1} in ZT, HT, RT, BP and CS, respectively (**Table 2**). Lower time for seeding indicated the machine used like ZT is due to no-tilled field condition but little more time taken in HT due to cutting and shredding of rice residue by PTO operated rotary blade in front of seeding unit (i.e. mulching of crop residue) and subsequently seeding was done in no tilled field (Egidijus Sarauskis et al., 2012). In case bed planting (BP), higher time for sowing was recorded than ZT, HT and RT, it was due to reshaping of bed and followed by seeding on bed which engaged more time over other treatments. Time spent was 9.15 h ha^{-1} for tillage operation of new bed formation which needs good tilth of soil that performed by different tillage operations (2 harrowing + 1 cultivator + 1 rotavetor) whereas, under conventional tillage sowing practice (CS), time spent about 11.40 h ha^{-1} to accomplish for tillage as 2 harrowing + 2 cultivator + 1 rotavetor. The field efficiency was observed as 49, 55, 50 and 43% in ZT, HT, BP and RT, respectively (Singh et al., 2005 and Chaudhary et al., 2010). The operating speed of seed drill was also recorded as 3.80, 3.70, 3.60, 3.20 m sec^{-1} under ZT, BP, RT and HT, respectively.

3.2. Fuel Consumption

The fuel consumption (l ha^{-1}) was recorded in tractor for operation of different conservation machineries as per treatments of experiments for seeding and seed bed preparation and presented in **Table 2**. Fuel consumption for land preparation was recorded as 35.80 l ha^{-1} in CS and 31.20 l ha^{-1} in BP in case new bed formation. Significantly lower fuel requirement for seeding was observed as 8.0 and 9.0 l ha^{-1} in ZT and HT result is agreed by Akbarnia et al., (2014) and Mileusnic et al., (2010). However, fuel requirement was found highest in RT (16.0 l ha^{-1}) followed by BP (12.0 l ha^{-1}). This was due to tilling and sowing in one operation needs more time and power to pull the implement (i.e. rotary tiller) by tractor that was only reason for higher fuel consumption in RT (Singh et al., 2005 and Chaudhary et al., 2010). The reshaping of bed also needs more time and power for operation of bed planting; this was the reason for second higher fuel burning operation. Further, the less width of coverage of bed shaper (i.e. 1,500 mm) than other implements expends more time to reshaping followed by sowing of one hectare needs more fuel requirement for wheat sowing. The total fuel consumption in CS was recorded as 47.10 l ha^{-1} which was due to more time and energy requirement in tillage operation by different farm equipment. The researcher reported (Egidijus Sarauskis et al., 2012) that the fuel consumption is more than 5 times higher in conventional tillage and sowing systems as compared to zero tillage systems, and in reduced tillage and sowing systems, the fuel consumption exceeds that in zero tillage systems by 2.5 to 4.8 times.

3.3 Cost Analysis

The cost of cultivation of different tillage practices adopted in wheat crop was estimated significantly higher in CS than treatments as RT, HT and ZT but at par with BP (**Tables 3** & **4**). Significantly higher cost of cultivation was observed in conventional tillage practice (CS, Rs. 47,199 ha^{-1}) than other treatments as RT (Rs. 37,702 ha^{-1}), HT (Rs. 37,007 ha^{-1}) and ZT (Rs. 36,211 ha^{-1}) and at par with BP (Rs. 38,078 ha^{-1}). The benefits in zero tillage method were mainly due to lower expenses on human labour, machine labour and irrigation which gave enough incentives to the farmers to adopt zero tillage. But the output cost was observed higher in HT (Rs. 121,570 ha^{-1}) and at par with ZT (Rs 120,970 ha^{-1}) than BP (Rs. 118,010 ha^{-1}), RT (Rs. 118,230 ha^{-1}) and CS (Rs. 118,420 ha^{-1}) which had no significant difference. The benefit and cost ratio (B:C ratio) was also revealed higher in ZT (2.34) and HT (2.29) than RT (2.14), BP (2.10) and CS (1.51). The net return of different wheat cultivation in conservation tillage was significantly higher in ZT than CS which had at par with HT, RT and BP (Aryal et al., 2015). It was due to the cost involved in tillage operation which was Rs. 11,607 ha^{-1} in CS and Rs. 9,496 ha^{-1} in BP. The excessive tillage was

Table 2 Fuel consumption and time taken under machineries used in different conservation practices in wheat cultivation

Treatments	Fuel consumption (l ha^{-1})			Time taken (h ha^{-1})			Effective field capacity (ha h^{-1})	Field efficiency (%)	Operating speed (km sec^{-1})
	Tillage	Sowing	Total	Tillage	Sowing	Total			
ZT	-	8.00	8.00	-	2.70	2.70	0.37	49.00	3.80
HT	-	9.00	9.00	-	2.80	2.80	0.36	55.00	3.20
BP	-	12.00	43.00	9.21	3.50	12.75	0.29	50.05	3.70
RT	-	16.00	16.00	-	3.25	3.25	0.31	43.17	3.60
CS	38.40	8.50	47.10	11.40	3.00	14.40	0.070**	-	3.20-4.00

**Total time all field operation including sowing performed in the both treatments (CS and BP), i.e. twice harrowing and twice cultivator and once/twice rotavetor operation which was adopted in farmers practices actually, it was not required for crop wheat crop establishment. The ZT and HT sowing method were performed in no tilled field without any land preparation before seeding crop. Due to no tilled field, besides saving of cost in land preparation, there was saving in irrigation cost reason behind it required less quantity and number of irrigation as compared to tilled field as CS and RT. However, the irrigation cost was observed lowest in BP due to by virtue the furrow irrigation needed less time and depth of irrigation than surface flooding. It was also observed in no tilled treatments (i.e. ZT and HT) required less time used in irrigation for flooding water as compared to tilled field wheat crop establishment. The second lowest irrigation cost was observed in HT treatment, where 6 t ha^{-1} rice residues was used as surface mulching which again the conserve the moisture that reduces the irrigation requirement of crop. This reduction was mainly due to reduction in the cost of preparatory tillage and irrigation (Sapkota et al., 2015).

3.4 Yield Attributes and Productivity

The yield attributes and yield parameters were presented in **Table 5** and **Fig. 2**. The yield attributes of wheat (i.e. plant height, number of tillers and test weight) were not significantly (P = 0.05) affected by different conservation tillage, however, the ear length, number of grains ear^{-1} were observed significantly (P = 0.05) higher in ZT and HT than CS (**Fig. 3**). However, higher value was observed in zero tillage (ZT) and happy turbo seeder (HT) due to better establishment of wheat crop under residue mulching field as compared to conventional tillage ultimately greater grain yield was also noticed in ZT and HT. The highest grain yield of wheat crop

Table 4 Cost analysis of wheat crop under different conservation practices

Particulars	Cost of cultivation, (Rs. ha^{-1})	Output cost, (Rs. ha^{-1})	Net income, (Rs. ha^{-1})	B:C ratio
ZT	36,211	120,970	84,759	2.34a
HT	37,007	121,570	84,563	2.29a
BP	38,078	118,010	79,932	2.10a
RT	37,702	118,230	80,528	2.14a
CS	47,199	118,420	71,221	1.51b
CD	11,185*	NS	13,562*	1.215*

NS, Not significant, *Significant at P < 0.05

Table 3 Cost of cultivation of wheat crop under different conservation practices

Particulars	ZT	HT	BP	RT	CS
A. Variable cost					
Land preparation cost (farm machineries depreciation, operation cost etc.)	0	0	1,899*	0	11,607
Seeding cost with tractor (machineries depreciation, other operation cost etc.)	2,502	3,252	4,543	5,292	2,845
Seed cost	2,000	2,000	2,000	2,000	2,000
Fertilizer cost	2,880	2,880	2,880	2,880	2,880
Herbicides and plant protection cost	3,631	3,631	2,350	2,350	2,350
Irrigation charges (pump depreciation, operation charges etc.)	900	840	720	1,440	1,620
Harvesting and threshing (machineries depreciation, labour & other charges etc.)	6,000	6,000	6,000	6,000	6,000
Transportation charges	1,650	1,740	1,500	1,560	1,530
Labour charges (machineries operation, fertilizer & pesticides application, irrigation application, intercultural operation, harvesting, transportation etc.)	12,300	12,300	11,800	11,800	11,800
Miscellaneous charges (2%)	637	653	674	666	853
Total variable cost	32,500	33,295	34,366	33,989	43,484
B. Fixed cost					
Land revenue	13	13	13	13	13
Rental value of own land	3,000	3,000	3,000	3,000	3,000
Depreciation value	180	181	182	183	184
Management cost (10% of working capital)	337	337	338	338	338
Interest on fixed capital (6%)	180	180	180	180	180
Total fixed cost	3,710	3,711	3,713	3,714	3,715
Total input cost (A + B), Rs. ha^{-1}	36,211	37,007	38,078	37,702	47,199

*Cost of land preparation in Ist year was divided by 5 because tillage was performed once in five year.

was observed in HT (5.68 t ha^{-1}) and followed by ZT (5.63 t ha^{-1}), BP (5.58 t ha^{-1}), RT (5.53 t ha^{-1}) and CS (5.47 t ha^{-1}) but difference among the treatments were non-significant. The total biomass and straw yield were also observed similar pattern as grain yield. The higher yield was due to good establishment of crop under no tilled sown wheat with previous crop residues used as mulching which preserved the soil moisture hence better germinations of crops as compared to conventional sown wheat. Mulching is also benefited to maintain the soil temperature during cold waves in month of December and January which also helps for vigorous growth of wheat crop. It was also reported by researchers that after decomposing of crop residues in soil increases the population of micro-organism in soil that enhances the oil organic carbon and microbial carbon in soil. This may be reason for higher yield in no tilled sown with 6 t ha^{-1} residues (HT) and without residues ZT as compared to conventional sown wheat crop.

3.5 Farmer’s Perception About Zero Tillage

We also recorded the data of farmers perception about adoption the zero till drilled. Farmers who had already adopted zero tillage in wheat, they were very much interested to continue this method of cultivation in future. According to farmer’s opinion regarding zero tillage technology, germination is good and yield is higher than conventional tillage in wheat. Sowing of crop could be done 10-15 days earlier than conventional tillage. It saves time and diesel cost during field preparation. The zero tilled and happy turbo seeder was demonstrated at many farmers field through farmer participatory mode about 150 experiments at farmers field which were covering 560 ha area in Western Uttar Pradesh.

Table 5 Yield attributes under various conversation tillage in wheat cultivation (pooled data)

Treatment	Plant height, cm	No. of tillers, m^2	Ear length, cm	No. of grain, ear^{-1}	Bio-mass, t ha^{-1}	Grain yield, t ha^{-1}	Straw yield, t ha^{-1}
ZT	101.6	355	10.5	72.5	12.8	5.63	7.20
HT	101.4	354	10.4	72.6	12.8	5.68	7.15
BP	100.1	350	10.3	70.2	12.7	5.58	7.10
RT	100.4	351	10.0	72.0	12.5	5.53	7.11
CS	100.5	360	9.8	69.8	12.7	5.47	7.20
CD	NS	NS	0.6*	2.6*	NS	NS	NS

NS, Not significant, *Significant at $P < 0.05$

Conclusion

The conventional tilled (CS) sown wheat crops spent higher about 75 to 81% time, 65 to 83% diesel fuel than ZT, HT, BP, RT. The ZT and HT required lower cost of cultivation and produced higher output cost as

Fig. 2 Yield of different conservation technology adopted in wheat cultivation (pooled data)

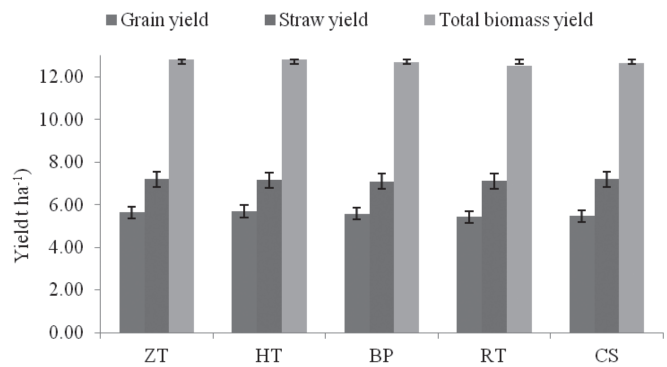
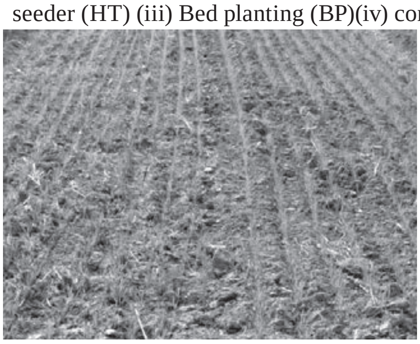
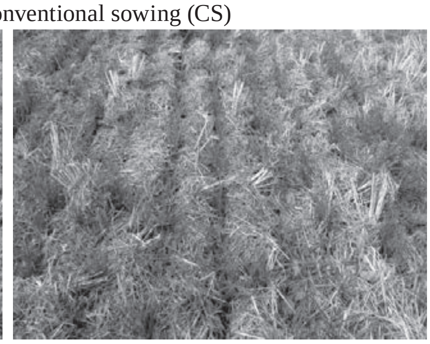
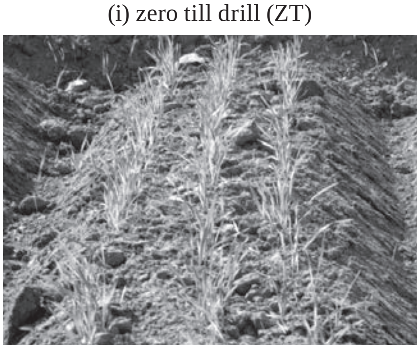
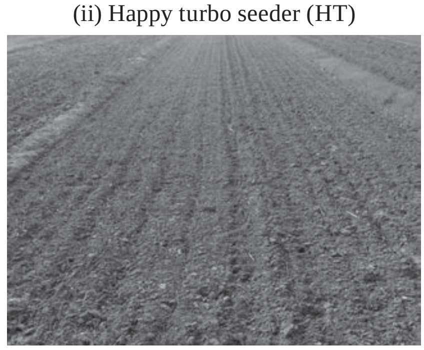


Fig. 3 (i) Germination of wheat crop sown with (i) Zero till drill (ZT) (ii) happy turbo seeder (HT) (iii) Bed planting (BP)(iv) conventional sowing (CS)


(i) zero till drill (ZT)


(ii) Happy turbo seeder (HT)


(iii) Bed planting


(iv) Conventional sowing

compared to CS. The benefit and cost ratio (B:C ratio) was significantly higher in ZT and HT followed by RT, BP and CS. The significantly higher grain yield was observed HT (5.68 t ha^{-1}) and ZT (5.63 t ha^{-1}) than CS (5.47 t ha^{-1}), RT (5.53 t ha^{-1}), BP (5.58 t ha^{-1}). Result clearly indicated that ZT and HT have less cost of cultivation, positive impact on yields and higher net returns than conventional practices (CS) adopted by farmers.

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■■

CONGRATULATORY MESSAGE

for Shin-Norinsha 90th Anniversary

Opeyemi Oyelade
Assistant Director (Engineering), Farm Power and Machinery Dept. National Centre for Agricultural Mechanization, Nigeria.
AMA Co-operating Editor, Nigeria

Congratulations sir for the journey so far. May your company continue to grow from rm.

* * *

Yanoy Morejon Mesa
Professor, Agrarian University of Havana.
AMA Co-operating Editor, Cuba

First of all, receive a cordial greeting and in the same way convey my greetings to Dr. Kishida and the rest of the editorial team of AMA magazine.

* * *

Gajendra Singh
Founding President, Asian Association for Agricultural Engineering.
AMA Co-operating Editor, India

My association with Mr Yoshisuke Kishida started in January 1971 when we met at the International Rice Research Institute, Los Banos, Philippines during a seminar on Farm Mechanization. The first issue of AMA was published in April 1971 with the title of “Agricultural Mechanization in Southeast Asia” changed to “Agricultural Mechanization in Asia” from 2nd issue. I published my first paper in AMA in 1974 on “Farm Mechanization and Crop Yield” and a second paper in 1976. In 1975, I joined the Asian Institute of Technology (AIT), Thailand where students came from all over Asia including a few from Europe, Africa and North America. Many of my graduate students conducted research related to mechanization in their home countries and we published many papers in AMA which in 1981 changed its title to “Agricultural Mechanization in Asia, Africa and Latin America”. For more than five decades AMA has been the most relevant journal in the field of agricultural mechanization in developing countries and an extremely rich source of literature in the field. Over the years I have published (as author/co-author) more than 30 papers in AMA. My paper with Bing Zhao published in Special Issue of AMA in 2016 with title “Agricultural Mechanization Situation in Asia and the Pacific Region” showed that during 1990 to 2013 the farm power available (kW/ha) from tractors, power tillers, irrigation pumps and harvesters in many Asian countries (China, India, Thailand Vietnam) increased about three times resulting in doubling the yields of the cereal crops. Agricultural mechanization has made significant contributions towards increasing labor and land productivities, increasing use efficiencies of inputs, improving timeliness, and reducing drudgery of farm operations.

In 1991 the Asian Association for Agricultural Engineering (AAAE) was established with Secretariat at AIT, Thailand. I became the Founding President with Mr Yoshisuke Kishida as Vice President. In 1989 I joined Club of Bologna as full member and since 2001 I am serving as members of the Management Committee along with Mr Kishida. We are both members of the CIGR Executive Board. We have been meeting very often at the ASABE, Club of Bologna and other agricultural engineering international meetings. I retired from AIT in 2004 and returned to India and got involved in the activities of the Indian Society of Agricultural Engineers (ISAE). Mr Kishida is a very strong supporter of ISAE and has attended several annual conventions of ISAE in addition to his other business trips to India.

In conclusion I would like to say that AMA has made tremendous contribution in dissemination of mechanization technologies throughout the world, especially among developing countries. I wish that AMA will continue to do so for many decades in future.

* * *

In-Bok Lee
Prof., Laboratory of Aero-Environmental & Energy Engineering (A3EL), Dept. of Rural Systems Eng., College of Agril. & Life Sciences, Seoul National Univ.
AMA Co-operating Editor, Korea

I am so happy to hear that you have been keeping your health very well.

I am also happy to hear Ninetieth Anniversary of the Shin-Norinsha.

* * *

Pavel Kic
Prof. Ing. Czech University of Life Sciences Prague, Czech Republic.
AMA Co-operating Editor, Czech

Greetings and Congratulations from

Prague.

My sincere congratulations to Shin-Norinsha Co., Ltd. Tokyo, for 90 years of activity in the popularization and development of the field of agricultural mechanization and agricultural technology throughout the world. I wish you many interesting articles and new technical ideas presented in your publications for the years and decades to come.

In particular, I wish good health, vitality, and many successes at work as well as satisfaction in his personal life to Mr. Yoshisuke Kishida, President of Shin-Norinsha Co., Ltd. in the coming years.

Yours sincerely

* * *

Reynaldo M. Lantin
Retired Professor, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Banos.
AMA Co-operating Editor, Philippinies

Congratulations and Happy 90th Anniversary to The Shin-Norinsha Co., Ltd.!

* * *

Alexandar Sun
Head of International Department, China Agricultural Machinery Distribution Association (CAMDA)

All our best wishes for your magazine, we are really grateful to have a partner like you, your magazine contribute a lot for building a bridge between Chinese agricultural market and Japanese agricultural market.

Your magazine supported many times for our delegations to Japan and bring Japanese delegation to China.

* * *

Suming Chen
Professor Emeritus, Dept. of Biomechatronics Engineering, National Taiwan University, Taipei, Taiwan.
AMA Co-operating Editor, Taiwan

We extend our most sincere congratulations from Taiwan to President Yoshisuke Kishida and all members of Shin-Norinsha on the occasion of the 90th anniversary of Shin-Norinsha. Shin-Norinsha (former name is “Chugai Norin Shinbun-sha”) has been established by former-president Yoshikuni Kishida in 1933. Shin-Norinsha has been publishing“Agricultural Machinery News” weekly and “Farming Mechanization” monthly and many other useful and specialized books for many years. The news and information related to agricultural machinery has been spread not only in Japan, but also to many other countries in the world. In Taiwan, we benefit a lot from these publications for valuable and useful information. As the parent company of Agricultural Machinery Industry Research Institute, AMA journal has thus also been published since 1971. It is an international English journal publishing the papers about the approaches to develop the agriculture in developing countries. Journal AMA has provided an important platform for the information exchanges and collaborations on the research and technology developments, not only in agricultural mechanization, but also in the engineering fields of agricultural, food, environment and energy in Asian, African and Latin American countries. Agricultural mechanization is very important to increase land productivity and to develop sustainable agriculture in order to meet the challenges of population increases and arable land scarcity. I believe that all the people in the field of agricultural machinery appreciate the great effort which Shin-Norinsha has done in the past. To sum up, founding 90 years is an important asset of Shin-Norinsha, and we would also like to extend our best wishes to Shin-Norinsha for the continuous success in the next 10 years and more to 200 years.

* * *

Megh R. Goyal
Retd. Prof. in Agric. and Biological Eng. University of Puerto Rico - Mayaguez Campus.
AMA Co-operating Editor, Puerto Rico

On anniversary celebration, I extend my heartiest best wishes for serving the agricultural mechanization community in the past, present, and future. My first article on cotton mechanization was published in 1977 in the AMA and then I had an opportunity to prepare special issue on abstracts of AMA that has become indispensable throughout the world. As a cooperating editor of AMA, I have related to my colleagues in the world. Under the leadership of Yoshisuke Kishida, President of Farm Machinery Industrial Research Corp and Shin-Norinsha Co., AMA has grown drop by drop in length, breadth, height, and depth.

* * *

Hideo Hasegawa
Professor, Graduate School of Science and Technology, Niigata University.
AMA Co-operating Editor, Japan

Following the AMA's 50th anniversary in 2020, I am honored to deliver a message for the 90th anniversary of Shin-Norinsha, which has supported the AMA's ongoing publication. As a university faculty member specializing in agricultural mechanics, I am an instructor for a training program on agricultural mechanization in developing countries established by Japan International Cooperation Agengy (JICA). The trainees in the training program are all highly motivated and I have been hoping that they will publish their challenges and perspectives on agricultural mechanization in academic journals from a perspective very close to the farmers. I believe that AMA, which is subscribed to by researchers from many countries at different stages of development in agricultural mechanization, is the best place for them to exchange information and discuss agricultural mechanization in their countries. In this sense, I would like to thank Mr. Yoshikuni Kishida, who leads Shin-Norinsha, and Mr. Yoshisuke Kishida, his successor and the founder of AMA, for their efforts.

* * *

Kiyoshi Soda
President, Soda Farm Machinery Design Office

President Kishida, the Best Locomotive of Agricultural Machinery.

Mr. Kishida, you have the best information not only in Japan but also in the world, and you have the best human relations, which is a great asset. Please use your greatest asset to save Japan. You are the only one who can save Japan.

It is a very worthy project that only you can do and pass on to future generations.

It has been about 55 years since the sales of agricultural machinery, combine harvesters, rice transplanters, and small tractors, which are commonplace today, were made without a fund, but today's sales are the result of the basic efforts of venture companies.

We should not forget this. At that time, rice farming was extremely difficult, with wet and muddy paddies, rice falling over, and the fall harvest taking about two months, as well as hard labor. The details of today's situation are different from those of those days, but the seriousness of the situation is the same.

As you know, Japan's rice production is in crisis today. The average age of rice farmers is over 73, and in 15 years it will be over 88.

If they cannot grow rice, they will be undermined by imports, which will increase the price of rice many times over, and the poor will not be able to eat rice.

The big tractors and other big machines have already been automated, but how much rice is produced by these big tractors? It is a sad fact.

The government is also advocating robotization, and although it is said that the government and academia are promoting technology, most of the creative research has been done by private companies in the past. In this way, small private companies can come to a conclusion and make a quick start.

We already had a concrete idea for a tractor that does not drive (this information is top secret), and then we came up with a more concrete idea, created a basic structure, and are now considering patenting it.

If a foundation is laid for the development of agricultural machinery, it will be a great contribution to future generations and will be admired by the public. September 28, 2023.

Attendance at the 90th Anniversary Celebration.

* * *

Ki-myung Lee
Professor Emeritus, Department of Bioindustrial and Mechanical Engineering, Kyungbuk National University

On the occasion of the 90th anniversary.

I would like to congratulate Shin-norinsha on its 90th anniversary. My connection with Shin-norinsha began in 1968, when I graduated from university and joined the Agricultural Mechanization Research Institute in Korea, and I started subscribing to Shin-norinsha's "Mechanized Agriculture," a world-class information paper on agricultural machinery, and picked up research ideas. I really became interested and involved in this field after studying in Japan with Dr. Osamu Kitani at the University of Tokyo in April 1979.

During my three years of study, I visited Shin-Norinsha for academic conferences and guided some visits by Korean scholars, I naturally established contacts with President Kishida and the late Chairman.

In particular, I have continued to keep contacts with him, because I am respecting President Kishida's international perspective on agricultural machinery and his keen eye for the future.

In 1982, I returned to Korea with my degree and played the role of translator and interpreter of President Kishida's lecture materials, whom I invited as a special speaker a dozen times at symposia on the policies and directions of agricultural mechanization in Korea. In this way, I believe that President Kishida had a tremendous influence on agricultural mechanization in Korea.

Now, 41 years after my return to Korea, agricultural mechanization in Korea has changed, with emphasis on smart farming, precision agriculture, and robotics, and agricultural machinery has become the center of agriculture. I believe that this advanced agriculture is due to Shin-norinsha's provision of technology and information on agricultural machinery and President Kishida's interest in and care for agricultural machinery in Korea.

As Shin-norinsha celebrates its 90th anniversary, I wish the company growth and development.

* * *

Indra Mani
Ph.D. Agricultural Engineering, Vice-Chancellor, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, India
AMA Cooperating-editor, India

Dear Mr. Yoshisuke Kishida Greetings frorn VNMKV (lndia) |

Congratulations on the Remarkable 90th Anniversary Shin-Norinsha Co. Ltd., on reaching this incredible milestone. Ninety years of dedication, innovation, and excellence in the field of agricultural machinery industry research is an awe-inspiring achievement! Your unwavering commitment to advancing agriculture and improving the lives of countless farmers around the world is truly commendable. From the very inception of the organization, you have sown the seeds of progress, cultivating groundbreaking technologies and solutions that have transformed the agricultural landscape. Your relentless pursuit of excellence has not only revolutionized the agriculture mechanization in Asia, Africa and Latin America but also contributed significantly to food security and sustainability in the region. As you celebrate this remarkable milestone, may you take pride in your rich history of innovation and the countless lives you've touched along the way. Your legacy serves as an inspiration to all, reminding us that with vision, determination, and a deep passion for what we do, we can overcome any challenge and pave the way for a brighter future. Here's to 90 years of growth, resilience, and success! May your journey continue to flourish, and may the next decades be even more fruitful and filled with groundbreaking discoveries. I am glad to know that AMA would like to publish, a special issue of Agricultural Machinery News and special issue of a Magazine 'Mechanized Agriculture', on the occasion of 90th anniversary of Shin-Norinsha Co. Ltd. Mr. Yoshisuke Kishida publisher and chief editor of AMA deserves a big accolade on this occasion. Mr. Yoshisuke Kishida is a great visionary and highly experienced person who has deep understanding of changing scenario in world agriculture, in general, and mechanization in particular. A great job was started by his revered father with publication of AMA way back in 1971 which he continued with much greater zeal, passion and dedication. AMA has surpassed all heights of publication in terms of content, quality, and continuity. AMA has witnessed number of landmarks in scientific publications. AMAs efforts have helped developing best human resource and in dissemination of inforrnation on mechanization scenario in Asia, Africa and Latin Arnerica. I personally have a great bonding with Mr. Yoshisuke Kishida. I pray almighty to bless him very good health and he continues to serve the cause of agriculture mechanization around the globe. Today civilization faces four most irnportant challenges i.e., global food, energy and water insecurities, in addition to frightening effect of climate change. AMA has been doing great effort to making people aware and helping professionals to equip themselves to face such challenges. I congratulate all tl-rose who are involved in bringing out this AMA special issue. [, on the behalf of fraternity of Agriculturat Engineering from India, as immediate past President of lndian Society of Agricultural Engineerings and the Vice-Chancellor of Vasantrao Naik Marathwada Agricultural University compliment Mr.Yoshisuke Kishida for this great job. Entire team of AMA deserves a big applause. Long liveAMA ! Witlr wann regards.

* * *

C. R. Mehta
Director, ICAR - Central Institute of Agricultural Engineering, Nabi-bagh, Berasia Road, Bhopal - 462 038, India.
AMA Co-operating Editor, India

Congratulation to Shin-Norinsha Co. Ltd., Japan for completing 90 years of its establishment and serving the agricultural machinery industry. The efforts made by Dr. Yoshikuni Kishida, the founder of the company for regularly publishing AMA since 1971 are appreciable. The regular publication of the journal has helped researcher and extension workers engaged in Agricultural Mechanization in the Asia, Africa and Latin America to exchange research and extension work done in the area in the region. The sharing of information related to Agricultural Mechanization has helped in promotion of farm mechanization in the region.

I wish all the best to the company to grow at rapid pace and reach new heights, and continue to make efforts for promotion of agricultural mechanization in the region.

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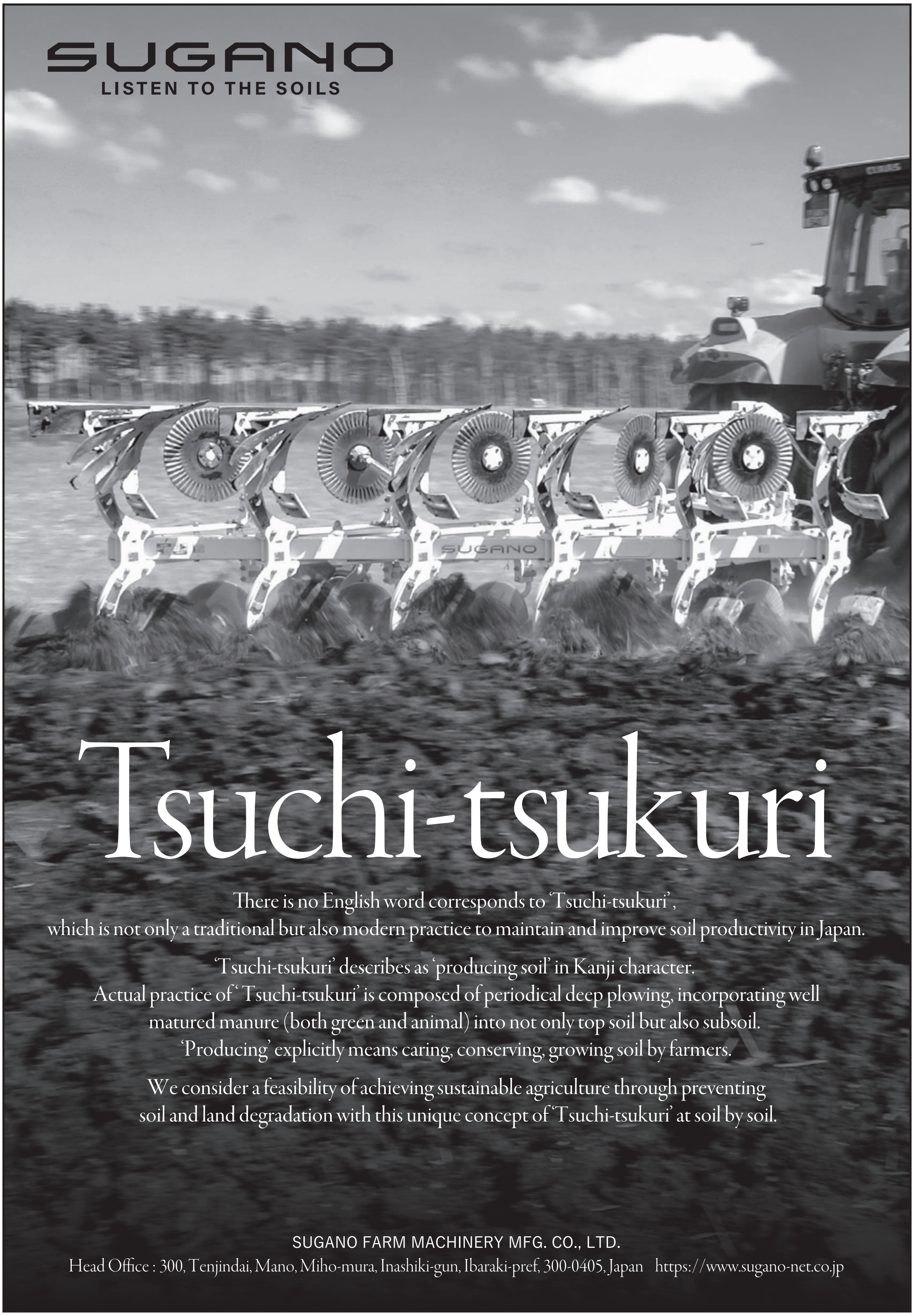
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