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AMA

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VOL.53, NO.1, WINTER 2022

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EDITORIAL

The term “SDGs” is now being spoken louder vociferously all over the world. Most agencies/companies are beginning to set mission on how to achieve the “SDGs.” I feel that the term “SDGs” is becoming the biggest source of corporate promotion. There is a big debate about controlling CO_2 emissions to prevent global warming. However, rising temperatures and increased CO_2 in the air are not always totally bad for agriculture. For example, in Japanese greenhouse horticulture, a CO_2 generator is used to enrich the greenhouse with CO_2 to increase the yield. In some areas where the temperature is usually low, the temperature rises and agricultural production improves. On the contrary, the yield decreases due to the rise in temperature in some desert areas. Then, all counter-measures against CO_2 must be prepared and taken from various points of view.

Under such circumstances, the coronavirus turmoil that started in 2019 is still sustained by mutant strains. However, the probability of harming humans by mutating is fortunately decreasing. Most meetings/gatherings are convened remotely for both domestic and international conferences. A large international agricultural machinery exhibition has also been canceled for the last two years. I’m expecting that soon we can visit the exhibitions in normal style at the venue with the actual machines displayed and demonstrated again.

As human beings, we are members of the holistic life system on the earth, and are kept alive in the form of life. There are many viruses such as this coronavirus in our life system. According to virologists, one human body has 380 trillion viruses inhabited. There are more than 100 trillion intestinal bacteria, which do various useful jobs for humans. In other words, humans live as symbiont with such microorganisms. Human beings as symbiont are connected to life systems all over the world.

Agriculture aims for better harmony with the world’s life systems. The work for better harmony means agriculture in a broad sense. Today, the world’s population continues to grow, surpassing 8 billion and growing to 9 billion or more. As a result, the amount of agricultural land that supports food per capita is decreasing every year. However, the most important thing in agriculture in the future is to increase the land productivity of agriculture. In order to increase the land productivity, we must realize the better agricultural mechanization.

Agricultural machinery contributes most to the two things: timely operation and accurate work. These two interventions must increase land productivity and agricultural production worldwide. Currently, AI is widespreading due to advances in computers; and the agricultural machines incorporating this new AI technology will become new agricultural machines in the future. In other words, it should be agricultural robots.

It is thought that the increase in the size of the machine will be unnecessary in a sense due to this robotization. Currently, the size of machines is increasing in the United States, Canada and other countries in order to increase labor productivity, but if robots are used, labor productivity can be increased without increasing the size of machine. Small farming robots will become very important in places where it is not possible to create large plots like agriculture in the Great Plains, such as farming in production areas. If we use a drone for spraying operation, we will be able to work unmanned on any form of farmland. Science and technology are constantly advancing, and new agricultural mechanization is about to emerge.

By the way I will lead the Asian Association for Agricultural Engineering (AAAE) as its President for 2022 to 2023. I sincerely request your cooperation.

Yoshisuke Kishida
Chief Editor
February, 2022

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Agricultural Machinery Cluster Formation Model under Import Substitution in Russia

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Abstract

A key strategy for Russia's new economic policy of import substitution in agriculture and the agricultural machinery industry (AMI) is to improve its competitiveness by stimulating innovative activity. Although some positive trends are evident, Russian agriculture continues to be affected by lack of adequate supply of basic materials and technological obsolescence. In this article, we suggest that formation of an industrial cluster in the Rostov region, where national machinery production has traditionally been concentrated, will boost the industry in general and will eventually enhance the individual competitiveness of the constituent companies. First, we provide an overview of the current state of the AMI and identify issues impeding its development. Next, we propose an analytic hierarchy process as a tool to select prospective participants for the cluster and present a cluster model. Finally, we evaluate the potential economic efficiency of the model using economic and mathematical modeling tools.

Keywords: Agricultural Machinery, Russia, Food Security, Import Substitution, Cluster Formation.

Introduction

Limited natural resources and environmental degradation make it crucial to ensure access to safe, high-quality food in sufficient quantities in all countries of the world, including Russia.

Russia is one of the largest grain producing and processing regions in the world, and it possesses 20% of the world's supply of fertile land. According to the Food and Agriculture Organization of the United Nations, Russia could potentially feed two billion people. However, this potential has been limited during the post-Soviet Union period, which adversely affected many sectors of the Russian economy, particularly agriculture (Kalabekov, 2010). A declining share of agriculture in gross added value, a lack of investment and a decrease in the competitiveness of domestic food products resulted in the state being forced to import significant volumes of food from abroad. This situation seriously hindered development of the agro-industrial complex and posed a threat to the food security of Russia (Ministry of Industry and Trade of Russia, 2017; Romanova and Starikov, 2009).

The EU and the US imposed sanctions on the Russian economy and Russia responded with countersanctions in 2014, resulting in a radical change in the geopolitical and economic conditions. This stimulated the Russian government to prioritize increasing the potential for import substitution in the real economy. In the anti-crisis plan adopted in January 2015, a “rational” import substitution policy was suggested, which involved promoting the development of companies that were already successfully operating as industry leaders on a countrywide scale. A key direction for Russia’s new economic policy of import substitution is to improve the competitiveness of domestic industry by stimulating innovative activity. The transition to this innovative path of development involves the acceleration of scientific and technical progress and the introduction of new technologies in the agriculture sector. However, Russian agriculture has struggled with lack of adequate supply of basic material and technological obsolescence, which have hampered the application of innovative technologies (Sandu, 2010).

Numerous studies indicate that, for regions seeking new development strategies, it is vital to implement industrial clusters because they are an effective instrument to stimulate significant achievements in an innovative economy (Kiminami, 2016). An industrial cluster is a group of technologically interacting enterprises and nonproduction institutions that are closely located geographically and united to ensure their sustainable and effective development, on the basis of partnership and alignment of interests (Delgado et al., 2016; Feser et al., 2008; Ketels, 2013; Krugman, 1991; Porter, 2000).

Policies to develop industrial clusters have been adopted since the 1990s, particularly in developed countries, and there is now a substantial wealth of academic work on clusters, consisting of theory, empirical analysis and policy implications, upon which we can draw (Porter, 1998; Enright, 2000; Krugman, 1991; Ellison and Glaeser, 1997, Kiminami, 2016). Furuzawa and Kiminami (2011) stated that if, say, three companies form a cluster through a business alliance, and each company simultaneously realizes process and product innovations, then their production costs will fall and their product quality will increase, as a result of spillover effects. If the entities making up the cluster are able to establish such win-win relationships, the competitiveness of the entire cluster would be improved, which would lead to a concurrent increase in consumer surplus.

In Russia, the principles for cluster policies are established in three documents, the Long-Term Development Concept 2030 (Ministry of Economic Development of Russia, 2013), the Innovative Development Strategy of Russia until 2020 and the Government Decision of July 31, 2015, No. 779 “On Industrial Clusters and Specialized Organizations of Industrial Clusters” (hereafter, the Decision). According to the Decision, cluster enterprises included in the register of industrial clusters established by the Ministry of Industry and Trade of Russia can apply for subsidies of up to 50% of costs, provided that joint cluster projects are implemented.

Despite such government support, to date, only one industrial cluster has been registered by the Ministry of Industry and Trade, the agricultural machinery (AM) cluster established on December 19, 2016, in the Altai region. Theoretical and empirical evidence of cluster formation under import substitution have been insufficient to promote greater cluster formation. Given the need for urgent action, we suggest that the formation of industrial clusters in other regions of Russia will accelerate import substitution.

Historically, AM production in Russia has been concentrated in the Rostov region. The situation in this region can be interpreted as representing a latent AM cluster. The enterprises produce heterogeneous products (although many small enterprises tend to work closely with a large customer, Rostselmash), but they face common problems and work in related markets, which are based on demand from the same consumers. The main AM producers in the Rostov region are Rostselmash, Millerovoselmash, Salskselmash, Kormmash, Klever and Aksaikardandetal. The Azov-Black Sea Agro-engineering Academy and the North-Caucasian State Zonal Machine Testing Station in Zernograd could take the lead in organizing the scientific research core of the cluster. Universities of the region, such as Southern Federal University, Don State Technical University and Don State Agrarian University, could provide the basis for fundamental research.

In this paper, we first provide an overview of the current situation and the various problems faced by the domestic agricultural machinery industry (AMI). Based on its actual performance, we assume that the Rostov region is an appropriate location for the rational import substitution program and suggest that the formation of a cluster in the region will positively affect the AMI in general and enhance the individual competitiveness of companies making up the cluster. Finally, we select and evaluate individual companies that are the potential participants of the proposed cluster.

Materials and Methods

Our analysis of the current AMI situation is based on a substantial study of relevant documents, including government regulations, government programs related to the AMI and official statistics. Data from the Federal State Statistics Service, the agency ASM-Holding, which specializes in consulting and analytics in the AMI, and the Association of Agricultural Equipment Producers (Rosspecmash) were used. In addition, data published by the manufacturing companies themselves were accessed.

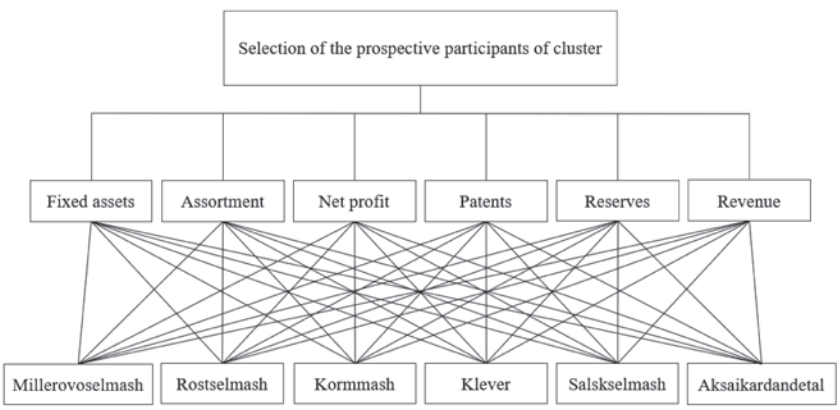
We examined the AMI companies in the Rostov region to substantiate the concept that the competitive potential of the AMI could be increased based on cluster formation under the rational import substitution policy. We propose an analytic hierarchy process (AHP) as a tool to select prospective participants of the cluster. After screening the accounting reports of all 12 AM manufacturers in the Rostov region, we rejected six on the basis of insufficient information or because their operations had ceased. We collected background information on the six remaining manufacturers operating in the region and then applied AHP to provide a targeted data synthesis and to hierarchically structure the results. Based on the results, we determined that three manufacturers were most suitable for involvement in the formation of a cluster. Then, we assessed the feasibility of the AM cluster creation in the Rostov region, focusing on measuring its efficiency (or inefficiency) for potential participants using economic and mathematical modeling tools.

2.1. The AHP

The AHP is a method of measurement involving pairwise comparisons. It is one of the most widely used multiple-criteria decision-making tools (Saaty, 2007). AHP enables qualitative decisions to be made more objectively and it supports systematic decision-making by expressing the interaction and hierarchy of factors, thus reducing the danger of a rough estimation (Chen and Huang, 2004). Owing to these advantages, we adopted AHP to evaluate the AM manufacturers for the cluster formation under the import substitution policy. The information obtained was processed through a web-based AHP online system (AHP OS).

AHP involves three steps: decomposition, comparative judgment and synthesis of priorities. The first step required the construction of a hierarchical network to present the problem, with the top level representing the overall objective, the middle representing the criteria and the lowest level representing the alternatives. In this study, the objective was to identify the AM manufacturers who would be best suited for the cluster formation under the import substitution policy. Therefore, the main objective, ‘‘selection of the prospective participants in the cluster’’, was placed at the top level of the analytic hierarchy, as shown in **Fig. 1**. The second step was to identify key evaluation criteria for assessing the objective. We adopted six key criteria, identified through a literature review, as follows: net profit, patents, assortment, fixed assets, revenue and reserves. Finally, six AM manufacturers were placed on the lowest level of the AHP model, representing the alternatives. These included Rostselmash, Millerovoselmash, Salskselmash, Kormmash, Klever and Aksaikardandetal.

Fig. 1 The AHP Model



The next step was to compare the factors at the same level in pairs and measure their comparative contribution to the main objective. A comparison matrix was set up to compare pairs of criteria or alternatives. A scale of values ranging from 1 (indifference) to 9 (extreme preference) was used for the preferences. This pairwise comparison allows the decision-maker to evaluate each factor’s contribution to the objective independently, thereby simplifying the decision-making process. Here, the six alternatives were compared in pairs to measure their importance under each criterion. In the final step, a synthesis of priorities was conducted to calculate a composite weight for each alternative, based on the preferences derived from the comparison matrix. Following calculation of the composite weight, we obtained the relative priority of the AM manufacturers for inclusion in the cluster. The work flow is described in **Fig. 2**.

Results and Discussion

3.1. Current State of the AMI

During the period 1990-2015, the efficiency of the domestic AMI decreased significantly. By 2017, companies producing domestic AM contributed only 0.13% to gross domestic product (GDP) (Ministry of Industry and Trade, 2017). This low share of GDP is the result of a number of factors affecting the AMI. For instance, the low solvency of agricultural producers means that the equipment manufacturing plants face low domestic demand for machinery and equipment. As a result, AM factories operate at 40-70% of their production capacity (Ministry of Industry and Trade, 2017). Figure 3 indicates that very little quantity of agricultural equipment are manufactured in Russia. However, a recent subsidy program allowing for renewal of obsolete machinery has led to an increase in its production (Federal State Statistics Service, 2018). During the period 1990-2016, the condition of the existing AM significantly deteriorated, and the availability of the main types of AM decreased each year (**Fig. 3**). In 2016, approximately 85% of the tractors and 58% of the grain harvesters in Russia were over 10 years old, meaning that their work life had already expired (Ministry of Industry and Trade, 2017). In 2014, tractor availability was equivalent to a total of 247.3 thousand units. However, considering the total area of cultivated land, the need for tractors was 900 thousand units. A deficit of AM for 1,000 ha of planted crops limits the technical capabilities of farmers and reduces labor productivity in agriculture. The annual load of one harvester is increased to almost 500 ha, extending the harvesting period to almost 2 months instead of the standard 7-10 days (Ushachev, 2015).

Low availability of equipment and inability to meet the requirements of modern intensive technologies with the existing machinery has resulted in harvest losses of 40-50% and uncompetitive agricultural products and it impedes the implementation of innovative technologies, which require a mechanization level of 60-65% (Ushachev, 2015).

Western sanctions and a food embargo of Russia in 2014 revealed the import dependence of the agrarian sector and highlighted the need to reduce the percentage of agricultural products and equipment imported. Although it is steadily declining, the share of imported agricultural equipment (**Fig. 4**) continues to account for more than 46% of the Russian machinery fleet (Federal State Statistics Service, 2017). Therefore, to achieve import substitution and overcome its domestic production shortage, Russia must take measures to modernize its AMI in the near future.

Today, approximately 1.5 thousand Russian companies are involved in the production of AM and its components, and it is the main activity for 57 of these companies (Butov, 2017). In 2016, the R&D expenditures of Russia's AM manufacturers were equivalent to 0.67% of their revenue, whereas the world's largest AM producers devote more than 4% of revenue to R&D. This significantly limits the capacity of industrial enterprises producing AM to realize their potential for growth. In addition, while the total number of AMI employees amount to 31.3 thousand, the number of mechanical engineers employed by AM producers is 737 employees,

Fig. 2 Methodological Steps in the Application of the AHP

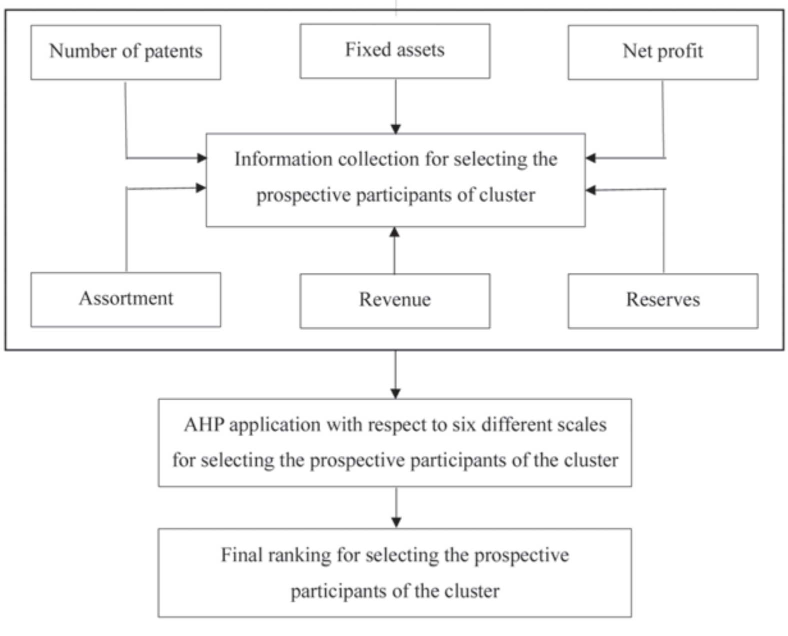
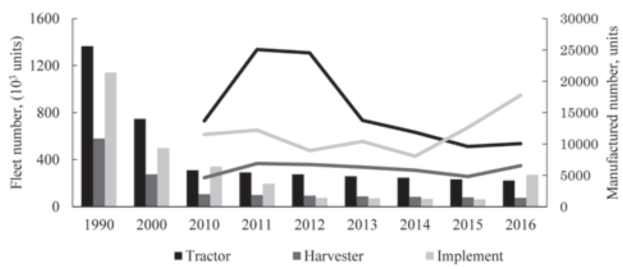
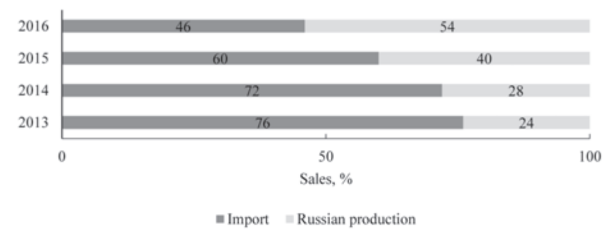


Fig. 3 Main Agricultural Machinery Possessed and Manufactured



Source: The Federal State Statistics Service, 2018

Fig. 4 Agricultural Machinery Market



Source: The Federal State Statistics Service, 2017 which indicates the low innovative activity of such enterprises (Ministry of Industry and Trade of Russia, 2017). At the same time, there are some clearly pronounced positive trends in terms of innovations. R&D expenditures have expanded 6.6 fold since 2014 and the number of employed mechanical engineers has increased by 98 people (+15.3%) (Butov, 2017).

Three main manufacturers of agricultural equipment-Combine Plant Rostselmash Ltd., Concern Tractor Plants, and JSC Petersburg Tractor Plant-account for 92% of the equipment produced in the country. Compared with foreign equipment suppliers, domestic equipment manufacturers have both disadvantages and advantages. Russian AM producers offer a poorer range of machinery and have low investment levels in technical and technological innovations. However, their main competitive advantages are low prices, service availability and the state's protectionist policy, which adds to the cost of imported equipment. Conversely, the competitive advantages of the foreign technologies are reliability and productivity (Poluhin and Plygun, 2015). Belarusian AM, although imported, holds a significant and dominant sales position because of its low prices. There is a tight economic interdependence between Russian and Belarus; the latter benefits from the Russian government's protectionist policies because of its common Soviet history and membership in the Customs Union.

Comparison indicators for domestic and foreign AM are shown in **Table 1**, based on the "Strategy of Development of the AMI of Russia until 2020". It indicates that Russian machinery lags behind foreign machinery in many indicators. Systemic problems hindering the effective development of the AMI can be divided into two main categories: general economic factors and industrial factors (Konstantinov, 2013). General economic factors include high bank interest rates (25-27%) and a reduction in government subsidies for agricultural producers, coupled with rapid price increases for raw materials and energy. Industrial factors are the low export share and the dependence on foreign component parts, arising from the insufficient quality and range of domestic materials. The lack of stable, effective demand in the domestic market is another hindering factor. The demand for AM depends on the financial situation of the agricultural producers. Therefore, the development of the AMI is curtailed by the low price of grain and by the low profitability of agriculture (Sandakova et al., 2017).

To stimulate investments in AMI, Russian Government Resolution No. 1432, dated December 27, 2012, has been implemented. Under the program, the state compensates the buyers of domestic equipment for 25% of its value, or 30% if the equipment is provided for Siberia and the Far East regions, respectively. The amount of state support is determined by the import substitution program adopted by the government from 2014 (Kolesnikova et al., 2017). Agricultural exports increased by 15.9% between 2015 and 2016, which demonstrates the effectiveness of the import substitution program. The 2014 devaluation of the ruble against the dollar and euro also had a considerable impact on trade. Spikes in the prices of imported AM and component parts led buyers to seek alternatives, including purchasing cheaper domestic equipment sold in the local currency.

For further dynamic development of AMI, it is essential to undertake the following actions: a) fully develop the capacity of the Russian AMI to produce tractors, grain and forage harvesters, tillers, seeding machines and other kinds of AM and equipment; b) improve the Russian AM market potential by establishing a dealer network, ensuring availability of spare parts and services, and offering low prices; c) increase investment in R&D for developing new technologies to expand the product range; and d) use state support programs efficiently. The industrial cluster strategy can contribute to the revival of Russia's AMI with a new innovation-based focus.

Table 1 Russian Agricultural Machinery versus Foreign Agricultural Machinery

	Indicator	Domestic production	Import production
Tractor	Engine power, kW	22-313	60–500
Tractor	Number of models, units	about 30	681 (European market)
Tractor	Environmental engineering standards	Euro 2-3	Euro 3-4
Tractor, harvester	Price, %	60-70%	100%
Harvester	Engine power, kW	<373	<612
Harvester	Number of models, units	23	147

Source: Ministry of Industry and Trade of Russia. 2011. Science research work: The strategy of development for agricultural machinery industry of Russia until 2020

3.2. AM Cluster Formation Model

The results of the calculations regarding the ranking of manufacturers that could potentially enter the cluster are provided in **Table 2**, based on the AHP methodology. The results indicated that the maximum priority should be given to the patents criteria (ranking of 0.43), whereas the minimum priority was the reserves criteria (0.03).

Further options were paired and compared with criteria. According to the weights of the net profit criteria, Rostselmash company had the maximum contribution (0.53)

Table 2 Global Priorities Calculation

Companies	Criteria						Global priorities
	Net profit	Patents	Assortment	Revenue	Fixed assets	Reserves	
	The numerical value of the priority vector						
	0.25	0.43	0.17	0.05	0.08	0.03	
Rostselmash	0.53	0.56	0.55	0.57	0.57	0.57	0.55
Millerovoselmash	0.04	0.05	0.06	0.03	0.04	0.04	0.05
Salskselmash	0.10	0.23	0.10	0.09	0.18	0.07	0.16
Kormmash	0.07	0.08	0.02	0.04	0.05	0.04	0.06
Klever	0.24	0.03	0.20	0.24	0.11	0.25	0.14
Aksaikardandetal	0.02	0.05	0.06	0.04	0.05	0.03	0.04

and Aksaikardandetal (0.02) had the minimum contribution. According to the weights for the patents criteria, Rostselmash with 0.56 and Klever with 0.03 had the maximum and minimum contributions, respectively. For assortment criteria, the maximum and minimum preferences belonged to Rostselmash (0.57) and Kormmash (0.02), respectively. Again, Rostselmash was the leader for the revenue criteria, with a weight of 0.55, whereas Millerovoselmash had the minimum preference (0.03). Based on the fixed assets criteria, the highest weight and maximum preference was allocated to Rostselmash (0.57), whereas Millerovoselmash (0.04) had the minimum preference. Finally, based on the weights for the reserves criteria, Rostselmash (0.57) and Aksaikardandetal (0.03) had the maximum and the minimum preferences, respectively. Next, we calculated the global priorities. Variables with a maximum global priority value were considered the best. According to the results, these are Rostselmash, Salskselmash and Klever manufacturers (**Fig. 5**).

Summing up the results from the viewpoint of AM cluster creation in the Rostov region, we identified the most preferable manufacturers (that is, based on justified expediency) as Rostselmash, Salskselmash and Klever. The AHP application allowed us to allocate those manufacturers according to their global priorities for innovative development, and to simultaneously highlight the strengths and weaknesses of each participant and the potential cluster in general. The proposed composition of the AM cluster in the Rostov region, focused on increasing the potential for import substitution, is shown in **Fig. 6**. We recommend that these companies form a cluster with Rostselmash at its center if additional proof of the effectiveness of such integration can be provided.

3.3. Economic Efficiency of AM Cluster Formation

The financial efficiency of a company is one of the most important economic criteria. Generally, it can be represented by the ratio of production costs and the obtained result (Revsine et al., 1999). We will assess the feasibility of creating an AM cluster in the Rostov region, focusing on the proof of its efficiency (or inefficiency) for potential participants. The following enterprises will be considered: Rostselmash (**Fig. 7**), Salskselmash (**Fig. 8**) and Klever (**Fig. 9**). The previous analysis indicated that these three companies had the highest potential as participants of the proposed cluster.

The efficiency of companies entering the cluster can be represented as follows:

E = R / C ...(1)

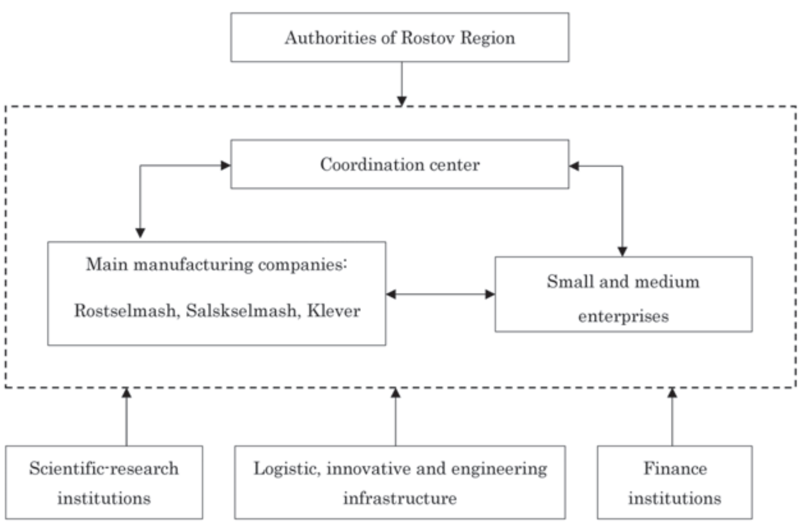
where, E denotes efficiency, R the result and C production costs.

The profit margin of the company, a resource indicator, was used for assessing the efficiency of the company's economic activities. We used the net profit (NP) of the company and, for costs, all assets of the company (A), for the period under study. Thus, the efficiency of the enterprise can be measured as follows:

E = NP / A ...(2)

For companies operating within the cluster, it is necessary to mea-

Fig. 6 Agricultural Machinery Cluster Model of the Rostov Region



sure the integrated efficiency because this is the key indicator. It enables assessment of whether the volumes of the final product produced correspond to the planned volumes, when all resources are used (Ilyenkova, 2007). The integrated efficiency of the cluster functioning shows the combined economic effect obtained by the cluster from the use of all cluster assets. We determine the efficiency of the cluster as follows:

$E_c = NP_c / A_c$ ...(3)

$NP_c = \sum_{i=1}^{n} NP_i$ ...(4)

$A_c = \sum_{i=1}^{n} A_i$ ...(5)

where, E_c is the efficiency of the cluster, NP_c is the net profit of the cluster, A_c is the total assets of the cluster, NP_i is the net profit of company i, A_i is the total assets of company i and n is the number of companies (in our case, three). Thus, the integrated efficiency of the cluster is equal to the quotient of dividing the total net profit by total assets. For the initial analysis of the cluster function, the integrated efficiency index is sufficient.

The question arises as to whether the functioning of enterprises in a cluster is more efficient than the functioning of each company separately and, if so, to what degree? The efficiency indicator (E) does not answer this question. To answer it, it is necessary to obtain an indicator that correlates the integrated efficiency of the cluster functioning with an indicator reflecting the overall efficiency of the enterprises when they operate independently. For the latter indicator, we can use the mean value of the efficiency indicators calculated using equation (2) for each company.

First, we use the formula of the arithmetic mean, then the formula of the geometric mean and, finally, the formula of the economic mean to find an acceptable formula for calculating the mean value. Further, we select an appropriate value. As the average for the value is the arithmetic mean of the efficiency indicators (E_{AM} = 0.10), we use the average economic value for further calculations. Thus, the formula for calculating the target indicator (TI) is as follows:

$TI = E_c / E_{AM}$ ...(6)

where, TI is the target indicator, E_c is the integrated efficiency of cluster and E_{AM} is the mean economic value of the efficiency indicators.

Let us refer to the target indicator as the interaction indicator (II). The II correlates the efficiency of the cluster and the mean efficiency of the cluster companies. For the sake of simplicity, the EAM will be denoted by Em. In general, the II can be represented as follows:

$II = E_c / E_m'$ ...(7)

Thus, to determine the quality of the interaction under the cluster, the integrated efficiency of the cluster and the mean efficiency of the clus-

Fig. 5 Weights of Alternatives

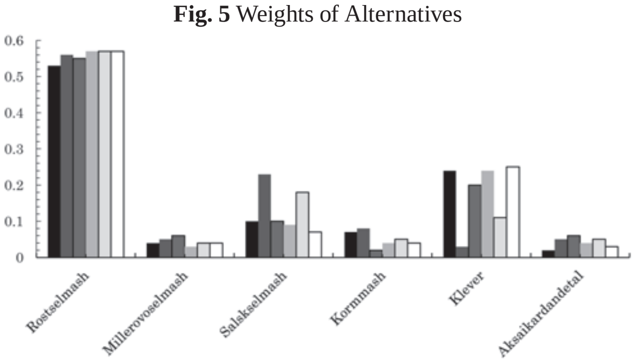


Fig. 7 Financial Results and Balance Sheet of Rostselmash

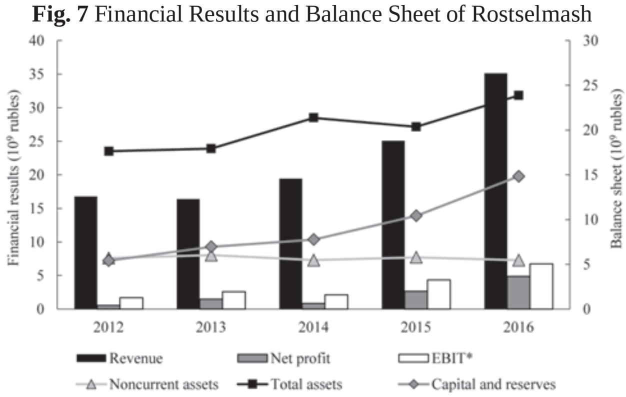


Fig. 8 Financial Results and Balance Sheet of Salskselmash

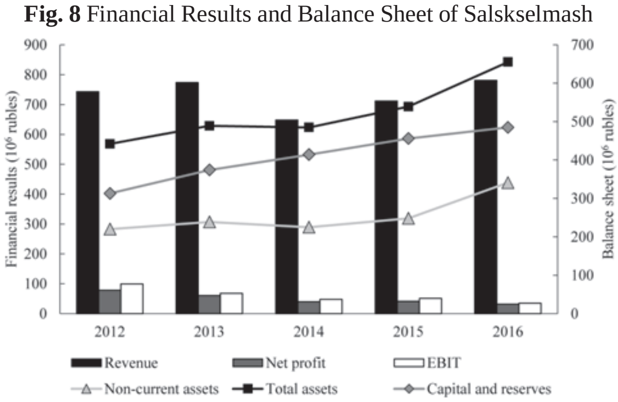
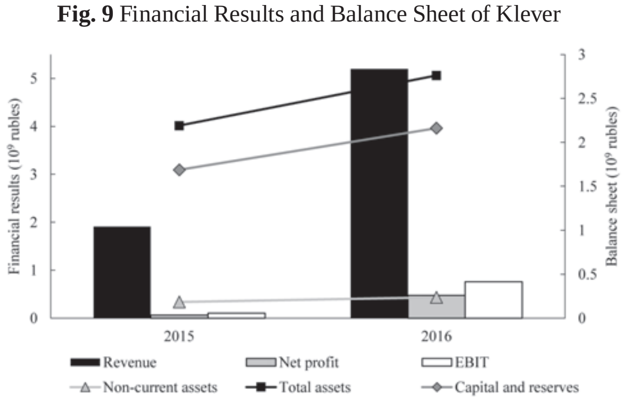


Fig. 9 Financial Results and Balance Sheet of Klever



*EBIT - Earnings Before Interest and Taxes. It is a measure of a firm's profit that includes all expenses except interest and income tax expenses. It is the difference between operating revenues and operating expenses.

ter companies must be correlated.

According to **Table 3**, the value of the interaction indicator exceeds the integrated efficiency of the cluster value. Therefore, we can conclude that functioning under the cluster is more economically efficient and effective than functioning as independent enterprises for Rostselmash, Klever and Salskselmash.

Conclusions

A period of stagnation following the collapse of the Soviet Union seriously undermined the overall efficiency of Russia's agriculture in general and the AMI in particular. Low quality and reliability and a narrow product range of domestic equipment, combined with inadequate state support, resulted in extremely high import dependence. Western sanctions and countersanctions that began in 2014 revealed these existing problems in the agrarian sector and led the government to make an urgent shift to an import substitution policy based on innovative strategies.

Government support programs, coupled with depreciation of the ruble, which has resulted in extremely high prices for foreign machinery and component parts, have proved to be beneficial for the AMI sector. Since 2014, import dependence on machinery has been steadily declining, whereas industry investments and the share of R&D expenditures of AM manufacturers have been increasing.

Despite this progress, several challenges prevail in the industry. Given the need for quick improvements, and the arduous geopolitical and economic context, traditional strategies of industrial development cannot provide the necessary solutions. Here, we have suggested the formation of an industrial cluster in the Rostov region, where the most efficient AM manufacturers have been traditionally concentrated.

Using an AHP model, we determined the most appropriate participants for the potential cluster. Then, based on Russia's new economic policy of import substitution, we proposed a model for cluster formation. We estimated the actual level of "innovative readiness" of AM companies in the Rostov region and their potential profitability in the cluster compared with individual profitability using economic and mathematical modeling tools.

It is economically profitable to unite the companies analyzed in an industrial AM cluster, focused on import substitution. We speculated that the formation of the cluster, centered on the manufacturer Rostselmash, will positively affect the productivity, innovation activity and development of all enterprises comprising the cluster. The development of its domestic AMI would allow Russia to conduct an independent policy of import substitution for food products, machinery and equipment, and contribute to the food security of the country.

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Table 3 Interaction Indicator Calculation

Indicator	Rostselmash	Salskselmash	Klever
Net profit	2779578	37975	269620
Total assets	21870628	559757	2476848
Efficiency i	0.127	0.067	0.108
Ec		0.123	
II		1.23	

* II denotes interaction indicator.
** We used Russian currency due to drastic fluctuations and devaluation of the ruble against the dollar as of 1 June 2018.
Source: Companies' accounting reports, averages for 2014, 2015 and 2016

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■■

An Overview of the Seed Sector in the Republic of Mozambique

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Abstract

This paper provides an overview of the seed sector in the Republic of Mozambique by reviewing relevant documents from the Ministry of Agriculture and Food Security, the Food and Agriculture Organization of the United Nations and the United States Agency for International Development. We assessed the seed value chain as well as the main companies involved in seed production across the country. We additionally analyzed seed production for the main crops grown in the Republic of Mozambique.

Keywords: seed sector, Mozambique, seed value chain, seed multiplication, certified seed

Introduction

In the "Green Revolution" narrative of our time, the low adoption rates of 'improved' or certified seed from the formal sector in sub-Saharan Africa is a major reason for the low rates of agricultural productivity seen on the continent (African Centre for Biodiversity, 2015). 'Improved' seed use is very low, with only a tiny percentage of the most commercially-focused farmers using them. Maize appears to be something of an exception. In general, maize cultivation in Mozambique is increasing and just under 10% of maize farmers are using 'improved' seed, which implies that smallholder subsistence farmers may also be using such seeds. The low fertilizer use, however, indicates that most farmers using improved seeds are not using fertilizer. This reduces the productive potential of such seed. Local production of agro-inputs, such as fertilizer and 'improved' seed, is practically non-existent, and the former is limited to some basic blending of imported products (Trade and Industrial Policy Strategies, 2017). The aim of this study was to analyze the seed sector in the Republic of Mozambique. We assessed seed production by the government as well as the private sector.

Materials and Methods

This research used data from several sources. We acquired information from the government of the Republic of Mozambique through the Ministry of Agriculture and Food Security (MASA), and from public seed companies, agro-dealer seed suppliers and service beneficiaries across the country. Information gathered from these sources were combined with survey data collected from various lectures, journals and official publications from the Food and Agriculture Organization of the United Nations (FAO). Updated data were obtained from seed sector research centers across the country.

Results and Discussion

Key Actors in the Seed System

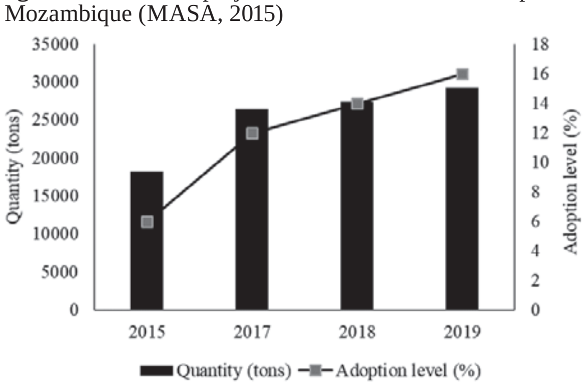
MASA

MASA is a public institution established in 2015 by Presidential Decree 01/2015 (MASA, 2015). MASA aims to contribute to food security, nutrition and income generation, ensuring social and gender equity. MASA's vision is a prosperous, competitive and sustainable agricultural sector, capable of offering solutions to the challenges of the sector and meeting the agrarian market at the global level. MASA coordinates the development and implementation of the policies and strategies in its four major areas of intervention: agriculture, livestock, agricultural hydraulics and food security and nutrition, which cover the following commodities: rice, soybean, cotton, maize, banana, sugar, cassava, legumes, poultry, cashew nut, bovine meat and forest products (USAID, 2015).

MASA considers inputs access and use as one of crucial measures for agricultural productivity improvement. **Fig. 1** provides the current estimates and projections of levels of use of seed.

In 2016, Mozambique had 63 registered seed companies, of which 59 were local. Among these 63 registered companies, only 15 were actively engaged in the production and marketing of at least one of the four focal crops. All 15 produced maize seed, 3 produced rice seed, 11 produced cowpea seed and 6 produced soya bean seed. Most of the seed companies produce maize and cowpea seed because these crops are highly suitable for the growing conditions in large parts of the country's central and northern regions. Consequently, most seed companies are also based in these areas. Most of Mozambique's companies are young, having been in operation for less than 5 years. The estimated aggregate seed sales in 2016, based on crop, were 4,375 tons of maize, 650 tons of rice, 364 tons of cowpea and 689 tons of soya bean (Edward et al., 2017).

Fig. 1 Estimates and projections of seed use in the Republic of Mozambique (MASA, 2015)



Overview of the Seed Value Chain

The public sector dominates the Mozambican seed market. Of the 90,000 tons of seed planted for food crops, 70% is farmer-saved seed, 20% is from informal trading and only 10% is acquired through the formal sector. Of that 10%, only one-fifth (1,800) tons is sold outside the government-subsidized system. Two large companies, SEMOC and PANNAR, produce over 90% of the open-pollinated maize seed, and they provide the production and marketing of improved maize varieties for the government at subsidized prices. Constraints on the seed sector include a lack of available quality seed, the crowding out of the private sector and a lack of awareness of the benefits of 'improved' seed (USAID, 2016).

Varietal Testing and Release

The Seed Services department within MASA is the primary implementer of the Seed Law. The Instituto Nacional de Investigação Agrária (IIAM) conducts varietal testing, although independent institutions can also submit their own data. Both Distinctness, Uniformity and Stability (DUS) and Value for Cultivation and Use (VCU) testing are required for a minimum of two seasons, although DUS testing can be performed for only one year if the breeder provides an additional description to supplement the test. The Seed Services department presents varietal testing results to the multi-stakeholder National Seed Committee that ultimately approves varietal releases and publishes the National Varieties List. Members of this committee include the National Director of Agriculture, IIAM, farmers' associations, seed growers' associations, seed companies and the Ministry of Agriculture and Food Security (MASA). The varietal release system is regarded as functioning poorly, with over 80 varieties awaiting approval. A major bottleneck is the capability of IIAM to conduct the required tests. To overcome this constraint, the MASA is allowing the provisional release of varieties based on data provided by breeders.

Access to 'Improved' Seed in Mozambique

Most farmers in Mozambique cannot access 'improved', high-quality planting materials. This section focuses on cereal and legume seed developed mainly by the public agricultural research system and expanded to the foundation seed stage mainly by public agencies. The terms "foundation seed" and "basic seed" are used interchangeably in this discussion. This section identifies key institutions and players in the seed production system, discusses their roles, lays out the legal and regulatory framework surrounding seed production, examines foundation seed production and seed multiplication, estimates 'improved' seed utilization for key field crops and identifies priority policy, regulatory and institutional issues for a broader public-private sector discussion.

Seed Certification and Quality Assurance

The Seed Services department is responsible for seed certification. Its primary tasks include field inspections, seed quality laboratory tests and the issuance of official certificates.

Common Sanitary and Phytosanitary Measures

Mozambique allows the import of both registered varieties of seed and non-registered varieties subject to obtaining an import license from the Seed Services department. An import license usually takes one to two weeks to process. Mozambique's quarantine regulations are in keeping with the Southern African Development Community's (SADC) Harmonized Seed Regulations (USAID, 2016).

Foundation Seed Production

Basic seed production is centralized at the Unidade de Semente Básica (USEBA) of IIAM. In 2009-10, Lozane Farms was the only private seed company that USEBA contracted to produce basic seed. During that year, the company produced ~25 tons, of which ~20 tons was sold to SEMOC and the balance to the MASA/ European Community (EC)/ FAO project. According to USEBA, private companies' production of foundation seed is limited because the low demand does not justify investing in a substantial increase in their production, with the exception of irrigated rice (owing to strong urban demand). Another constraint is the lack of financial resources for contracting seed producers. Unlike Ghana, Mozambique has no prohibitions on private firms producing foundation seed. Information on basic seed production is unfortunately scanty and inconsistent across sources. Some informants report that the quality of basic seed is also suspect. According to the GCP(Global Compact Program)/MOZ/099/EC Project progress report of March 2011, 470 tons of basic seed were produced in 2009-10 with support of the MINAG/ EC/FAO project, the GCP aims to provide technical Assistance. Of that, 227.5 tons (48%) was maize seed, 165 tons (35%) rice and 76.8 tons (16%) soya bean. The total quantity of basic maize seed produced in 2009-10 was theoretically enough to produce 9,100 ha of maize C1 seed in 2010-11 (assuming a planting rate of 25 kg/ha), but this amount was not close to that achieved in practice. The total quantity of basic rice seed produced in 2009-10 was theoretically enough to produce around 2,000 ha of rice C1 seed in 2010-11 (assuming a planting rate of 80 kg/ ha). This estimate appears to be high, as MozFoods reports having grown 2,450 tons of certified seed in 2009-10 (likely on ~800 ha, with mean yields of ~3.0 tons/ha). According to USEBA, 826 tons of all types of foundation seed were planned for 2010-11, of which 33% was maize and 53% was rice. Private seed companies concluded that, at best, IIAM can meet only 50% of the estimated demand for basic seed. USEBA asserts that the proportion was greater in the past and that the production of basic seed of the main varieties met the multiplying firms estimated demand in 2009-10. USEBA's constraints to producing basic seed are as follows:

a) Low availability of breeder seed: No stocks of breeder seed exist for ~50% of the released varieties;
b) Inadequate facilities to store foundation seed at IIAM and Zonal Centers; and
c) An inadequate irrigation infrastructure required for seed multiplication.

Seed Multiplication

Local Production of Unimproved Seed

Through the Departamento de Sementes and Provincial Directorates of Agriculture, the government has been promoting local seed production by individual farmers, farmer groups and associations in cooperation with certain non-governmental organizations. This activity is coordinated through regional farmer associations and federations (Southern, Central and Northern). The commodities covered under these programs include maize, rice, groundnuts, sesame, beans (feijão vulgar), and cowpeas (feijão nhemba). The amount of seed produced under these programs increased from a 3 year average of 5,871 tons from 2004-05 to 2006-07 to an average of 6,474 tons from 2007-08 to 2009-10. The seed produced is

Fig. 2 Area and production of local unimproved seed by year (Ministry of Agriculture/National Directorate of Agrarian Services/Seed Department, 2010)

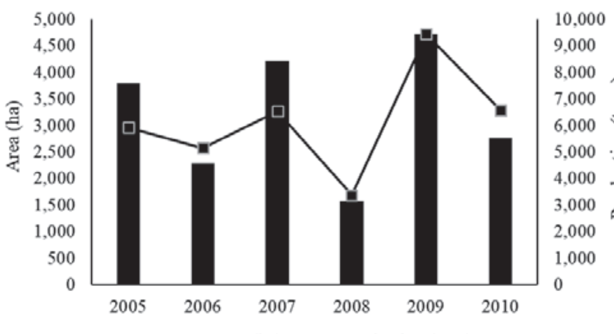
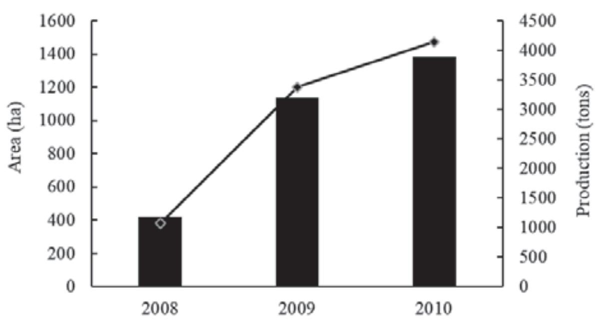


Fig. 3 Area and production of certified rice seed by year (Ministry of Agriculture/National Directorate of Agrarian Services/Seed Department, 2010)



used for local distribution through farmer organizations, cooperatives and traders; it is also used in some government seed support programs (**Fig. 2**) (World Bank, 2012).

Private Sector Certified Seed Production and Sales

SEMOC and PANNAR produce over 90% of open-pollinated maize seed, and MozFoods/MIA is the only registered rice seed producer, growing 70% of its certified seed on its own farm and 30% under contracts without growers. Hybrid seed production in Mozambique is limited. PANNAR was the only company producing hybrid maize seed in 2010 (180 tons of 'PAN 67' were multiplied in Mozambique and 150 tons were imported). In 2009, PANNAR imported 1,469.5 tons of 'PAN 67'. PANNAR contracts with MozFoods/MIA and a few commercial seed growers to multiply the hybrid seed in Mozambique. The other 16 registered companies are smaller, producing less than 150 tons annually of seed, mainly open-pollinated varieties (OPVs) of maize and rice, as well as small quantities of sorghum, cowpea, common bean and groundnut varieties. Lozane Farms produced 168 tons of seed in 2009-10, and some of it was under contract to PANNAR and SEMOC. IKURU, a federation of smallholder organizations, is a supposed importer and producer of soya bean seed and sesame, although one source notes that its seed has had major germination problems in the past several years. IKURU-multiplied seed is produced under contract with smallholder companies and some agribusinesses as part of the Techno Serve program, the selected commodities of certified seed production are shown in **Figs. 3-5** (World Bank, 2012).

Government Distribution of 'Improved' Seed

The government is the main supplier of seed to farmers and this occurs through the Plano de Acção para Produção de Alimentos, its food production support program, and the European Union voucher program implemented by the International Fertilizer Development Center.

Rural Extension

The public extension services are more predominant than private services. The extension directorate at MASA intervenes in the process of technology transfer to the farmers and brings the farmers' feedback regarding the acceptability of the existing varieties to researchers. In addition, the extension services bring farmers' needs to the attention of researchers to guide breeders in the development of demand-oriented varieties. The Directorate of Training, Documentation and Technology Transfer at IIAM, handles the transfer and dissemination, as well as socio-economic-related studies, of technologies developed by IIAM, including crop varieties. The dissemination activities by those units involves the establishment of demonstration plots at the farmers' fields and research stations as well as result demonstration plots and technology exhibition centers. They provide technical assistance and consider farmers' preferences and assessments of varieties and other technological packages.

The extension approach is slightly different for maize hybrids in comparison to OPVs. For hybrids, demonstration plots are carried out by researchers from the public national research system, CGIAR and the private sector, because the trials require high-level technical skills, which are limited at the extension office level. However, the extension office can easily handle the OPV demonstrations (USAID, 2015).

Enhancement of Seed Legislation

In 2013, the government approved a new national legislation on seed production, trade, quality control and seed certification. This legislation aims at developing seed; granting accreditation to private sector agents in seed breeding and providing protection to new varieties of plants. Mozambique was expected to align its national legislation on seed with SADC regulations. In April 2014, the MASA, with its partners, launched the National Platform of Dialogue of Seed Sector to enhance the business environment

Fig. 4 Area and production of certified maize seed by year (Ministry of Agriculture/National Directorate of Agrarian Services/Seed Department, 2010)

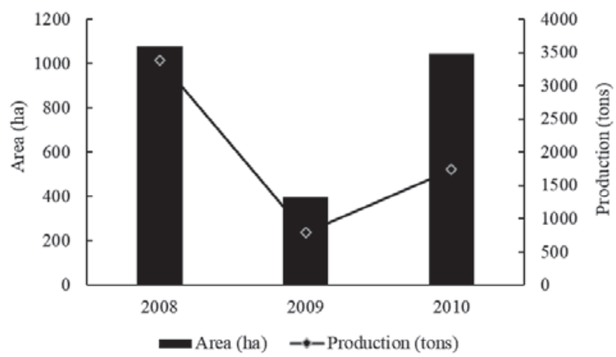
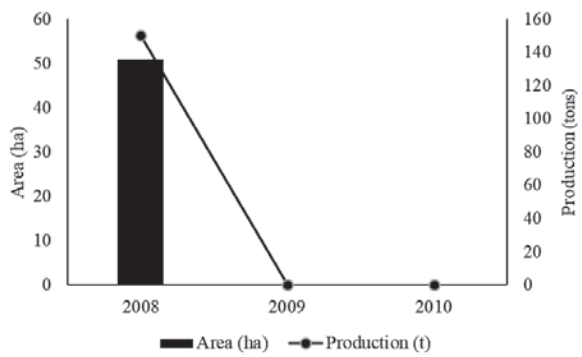


Fig. 5 Area and production of certified wheat seed by year (Ministry of Agriculture/National Directorate of Agrarian Services/Seed Department, 2010)



in this sector. This platform will address the challenges and offer solutions to improve the performance level of the sector and those of different actors in the seed value chain, including public and private sectors and the end users (FAO, 2016).

Seed-related Policies

The Seed Law of 1994 (Decree 41/94) focuses on production and marketing in formal seed systems, but it does not even mention the informal seed system. The same applies to all of the strategic and regulatory documents that were subsequently created to regulate and implement The Seed Law, with the exception of the National Seed Strategy (1997-2001), which recognizes the role of the informal sector (Pereira and Heemskerk, 2012).

The Seed Services department of the MASA is responsible for all seed-related regulatory activities, including the provision of import and export licenses. It operates three regional seed laboratories. The central laboratory in Maputo received several seed germination cabinets from FAO but none are in working order. Several private sector seed companies complained about the lack of staff and the long delays in seed certification and seed testing results. The Seed Services department itself indicated that equipment needs and staff training are key problems. PANNAR stated that varietal testing takes 3 years and costs US$2,300/variety/year, which is more expensive than in other SADC countries (USAID, 2016).

Conclusions

Low agricultural productivity and the need to feed an increasing African (and global) population in an era of climate change will require the adoption of 'improved' or certified seed. The private sector is seen as the primary agent for achieving this goal.

There are several limitations in terms of socio-economic research and dissemination work that is performed prior to varietal releases. The dissemination work is mainly limited to field days and is sometimes restricted to groups of farmers involved in on-farm trials. This could be improved through multi-disciplinary engagements at the end stage, prior to release, considering the value chain actors and taking into account the main outcomes of the 'improved' variety.

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Table 1 Estimates of domestic certified seed sales (Swiss Development Corporation (SDC), 2011)

Company	Types of seed produced	Quantities sold (tons)
SEMOC[a]	OPV[b] maize, beans, rice, sorghum, peanut	5,000
MozFoods	Rice, OPV/hybrid maize, wheat, beans	2,050
PANNAR	OPV/hybrid maize, sorghum, peanuts	1,500-2,000
Dengo Comercial	OPV/hybrid maize, beans, sorghum	555
Morais Comercial	OPV/hybrid maize, beans, peanuts, horticultural crops	270
IKURO	OPV maize, soybeans, peanuts, beans, sesame	250
Lozane Farms	OPV maize, beans, sorghum, soya beans	168
Semente Perfeita	Horticultural crops and broad mix grains, legumes	60
Quiniho Comercial	Grains, horticultural crops	40
JNB Empreendimentos	OPV/hybrid maize, beans, horticultural crops	15-20
IAV[c]	Horticultural crops, maize, beans	21.5

Mini Tractor-mounted Sensor-based Aqua Groundnut Planter

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Abstract

Groundnut is grown on large scale in almost all the tropical and sub-tropical countries of the world. Groundnut is the sixth most important oilseed crop in the world. In India, most of the farmers are small and marginal farmers, hence there is a demand of small implements that could be used as multifunctional devices. Hence a mini tractor-mounted sensor-based groundnut aqua planter was designed and developed. Mostly in India, the groundnut crop is planted during starting of the rainy season i.e. from the month of May to July, and most of the crop is cultivated under rain fed conditions. Few of the farmers irrigate the crop using conventional methods such as sprinkler and drip irrigation, but it requires high capital investment. The basic idea of mini tractor-mounted ground nut planter cum site specific precision water applicator is that the dropped seed from the metering mechanism of planter can be detected by an infrared (IR) sensor and activate the solenoid valve to discharge water close to the dropped seed. With this system, seed planting and water application can be done simultaneously in a single operation. This increases the moisture content of soil and sustainability of seed for germination. With this technology, the water can be applied along with the seed at the targeted location which helps the farmers to plant the crop even under low rainfall conditions (low moisture content of the soil).

Keywords: Groundnut planter, Aqua Planter Mini tractor, Sensor.

Introduction

Groundnut (*Arachis hypogaea* L.) is the sixth most important oilseed crop in the world. The major groundnut producing countries in the world are India, China,Nigeria, Senegal, Sudan, Burma and the United States of America. It contains 48-50% oil and 26-28% protein and is a rich source of dietary fiber, minerals and vitamins. It is also used in soap making and in manufacturing cosmetics and lubricants, olefin, stearin and their salts. Kernels are also eaten raw, roasted or sweetened. They are rich in protein and vitamins A, B and members of the B2 group (Chennakrishnan, 2012). The cake can be used for manufacturing artificial fiber.

Planting operation is one of the most important cultural practices associated with crop production. Increase in crop yield, cropping reliability, cropping frequency and crop returns all depend on the uniform and timely establishment of optimum plant population. In India, most of the farmers are small and marginal farmers; hence, there is a demand of small implements which could be used as multifunctional devices by attaching simple components to be fitted to the low hp tractor. The short growing season and the scarcity of labor make high need for the intermediate technology to be used for deep loamy and clayey mixed red and black soils.

The cost of agricultural inputs is increasing day by day and there is a clear preference to reduce the use of waters in agriculture, hence to make agriculture profitable and to reduce the water usage precision agriculture can be a promising alternative.

The recent advancement in technology creates a need for precision agriculture which include right amount of input at right time of application and in right quantity to increase farm productivity by reducing farm losses. One of the objectives of precision agriculture is to minimize the volume of water by using site-specific application system.

The groundnut is the only nut that grows below the earth. The groundnut plant is variable annual herb, which grows up to 50 cm in height. The flowers of the plant develop a stalk that enters into the soil, forms a pod containing generally two seeds that mature in about two months. When they leave off, the plant turns yellow. The plant is then removed from the earth and allowed to dry.

The tractor is most versatile machine used in India for various farm operations and transportation. In India there is a trend of mounting various machines like Combine and other implements to the tractor as most of the operations are seasonal in nature so there is a need to develop tractor mounted implement to decrease its ideal time. The planting and water application can be done by integrating ground nut planter and site specific water applicator to the mini tractor which could be useful to the small and marginal farmers. This technique helps the farmers those completely depend on the rain fed irrigation like less rainfall region in Andhra Pradesh. It also permits the farmers to go for cultivation with minimum quantity of water, since the water will be applied only on targeted location, application of water avoided in non-targeted areas, hence possibility of water saving. By keeping above mentioned parameters in mind, the objectives of the present study are to design and develop a groundnut planter suitable for mini tractor, to develop a sensor based site-specific precision water applicator and integrate to the planter and to evaluate the developed groundnut aqua planter cum under laboratory and field conditions.

Material and Methods

The self-propelled groundnut planter was designed as a functional and experimental unit. The design of machine components were based on the principles of operations, tested and compared with the conventional method, to give a correct shape in form of prototype. The mechanical design details were carefully laid out so as to give adequate functional rigidity for the design of machine.

Physical Characteristics of Seed

Initially the physical characteristics of groundnut seed were measured. It was observed that, the average length, width and thickness of dry seed were found as 13.11, 7.43 and 6.40 mm, respectively. However, the length was found to vary between 13.36 to 14.04 mm, the seed width was found to vary between 7.33 to 7.69 mm whereas the seed thickness was varied between a maximum and minimum of 6.33 to 6.60 mm, respectively.

General Design Considerations of Planter

The design of planter consists of several steps and would require basic information on the following were considered:

a) Crops and their characteristics.
b) Soils and climatic conditions during sowing seasons.
c) Agronomic requirements of crops and yield levels.
d) Sources of power available.
e) Labor requirements for seeding.
f) Socio-economic conditions of farmers.
g) Size of holding.
h) Level of manufacturing skill at small finished components.
i) Ease of operation, calibration and maintenance.
j) Safety and operation, calibration and maintenance.
k) Safety and operator's comfort.
l) Expected level of cost of machine and cost of machine operation.
m) Net benefit expected at farmer's level.

Basic specifications of seed drill planter should be derived from agronomic and operational parameters, source of power, labor requirements and economic condition of farmers hence mainly concentrated in this study.

Development of Groundnut Planter

A groundnut planter was designed and developed that is suitable for a mini tractor at Dr. NTR College of Agricultural Engineering, Bapatla. Before mounting of groundnut planter to the mini-tractor, Auto-CAD drawings were used for fabrication of the machine. The seed and fertilizer box were made up of 1 mm MS sheet. The seed box having three sections were made as per designed and a funnel was also provided inside the seed box to carry the groundnut from spoons and deliver it to the furrow opener through the seed delivery tube.

The shafts of seed and fertilizer metering device having 20 mm diameter cold rolled round section steel shaft were used. Two bushes were provided as bearings of shaft at both ends. The metering device of the seed has been made up of 3 mm thick black MS plate with 20 cm diameter of round plate. Round bars of MS having 4 mm diameter and 50 mm length were taken for joining the spoons with the round plate. The spoons were made up of 2 mm thick round MS coins having 35 mm diameter by stamping of coins with specified die to give proper shape of the spoons. The gears of fertilizer metering device were made up of MS round pipe and 8 × 7 mm rectangular section 12 bars having 35 mm length were welded at the periphery of the round pipe. A ground wheel was made up of 30 × 5 mm MS flat having length 120 cm by bending in circular shape and 12 pentagonal pegs were welded at the periphery of the wheel for better griping with soil. The ground wheel was attached with the main frame by providing a hinged

Table 1 Specifications of the developed planter

SI. No.	Seed damage, %
Overall height, mm	1200
Overall length, mm	1450
Overall width, mm	900
Weight, kg	90
Metering mechanism	Vertical plate cup or spoon
Power source, hp (Tractor Mitsubishi 180D)	18.5
No. of rows	Three
Planter price, Rs.	13000
Plant to plant spacing, cm	10 ±0.5
Row to row spacing, cm	30
Type	Fully mounted

joint of 30 × 8 mm MS flat. Two gauge/depth control wheels made up of 30 × 5 mm MS flat used developed mounted for the frame. These were fabricated by bending in circular shape. Three tines were made up of medium carbon steel, heat treated to shovel hardness of RC – 40/45. A three point hitch system was connected to the frame of the developed groundnut planter to mount to the mini tractor three point linkages. The developed groundnut planter with selected that tractor has been presented in **Fig. 1**. The specifications of the developed planter are given in **Table 1**. The Complete driving system attached in the groundnut planter for transmission of power from ground wheel is shown in **Fig. 2**.

Development of Electronic Control Unit for water application

Electronic Control Unit (ECU) was developed for delivering the précised fungicide at required time and right place, by detecting the seed in seed delivery tube using IR obstacle sensor and to activate the solenoid valves for site delivering specific precision fungicide. The developed groundnut planter is a three row planter; hence in the present study three IR sensors were used for detecting the seeds in three seed delivery tubes and three solenoid valves used for delivering the fungicide in each row. Accordingly three relay switches were also used for activation of the solenoid valves by multiplying the voltage power supply. An Arduino Mega 2560 Microcontroller board was used to read, process the three IR sensor signals and also to activate the three solenoid valves simultaneously. The output pin of the IR sensor was connected to the digital pins of 2, 3 and 4 of the microcontroller.

Integration of Groundnut Planter with ECU

The developed ground nut planter and electronic control unit for site specific precision water application units were integrated to work as a single unit for planting as well as site specific water/water applications simultaneously. The developed electronic control unit was attached on the groundnut planter with suitable attachments as shown in **Fig. 3**. The step by step procedure for integration of ground nut planter and electronic control unit is given below.

a) Water tank was connected to the planter fertilizer hopper, with angle iron by making a similar cross-section of tank using nut and bolt arrangement.
b) Electronic control unit was placed just above the seed hopper by placing it in a plastic container at bottom of the water tank and close to the seed delivering tube.
c) 12 V DC High pressure water pump was connected to the front side of seed hopper using an angle iron, nut and bolt arrangement.
d) 12 V DC Battery was kept a side of the fertilizer hopper for giving power supply to the ECU and water pump.
e) Three solenoid valves were connected at the top of the three fur-

Fig. 3 Developed planter cum site specific precision water applicator

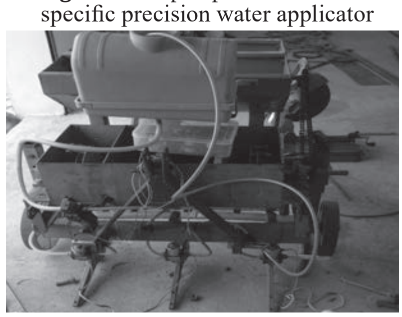
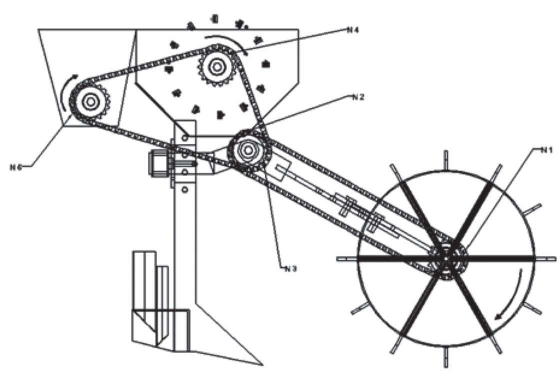


Fig. 1 Developed groundnut planter with test tractor

Fig. 2 Driving system of groundnut planter



row opener's shaft using nut and bolt arrangement for delivering the water at required time.

f) The water tank, DC pumps and solenoid valves were connected using 10 mm hose pipe, adapters and T Joints. Pump inlet was connected to the water tank and outlet was connected to the main line of water supply system of water using T-joints. The inlet of solenoid valve is connected to the T-joint of main line and outlet is connected to a pipe discharge the water on the ground.

Table 2 Measurement of water saving percentage

SI. No.	Sensor Status	Water consumption, litre			Mean, litre
		T1	T2	T3	
1	With activation	2.0	2.5	2.7	2.4
2	Without activation	10.0	10.8	11.0	10.6
3	Water saving (%)	80.0	76.8	75.5	82

Results and Discussions

Evaluation of the Sensor-Based Groundnut Aqua Planter

The developed groundnut planter cum site specific precision water application was evaluated under actual field conditions. The parameters measured and results obtained during the evaluation are presented in **Table 2** and discussed in the below sections.

Measurement of Draft Force

During evaluation of the planter under actual field condition, it was observed that, the draft force requirement of the planter found to vary from 125 to 139 kg at an average depth of 5.3 cm as change in speed of operation from 1 to 2.5 km/h. Similarly, the draft force requirement of the planter found to vary from 160 to 171 kg at an average depth of 8.7 cm as change in speed of operation from 1 to 2.5 km/h, whereas, the draft force found to vary from 285 to 296 kg at an average depth of 11.5 cm as change in speed of operation from 1 to 2.5 km/h.

It was also observed that the draft force requirement of planter has been increased with increase in speed of operation. It may be due to the acceleration of the soil particles and imparted kinetic energy to the soil. The effect of depth of operation on draft force of the implement is shown in **Fig. 4**.

Missing Index (MI)

The seed missing index of groundnut planter was observed during its evaluation. It was found that during 10 m distance coverage of the planter at constant depth, the average number of seeds missed during pickup by the metering mechanism of the planter was 2.7 in a row at a speed of 1 km/h. Similarly the number of seeds missed during pickup by the metering mechanism of the planter was 4.8 in a row at a speed of 1.5 km/h, whereas the number of seeds missed during pickup by the metering mechanism of the planter was 9 in a row at a speed of 2.5 km/h. Thus the missing indexes of planter were found as 2.7, 4.8 and 9% at an operating speed of 1, 1.5 and 2.5 km/h respectively.

The seed missing index of the planter at different speed of operation is shown in **Fig. 5**. It was observed that as increasing the speed of operation of the planter, the seed missing index of the planter also increased. This is also may be due to increasing wheel slippage of the ground wheel.

Uniformity of Seed Spacing

The uniformity of seed spacing was measured under actual field condition. It was observed that during 10 m distance coverage of the planter, the seed to seed spacing of the planter in all the rows found to vary from 9.6 to 11.5 cm with an average depth of 10.2 cm. This variation may be due to seed displacement in the furrow due to sudden fall. It was also observed that, the developed seed metering mechanism dropped only single seed. The row to row spacing of the developed groundnut planter was observed as 30 cm in the field. A provision was also made on the planter to increase or decrease the row to row spacing by adjusting the U-clamps of the tines as per the requirement.

Measurement of Wheel Slippage of Ground Wheel

The percentage wheel slip of the

Fig. 4 Effect of depth of operation on draft force of planter

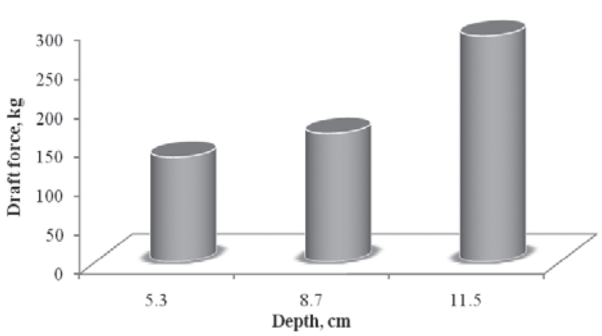


Fig. 5 Seed missing index of the planter at different speeds

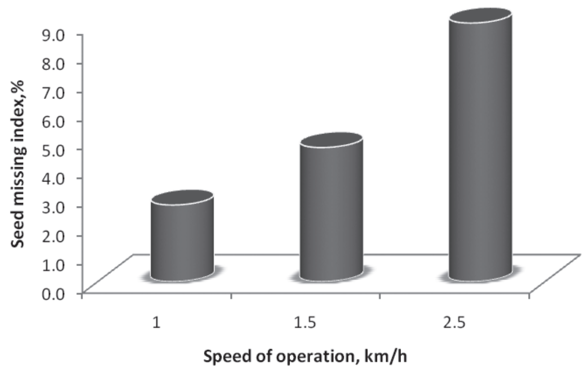


Table 3 Measurement of seed damage percentage

SI. No.	No. of revolution of ground wheel	No. of seeds dropped			No. of seeds damaged			Seed damage, %
		T1	T2	T3	T1	T2	T3	
1	0	0	0	0	0	0	0	0.0
2	5	19	21	19	1	1	2	5.0
3	10	39	40	39	2	3	1	5.1
4	20	77	79	81	3	4	6	5.5

groundnut planter was measured under actual field condition. It was observed that the distance covered in 10 revolutions of the ground wheel is 3.7 m at no load condition, whereas, the distance covered in 10 revolutions of the ground wheel with load is 3.4 m at a depth of 5.3 cm. The wheel slip was obtained as 10.52%.

The wheel slip was observed at different speeds and depths of operation of tractor implement combination. It was found that during different depths at constant forward speed of the planter, the wheel slip was increased while increasing the depth of operation as shown in **Fig. 6**. The reasons for increasing the wheel slip while increasing the depth of operation maybe due to increase in draft force of the planter.

Theoretical and Effective Field Capacity

The theoretical field capacity and effective field capacities of the planter were calculated. Theoretical field capacity found to vary from 0.06 to 0.15 ha/h with an average value of 0.1 ha/h and effective field capacity found to vary from 0.05 to 0.11 ha/h with an average value of 0.076%, as the change in speed of operation from 1.0 to 2.5 km/h respectively. The field capacity was increased with increase the speed of operation; it may be due to the increase in rated time of operation. The **Fig. 7** shows the effect of operating speed on field capacity of developed planter. During field evaluation, it was observed that, the field efficiency seen to vary from 83.3 to 73.6% as the change in speed of operation from 1 to 2.5 km/h (**Fig. 8**). It may be due to the less theoretical time consumed while increasing in speed.

Seed Damage Percentage

The seed damage percentage of the planter was measured under laboratory condition. It was observed that, for 10 revolutions of the ground wheel on lifted position, the total quantity of collected seeds were 40 in each row, in which the number of damaged seeds were observed as 2 and is presented in **Table 3**. Therefore, the seeds damaged percentage was obtained as 5%. During testing it was observed that the timing of seed drop was irrespective of the rotation of ground wheel speed. The experiments were conducted for 20 revolutions of the ground wheel, and then also found the similar type of results. It clearly shows that the developed ground planter is suitable for planting of groundnut seeds without any damage.

Measurement of Water Saving Percentage

The water saving of the site specific precision water applicator was observed under actual field condition. It was found that the average water consumption without activation of IR sensor is about 10.8 litre,

Fig. 6 Effect of depth of operation on wheel slippage of ground wheel

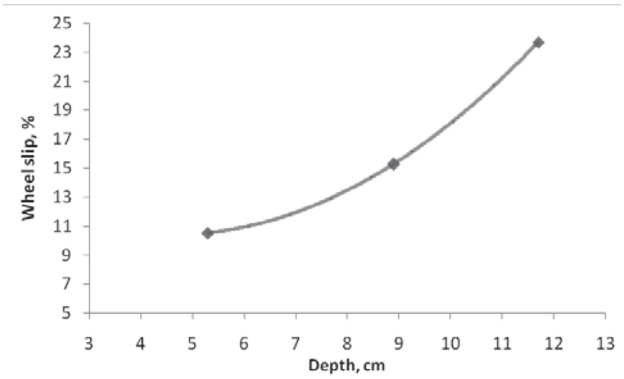


Fig. 7 Effect of operating speed on field capacity

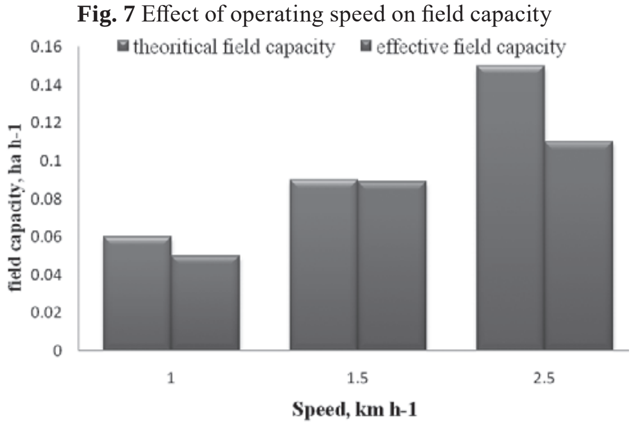
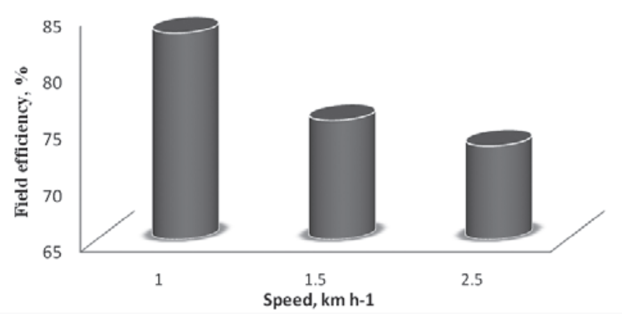


Fig. 8 Effect of operating speed on field capacity



whereas the water consumption of the system with activation of the sensor system is observed as 2.4 litre. It was also observed that the percentage water saving of the developed site specific precision water application is about 77%. The experiment was replicated three times for its better performance.

Conclusions

The following major conclusions may be drawn from the present study:

a) A mini tractor mounted groundnut aqua planter was designed and developed; however, it can also be fitted to any agricultural self propelled unit with suitable modifications.
b) The developed groundnut planter is able to plant the seeds at required depth and interval.
c) The designed seed metering mechanism was able to deliver the precise amount of seeds (only one seed).
d) An electronic control unit (ECU) was developed for site specific precision water/water application after seed delivery.
e) The developed IR obstacle sensor object detection unit was able to detect the seed up to the range of 3 cm without any malfunction.
f) The developed ECU is able to detect the seeds in three seed tubes and activate the corresponding solenoid valves simultaneously if seed is detected
g) The developed ground nut planter and ECU was integrated to work as a single unit for planting as well as site specific water/water application simultaneously in a single operation.
h) The planter cum site specific precision water application unit was tested under laboratory and field condition and found satisfactory results.
i) The developed site specific precision water applicator unit can also be used as herbicide applicator by replacing the water.
j) By using this Electronic Control Unit (ECU) technology an amount of 77% water consumption can be saved.
k) With this sensor based technology application of excess liquid water consumption could be saved which leads to reduction in environmental pollution.

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Design, Development and Performance Evaluation of a Power Operated Rice Seeder for Dry and Wet Seeding

by

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Abstract

Direct seeded rice (wet or dry row seeding) is one of the methods suitable for rainfed rice cultivation in Chhattisgarh, India. In wet seeded rice (WSR), the pre-germinated seeds are broadcasted or sown in rows on the saturated soil surface, after puddling. Dry seeded rice (DSR) involves broadcasting or drilling the seed into non-puddled soil, usually after dry tillage. There is no such single versatile machine available for used in both WSR and DSR cultivation. Thus, a power operated 8-row riding type commercially available rice transplanter was modified for direct-seeded rice for the wet and dry condition. It consists of a 4-stroke 2.94 kW, 2600 rpm air cooled diesel engine, power-driven traction wheel, gear box, universal coupling, sets of bevel and spur gear, float for wet seeding and hoe type furrow openers for dry seeding, and cup feed metering mechanism. The cup dimensions of 12 mm diameter and 10 mm depth were found best with a permissible peripheral velocity up to 20.5 m/min. A series of cup type metering mechanism containing seed disc with a funnel was linked horizontally. It could cover 8 rows of seeds in a single pass. The row to row spacing was 20 cm. An opening was made in the upper part of the seed box for storing the dry seeds or pre-germinated seeds at the time of operation under dry or wet field conditions respectively.

The plant to plant spacing can be varied from 20, 15 and 10 cm by using 4, 6 and 8 numbers of cups, respectively. The average seed rate for 20 cm row to row and 15 cm plant to plant spacing was found to be 17.8 kg/ha and 22.1 kg/ha for wet and dry conditions. The actual field capacity and field efficiency for wet and dry conditions of the machine was 0.22 ha/h & 0.25 ha/h and 71.8% & 77.6%, respectively. The average fuel consumptions were found to be 2.88 l/ha and 2.56 l/ha for wet and dry conditions. The cost of operation of sowing of rice by power operated rice seeder was Rs.1043/ha which was 7.8 times less than from manual transplanting of rice and 2.3 times less than riding type mechanical rice transplanter. Per hectare cultivation cost of rice by power operated rice seeder on wet and dry field condition was Rs 22,025 and Rs 25,110, with B:C ratio as 2.9 and 3.5, respectively.

Introduction

Rajkumara et al. (2003) reported that transplanting is becoming an increasingly difficult option due to shortage and high cost of labour, scarcity of water and the reduced profit. Wet seeding on puddled soil either through broadcasting or in rows is gaining popularity due to lower labour requirement, shorter crop period and efficient water use.

Direct-seeding of rice has the potential to provide several benefits to farmers and the environment over conventional practices of puddling and transplanting. The various benefits are enumerated below:

a. Saves labour (1-2 v/s 25-30 labour/ha for transplanting system).
b. Sowing can be done in stipulated time frame because of easier and faster planting.
c. Early crop maturity by 7-10 days which allows timely planting of subsequent crops.
d. More efficient water use and higher water stress tolerance.

e. More profitability especially under assured irrigation facilities.
f. Better soil physical conditions.

Limited operation window is available for DSR in the rainy season. If rains continue, the soil becomes saturated. Under such circumferences using the conventional seed drill for DSR becomes difficult due to clogging and chocking of furrow openers. Under such circumstances, manual sprouted rice drum seeder is one of the options for sowing pre-germinated paddy seeds. Balasubramaniam et al. (1998) defined drum seeder is the machine, which sows dry seeds at specified rates on seedbed. The wet seeder means the machine that uses wet seeds (soaked and incubated seeds) and spread seeds on wet seedbed on wet puddled soil. Suibbaiah et al. (2002) evaluated the performance of a drum seeder in farmer's fields. Crop established with the drum seeder resulted in higher mean grain yield (4.63 t/ha) that was at par with transplanting (4.25 t/ha) and superior over broadcasting (3.34 t/ha).

Visalakshi and Shreesha (2013) evaluated the performance of a drum seeder in direct sown paddy under puddled condition during *Kharif* season for three years to evaluate the efficiency of drum seeder at different seed rates (20, 30 and 40 kg/ha) and optimum seed rate was quantified. The results showed that use of the drum seeder at 30 kg seed/ha recorded increased grain yield by 26% and 22% (7.58 t/ha), respectively over that of 20 and 40 kg/ha seed rate. It was also found superior to normal transplanting and broadcasting of sprouted seed @ 75 kg/ha. Drum seeder technology @ 30 kg seed per ha reduced the seed rate by 45 kg/ha as compared to the broadcasting of seed on puddled soil and resulted in a higher return to farmers over normal transplanting/broadcasting of sprouted seeds.

The constraints to adopting drum seeder technology are the requirements of adequately puddled, leveled and properly drained fields. Pulling them on puddled fields involves drudgeries. Besides this, their capacity is rather low. Hence covering larger areas of rice is tedious and time consuming. Therefore it is necessary to develop a machine which can be operated in both dry and wet field conditions.

Materials and Methods

Commercially available 8-row riding type power operated rice transplanter was modified for dry seeded rice (DSR) and wet seeded rice (WSR) with some modification in the transmission system and development in the metering unit for the sowing of dry or germinated rice seeds. So that uniform distribution of seeds in both conditions by the single machine should be done. The engine power was utilized for the forward movement of the driving wheel as well as for rotation of metering mechanism. The design of machine components was based on the principles of operations. The mechanical design details were also given due consideration.

Assumptions for the Design

The following assumptions were made while designing of the power operated paddy seeder:

a. The power operated paddy seeder should be capable of working in both dry as well as wet field condition. The design should be simple for quick interchangeability with limited tools.
b. The number of seeds placed simultaneously in particular rows should be roughly the same over each meter of row length.
c. The seed rate of power operated paddy seeder can be changed from 15 to 25 kg/ha.
d. The number of seeds requires 3 to 4 seeds per drop for DSR and 2-3 per drop for WSR.
e. The row to row spacing should be 20 cm.
f. The distance between plant to plant distance should be maintained either 20 cm, 15 cm or 10 cm as per requirements through by changing the number of cups in the metering disc of the cup feed mechanism.
g. Placing of seeds at an appropriate depth and covering with soil layer.
h. Seeds should not be injured by the seed metering and placement devices.
i. The material of construction of different components should be easily and locally available. Use of standard sizes of steel section, fasteners and chains would help in easy inter-changeability and replacement of any part as per re-

Fig. 1 Conceptual design for Direct Seeded Rice (DSR) and Wet Seeded Rice (WSR)

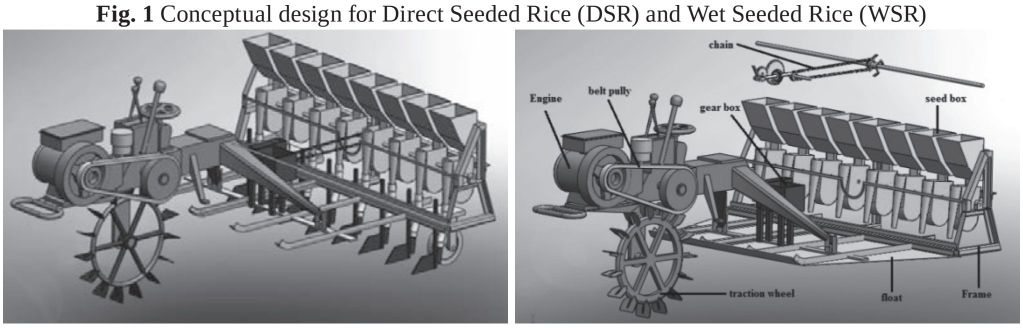


Table 1 Brief specification of the power operated rice planter for wet and dry field

Particular	Specification
Engine	Air cooled diesel
Power	2.9 kW (4 hp)
Rated rpm	2600
Traction wheel	0.67 m, No. of lugs -15
Transport wheel cum depth control wheel	240 mm diameter, width -50 mm
No. of rows	8
Row spacing (cm)	20
Plant to plant spacing (cm)	10, 15 and 20 cm
Seed metering	Cup feed type
Metering shaft speed adjustment	Change of sprocket
Float for wet field	Stainless Steel
Furrow opener for dry field	Hoe type
Overall dimension (L × W × H)	2550 mm × 1980 mm × 1100 mm

quirement.

Design of Power Operated Paddy Seeder for Dry and Wet Field Conditions

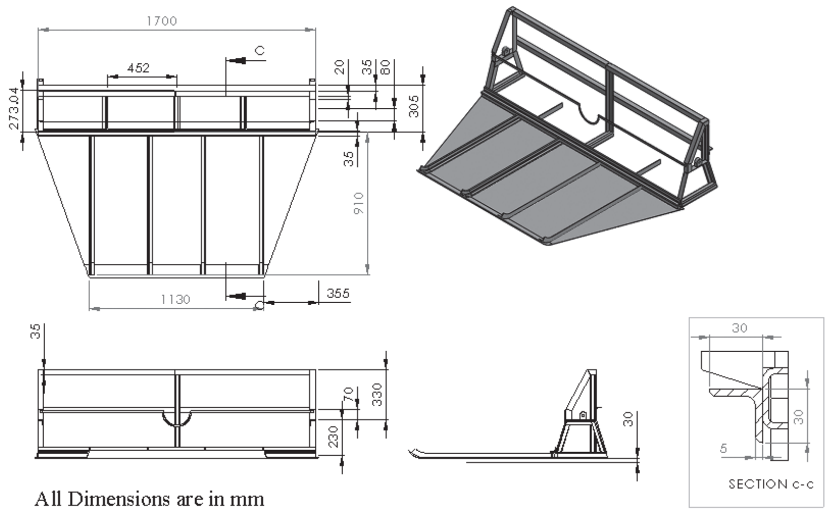
Based on the agronomic requirement of paddy and assumption made, the power operated paddy seeder for dry and wet field condition was developed by designing the individual components. The conceptual design of the machine for Direct Seeded Rice (DSR) is shown in **Fig. 1a** and wet seeded rice (WSR) in **Fig. 1b**.

Brief Details of the Developed Power Seeder

The specifications of the machines are presented in **Table 1**.

It is a single wheel, 8-row riding type machine fitted with a 2.94 kW, 2600 rpm, single cylinder, air cooled diesel engine which powers the forward movement of the driving wheel and rotary motion to the metering mechanism. The drive wheel receives power through V-belt, cone clutch and gear box. Gear box for ground wheel comprises three sets of the spur gear. The input shaft of gear rotates at speed of 1300 rpm and then according to the shifting of gear lever it reduced up to 185 rpm. A universal shaft from the gear box provides power to the sets of bevel and spur gear box and from then power is transmitted to input shaft of gear box of metering mechanism as 468 rpm and then finally reduces up to 20.5 m/s peripheral speed to the cup feed metering mechanism through chain sprocket assembly mounted over the float. The row to row spacing maintained by power seeder was 20 cm and plant to plant spacing can be varied from 10 cm to 20 cm by changing the number of cups. It is sowing the seeds in eight rows in a single pass. The design was simple and easy for farmers to use. An opening was made in the upper part of the seed box for storing the pre-germinated seeds at the time of operation under wet field condition. Funnel and seed disc with cup feed was placed inside the seed box for the effective dropping of seeds from the seed box to the field.

Fig. 2 Isometric view of the frame



Design of Frame

Mild steel (MS) square section frame was designed to mount furrow openers for dry sowing and stainless steel float for wet seeding. The seeding mechanism was mounted on a frame at the rear side of power seeder. The main frame was designed for maintaining the proper height of the drop of seed during sowing. Eight furrow openers 20 cm apart were arranged on tool frame for dry seeding. The frame design was based on the stresses produced. The frame was subjected to torsion and bending due to induced draft. On the basis of the cross-sectional area of furrow opener (11.4 cm^2) specific soil resistance for the heavy soil (0.2 kg/cm^2), 8 furrow openers were arranged in a single bar. By the calculation, a hollow square bar section 30 × 30 × 5 mm was selected. The overall dimension of the frame was 1130 × 1700 × 910 mm. The height was kept to 55.5 cm. The isometric view of the main frame is shown in **Fig. 2**.

Float

The floating mechanism was an important part of the machine, as it helps the machine to float in muddy conditions without sinking. The floats reduce the ground reaction due to the buoyancy effect. In the present study float made of the stainless sheet which controls the depth of shearing as required in different ground conditions. The float was curved at the front end to avoid the entry of puddled soil on it. The shape of the float was trapezoidal and the front width was 1140 mm and rear width was 1700 mm. The length of the float was 800 mm.

Design of Cup Feed Metering Device

The cup feed metering mechanism was chosen for maintaining the plant to plant distance within the row. The design methods were adopted as given by Sharma and Mukesh (2010) for a seed metering mechanism. The average length of the rice seeds commonly grown varieties by the farmers was 9.3 mm. Therefore, taking 25-30% additional length for sprouted rice, the diameter of the cup of the metering device was taken as 12 mm. The diameter of the shaft for revolving metering was 30 mm. The metering unit consists of seedboxes, cup feed, Seed conveyor, receiving the box.

The cross-section of the seed box was trapezoidal in shape. It was made of MS sheet of 18G. The bottom was kept inclined from the horizontal. The dimension of seedbox was 195 × 180 × 240 mm. The capacity of each seed box was 3.25 kg. Total 8 numbers of seed boxes were mounted in the mainframe. Seed conveyor having the dimension of 40 × 15 × 10 mm was used to covey seed from cup to receiving a box from which seed goes to the furrow through the tube in dry field condition and for wet condition, the seed goes directly into the puddled soil. The row to row spacing maintained by seeder was 20 cm and plant to plant spacing was 20, 15, 10 cm by using 4, 6 and 8 cups of seed metering units. The cup feed and seed conveyor is shown in **Fig. 3**.

Receiving boxes were attached just below the metering device for receiving the seeds which were dropped from the metering unit to the soil. The dimension of the box is 210 × 200 × 50 mm made of MS. Details of the receiving box is shown in **Fig. 4**.

Power Transmission System

The forward motion of seeder was achieved through the drive wheel. The drive wheel works in puddled soil offers rolling resistance, as well as tractive efforts. The engine was mounted at the front side of the seeder. Hence most of the weight was available on the drive wheel of the machine. Power seeder consists of two gear boxes. The first gear box was used to provide power to the traction wheel and the second gear box was used to give power to the shaft of the metering mechanism (**Fig. 5**). The power transfers from the engine to the gearbox through the universal cross shaft and finally to the metering mechanism. Gearbox comprises of three sets of the spur gear. The input shaft of gearbox rotates at speed of 1300 rpm in which one spur gear was attached having 20 numbers of teeth. This spur gear was engaged with another spur gear having 40 numbers of teeth which rotate the countershaft and it reduces 1300 rpm to 650 rpm. In first gear, 20 number of teeth serve as driver gear that meshed with driven gear having 70 number of teeth, which reduced the speed from 650 rpm to 185 rpm. When second gear engages then 22 num-

Fig. 3 Cup feed and seed conveyor

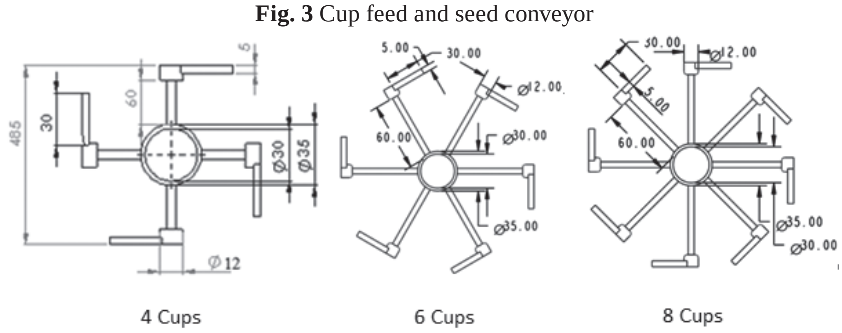


Fig. 4 View of receiving box

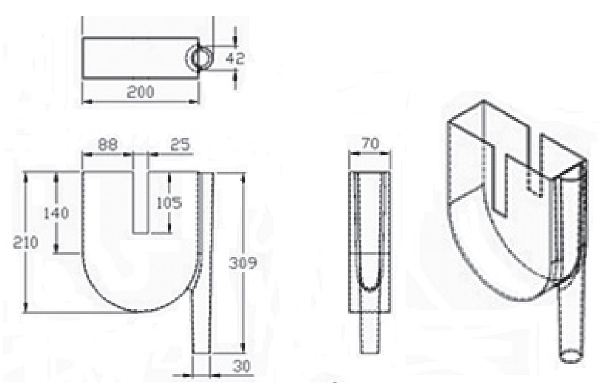
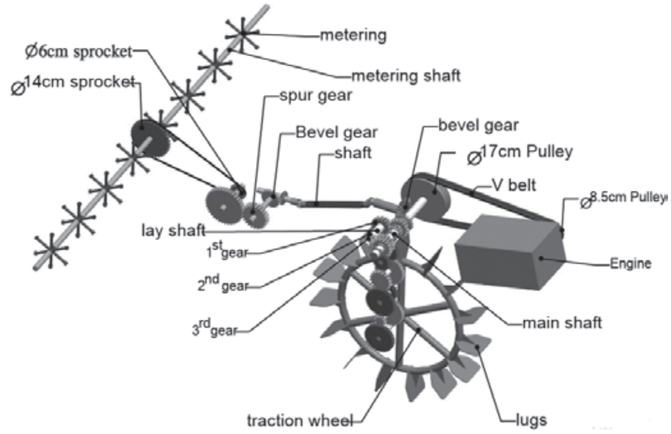


Fig. 5 Power transmission system of Power operated paddy seeder



ber of teeth of driver gear rotates along with 38 numbers of teeth with a speed of 376 rpm. When the third gear engaged then 24 numbers of teeth of driver gear rotates along with 22 numbers of teeth with a speed of 709 rpm.

Gearbox for the metering mechanism was placed over float it consists of an assembly of bevel and spur gear. Input speed to the gearbox was 520 rpm which is received by the bevel pinion having 16 numbers of teeth which was engaged with bevel gear of 40 numbers of teeth and transmitted to the spur gear having teeth 28 with the help of revolving shaft of 30 mm diameter. The speed received by this spur gear was engaged with another spur gear having 44 numbers of teeth and transmitted to the metering shaft with the help of chain sprocket mechanism. The number of teeth in pinion sprocket was 12 and the number of teeth in driving sprocket was 48.

Ground Wheel

The ground wheel is a device which receives power from the engine through several sets of gear and makes possible to the forward motion of the power seeder. The peripheral speed of the ground wheel was 21 rpm with a diameter of 0.67 m. Lugged type wheel was used for designing of the ground wheel which was made of cast iron because of its suitability under wet or sticky soil whereas pneumatic wheel was used in road condition.

Results and Discussion

Power operated paddy seeder was designed, fabricated and performance evaluated in the field of Indira Gandhi Agricultural University Raipur. The variety of paddy seeds taken for the study was MTU-1010. The field testing was performed by 6 cups per disc metering mechanism in both DSR and WSR. The average length, width, and thickness of dry rice seeds were 9.18 mm, 2.41 mm and 1.93 mm respectively. The soil of the study area was silty loam (Inceptisols). The average bulk density of paddy was 0.6 g/cc. For DSR the field was prepared by two passes of the cultivator and one pass of disc harrow. The average moisture content at 20 cm depth was 15.2% on a dry basis. The bulk density of the soil sample was 1.45 g/cc. The mean diameter of soil clod size was 38.4 mm after seedbed preparation. For the preparation of the puddled field for WSR one summer ploughing was done at friable moisture condition (17.4% dry basis). Pre-germinated rice seeds were sown in the puddled field after 36 h of the soil settlement period. The average float sinkage was observed at 2.4 cm.

Germination Test of Paddy Seed

Seed germination test was conducted for dry seed (T_1), 24 h water soaking than 12 h incubation period (T_2), 24 h water soaking than 24 h incubation period (T_3), 24 h water soaking than 36 h incubation period (T_4) and 24 h water soaking than 48 h incubation period (T_5). For all the treatments 300 seeds were sown into the randomized block field and plant population after 10 days was noted. The plant germination of paddy seed from the dry seed was observed as 61.2 percent. The pre-germination test of paddy seed incubation period from 12 h, 24 h, 36 h, and 48 h after 24 h of soaking the germination percentage was obtained as 62.7 %, 67.2 %, 79.3 and 74.2 % respectively (**Table 2**). The result shows that there was a significant difference in germination percentage at various incubation periods at 5% level of significance.

Methodology for Measurement of Performance Parameters

The performance testing of power operated eight-row paddy seeder was carried out as per test code and procedure provided by RNAM (1995) during the year 2017 & 2018. The power operated paddy seeder was calibrated in the laboratory for desired seed rate. Three different numbers of cups viz. 4, 6, and 8 on each seed metering units were used. The calibrations results are as given in **Table 3**.

Table 2 Germination percentage of paddy seed

Treatment	Number of seed taken	The average length of sprout, mm	Average Germination %
T_1	300	-	61.4
T_2	300	0.68	62.3
T_3	300	1.23	67.3
T_4	300	1.96	79.3
T_5	300	2.93	75.7

Table 3 Average seed rate by using different numbers of cups in the metering unit

	Average seed rate (kg/ha)		
	Four Cups	Six Cups	Eight Cups
Average	11.60	17.81	22.03
SD	0.83	0.78	1.09
CV (%)	7.19	4.36	4.96

Table 4 Plant to plant spacing

Number of cups in metering disc	Spacing (cm)		
	Mean	SD	CV (%)
4	18.91	2.14	11.30
6	13.93	1.10	7.88
8	9.05	1.46	16.17

Performance Evaluation of Power Seeder for Dry Seeded Rice

Machine Parameters

The field performance parameters viz. row to row spacing, depth of seed, number of seeds per drop, number of seeds per square meter, speed of operation, sinkage, miss index and multiple index, etc. were measured during the field test. The row to row distance was 20 cm. the average depth of the seed in the row was 3.24 cm. The average number of seeds dropped per hill was observed 2-3 seeds per hill. The average hill spacing was influenced by the number of cups per metering disc. The hill spacing increased with the decrease of cups in disc irrespective of germination conditions (**Table 4**).

Miss index (MI) and multiple index (DI) values for WSR are given in **Table 5**. Miss index (MI) was highest (5.12%) for 8 cups metering mechanism. It was found lowest with 4 cups metering mechanism. Multiple index (DI) was counted among the randomly selected 5 m segment of eight rows. MI was also found the minimum for 4 cups. Lower values of the MI and DI indicate the better performance of the machine as compared to 6 and 8 cups. However, 6 cups and 8 cups were also performed satisfactorily. The actual field capacity varies according to the speed of operation and time taken to cover the field. The actual field capacity and field efficiency were found at 0.25 ha/h and 77.6%. Fuel consumption of the power seeder was calculated by topping method. The average fuel consumption was 2.68 l/ha in dry seeding condition.

Crop Parameters

The plant height and effective tillers per m^2 at 30 DAS, 60 DAS and at harvest was taken on DSR during the year 2017 and 2018 (**Table 6**).

Performance Evaluation of Power Seeder for Wet Seeded Rice

Machine Parameters

The field performance parameters viz. row to row spacing, number of seed per drop, number of seeds per square meter, speed of operation, sinkage, miss index and multiple index, etc. were measured during the field test. The average number of seeds dropped was close to the theoretical no. of seeds per hill i.e. 2-3 seeds. The average hill spacing was influenced by the number of cups in the metering disc (**Table 7**).

Skips or misses created when seed drooping cup fail to drop seed during sowing. It was observed that miss index and multiple index were 2.5, 4.1 & 4.5% and 3.9, 4.7 and 5.1% for 4, 6 and 8 cups respectively. It was noticed that lower values of miss index and multiple index were found in wet seeded rice as compared to direct seeded rice. The actual field capacity and field efficiency were found as 0.23 ha/h and 72% respectively. This was less

Table 5 Miss index (MI) and multiple index (DI)

S.No.	4 Cups		6 Cups		8 Cups	
	MI %	DI %	MI %	DI %	MI %	DI %
Mean	3.22	3.63	5.12	4.35	5.12	5.57
SD	1.17	1.09	1.34	1.33	0.94	2.12
CV	36.39	30.01	26.25	30.62	18.39	38.09

Fig. 6 Power operated paddy seeder for dry seeding and sown crop

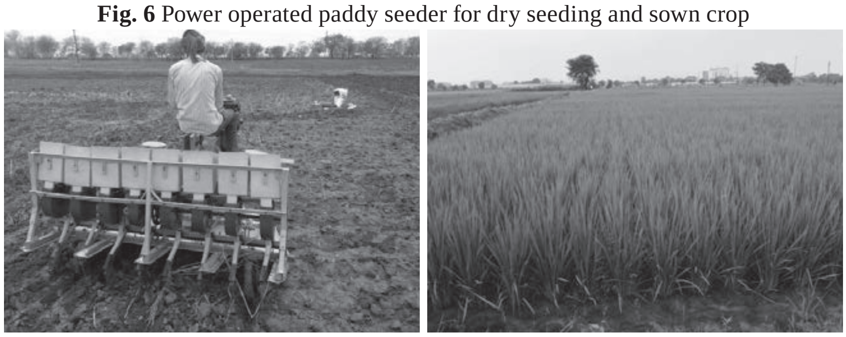


Table 6 Crop Parameters under direct dry seeded rice

Observation	30 DAS						60 DAS						At Harvest					
	Year						Year						Year					
	2017			2018			2017			2018			2017			2018		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Plant height (cm)	39.9	5.0	12.5	44.4	3.2	7.3	62.5	5.1	8.1	72.8	2.7	3.7	108.1	4.2	3.9	113.8	2.4	2.1
Number of tillers/m^2	211.6	9.2	4.3	199.8	13.4	6.7	215.9	8.6	4.0	204.2	14.4	7.0	222.8	7.1	3.2	217.6	14.9	6.8
Panicle length (cm)	-	-	-	-	-	-	-	-	-	-	-	-	18.7	1.5	7.9	19.4	0.9	4.6
Grain yield (q/ha)	-	-	-	-	-	-	-	-	-	-	-	-	41.1	1.8	4.4	43.7	1.7	3.9
Straw yield (q/ha)	-	-	-	-	-	-	-	-	-	-	-	-	47.5	1.5	3.2	51.9	2.8	5.4
Harvest Index (%)	-	-	-	-	-	-	-	-	-	-	-	-	46.4	1.8	5.8	45.7	1.9	4.8

Table 7 Plant to plant spacing on wet condition

Number of cups in metering disc	Spacing (cm)		
	Mean	SD	CV (%)
4	19.8	1.9	9.4
6	14.6	1.4	9.6
8	9.7	1.2	12.3

as compared to dry field condition because of the low operating speed of the machine and more turning losses. The average fuel consumption was found at 2.83 l/ha.

Crop Parameters

The plant height, number of tillers, panicle length at 30 DAS, 60 DAS and at harvest was taken and the result is given in **Table 8**. The average spacing was closed to the theoretical spacing of 15 cm with 6 numbers of cups in the metering unit. The fuel consumption varied between 2.78 to 2.98 l/ha with an average of 2.83 l/ha in wet condition. The actual average seed rate was found to be 17.81 kg/ha in six cups. The field efficiency of paddy seeder in wet condition was 71.88 %. The average length of panicle was found 20.7 cm. It was observed that the length of panicles varies significantly at 5 % level of significance for DSR and WSR. The yield was found 57.4 q/ha in the year 2016 and 57.8 q/ha in the year 2017.

Cost Analysis

The cost of the developed self-propelled paddy seeder was calculated to be Rs. 95,100. The costs of operation of power operated rice seeder for dry and wet seeding has been computed and are given in **Table 9**. The per hectare cost of operation for manual transplanting and mechanical rice transplanting by 8 rows riding type rice transplanter were calculated on the basis of prevailing rates and it was found to be Rs. 8,149 and Rs. 2,403 respectively.

Costs of production were assumed to be the money expenditure incurred for the resources used to produce rice. The total cost of production of rice under DSR and WSR was calculated and it was found Rs 22024/ha and Rs 25112 /ha, respectively. The Benefit-Cost ratio (BCR) was found as 2.9 for DSR and 3.5 for WSR. Based upon the result it was concluded that farmers are able to grow rice if they fail to direct dry sowing due to continuous rains comes and saves the cost of operation of sowing of paddy from power operated paddy seeder it was Rs.1043.3/ha which was 7.83 times less than manual transplanting of rice and 2.3 times less than mechanical rice transplanter.

Fig. 7 Power operated paddy seeder for wet seeding and sown crop

Conclusions

1. A self-propelled 8-row riding type mechanical transplanter has been modified for wet seeded per-germinated rice on puddle field or direct seeded dry rice into non-puddled soil after dry tillage. The actual field capacity for wet and dry conditions of the machine was 0.22 ha/h & 0.25 ha/h respectively. The developed machine can be used for both the conditions as per the requirement.
2. The seed rate can be varied with

Table 8 Crop parameters under direct wet-seeded rice

Observation	30 DAS						60 DAS						At Harvest					
	Year						Year						Year					
	2017			2018			2017			2018			2017			2018		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Plant height (cm)	37.8	3.7	8.6	47.0	0.6	1.3	66.2	2.6	3.9	74.1	3.7	5.0	106.1	6.0	5.7	114.6	2.7	2.3
Number of tillers/m^2	196.6	12.9	6.6	211.1	4.3	2.0	200.8	13.4	6.7	214.3	4.7	2.2	227.8	18.5	8.1	234.5	3.4	1.4
Panicle length (cm)	-	-	-	-	-	-	-	-	-	-	-	-	20.9	1.0	4.6	20.5	0.7	3.8
Grain yield (q/ha)	-	-	-	-	-	-	-	-	-	-	-	-	57.4	1.68	3.07	57.8	1.4	2.7
Straw yield (q/ha)	-	-	-	-	-	-	-	-	-	-	-	-	61.3	1.2	2.0	61.0	1.6	2.7
Harvest Index (%)	-	-	-	-	-	-	-	-	-	-	-	-	47.2	1.3	4.8	46.6	1.7	5.2

changing the hill spacing 20 cm, 15 cm and 10 cm by using 4 cups, 6 cups and 8 cups, respectively in the metering mechanism. The plant to plant distance increased with a decrease in the number of cups on metering unit irrespective of germination and hopper filling conditions. The corresponding seed rates obtained were, 11.60 kg/ha, 17.81 kg/ha and 22.03 kg/ha.

3. The average number of seeds dropped per hill was 3-4 seeds in dry seeding and 2-3 seeds in wet seeding for pre-germinated seeds of sprout length 2 mm. The plant germination of dry paddy seed was observed as 61.2% and pre-germinated seeds after 24 h soaking and then incubation period of 12 h, 24 h, 36 h, and 48 h was obtained as 62.7%, 67.2%, 79.3% and 74.2%, respectively.
4. The cost of operation of sowing of rice by power operated rice seeder was Rs.1043/ha which was 7.8 times less than from manual transplanting of rice and 2.3 times less than riding type mechanical rice transplanter. The B:C ratio found 2.9 and 3.5 by using power-operated rice DSR and WSR respectively.

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Table 9 Cost of operation of developed paddy seeder and cost of cultivation of rice

Particulars		Cost, Rs.
The capital cost of the machine	C	95100
Life of Machine in Years	L	10
Working Hours per Year	H	200
Salvage Value	S	9510.0
Interest value	I	0.1
Fixed Cost		
Depreciation, Rs/h		42.79
Interest on the capital, Rs/h		26.15
Housing Rs/h	1 % C	4.75
Taxes	1 % C	4.75
Insurance	1 % C	4.75
Total Fixed Cost, Rs/h		83.19
Operating Cost		
Repair and Maintenance cost @ 6% of capital cost per annum, Rs/h		28.53
Fuel Cost @ 71 Rs per liter, Rs/h		49.7
Lubrication cost @ 30% of the fuel cost, Rs/h		14.91
Wages of 2 operators (Rs. 281/day) Rs/h		70.25
Total operational cost		163.39
Total cost, Rs/h		246.58
Total cost, Rs/ha (Dry seeding)		986.32
Total cost, Rs/ha (Wet seeding)		1072.09

Comparative cost of cultivation of rice under different prevailing practice

	Rice seeder for dry and wet seeding	Rice Transplanter	Manual transplanting
Cost of operation (Rs./h)	1072.09	2402.63	8149.0

Effects of Tillage Systems on Grain Production in the Republic of Buryatia, Russia

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Abstract

We determined the impact of different tillage systems on grain yield and costs on Kolkhoz Iskra farm near Ulan-Ude, in the Mukhorshibirsky region, Republic of Buryatia, Russia, in 2013-2015. On average, the productivity of oats cultivated by no-tillage and minimum tillage systems increased over the three years. Minimum tillage and no-tillage systems are expedient, profitable alternatives to conventional moldboard soil tillage because they cost less, and lead to an increase in crop yield and conservation impacts on the soil as compared with the conventional system.

Keywords: grain production, tillage systems, yield, resource-saving technology, Republic of Buryatia

Introduction

Grain production is one of the main agricultural sectors in the Republic of Buryatia, Russia. Severe climatic conditions, specific landscape traits, and soil diversity are among the causes of unsustainable grain production in the Republic (Bolonev, 2001). The total sown area is 152 600 ha, with grain and leguminous crops occupying about 56% of this total. Wheat represents the most significant share of grain crops, accounting for over 52.7%, followed by oats and barley (Federal State Statistic Service, 2016).

The main types of soils in the arable land of Buryatia are chestnut soil (43.2%), gray forest soil (22.5%), and black earth (12.3%) (Batudaev et al., 2010). The conventional moldboard cultivation technology, which involves multiple passes of tractors and machines in the field, was implemented in the Republic during the Soviet period. Theoretical and technological recommendations for farming that did not consider local specifics were developed in the central regions of the USSR. As a result, problems of soil compaction and fertility preservation of arable land have arisen and become more acute every year (Batudaev et al., 2010).

The following critical problems of grain production have to be addressed: (1) Cultivated crop yields must be increased; (2) Costs must be reduced and crop production profitability increased; and (3) Soil fertility must be restored and improved. The key to solving these problems requires involvement of all technologies toward resource saving, based on Russian and world experience (Revyakin et al., 2011).

Sustainable agriculture should be organized into a system and analyzed as a relationship: soil-plant-climate area-socioeconomic conditions-crop efficiency (Wang et al., 2008; Bucur et al., 2011; Afzalinia et al., 2012; Domuta et al., 2012). Multifunctional technologies aim to reduce resource consumption, particularly in the area of aggressive soil tillage, while simultaneously obtaining high yields, soil conservation, and environmental protection. (Ailincai et al., 2011; Marin et al., 2011; Gao et al., 2012).). The influence of soil tillage systems on soil properties and resource efficiency is shown by the important effects they have on conservation of soil fertility and the sustainability of agricultural systems. (Uhlin, 1998; Sarauskis et al., 2009; Vural and Efecan, 2012).

Currently, the most promising soil-protecting, resource-saving methods include minimum tillage and no-tillage. Minimum tillage and no-tillage aim for maximum accumulation and conservation of moisture in the soil, reduction of machinery passes over the field, and reduction in total costs for grain production (Rusu, 2014; Sandakov et al., 2019).

The most evident effect of tillage is documented for soil organic matter. Reicosky (2001) reports that under comparable rotation there is a gradual increase in soil organic matter under minimum tillage regimes. The highest humus content is found in no-tillage and the lowest in plowing systems. Moreover, the distribution pattern of organic matter in the soil profile matches very closely the concentration of soil biota, showing high levels in the topsoil and declining with depth. Carbon enrichment of unplowed soils indicates that the conservation of soil organic matter contributes to carbon sequestration and lower global warming impacts (Reicosky, 2001). Domestic studies on the use of resource-saving technologies also affirm humus increase in the soil (Panov et al., 2008).

Over the last decade, several studies (Larionova et al., 2003; Ro-

Table 1 Machine Specification

Specification of Tractor K-701	
Type of machinery	Harrowing, moldboard plowing, and cultivating.
Manufacturer	Peterburgsky Traktorny Zavod
Engine power, kW	220
Dimensions: length/width/height, m	6.82/2.85/3.68
Total weight, kg	11450
Specification of Plow PLN 8-40	
Type of machinery	Plowing to a depth of up to 30 cm in various soils that are not clogged with rocks, stones, or other obstacles
Manufacturer	Belagromash
Field capacity, ha / h	2.9
Number of furrows	11
Working width, m	2.8
Dimensions: length/width/height, m	4.55/3.91/1.22
Total weight, kg	1025
Specification of Cultivator KPE-3.8	
Type of machinery	Presowing (up to 16 cm depth) and autumn soil tilling, with up to 50% stubble remaining on the surface
Manufacturer	LesAgroMash, Kirov
Working width, m	3.91
Field capacity, ha / h	2.35-3.50
Dimensions: length/width/height, m	6.55/3.91/0.22
Total weight, kg	1150
Specification of Seeder SZU-3.6	
Type of machinery	Grain seeding and applying fertilizer
Manufacturer	TD Agro-Resurs, Lipetsk
Working width, m	3.6
Field capacity, ha / h	3.2-4.3
Insertion depth, m	0.4-0.8
Dimensions: length/width/height, m	4300/3700/1650
Total weight, kg	1380

Fig. 1 Map of the study site

Table 2 Crop calendar for oat production in Buryatia

	Apr.			May			June			July			Aug.			Sept.			Oct.		
Tillage			↔	↔																	
Seeding					↔	↔	↔														
Cultivation									↔	↔											
Harvesting															↔	↔					
Straw Harvesting																	↔	↔	↔		

manovskaya, 2008; Vuichard et al., 2008; Kurganova et al., 2010, 2014; Schierhorn et al., 2013) aimed to estimate the total carbon sequestered in Russian soils due to the croplands abandonment. However, such estimations were not performed for the croplands of the Republic of Buryatia, leaving this important research topic unexamined. Nor has there been sufficient past research, or scientific results, in the area of soil compaction mitigation and its evaluation from the standpoint of yield and costs in Buryatia. This article, therefore, aims to add to the robust experiment-based knowledge that does exist and to determine the impact of different tillage systems on grain yield and costs in Buryatia.

Materials and Methods

Study Site

We carried out experimental work on Kolkhoz Iskra farm near Ulan-Ude (51° 8' 11.4828" N, 108° 14' 14.2908" E) of the Mukhorshibirsky region in the Republic of Buryatia, Russia, in 2013-2015.

Experimental Conditions

To test the efficiency of minimum tillage compared with conventional tillage, we carried out a production experiment according to the following conditions (**Table 1**):

A: Conventional. Moldboard plowing - K-701, PLN 8-40. Separate seeding with SZU-3.6.

B: Resource saving. Cultivation with APD-7.2. Separate seeding with SZU-3.6.

C: Resource saving. Cultivation with APD-7.2. Seeding with Kuzbass-8.5.

D: Resource saving. Simultaneously cultivating and seeding with Kuzbass-8.5.

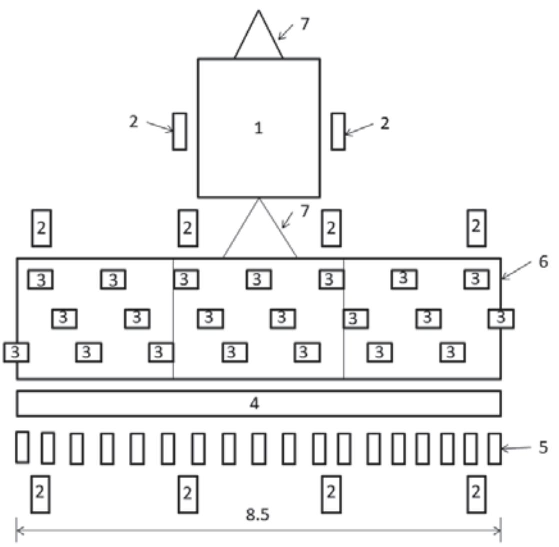
The oats variety was Dogoi, the seeding rate was 4.5 million pcs grains per ha, and the sowing date was 27 May. Crop care and harvesting were the same in all variants of the experiment (**Table 2**).

Seedling Complex Kuzbass-8.5

We also carried out a comparative test of wheat seeding with Kuzbass-8.5 on 1000 ha. Calculations of the costs per hectare of arable land for various agro-technical works were made while comparing conventional and minimum tillage.

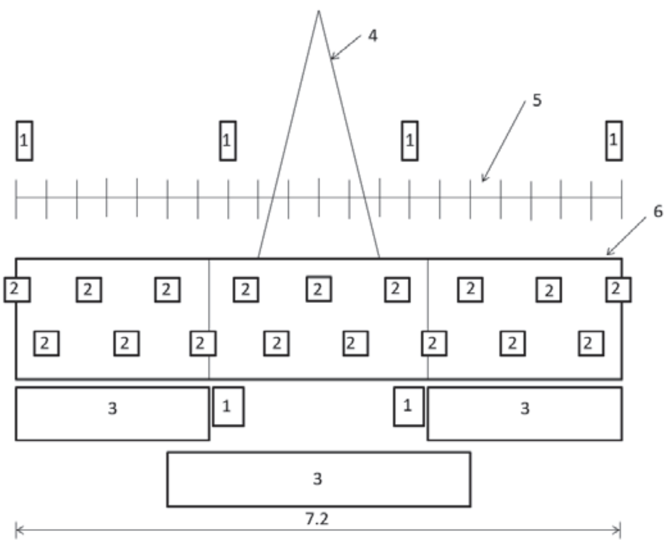
The seeding complex Kuzbass-8.5 (**Fig. 2**) performs multiple operations in one pass: cultivating, harrowing, seeding, applying fertilizers, packing and leveling the soil. Use of this complex allows the gap between soil preparation and seeding, which is typical in conventional technology in Russia, to be eliminated. Favorable conditions are created for germination and the formation of a normally developed plant

Fig. 2 Schematic Diagram of Kuzbass-8.5



1: tank of seed and fertilizer, 2: wheel, 3: furrow-opener, 4: harrow, 5: soil packer, 6: frame, 7: hitch attachment. Unit: m

Fig. 3 Schematic Diagram of APD-7.2



1: wheel, 2: chisel, 3: rollers, 4: hitch attachment, 5: soil disker, 6: frame. Unit: m in the future (Agro LLC, 2018).

Tillage Unit APD-7.2

The design of the tillage unit APD-7.2 (**Fig. 3**) means that damp soil is not extracted from the lower layers, so retaining moisture; soil cultivation is carried out at a given depth; and the use of this implement allows the saving of energy resources, as several soil tillage operations are performed in one pass (Sibselmash OJSC, 2018).

Soil and Climatic Characteristics of the Republic of Buryatia

Buryatia is in the center of the Eurasian mainland. The average annual air temperature is −0.5 °C to −2.8 °C. January is the coldest month, with average temperatures of −25 °C to −35 °C, at an absolute minimum; they can reach −40 °C to −58 °C. This leads to deep-freezing of the soil to a depth of 3-3.5 m. In July, the average monthly temperature reaches 15-25 °C (Batudaev et al., 2010). Annual precipitation is 250-340 mm. Chestnut soils comprise the greatest proportion of older plowed lands, which occur along steppe and intermontane depressions, and the southern slopes of ridges and foothills. These soils make up 60%-66% of the Republic's land area and about 42% of cultivated arable land (Bokhiev and Urbazaev, 1979; Batudaev et al., 2010).

Bokhiev and Urbazaev (1979) and Batudaev et al. (2010) note that the chestnut soils of Buryatia are significantly different from their analogues in the European part of Russia, especially with respect to the humus content. The former develop on light soil-forming rocks (sands, loam) in dry steppe conditions. They are referred to as loam, sandy loam, and sandy soils by virtue of their mechanical composition. The content of natural clay throughout the soil profile is no more than 30%; the fine sand fraction is 38-53%; the coarse dust is 10%-21% and the silt is 3%-12%. In contrast to similar soils in the European part of Russia, chestnut soils in Buryatia have a light granulometric composition. This feature determines their fundamental physical water properties: high overall porosity, high water permeability, low water retention capacity, and a small range of active moisture. To increase their yield, measures to save and accumulate moisture are first needed. Lack of moisture in the spring and early summer periods means that plants significantly reduce their productivity. Soil fertility has been measured as 13-15 points, which is almost two times lower than in western Siberia, and the agroclimatic potential is 0.46-0.48 (the average for Russia is 1) (Batudaev et al., 2010).

Results and Discussion

We found a significant difference in favor of the seeding complex Kuzbass-8.5 in wheat cultivation on

Fig. 4 Conventional and Minimum Tillage for Wheat Seeding on 1000 ha

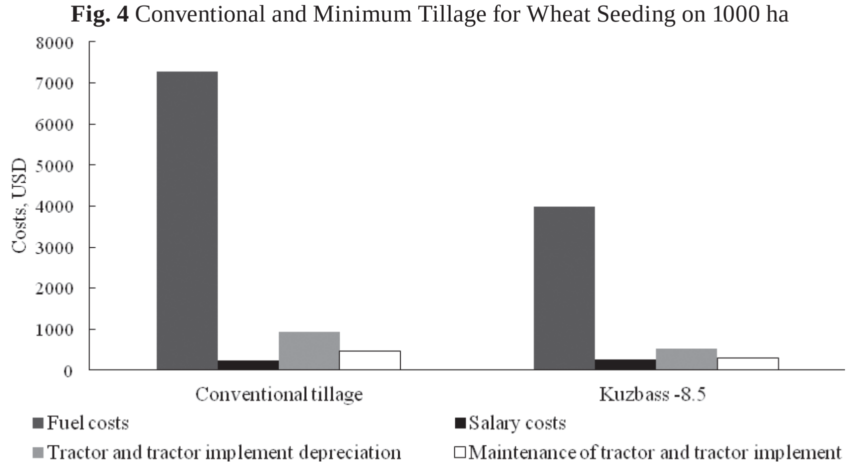
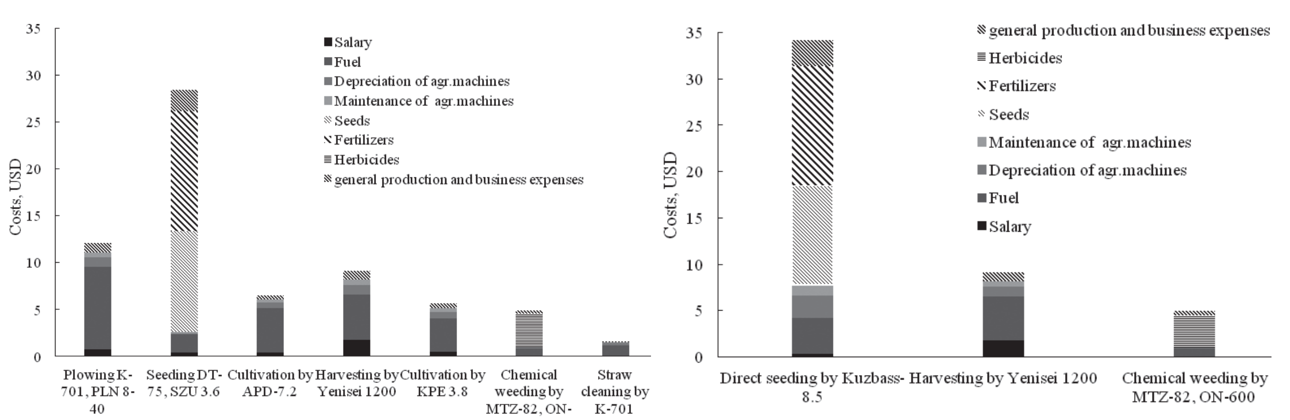


Fig. 5 Conventional and Minimum Tillage for Wheat Seeding on 1000 ha*



(a) Conventional tillage

(b) Minimum tillage

* Costs per ha of arable land for different agro-technical works

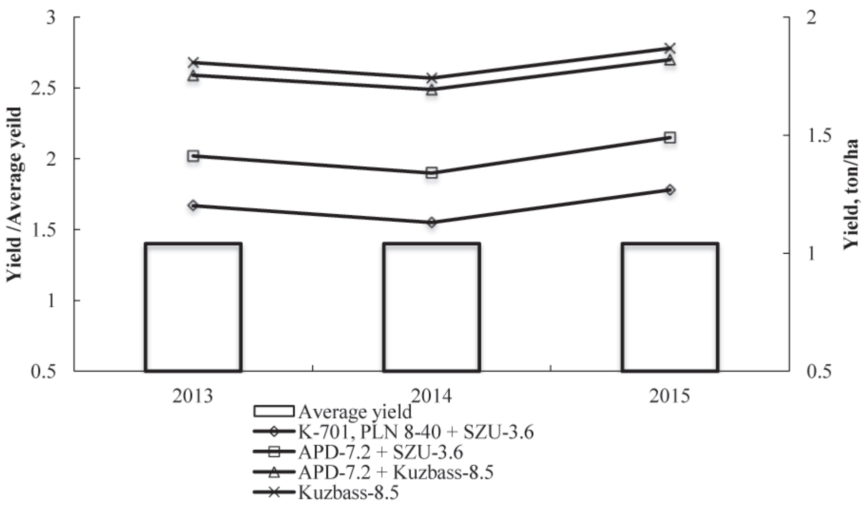
1000 ha (**Fig. 4**). This was explained by the machinery performing all operations inherent in conventional tillage in one pass.

We calculated the costs per hectare of arable land for various agrotechnical works when comparing conventional and minimum tillage (**Fig. 5**).

Fig. 5 shows that the total cost for 1 ha was 65 USD for the following conventional sequence of technological operations during the vegetative period: spring plowing (K-701 + PLN 8-40), cultivation (K-701 + KPE-3.8), seeding (DT-75 + SZU-3.6), chemical weeding (MTZ-82 + ON-600), combining (Yenisei-1200), and straw harvesting (K-701). By including Kuzbass-8.5 (i.e., direct seeding) the cost was reduced by 24% to 52.5 USD for 1 ha.

Fig. 6 shows the ratio of yields obtained in a differentiated way to average yield of oats for Buryatia. It shows that within 3 years the highest yield was obtained with the direct seeding technology by Kuzbass-8.5. Almost the same yield of oats was obtained with APD-7.2 + Kuzbass-8.5 (minimum tillage). Therefore, the experiment has shown a high efficiency of using APD-7.2 and Kuzbass-8.5. Even in the hot, dry summer of 2014, there was no significant change in the yield of grain grown with minimum tillage and no-tillage. Hence, we conclude that the use of minimum tillage and no-tillage in grain cultivation is expedient and profitable. The soil tillage system influences the yields obtained in a differentiated way.

Fig. 6 Yield of Oats by Different Seeding Technologies*



* A: Conventional. Moldboard plowing: K-701 and PLN 8-40. Separate seeding with SZU-3.6.
B: Resource saving. Cultivation with APD-7.2; separate seeding with SZU-3.6.
C: Resource saving. Cultivation with APD-7.2; seeding with Kuzbass-8.5.
D: Resource saving. Simultaneous cultivation and seeding with Kuzbass-8.5.
E: Average yield of oats throughout the Republic of Buryatia.

Carbon Sequestration and Humus Content

Most land use changes significantly affect the amount of carbon sequestered in vegetation and soil, thereby shifting ecosystem carbon balance (Houghton, 2010). Mehra et al. (2018) suggest that future research should focus on monitoring the factors responsible for soil ecology and the “carbon-in” versus “carbon-out” equation when considering the contribution of minimum tillage and no-tillage technology in mitigating climate change. The profitability of conservation agriculture systems across a great diversity of cropping environments will ensure that local farmers will increasingly be convinced to adopt minimum tillage and no-tillage, and create a significant impact on maximizing global carbon sequestration. Increased farming operations efficiency will contribute to an overall mitigation of greenhouse gas emissions (Mehra et al., 2018).

Disintegration of the Soviet Union and the collapse of the collective farming system that followed led to abandonment of former croplands in Russia, including in the Republic of Buryatia. The area of agricultural land in Russia decreased from 639.1 million ha (as of 1 January 1990) to 400 million ha (as of 1 January 2010). Reductions were also noted in the Republic. From 1990 to 2010, agricultural land in Buryatia declined by 18.7 thousand ha (or 0.6%), and arable land by 122.6 thousand ha (or 12.8%). In 1990 arable land covered 954.6 thousand ha, hayfields 355.7 thousand ha, and pastures 1788.2 thousand ha; in 2010, these figures were 832.0 thousand ha; 389.8 thousand ha; and1858.0 thousand ha, respectively (Administration of the federal service of state registration, cadastre and cartography for the Republic of Buryatia, 2011).

These were the most widespread and abrupt land use changes in the northern hemisphere in the 20th century (Lyuri et al., 2010). The sudden withdrawal of croplands in the 1990s resulted in several environmental benefits, including substantial carbon sequestration in post-agrogenic ecosystems. Kurganova et al. (2015) estimated the total extra carbon sink in abandoned croplands in Russia to be 45.5 Mha, at a rate of 155 ± 27 Mt C/year. This additional carbon sink could cancel out about 18% of the global CO2 released by deforestation and other land use changes, or compensate annually for about 36% of the current fossil fuel emissions from Russia. The extra carbon sink provided by post-agrogenic ecosystems in Russia contributes possibly about one-third of the total current carbon balance of the former Soviet Union (Kurganova et al., 2015). Hence, the disintegration of the former Soviet Union significantly affected the national and global carbon budget over a few decades after land use changes. Kurganova et al. (2015) also stated that the soil carbon buildup due to natural vegetation establishment occurs much more slowly than soil organic carbon losses after converting of grassland or forest to arable land. This should be borne in mind if, in future, there is a new expansion of unused land. Kurganova et al. (2015) conclude that the disintegration of the Soviet Union and the subsequent collapse of the collective farming system in the early 1990s had prolonged and positive ecological implications, including powerful effects on the carbon cycle and budget.

Long-term use (25 years) of minimum tillage to a depth of 8-10 cm for grains promotes the formation of a composite soil structure with a marked improvement in the agrophysical, agrochemical, and biological indicators of its upper layer fertility (Panov et al., 2008). Multifactorial field experiments carried out by scientists of the Moscow Agricultural Academy found that the humus content in the upper soil layer increased from 1.71% to 2.6%, soil density decreased from 1.4 to 1.2 g/cm^3, and the content of waterproof aggregates increased from 27% to 40% (Panov et al., 2008).

Conclusion and Implications

Minimum tillage and no-tillage systems present expedient, profitable alternatives to the conventional moldboard system of soil tillage because of increases in crop yield, reductions in cost, and to their conservation effects on the soil as compared with the conventional system. To date, resource-saving studies of Buryatia have concentrated mainly on cost factors. However, focus should be on the effects of systems and resource saving in terms of environmental resources, as only then can agricultural systems be sustainable and durable in agronomic, economic, and ecological terms.

The carbon enrichment of unplowed soils indicates that the conservation of soil organic matter contributes to carbon sequestration and lower impacts on global warming. We suggest, therefore, that future research into tillage methods in the Republic of Buryatia should focus on monitoring the factors responsible for soil ecology and the “carbon-in” versus “carbon-out” equation when considering the contribution of minimum and no-tillage technology to mitigating climate change.

The advantages of minimum and no-tillage soil systems in Buryatia can be used to improve methods in low-producing soils with reduced structural stability, as well as measures for water and soil conservation throughout the ecosystem.

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■■

Design and Development of a Two-row Self-propelled Rotary Weeder for Narrow-spaced Crops

by

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Abstract

Improper weed control can cause about 30-35% reduction in crop yield. Weeding is mostly done manually in narrow-spaced crops in India. Mechanical weed control in row crops reduces drudgery, save time, cost of operation and labour requirement. Presently, single-row weeder for wide-spaced crops are available and being used, but for narrow-spaced crops weeding is done manually. A two-row self-propelled rotary weeder for narrow-spaced crop was designed and developed. The developed rotary weeder consists of 5 hp engine, main frame, rotary unit, handle, transport wheel and J-type blade. The field capacity, field efficiency, weeding efficiency and plant damage by the developed rotary weeder were found to be 0.09 ha h^{-1}, 67.98%, 80.12%, and 2.9%, respectively. The cost of operation, payback period and breakeven point of developed rotary weeder were calculated as Rs 1733 ha^{-1}, 1.18 year and 91.84 h yr^{-1}, respectively. The developed rotary weeder saved 93% labour requirement over manual hand hoe i.e. Kasola.

Keyword: Rotary weeder, weeding.

Introduction

In India, large proportion of the population depends on agriculture. There are several constraints in agriculture like climate change, insect, pests but, weeds are the major reason for lower yield per unit agricultural area. A weed is any plant growing in the wrong place at the wrong time and harming the crop production. It competes with crops for water, nutrient and light which ultimately reduce the crop yield. Delay and negligence in weeding operation may cause 30 to 60% decrease in crop yield (Singh, 1988).

Mechanical weed control is very effective as it helps to reduce human drudgery involved in manual weeding. It kills the weeds and also keeps the soil surface loose ensuring proper soil aeration and water intake capacity. Mechanical weeding using improved hand tools or power operated machines appear to be the most practical and efficient method. Human power in agriculture is declining day by day. In addition labours wages are also increasing. On the contrary, the machines are becoming popular as a source of power and are replacing costly labour and reducing drudgeries of manual operations. Therefore, use of power weeder is the need of the day because it reduces the cost of weeding, maintain timeliness, meet-up scarcity of agricultural labour, are environment friendly as compared to use of weedicide and also pulverize the soil. Environmental degradation and growing demand for organically produced food, is also increasing interest in the use of mechanical weeders. Nonchemical weed control also ensures food safety. The precise inter and intra-row weeders could contribute significantly to the safe food production. Though there are rotary weeder available for wide row spacing crop, the problem exist with narrow spaced crops.

Most of the power tiller manufactured in the country are in the range of 8-10 hp. i.e. power tillers are not used in narrow spaced row crops due to the lack of its manoeuvrability. Presently, no effective rotary power weeder is being used commercially in India for narrow-spaced crops. Therefore, this study was undertaken to develop a rotary power weeder for narrow-spaced crops.

Material and Methods

The developed rotary weeder consists of the following main components.

Power source: It is required for providing power to the rotary unit and driving wheels of the weeder.

Rotary unit: It is required for the weeding operation.

Main frame: All functional unit of rotary weeder are mounted on the main frame.

Power transmission system: To transmit power to different components of the rotary weeder.

Tyre: Tyre are required for easy movement of weeder in field.

Clutch system: For controlling the weeder.

Power Requirement of Weeder

To estimate power requirement of weeder , average walking speed of man was taken as 3 km h^{-1}, for sandy loam soil specific draft of soil as 2-5 N cm^{-2} (Kepner et al., 1978), the maximum width of cutting blades as 22 cm (because plant leaf spreads in crop rows and there was chances for plant damage) and depth of operation as 5 cm (because at weeding stage, depth of root growth of weeds not more than 5 cm) (Thorat et al, 2014), the power transmission efficiency of belt-pulley system as 70%, minimum revolutions required for weeding as 150 rpm (Chertkiattipol et al, 2010).

The furrow cross-section cut by two row weeder = 2 × (22 × 5) = 220 cm^2

Draft of weeder = Specific draft × furrow cross section = 1100 N

Total power requirement for weeder in hp,

= (Draft × Speed) / (Efficiency)

= 1.309 kW = 1.75 hp

= 1.75 × 2.5 (Take factor of safety 2.5)

= 4.37 hp

Therefore, a commercial engine of 5 hp was selected as a power source for the weeder.

Rotary Shaft

For designing the rotary shaft, the maximum tangential force which can be endured by the rotor was considered. The maximum tangential force occurred at the minimum blades tangential speed which was calculated by the following equation (Bernacki et al., 1972):

$$Ks = Cs\,(75\ Nc\ nc\ nz / Umin) \quad ...(1)$$

Where,

Ks = Maximum tangential force

Cs = Reliability factor that is equal to 1.5 for non-rocky soils and 2 for rocky soils

Nc = Power of the engine

nc = Traction efficiency, value for the forward rotation of the rotor shaft is 0.9

nz = Coefficient of reservation of engine power which is between 0.7-0.8

Umin = Minimum tangential speed of blades, m s^{-1}

Tangential peripheral speed, Umin was calculated by using following equation

$$Umin = (2\pi N R) / 6000$$

Where,

N = Revolution of rotor, 150 rpm, and

R = Radius of rotor, cm. (Taken as approximately equal to blade length) = 19.5 cm

Umin = 3.06 ms^{-1}

By using equation Eqn, Ks,

Ks = 124.08 kg

The maximum moment on the rotor shaft (Ms) is calculated by the following equation

$$Ms = Ks \times R$$

Where,

R = Rotor radius, cm

Ms = 2419.5 kg cm

The rotary shaft was made from mild steel having yield stress of 520 MPa. The allowable stress on the rotor (τ) was calculated by the following equation (Mott, 1985):

$$\tau = (0.577\ k\ \sigma) / f$$

Where,

τ = Allowable stress on rotor

Fig. 1 Schematic of rotary weeder

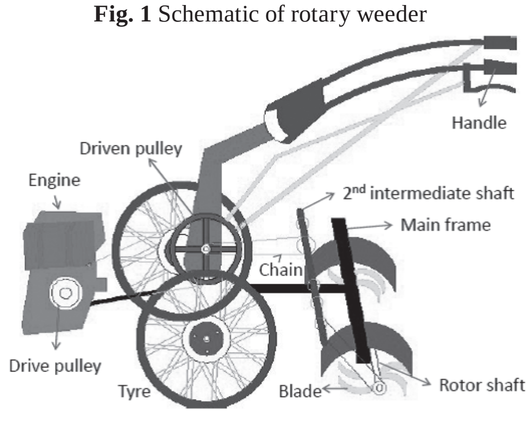
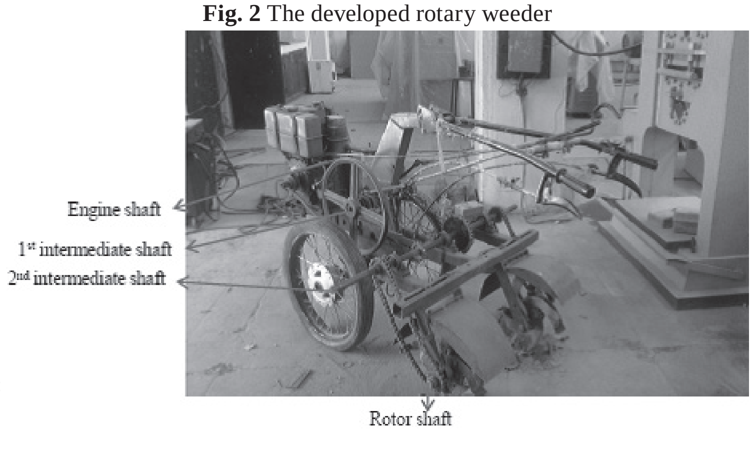


Fig. 2 The developed rotary weeder



shaft, kg cm^{-2},

k = Coefficient of stress concentration equal to 0.75,

σ = Yield Stress, 520 MPa, and

f = Coefficient of safety is equal to 1.5.

τ = 150 MPa = 1500 kg cm^{-2}

The torsional moment is the most important factor that significantly affects the rotor shaft design. Considering the equation for calculating the torsional moment on rotating shafts, the required diameter for the rotary tiller shaft was obtained as:

$d = \sqrt[3]{(16\ Ms) / (\tau\pi)}$

$d = \sqrt[3]{(16 \times 2419.5) / (1500 \times 3.14)}$

= 2.02 cm

Therefore, 2.5 cm diameter rotor shaft was selected.

Cutting Blade

The total power of the machine was distributed between the blades. Number of flanges were calculated by the following equation:

i = b / bi

Where,

b = Working width, cm, (Taken as 22 cm because plant leaf spreads in row)

bi = Distance between the flanges on the rotor, cm (Assumed 6 cm)

i = 22 / 6

= 3.67 (approx. 4)

Four blades were considered on each of the flanges (Ze = 4). Therefore, the total number of the blades obtained was:

N = i × Ze

= 4 × 4 = 16

The soil force acting on each of the blades (Ke) was calculated by the following equation:

Ke = (Ks Cp) / (i Ze ne)

Where,

Ks = Maximum tangential force, kg,

Cp = Coefficient of tangential force,

i = Number of flanges,

Ze = Number of blades on each side of the flanges, an

ne = Number of blades which act jointly on the soil, by total number of blades for particular flange.

Ke = 62.04 kg

Development of Rotary Weeder

Based on design values of different components, a two row self-propelled rotary weeder was developed in the workshop of Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, CCS HAU, Hisar, Haryana. Main frame of rotary unit made of mild steel, Rotor shaft was made of mild steel having 30 cm length and diameter of 2 cm. Tyres were provided for transportation and handle for operating the rotary weeder. The rotary unit consisted of four flanges and four blades were mounted on each flange. Numbers of blades used were 16. The rotary weeder covered two rows each 22 cm. The power was transmitted from engine to intermediate shaft and from intermediate shaft to rotor shaft on which blades are mounted. The specification of developed weeder is shown in **Table 1**.

Results and Discussion

The rotary weeder was developed and evaluated in mustard crop, row to row spacing of crop was 45 cm.

Table 1 Specifications of weeder

Sl. No.	Parameter	Parameter value
1	Engine	Diesel
2	Engine HP	5
3	Starting system	Recoil
4	Cooling system	Air cooling
5	Clutch	Dog clutch
6	Size of tyre, inch	2.75-18
7	Overall length of machine, mm	1900
8	Overall width of machine, mm	950
9	Overall height of machine, mm	1070
10	Main frame, mm	
	Length	950
	Width	250
	Thickness	250
11	Rotor shaft on which blade are mounted, mm	
	Length	300
	Diameter	20
12	Type of blade	J type
13	Rotary unit wt, kg	52
14	Overall unit wt, kg	178

Table 2 Performance of two row weeder in comparison of manual hand hoe *i.e. Kasola*

Sl. No.	Parameter	Rotary power weeder	Manual weeding, *Kasola*
1	Depth of operation, mm	50-55	40
2	Field capacity, ha h^{-1}	0.09	0.05
3	Field efficiency, %	67.98	-
4	Fuel consumption, l h^{-1}	1.6	-
5	Weeding efficiency	80.12%	
6	Plant damage	2.9%	
7	Cost of operation, Rs ha^{-1}	1733	7060
8	Time saving over manual weeding, %	93	-
9	Payback period, yr	1.18	-
10	Break Even Point, h yr^{-1}	91.84	-

As presented in **Table 2**, the depth of weeding ranged from 50 mm to 55 mm and fuel consumption was 1.6 l h^{-1}. The field capacity and field efficiency of developed rotary weeder was 0.09 ha h^{-1} and 67.98%. The weeding efficiency, and plant damage of the developed rotary weeder were 80.12%, and 2.9%, respectively. The cost of operation for weeding by manual hoe *i.e. Kasola* was Rs 7060 per hectare and for rotary weeder it was Rs 1733 per hectare. The rotary weeder saved Rs 5327 per hectare as compared to manual hoe i.e. Kasola. Rotary power weeder saved 93% time over manual weeding. The payback period and breakeven point of developed rotary weeder were calculated as 1.18 year and 91.84 h yr^{-1}, respectively.

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■■

ABSTRACTS

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

2016

Energy Auditing of Pearl Millet Production in Irrigated Region at Hisar in Haryana State of India: Raveena Kargwal (raveenakargwal@gmail.com), Yadvika, M. K Garg, V. K. Singh

The aim of this study was to examine the energy consumption pattern for pearl millet production in irrigated region of Haryana state of India. Farmers with marginal, small and medium land holdings were selected for the study. The data were collected through a questionnaire by face to face interview of farmers. Different unit operations performed in pearl millet production were studied in irrigated region. Both the source-wise (Direct and Indirect energy) and operation-wise energy consumption were calculated for all categories of farmers. Energy that was consumed in preparatory tillage, sowing, interculture, fertilizer, irrigation, pesticide, harvesting, threshing and transportation were calculated for pearl millet cultivation. The energy inputs such as human energy, animal energy, machinery, fuel/diesel, fertilizer, chemical and seed energy were determined. The average energy input of marginal, small, and medium farmers were 2853.09 $MJha^{-1}$, 3032.21 $MJha^{-1}$ and 4024.50$MJha^{-1}$, respectively. The energy ratio varied from 3.92-13.80.

2022

Performance of Agricultural Equipment for Field Transplanting of Sugarcane Sprouts: H. Ortiz-Laurel* (*Corresponding author: hlaurel@colpos.mx), H. Debernardi-de-la Vequia, D. Rosas-Calleja, A. A. Gomez-Jimenez, I. A. Gomez-Juarez

The conventional billet planting of sugarcane (Saccharum spp) in Mexico is slow, expensive and germination-deficient. New planting methods are explored for improving crop field productivity. This work shows the field assessment of an agricultural tractor-mounted prototype for transplanting two-months old sugarcane (Saccharum spp) sprouts, according to the following parameters; uniform sprouts treatments, field separation between seedlings, up right placement into the soil, good soil covering and field uniformity at planting. The device was subjected to field performance trials on a readily tilled soil for planting, although slightly stoned on the surface. Tractor and implement combination travelled at a field speed of 0.3 m s-1 when adjusted to place seedlings at 900 mm separation on a row. In the field, transplanting separation between seedlings had a variation of 3.4%. The prototype had just one transplanting unit. When assisted by two laborers, it can achieve a field capacity of 2.5 ha day^{-1}. Thus, for a field capacity of 2 ha day-^{1} and operating for 120 days per planting season, investment on the machine can be recovered in two years. Planting operation by using the prototype is up to 8 times more economical when compared with manual transplanting.

Evaluating Effects of Post-Sowing Compaction and Sowing Speed on Soil Properties, Distribution of Seed Placement and Second Crop Maize Performance

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Abstract

Planting and post-planting applications are important in soil physical properties, seed distribution, seedlings emergence and yield of maize (*Zea mays* L.). Main objective of this research was to evaluate the effects of field traffic and sowing speeds on soil physical properties, seedling emergence, sowing performance and crop yields for maize production. This two-year study was conducted on Iğdır plain soils (clay Petrocambids) in the eastern region of the Turkey from 2014 to 2015. A tractor used for three different wheel traffic applications; no traffic (C0), one pass (C1) and two passes (C2) with three different sowing speed; 5.4 (V1), 7.2 (V2) and 10.8 (V3) km.h^{-1}. The hypothesis of this work included that the field traffic would cause changing in soil physical properties that maize yields would be affected and also an increasing in sowing speed would affect the sowing quality. Results showed that penetration resistance value produced by C2 treatment was higher. The highest average green herbage yield and plant height values were found in 2015 the measurement for C2 treatments were 650.5 kg.ha^{-1} and 2580 mm, respectively. Soil water content (42.71%, 53.05%, 55.35%) and soil temperature (19.46 °C, 19.65 °C, 19.76 °C) increased with increase in C0, C1 and C2, respectively. Increase in sowing speed cause disturbance of uniformity of seed in seedbed. Seedlings emergence were positively affected by soil compaction but there was no statistically significance seed distribution and seed uniformity.

Keywords: compaction, seed placement, sowing performance, traffic, yield

Introduction

Soil compaction is an important parameter for soil physical properties, seedling emergence and crop yield. If field soil is compacted, the soil bulk density (Pagliai and Vignozzi, 2002), root growth (Ikeda et al., 1997), seedlings emergence and crop yield reduce (Botta et al., 2009). Reduction in soil porosity reduces root penetration into the soil (Botta et al., 2007). Nutrient availability reduced (Grath and Hakansson, 1992) and it causes reduction growth and yield (Veen et al., 1992). Additionally, microbial and enzyme activity occurs less in compacted soil compared with non-compacted soil (Dick et al., 1988). However, total denitrification rate is higher in the compacted soils (Ball et al., 1999).

The optimal bulk density for plant growth is 1.3 g.cm^{-3}. It has been determined that the bulk density, which causes the plant growth to stop is 2 g.cm^{-3} (Singh et al., 1992). Penetration resistance can affect plant root development and cause alterations in crop yield. The penetration resistance of 3 MPa or more is considered to be the limiting barrier to root development (Hakansson and Lipiec 2000). In addition, Silva et al. (2000) indicated that penetration resistance greater than 2 MPa is one of the most important criteria defining extreme soil compaction. It is necessary to compact to the soil at certain levels in order to increase the contact between the seed and the soil and to provide uniform germination.

Field traffic with high axle load is one of the biggest factors for soil compaction. Hakansson and Reeder (1994) stated that a 14% loss on maize yield takes place after repeated wheel traffic on agricultural soils. Ressia et al. (1998) found that soil compaction produced a 30% reduction in maize (*Zea mays* L.) yields at the condition of 1.2 $Mg.m^{-3}$ bulk density. Similarly, Canarache et al. (1984) stated that increase in bulk density (per $1000.g.cm^{-3}$) caused a reduction in maize grain yield 18%. They also indicated that number of tractor passes change the soil physical properties and biggest alterations were observed between 0 to 8-10 passes.

Maize (*Zea mays* L.) shows poor leaf plasticity, scarce tillering capacity and a low prolificacy which leads to a reduced ability to compensate low plant densities (Tourn et al., 2003). For this reason, sowing quality such as uniform sowing depth, intra and inter row seed distribution area, mean spacing, standard deviation of the sowing depth and variation coefficient are very important for maize sowing (Altikat, 2011).

Precision seeder is generally used for maize. This machine theoretically places seeds at an optimum spacing and to obtain a better growing volume per seed (Karayel and Ozmerzi, 2002). The efficiency of this machine depends on its use at the sowing speed. Sowing speed effects coefficient of variation of seed distribution. Stable sowing depth is an important factor to achieve uniformity of seedlings emergence (Stockton et al., 1996). Gan and Stobbe (1995) stated that variable sowing depths reduced wheat (*Triticum aestivum* L.) yield in comparison with uniform sowing. Karayel (2009) stated that increase in the sowing speed resulted increase in coefficient of variation of soil depth and distribution of seeds along the length of row. Also, the highest emergence time and percent emergence obtained at the sowing speed was 1.0 $m.s^{-1}$.

Increased mechanization increases soil compaction because heavy agricultural machineries are used during the plant growing season (Altikat, 2013). As a result of soil compaction, distribution of soil aggregate size and soil porosity alters, this situation affects soil microbial properties and functions because of the reduction in C mineralization (Grigal, 2000) and C-N ratio (Li et al., 2004). Soil pore system in the compacted soil is generally an unfavorable condition for microorganisms because this situation generally restricts gas-water ratio (Beylich et al., 2010) and causes lower oxygen diffusion rate (Bilen et al., 2010).

The main objectives of this study were (1) to compare the effects of different field traffic levels on soil physical properties and yield of maize and (2) to determine the effects of different sowing speeds on sowing quality and yield of maize.

This study hypothesized that (1) maize yields are affected by field traffic and (2) changing in sowing speed affect distribution of seed and hence yield of maize.

Table 1 Initial soil physical properties for 0 to 0.3 m depth range (mean of 2014 and 2015)

Properties	Values
Sand (%)	18.50
Silt (%)	32.00
Clay (%)	49.50
Texture class	Clay
Bulk density ($g.cm^{-3}$)	1.18
Cone index (MPa)	0.864
Water content (% d.b.)	20
Organic matter ($g.kg^{-1}$)	1.16

Table 2 Climatic data belong to experimental area

Months	Average temperature (°C)			Monthly and annual total precipitation (mm)		
	2014	2015	(1950-2015)	2014	2015	(1950-2015)
January	-4.5	1.2	-3.3	15.3	2.2	13.6
February	2.1	4.3	-0.2	3.6	4.4	16.3
March	10.1	8.5	6.5	17.2	52.0	20.8
April	15.7	13.8	13.3	30.5	44.1	34.2
May	19.6	18.3	17.8	49.9	41.5	47.7
June	23.5	25.1	22.2	34.6	27.8	33.4
July	27.7	28.7	25.9	7.7	0.3	13.8
August	28.1	27.2	25.2	5.0	14.3	9.8
September	22.4	37.2	20.1	15.2	1.4	11.1
October	13.6	16.6	12.8	27.1	96.2	25.1
November	5.4	9.2	5.8	20.5	4.5	17.1
December	3.4	1.5	-0.4	11.0	13.7	13.1
Aver./Total(*)	13.92	15.96	12.14	237.6	302.4	256

Material and Methods

2.1. Site Description and Weather Data

A two-year (2014 and 2015) field study was managed at the Iğdır University experimental fields (39° 48' 06.69" N, 44° 34' 58.30" E, 800 m altitude), which are located in the east of Turkey. The site has different climatic characteristics from other cities in the region. Cropping system is two harvest a year in the site where the major crops are winter wheat (*Triticum aestivum* L.) and spring maize (*Zea mays* L.). Soil classification is Aridisol, Petrocambids (USDA-NRCS, 2010) soil texture is clay and the other properties of soil as, $CaCO_3$ (6.53 $g.kg^{-1}$), EC (1228 $\mu S.cm^{-1}$), pH (8.0), P (27.24 ppm), K (0.037 $meq.100g^{-1}$) and concentration of organic matter in soil was 1.06%. The experimental field had been tilled with conventional system for ten years. Soil physical and mechanical properties are given in **Table 1**. The monthly air temperature, total precipitation of the experimental area is summarized in **Table 2**. Data for the experimental years 2014 and 2015 as well as long-term averages (1950-2015) are presented.

2.2. Field experiments and crop management

A completely randomized design (3 × 3) with three replications was used for the experiment. The treatments consisted of the combination of three different sowing speeds (5.4, 7.2 and 10.8 $km.h^{-1}$) and three different wheel traffic for intra-row compaction (no traffic, one pass and two passes). There were nine treatments in each block and size of blocks were 4.5 m by 30 m. Blocks within the treatments were separated by buffer strip 5 × 5 m interval to allow equipment maneuvering. Conventional tillage system was used in the experiment. For this purpose, a moldboard plough was set to a depth of 300 mm, followed immediately by two passes with a tandem disk harrow and one pass of a shaped spring tooth harrow. Hido hybrid maize (*Zea mays* L.) (0.025 $t.ha^{-1}$) was sown on April 20, 2014 and April 22, 2015 with a pneumatic seeder equipped with axe type opener and press wheel. Press wheel of the seeder were used for depth control. They did not affect the seed-soil compaction level. Maize seeds were sown at the 50 mm sowing depth, row space 150 mm and intra-row space 750 mm. The process of irrigation was performed at first when height of plants was around 150-200 mm. During growing season, three surface irrigations were made in interval of three weeks for whole year. A tractor (New Holland TD85D) was driven at 7.2 $km.h^{-1}$ for intra-row soil compaction (one pass and two passes) on the treatments in three blocks to account for spatial variability. An online decision support tool Terranimo (Schjønning et al., 2016) used to evaluate the tyre contact area and vertical stress distribution. Terranimo estimated front and rear wheels soil contact area as 0.1 m^2 and 0.17 m^2, maximum soil stress 206 kPa and 154 kPa, respectively. Tractor tyres were inflated to a pressure of 1.1 bar. The total weight of the tractor was 3.4 Mg. The mean of water content (%) of soil surface measured just before sowing and data were 13 $g.kg^{-1}$ and 14 $g.kg^{-1}$ for 1st and 2nd experimental periods, respectively. The water content of soil at the time of planting was 18% for the first year and 20% for the second year.

2.3. Physical Properties of Soil

Soil bulk density was determined for the depth ranges of 0-200 mm with 50-mm intervals using stainless steel rings having dimensions of 50 mm diameter by 50 mm height. Each treatment was sampled three times. A penetrometer (Field Scout SC 900 Soil Compaction Meter) was used for determination of penetration resistance for soil compaction. Penetration resistance were determined in 0-200 mm soil depth with 50-mm intervals.

During seedling emergence period, measurements at 0-120 mm depth in each treatment were conducted to determine seedbed temperature and water content of soil content. Water content of soil content during emergence period was measured using a time domain reflect meter, TDR (Spectrum Equipment, Model Field Scout TDR 300). 20 measurements were taken randomly in each treatment by using 120 mm rods. The data were saved into the data logger and then transferred to a computer. Seedbed temperature was measured using a Barnat 90 type digital soil thermometer. Temperature data were taken for 100 mm depth by using 120 mm rods, with 5 replications in each treatment.

2.4. Seedlings Emergence

Percentage of emergence (PE), mean emergence time (MET), emergence rate index (ERI), and were determined using the following equations (Karayel and Ozmerzi, 2002).

$$PE = (Ste / n) \times 100 \quad ...(1)$$

$$MET = (N_1T_1 + N_2T_2 + \cdots + N_nT_n) / (N_1 + N_2 + \cdots + N_n) \quad ...(2)$$

$$ERI = Ste / MET \quad ...(3)$$

Where PE is the percentage of emergence (%), MET is the mean emergence time (day), ERI is the emergence rate index ($seedling.day.m^{-1}$). $N_1 \cdots N_n$ is the number of seedlings emerging since the time of previous count; $T_1 \cdots T_n$ is the number of days after sowing, Ste is the number of total emerged seedlings per meter. n is the number of seeds sown per meter.

2.5. Sowing Quality

Measurement of the sowing depth was taken in the vertical plane. Mean sowing depth and coefficient of variation were determined by measuring the mesocotyl length of 30 maize plants for all treatments and replications. Uniformity of inter and intra row seed distribution was examined using the distances between emerged plants randomly selected at 1 m distance in each treatment. Theoretical inter and intra row distances were used to calculate the standard deviation, the variation coefficient and means (Altikat, 2011).

Standard deviation ellipse method was used to determine the seed distribution area (Karayel and Ozmerzi, 2007). In this criterion, seed points were drawn on a graph and their distribution met the ellipse criterion. Semi-length of major axis of ellipse was standard deviation from row center of seeds and semi-length of minor axis of ellipse was the standard deviation of sowing depth. The seed distribution area (A) was calculated using the following equation:

$$A = S_a \times S_b \times \pi \quad ...(4)$$

S_a: Standard deviation from row center of seeds (mm)

S_b: Standard deviation of sowing depth (mm)

A: Area (mm^2)

There are some pneumatic planter

performance analysis methods identified in Kachman and Smith (1995). The multiple index (I_{mult}) is the percentage of plant distance that are less than or equal to half of the set plant spacing and the percentage of multiple seed drops. Miss index (I_{miss}) is the percentage of plant distance greater than 1.5 times the set seed distance and indicates the percentage of missed seed locations or skips. Quality of feed index (I_{fq}) is the percentage of plant spacing that is more than half but no more than 1.5 times the set distance. A practical upper limit of precision is 29%. Although there is upper limit of 50% on the precision in theory, the values bigger than 29% should be approach with suspicion.

$$I_{mult} = n_1 / N \qquad ...(5)$$

$$I_{miss} = n_2 / N \qquad ...(6)$$

$$I_{fq} = 100 - (I_{miss} + I_{mult}) \qquad ...(7)$$

2.6. Crop Yield

In order to determine the yield values, 10 corn plants were randomly selected from each treatment. Harvesting was done taking into consideration the common methods such as green herbage yield (kg. da^{-1}), plant height (mm), ear diameter (mm), 1000 seed weight (g), seed number in ear (seed) used by Keskin (2001).

2.7. Statistical Analyses

The ANOVA procedure, appropriate for randomized complete block design, was the procedure used to analyze the variance of the obtained data. Means were compared using Duncan's multiple range tests.

Results and Discussion

3.1. The Soil Water Content and Seedbed Temperatures

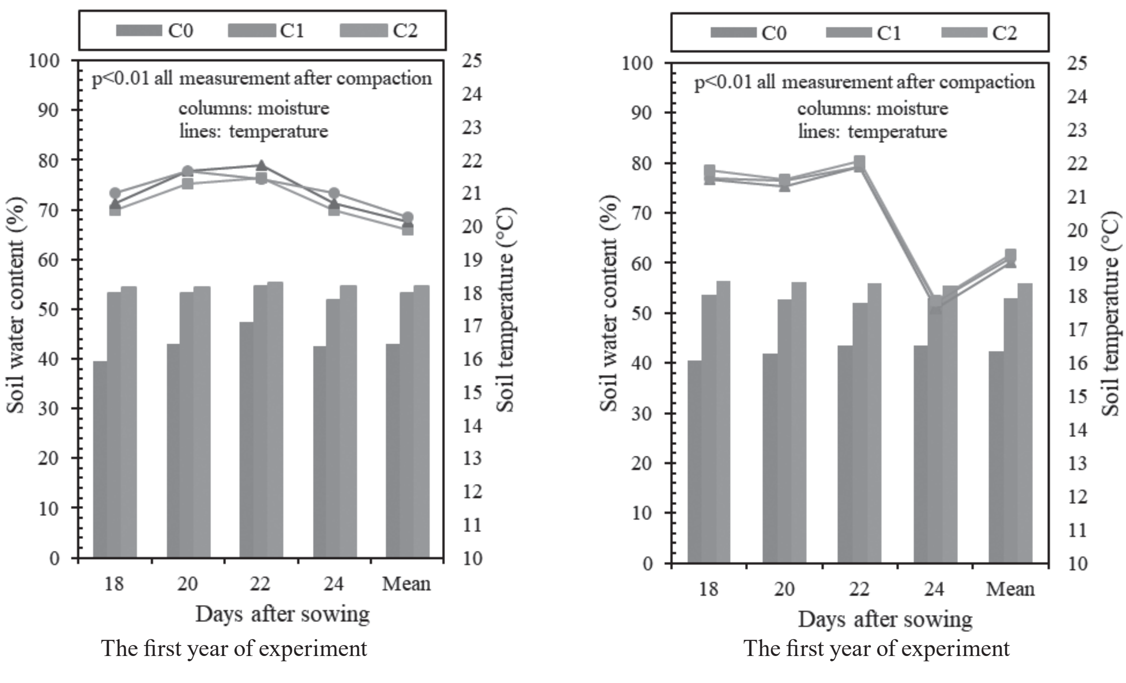
Effects of soil compaction on the seedbed temperature and water content are given in **Fig. 1**. During the germination, maximum seedbed temperature and soil water contents were determined at the C2 (two passes) compaction level for both 1st and 2nd experimental periods.

The first year of the experiment, average seedbed water content and temperature values were 43.07%, 53.19%, 54.69% and 19.90 °C, 20.14 °C, 20.26 °C, in the second year of the experiment, these values were observed 42.35%, 52.91%, 56.00% and 19.01 °C, 19.16 °C, 19.27 °C, for C0, C1 and C2, respectively. Greater soil compaction increased soil water content (Altikat and Celik, 2011) and soil temperature (Diener, 1974). For both experiment years, maximum rainfall was 9 mm at study area. This value was not suitable for seedling emergence and rainfall was not affect the soil water content. In study of the growing period of maize air temperature and rainfall ran its course. The average air temperature was moderate and similar in growing period and not exceeded 30 °C in both years of experiment. Tourn et al. (2003), soil and air temperature affect plant maturity time from seeding to harvest.

3.2. Penetration Resistance and Soil Bulk Density

This study found that compaction by passing two times (C2) caused greater changes in topsoil properties than compacted by passing one time (C1) or no-pass (C0). **Fig. 2** shows the penetration resistance (PEN) and soil bulk density (BD) measure-

Fig. 1 Changes in soil water content (%) and seedbed temperature (°C) for two experimental year after compaction. C0: No pass, C1: one pass, C2: two passes, (ns): not significance



The first year of experiment

The first year of experiment

ments for both year of experiment. In the experiment, average PEN values for the first year 1.40, 1.51, 1.69 MPa and for the second year 1.23, 1.46, 1.80 MPa for C0, C1 and C2 respectively. The greatest PEN values obtained at the 300 mm soil depth. These values were 2.18 and 2.36 MPa at C2 treatment for the first and second year of experiment, respectively. It is important to note that typical tillage depths in Turkey are approximately 300 mm and it is considered the topsoil layer from 0 to 300 mm in this experiment. According to Botta et al. (2008), yield reduction can be observed in case of exceeding 2.5 MPa. PEN values in this study were above the critical limits (2.5 MPa) to avoid yield reduces.

The statistical analyses for BD indicated a significant interaction of compaction × depth, with the greatest values ($P < 0.01$) for all depths and both year of experiment. **Fig. 2** presents BD values 0 to 300 mm depth at two experimental years and different compaction levels. Results indicated that greater compaction increased the BD. The highest BD value observed at C2 with 1.37 g.cm^{-3} at 300 mm depth for both year and the lowest BD observed at C0 with 1.03 and 1.01 g.cm^{-3} at 50 mm depth for the first and the second year of experiment, respectively.

The data for both PEN and BD shows that compaction was created for C1 and C2 treatments in 50-300 mm depth. As expected, the soil was more compacted in C2 than C1 and C0. Increasing the number of passes increased both BD and PEN at topsoil (above 300 mm) depths. These results agree with observations made by (Servadio et al., 2005).

3.3. Seedlings Emergence

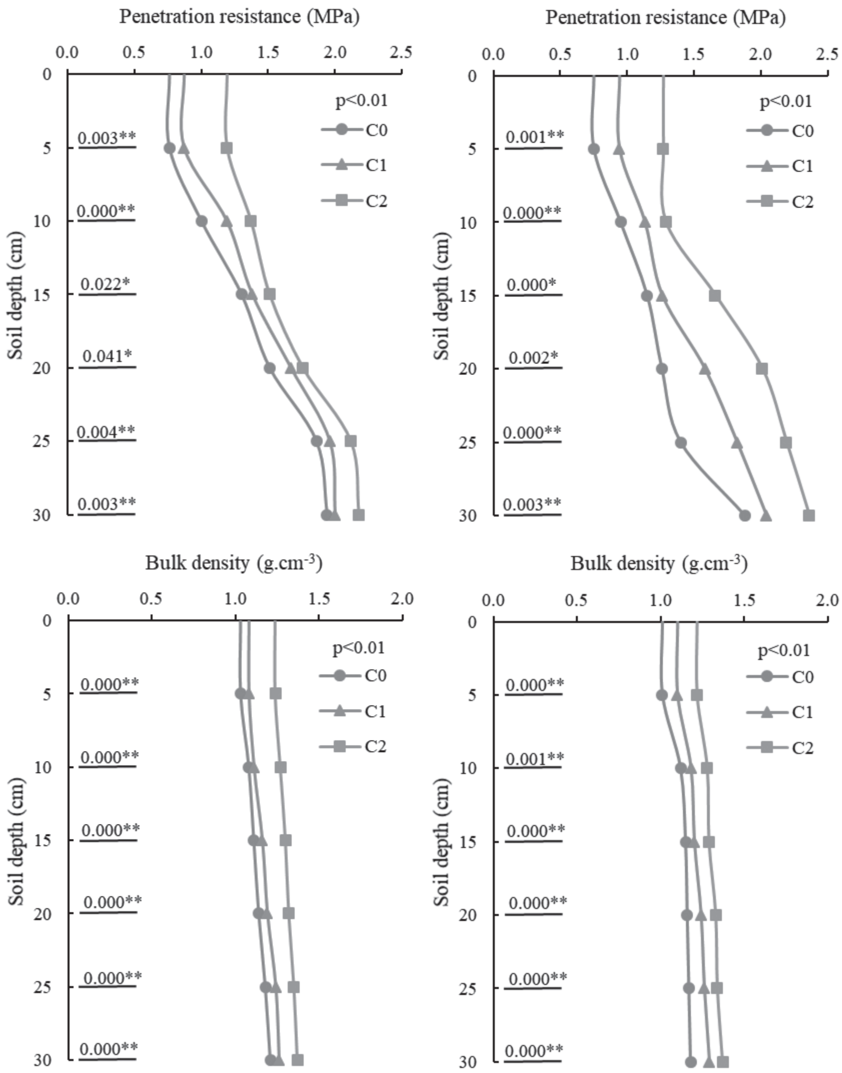
Seedlings emergence parameters were generally statistically significant and were affected by sowing speeds and compaction levels. During the first year of the experiment, average seedlings emergence were determined as 88.35%, 15.76 days and 0.42 seedlings.d^{-1}.m^{-1} for PE, MET and ERI, respectively. In the

Table 3 Statistical analysis of sowing performance values

Factors	Percentage of Emergence (%)		Mean Emergence Time (day)		Emergence Rate Index (seedling.day.m^{-1})	
	2014	2015	2014	2015	2014	2015
V1	93.47a√	90.18a	16.42a	15.10ns	0.402b	0.47ns
V2	88.87b	85.94b	15.49b	15.14ns	0.426a	0.46ns
V3	82.70c	83.35c	15.38b	15.16ns	0.429a	0.46ns
P	0.000**	0.000**	0.000**	0.943	0.000**	0.782
C0	85.94b	84.96b	16.34a	16.01a	0.404b	0.43c
C1	88.88a	86.28ab	15.50b	15.25b	0.425a	0.46b
C2	90.21a	88.23a	15.45b	15.20b	0.428a	0.50a
P	0.011*	0.021*	0.000**	0.000**	0.000**	0.000**

√: Means within the same column followed by the same letter are not significantly different C0: Control (No pass); C1: One pass; C2: Two passes, V1: 5.4 km.h^{-1}, V2: 7.2 km.h^{-1}, V3: 10.8 km.h^{-1}.

Fig. 2 Penetration resistance (MPa) and soil bulk density (g.cm^{-3}) for two experimental year after compaction. C0: No pass, C1: one pass, C2: two passes, (ns): not significance



The first year of experiment — The second year of experiment

Table 4 Statistical analysis of sowing performance values

Factors	Sowing depth (CV %)		Inter row seed distribution uniformity (CV %)		Intra row seed distribution uniformity (CV %)		Seed distribution area (mm^2)
	2014	2015	2014	2015	2014	2015	2014
V1	45.36a	46.08a	185.24b	12.40ns	149.57b	13.83b	192.5b
V2	40.86b	43.31a	174.44b	11.86ns	184.65ab	13.34b	284.3b
V3	38.69c	39.34b	218.00a	13.25ns	214.11a	15.56a	560.9a
P	0.001**	0.003**	0.000**	0.140ns	0.780ns	0.033*	0.000**
C0	45.19a	39.42b	196.26ns	14.19a	181.02ns	13.42ns	328.7ns
C1	39.55c	44.95a	192.15ns	11.67b	183.39ns	14.34ns	306.2ns
C2	40.18b	44.36a	189.26ns	11.65b	183.94ns	14.96ns	402.7ns
P	0.002**	0.007**	0.743ns	0.001**	0.986ns	0.190ns	0.416ns
Factors	Sowing depth (CV %)		Inter row seed distribution uniformity (CV %)		Intra row seed distribution uniformity (CV %)		Seed distribution area (mm^2)
	2014	2015	2014	2015	2014	2015	2015
V1	6.53b*	8.31a	2.93b	2.21b	8.11ns	5.94ns	286.1b
V2	7.91a√	2.31b	17.04a	9.7a	6.04ns	3.57ns	292.9b
V3	7.61a	6.48a	16.08a	6.67a	4.78ns	6.74ns	450.2a
P	0.023*	0.000**	0.009**	0.000**	0.289ns	0.326ns	0.021*
C0	7.37ns	8.17a	10ns	7.51ns	6.16ns	5.06ns	374.4ns
C1	7.41ns	6.33a	8.7ns	6.39ns	5.59ns	7.48ns	374.1ns
C2	7.26ns	2.60b	17.2ns	8.40ns	7.21ns	3.70ns	280.7ns
P	0.974ns	0.077ns	0.986ns	0.537ns	0.724ns	0.226ns	0.221ns

√: Means within the same column followed by the same letter are not significantly different C0: Control (No pass); C1: One pass; C2: Two passes, V1: 5.4 $km.h^{-1}$, V2: 7.2 $km.h^{-1}$, V3: 10.8 $km.h^{-1}$.

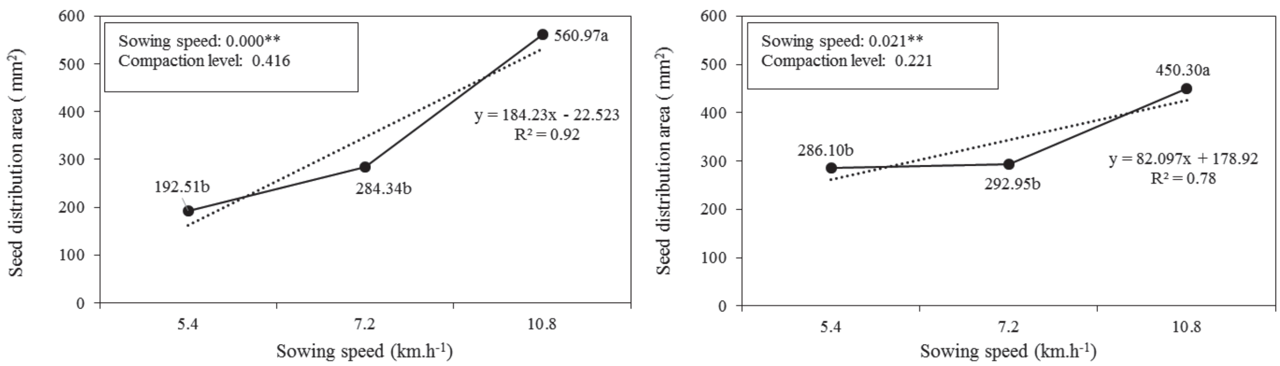
second year of the experiment these values were observed as 86.49%, 15.13 days and 0.46 $seedlings.d^{-1}.m^{-1}$. Sowing speed has an important effect on the seedlings emergence in both 1st and 2nd years of the experiments. Increasing the sowing speed reduced PE and MET but increased ERI during all of the experiments. Similar effects were observed at the compaction treatments except percentage of emergence values. In all of the experimental periods the best seedlings emergences were determined at the C2 (two passes) compaction levels. Generally, optimum seedlings emergence was observed at the treatment with V1 sowing speed and C2 compaction level in both 1st and 2nd experimental periods (**Table 3**).

Soil can be compacted at moderate level with press wheel or roller in order to reduce soil water content loss and provide enough soil-seed contact. According to Wilkes and Hobgood (1969), moderate compaction could obtain a better seed germination and seedling establishment. Gemtos and Lellis (1997) stated that seedling emergence time reduced at 150-200 kPa compaction levels in 15% and 23% initial volumetric soil water content for sandy loam and clay loam soil respectively. Altikat et al. (2006) stated that increase in intra-row compaction level increased seed germination of wheat and soil water content but there was not statistically significant effect was on the seedbed temperature. Among the intra-row compaction levels (0, 15, 30, 45, 60 kPa), blocks compacted 60 kPa showed higher percentage of emergence and water content of soil.

3.4. Sowing Performance

In order to determine the effects of factors on planting performance in the study, seed depth variation coefficient, inter and intra-row seed distribution area, seed distribution area, multiple index, miss index and quality of feed index were evaluated. For a homogenous seedlings emergence in sowing, it is desirable that the coefficient of variation at sowing depth is minimum. Vertical fluctuations in the sowing depth of seeds cause different germination and harvesting times. This situation directly affects crop yield. Increasing forward speed showed a reduction in mean sowing depth but increased the coefficient of variation of depth. The actual mean sowing depths were nearly equal to nominal sowing depth for the forward speed

Fig. 3 Changes in seed distribution area (mm^2) according to sowing speeds



The first year of experiment   The second year of experiment of 5.4 km.h^{-1} (Ivancan et al., 2004; Brandelero et al., 2015). In addition, the increase intra-row compaction level resulted in a reduction of the coefficient variation in sowing depth. However, this effect was only observed in the second year of the experiment. It is desirable to distribute the seeds into a narrow area in the sowing technique. This rule is important for the optimum growth area of seeds. The increase of the tractor forward speed in the study caused the seeds to spread over a wider area (**Fig. 3**). However, this result was observed only in the first year of the study (**Table 4**). In both years of the study, the increase in the sowing speed led to an increase in the miss and multiple index.

Fig. 3 and **Table 4** generally support our hypothesis that changing in sowing speed affect seed distribution. Önal (1987), optimum working speeds in the intra-row spacing range of 205.8 and 87.3 mm are 12.5 and 5.4 km.h^{-1}, respectively. Raoufat and Matbooei (2007) reported that the most suitable sowing depth, minimum miss index and variation coefficient among the 4, 7 and 10 km.h^{-1} forward speed was obtained the treatments at 7 km.h^{-1} forward speed. Ivancan (2004), when increase the forward speed from 1.8 km.h^{-1} to 5.2 km.h^{-1}, intra-row spacing increase from 75 mm to 83 mm, respectively.

The best intra-row distribution was recorded at the speed of 1.8 km.h^{-1}. Sowing quality was 80.4% at this speed. This value was 79.3%, 79.4% and 76.6% at 2.4 km.h^{-1}, 3.6 km.h^{-1} and 5.2 km.h^{-1}, respectively. The best quality of feed indexes are obtained at low sowing speeds (Karayel and Ozmerzi, 2001). The effect of compaction was observed only in the second year of the study quality of feed indexes and miss index (**Table 5**). The most appropriate compaction value on these factors is determined as C1 compaction level.

3.5. Crop Yield

In the study, green herbage yield, plant height, ear diameter, 1000 seed weight and seed number in ear were determined in order to ascertain the effects of tractor forward speed and compaction levels. It was observed that the compaction levels were significantly effective on crop yield in each year of the study. However, this effect could not be determined at the tractor forward speeds. In both research years, the highest yield values were obtained in the parcels where the maximum compaction was applied. In addition to this, in the control treatments where compaction is not applied, the crop yield values reduce considerably. The observation supports our hypothesis that maize yield is affected by field traffic. Botta et al. (2013) examined the effects of field traffic on yield of maize. In this study, the highest yield was observed at 2 and 2.5 MPa compaction level. This compaction level was similar with the highest compaction level in our study. These data of the study show similar results with the other studies carried out (Chen and Weil, 2011, Altikat and Celik, 2011). Obtained results showed that no differences were found between forward speed and crop yields parameters. In **Table 6**, the effect of factors on product yield is shown in detail. The intra-row soil compaction increases the soil-seed contact, causing the seedlings emergence to be homogeneous and early.

Conclusion

Physical properties of soil, sowing quality, productivity and yield are strongly influenced by compaction

Table 5 Statistical analysis of seed uniformity values

Factors	Quality of feed index (%)		Multiple index (%)		Miss index (%)	
	2014	2015	2014	2015	2014	2015
V1	90.15a√	93.55a	0.00b	1.78b	9.84c	4.66b
V2	68.21b	84.82b	6.79ab	8.59a	24.99b	6.57b
V3	50.33c	71.16c	11.97a	8.61a	37.69a	19.29a
P	0.000**	0.000**	0.042*	0.220	0.785	0.000**
C0	66.24ns	82.19b	7.45ns	5.14ns	26.31ns	12.65a
C1	73.39ns	93.68a	4.36ns	4.37ns	22.24ns	1.01b
C2	69.06ns	73.65c	6.94ns	9.47ns	23.99ns	16.87a
P	0.451	0.000**	0.752	0.056	0.001**	0.000**

√: Means within the same column followed by the same letter are not significantly different C0: Control (No pass); C1: One pass; C2: Two passes, V1: 5.4 km.h^{-1}, V2: 7.2 km.h^{-1}, V3: 10.8 km.h^{-1}.

Table 6 Statistical analysis of crop yield values

Years	Factors		Green herbage yield (kg/ha)	Plant height (mm)	Ear diameter (mm)	1000 seed weight (g)	Seed number in ear (grain)
2014	Compaction Level	C0	414.4c√	2139b	42.43b	200.7b	508.7b
		C1	562.2b	2395a	44.63ab	209.9b	573.5b
		C2	631.1a	2470a	45.84a	240.9a	661.1a
		P	0.000**	0.000**	0.018*	0.029*	0.000**
2015		C0	445.6 b	2185b	41.8a	211.7c	524.0c
		C1	509.0 b	2441a	43.7a	231.1b	582.4b
		C2	650.5 a	2585a	43.2a	251.0a	635.0a
		P	0.020*	0.002**	0.166	0.030*	0.000**

√: Means within the same column followed by the same letter are not significantly different C0: Control (No pass); C1: One pass; C2: Two passes, V1: 5.4 km.h^{-1}, V2: 7.2 km.h^{-1}, V3: 10.8 km.h^{-1}.

and forward speed of sowing machine.

When number of tractor passes increased, bulk density, penetration resistance and water content of soil were increased. These increases positively affected the yield of maize. It was clear that the difference between C0 and C2 treatments caused a higher yield in maize. Results indicate that sowing speed have no statistically effect on seedbed temperature and water content of soil content. But, increase in compaction level led to an increase in temperature and water content of soil around the seedbed.

Increase in sowing speed reduced PE and MET values but increased ERI value. In addition, increase in the compaction level reduced PE and ERI also increased MET values. The best seedlings emergence values were observed PE (V1, C2), MET (V3, C2) and ERI (V3, C3).

Greater sowing speed increased, but greater compaction reduced, planting depth variability. Seed distribution areas increased with increasing sowing speed in both experimental years but it was not affected by compaction levels. As a reflection of all these examined parameters, the increase in compaction level positively affected the yield values. In both experiment years, increase in the compaction level also increased the yield values.

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Design and Development of a Tractor-Operated Biomass Incorporator

by
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Abstract

A tractor-operated two-bottom biomass incorporator was developed for efficient incorporation of green manure crop. The machine is a combination of cutting unit, shortened mould board and vertical rotating clod-crusher. The cutting unit cuts the crop mass into small pieces. The share of mould board plough cuts the furrow slice, the shortened mould board lifts it and finally the vertically-rotating auger behind each bottom pulverizes the furrow slice and buries the crop biomass efficiently. Field trials were conducted to incorporate green manure crop (*Sesbania aculeata*) in loamy sand type soil at two stages of crop growth, 36 days after sowing and 50 days after sowing. The above ground biomass density at crop growth stage I and II was 154 q/ha and 224.63 q/ha, respectively. The average depth of operation of biomass incorporator was 17.47-17.90 cm. The effective field capacity and fuel consumption rate of the machine was 0.25-0.28 ha/h (at forward speed of 3.4 km/h) and 6.66-8.31 l/h, respectively. The soil pulverization index with the machine varied from 5.37 to 9.70 mm. The bulk density index ranged between 23.31-26.57%. The mixing index with soil varied from 97.07 to 98.00%.

Keywords: Biomass incorporation, Green manuring, Mixing index.

Introduction

Rice-wheat system (RWS) is highly productive and important for food security and livelihoods of millions of people. It is practiced on around 13.5 million ha area across the Indo-Gangetic alluvial plains (IGP) of South Asia (Ladha et al., 2009). Sustainability of conventional rice-wheat production system in many parts of South Asia including northwest India has become a major concern owing to falling water tables, low input-use efficiency (fertilizers, pesticides), farm-related pollution, farm labor scarcity, stagnating system productivity and diminishing economic returns (Ladha et al., 2009; Humphreys et al., 2010). Modern farming practices in the region include irrational use of chemical fertilizers. Excessive and continuous chemical fertilization causes accumulated side effects on human and animal health, environment and increases agricultural production cost (Bahnas and Khater, 2015). In monoculture cropping system, overuse of chemical fertilizers in the long term causes decline in soil organic matter (Reganold et al., 1987), formation and concentration of mineral salts of fertilizers leading to compaction layer and soil degradation (Massah and Azadegan, 2016). The use of synthetic fertilizers not only increase water demand of crops but also reduces water holding capacity of already light Indian soils (Faroda et al., 2008). Repeated application of high fertilizer nitrogen dose adversely affects soil microbial life and associated microbial transformations. This may also lead to soil acidity which is a negative soil health trait (Singh, 2018).

Energy crisis, higher fertilizer cost, sustainability in agriculture production system and ecological stability are the important issues which have renewed the interest of farmers and research workers to opt for non-chemical sources of plant nutrients i.e. organic manures, viz. farm yard manure, vermi-compost, poultry manure and green manure (Eagan and Dhandayuthapani, 2018). Green manuring is an effective and low cost technology which replenishes soil health naturally and also helps in minimizing the cost of chemical fertilizers while safeguarding productivity. A fallow period of about 60-65 days is available after the harvest of wheat, which can be utilized for growing of pre-rice green manure (Singh et al., 2010). The addition of green manure, having low C/N ratio, to lowland rice brings about many changes in chemical properties of soil and various nutrient transformations which can improve the sustainability of soil N fertility in lowland rice. The soil compaction due to puddling in rice adversely impacts soil structure and root growth of succeeding wheat crop resulting in inefficient use of both water and nutrients (Kirchhof and So, 1996; Gathala et al., 2011) whereas integration of legumes in RWS has been demonstrated to improve soil fertility and provides nitrogen to rice (Singh et al., 2010; Chauhan et al., 2012).

The most commonly grown green manure/legume crops in northwest India are Sesbania aculeata, Viqna sinensis and Crotalaria juncea. These crops have rapid growth which helps in suppressing the weeds and ample nodulation activity by them is also preferable. Due to succulent nature of its foliage, these decompose very quickly and fit it in the prevailing cropping systems. In RWS, growing and burying of 6-8 weeks old green manuring crop before transplanting of rice results in saving of 62.5 kg of nitrogen (137.5 kg urea) per hectare. Green manuring also controls deficiency of iron in rice crop (Anon., 2018).

Effective incorporation of the green manure crop is as important as the growing of the crop. The significance of green manuring lies in the fact that organic matter be incorporated properly into the soil (Dubey et al., 2015). Thorough covering of biomass with soil is necessary for complete and faster conversion of crop material to humus. For many residue types, the rate of decomposition have consistently been found to be 2-4 times faster in buried condition than in surface placed condition (Ghidey and Alberts, 1993; Varco et al., 1993; Beare et al., 2002). Uncovered plants lying on the soil surface do not decompose rapidly; rather they dry up gradually and interfere in subsequent operation of tillage or seedbed preparation machinery. Further, chopping of biomass before incorporation leads to faster decomposition rate (Tarafdar et al., 2001). In view of the above, a tractor operated biomass incorporator was developed which chops the biomass and simultaneously incorporates it in the soil. This would help in early decomposition of biomass, resulting in reduced requirement of inorganic fertilizers.

Material and Methods

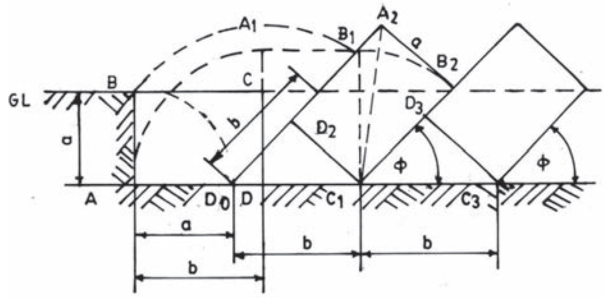
Design Concept of Biomass Incorporator

The design concept of biomass incorporator was based on broad idea of using two or more dissimilar tools or implements concurrently for effective work with reduced number of field operations. The objective of biomass incorporator was to reduce the size of the green manure crop, to place it in the field at appropriate depth and to provide proper cover over it with pulverized soil. For chopping of crop, a cutting unit was needed covering the entire width of the machine. An adequate amount of pulverized soil was needed to properly cover the chopped biomass. For digging sufficient quantity of soil mass, soil cutting concept of conventional mould board plough was needed but complete inversion of lifted soil slice was not desired. As most of the turning and inversion of the soil is accomplished by the upper part of the mould board, it was planned to use truncated mould board. For this general purpose type mould board was truncated from the upper side. Breaking the soil clods immediately after ploughing prevents development of high strength in clods due to drying of the soil. Thus, before the inversion of soil mass, pulverization and spreading of the evacuated soil slice was needed with a clod crusher.

Design Basis for Truncated Mould Board

During the translatory motion of plough, each bottom cuts a soil layer of rectangular cross section, the dimensions of which depend on the operating width and depth of the bottom (Bosoi et al., 2016). While studying the process of slice

Fig. 1 Slice turning during working of mould board plough bottom



turning during operation of mould board plough, it was assumed that the falling soil slice does not change its dimensions, that is, it is turned without crumbling (**Fig. 1**). Further, the average speed of movement of the soil across mould board would be approximately same as the forward speed of biomass incorporator.

Design to Protect Overflowing of Furrow Slice

In **Fig. 1**, the operating width of plough bottom is denoted by 'b' and ploughing depth is denoted by 'a'. During lifting of the soil slice ABCD, which is cut in the horizontal plane by the share on the mould board, it is first rotated about the rib D until it occupies the vertical position $DA_1B_1C_1$. Afterward, the slice is rotated about the rib C1 to the final position $C_1D_2A_2B_2$ until it lies with the face C_1B_2 on the previously cut slice. During the movement of the soil slice in single run, soil travels through the contour BA_1B_1. So A_1 represents the highest point during the movement of soil slice. Similarly during the previous run of the machine, A_2 is representing the highest point. In right angled triangle $C_1A_2B_2$, side C_1A_2 is the hypotenuse while other sides are having length 'a' and 'b'.

Therefore, maximum height of upper edge of truncated mould board, $H_{max} = \sqrt{(a^2 + b^2)} + \Delta H_{max}$

Where, ΔH_{max} = 0-20 mm

The height of the upper end of truncated mould board was kept as H_{max} so that the soil slice does not over flow the mould board when machine is operated up to 24 cm depth. For medium tillage, the width of cut of a bottom was taken as 43.2 cm.

Design to Protect Overturning of Slice Backward into the Furrow

From the right-angled triangle $C_1D_3C_3$ (**Fig. 1**) with sides C_1C_3 = b and C_3D_3 = a, the angle of inclination φ of the pulled slice to the horizontal is given by:

$\sin \varphi = C_3D_3 / C_1C_3 = a/b = 1/k$ (where k = b/a)

In slice turning, the position at which the diagonal of its cross section A_2C_1 is perpendicular to the furrow bottom will be the limiting position. A slight deviation of the diagonal to the left will result in the overturning of the slice backward into the furrow. The limiting ratio k = b/a was found using identity of the right-angled triangles $C_1A_2B_2$ and $C_1D_3C_3$.

Therefore, from **Fig. 1**

$C_3D_3 / C1C_3 = C_1B_2 / C_1A_2$

$a/b = b/\sqrt{(a^2 + b^2)}$

$$1/k = 1/\sqrt{(1 / k)^2 + 1} \quad ...(1)$$

Transforming the expression (1) into an equation and by solving that we get

$1/k = \sin \varphi = 0.787$

i.e. k = 1.27

Therefore, the limiting value of k was 1.27 and value of k > 1.27 was found to be necessary to protect overturning of slice backward into the furrow. The truncation of mould board on curvature was done keeping in view that there should be no inversion (upside down) of the soil slice and soil slice is directly subjected to clod crushing unit after lifting by mould board. The computer aided design software SolidEdge V20 was used to make a model of the design. The computer aided drawing of truncated mould board is shown in **Fig. 2**.

Arrangement of Bottoms of Mould Board Plough

The bottoms on the plough body are arranged as shown in **Fig. 3**. It was assumed that the soil reaction (R) to cutting, arising during motion of the bottom, is applied at the middle of the share blade length i.e. L/2 and directed at angle of friction φ to the plane, perpendicular to the blade. If we draw a straight line parallel to the direction of action of the force R through the front share tip, then the tip of the next bottom will be found on it at the point C, at a distance $\sqrt{(L_1^2 + L_2^2}$ and so on. Here L_1 is the distance between tip of share of bottom 1 and bottom 2 in longitudinal direction i.e. in line of direction of travel of the machine and L_2 is the width of cut of the single bottom i.e. 'b'.

The arrangement of bottoms in the longitudinal direction was determined by expression:

$L_1/L_2 = \tan (\theta_1 + \varphi)$

$L_1 = L_2 \tan (\theta_1 + \varphi)$,

where,

θ_1 is the angle of inclination of the share to the furrow wall

φ is the angle of friction of the soil with metal

Taking θ_1 = 40-45° (say 43°) and φ = 20° at operating width (L_2) = 43.2 cm

L_1 = 43.2 tan (43 + 20)°

L_1 = 84.8 cm

Elevation of position of plough body above the plane of support of bottom is given by

H = b + 2a / 3

= 43.2 + (2 × 24) / 3

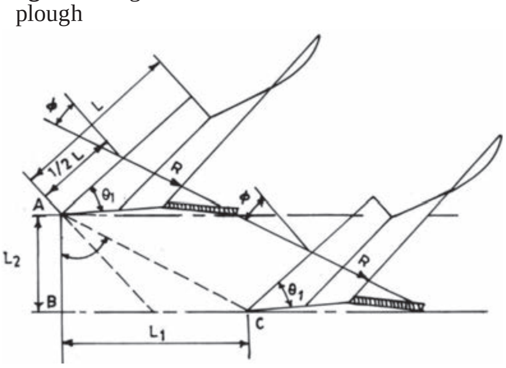
= 59.2 cm

Design Basis for Cutting Unit

The working of cutting unit was

Fig. 2 Computer aided drawing of truncated mould board

Fig. 3 Arrangement of bottoms of mould board plough



based on various principles of cutting plants i.e. whether the plant is supported against a counter edge or the plant remains unsupported. During the field working of biomass incorporator, the green manure plants remained unsupported from one side. Its bending was restricted by its own rigidity, inertia and partly by support it received from the adjacent stalks. An impact cutting mechanism was selected for the machine. This mechanism comprised a high-speed cutting element, rotating in horizontal plane, and relied primarily upon the inertia of the material being cut to furnish the opposing force required for shear.

Type of Blades and Their Arrangement on Rotor

Straight blades with serrated teeth were selected for the cutting unit as these are suitable for soft biomass (Liu, 2012). These high carbon steel blades result in good chopping quality and low fuel consumption. Straight blades with serrated teeth, having length of 120 mm, were selected for the cutting unit. The arrangement of blades at different levels on the cutting unit was adopted so that smaller cut size of the stalks could be achieved. The straight blades were arranged horizontally at equal spacing and the pattern was kept symmetrical about the longitudinal centreline. The diameter of blade tip circle was selected keeping in view the working width of the machine. As the working height of the machine lowers when mould board is working in the soil, the lowest point on the cutting unit was kept more than maximum depth of cut of the machine. Therefore, height of the lowest point on the cutting unit was kept 240 mm above the ground level. Keeping in view the safety aspect, an inverted L-shaped sheet metal safety covers having dimensions as per the dimensions of the cutting unit were developed. These covers were fitted on the main frame of the machine with hinged joints.

Speed of Rotation

For efficient cutting of unsupported stalks, the cutter speed must be 18-50 m/s. The cutting speed has a significant influence on resistance to cutting. The resistance decreases with increasing cutting speed (Klenin et al., 1986). Keeping in view that green manure crop was having soft biomass and cutting along with incorporation of the crop was to be done at succulent stage, the lower limit of the peripheral speed was selected for the cutting unit. The computer aided drawing of cutting unit is shown in **Fig. 4**.

Design Basis for Clod Crusher

Design of clod crusher was based on the principle of using small cuts in a consolidated soil to obtain maximum fragmentation and dispersion. The most efficient method of producing a desired clod mean mass diameter is to apply the forces in such a manner that soil breakup occurs in one step. The following design factors were considered while development of clod crushing unit:

Type of Blades and Their Arrangement

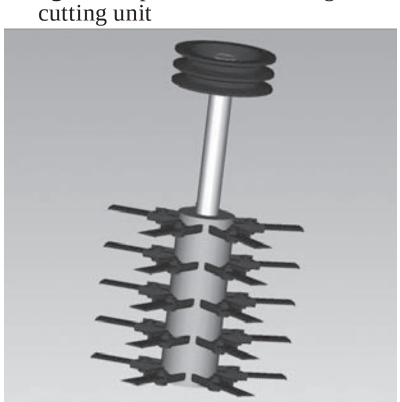
The clod crushing unit was not intended for loosening and lifting of soil. As only cutting action was desired, flat blades were used to incise the soil (Gill and Berg, 1968). The rotating flat blades caused impact force and soil inertia further assisted in better fragmentation. The mechanical rigidity of the soil mass was used as the holding body. The commercially available L-shaped blades having trapezium shaped cutting area with outer and inner width of 75 and 65 mm, respectively and straight cutting length of 110 mm were selected for clod crushing unit. These high carbon steel blades are presently being used in rotavators also.

The staggering of blades at different levels was adopted as small cuts reduce the total force on the tool due to reduced soil confinement or due to lesser weight of soil on the tool. The blades were arranged at equal spacing and the stagger pattern was kept symmetrical about the longitudinal centreline. The clod crusher unit made three cuts per revolution at each level of blades. Similar concept is followed in conventional rotary tillers (Kepner et al., 2005). The diameter of top most blade tip circle was kept same as that in commercially available rotavators. During operation of the machine, the clod crushing unit and mould board were supposed to work at fixed relative position. Therefore, the blades were arranged such that top layer of blade was below the top most edge of truncated mould board. Keeping in view the lifting and movement of soil slice through truncated mould board, the blades of clod crushing unit were given clockwise rotation (as viewed from top) for better hitting effect and thereby efficient soil crumbling and dispersal. The computer aided drawing of clod crushing unit has been shown in **Fig. 5**.

Speed of Rotation

The clod crushing unit of biomass incorporator was not intended for hitting, loosening and lifting of the soil mass as is done in case of rotavator. It was intended for hitting loosened soil mass for pulverization. Further, availability of blades at different levels made this work less energy intensive. Therefore, depending upon the required soil dispersion, peripheral speed of top level blades was kept as 8.6 m/s which was twice the peripheral

Fig. 4 Computer aided drawing of cutting unit



speed of blades of commercially available rotavators (4.3 m/s).

Design of Power Transmission

The PTO power of the tractor was used to operate cutting unit and clod crushing unit. The power from tractor PTO was transmitted to gear box with the help of shaft. The transmission ratio of gear box was 1:1. A pair of straight bevel gears (miter gears) of equal size, having equal number of teeth and with shaft angle (θ) 90° was used in the gear box. V-belt drive can be used for prime mover power capacity up to 200 kW (Sharma and Aggarwal, 2011). Further, in agricultural machines, V-belts can be operated at a speed as high as 33 m/s (Kepner et al., 2005). During operation of biomass incorporator, the selected speed for cutting unit and clod crushing unit was 18 m/s and 8.6 m/s, respectively. Moreover PTO power of selected tractor was also considerably below 200 kW. Keeping in view, power from gear box to cutting unit and clod crushing unit was transmitted using V-belt drive.

Design of Gear Box

Tractor bhp = 50 hp = 37.3 kW

The gear box system was designed for maximum input PTO power.

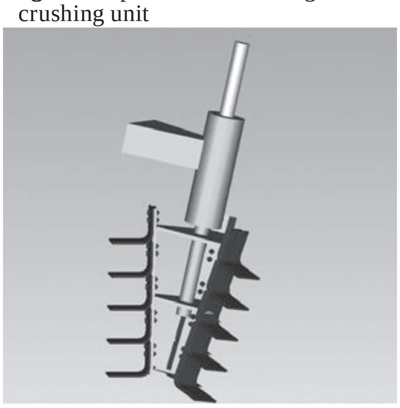
PTO power of tractor (P) = 0.75 × 37.3 = 27.97 kW (Sharma and Mukesh, 2013)

Maximum torque to be transmitted by PTO shaft of tractor,

T_{PTO} = (PTO power × 60) / 2πN

Where,

Fig. 5 Computer aided drawing of clod crushing unit



N = standard PTO speed i.e. 540 rpm

Therefore,

T_{PTO} = (27.97 × 1000 × 60) / 2 × 3.1416 × 540

= 494.6 N-m = 49.46 kgf-m

Selected speed ratio of gear box = 1:1

Let teeth in driving gear, Z_p = 21

Teeth in driven bevel gear, Z_g = 21 × speed ratio = 21

Therefore,

speed of driven shaft = 540 × (21/21) = 540 rpm

Torque in driven shaft = 49.46 × (1/1) = 49.46 kgf-m

Pressure angle, φ = 20°

Let gear tooth module (m) = 6 mm

Diameter of pinion gear, D_p = 6 × 21 = 126 mm

Therefore,

Diameter of driven gear, D_g = 126 × 1 = 126 mm

Pitch cone angle, $\Upsilon_p = \tan^{-1}(Z_p / Z_g) = \tan^{-1}(21 / 21) = 45°$

$\Upsilon_g = 90° - 45° = 45°$

Cone distance, $L = \sqrt{(R_g^2 + R_p^2)} = \sqrt{(0.063^2 + 0.063^2)} = 0.089$ m

Design load

Pitch line velocity (V) = (π × 0.126 × 540) / 60 = 3.56 m/s

As power from gear box was to be transmitted to non-soil engaging parts, service factor or overload factor Co was taken as 1.25.

Design transmitted load, $F_t = (P \times 1000 \times C_o) / V$ = (27.97 × 1000 × 1.25) / 3.56 = 9.82 kN

Velocity factor, $C_v = 3/(3+V)$ (for V up to 7.5 m/s)

C_v = 0.50

Dynamic load, $F_d = F_t / C_v$ = 9.82 / 0.50 = 19.64 kN

Strength

Applying Lewis strength equation for gear

$F_b = f_b \times f \times m \times Y (1 - f/L)$

Where,

f = active width of pinion gear, m

Taking f = L/3 = 0.089/3 = 0.03 m = 30 mm

f_b = 490 MPa for pinion (driving) and gear (driven) made of steel having BHN 200 (Sharma and Aggarwal, 2011)

To find Y, formative number of teeth in gear was calculated

$Z_{fg} = Z_g / \cos \Upsilon_g$ = 21 / Cos 45° = 29.7

Similarly, Z_{fp} = 29.7

Therefore,

Y = π (0.154 − 0.921/29.7) = 0.386

Therefore, from Lewis equation,

$F_b = 490 \times 10^6 \times 0.03 \times 0.006 \times 0.386 (1 - 0.03/0.089)$ = 22.57 kN

As $F_b > F_d$

Therefore, design is safe for dynamic loading.

Design of Power Transmitting Shaft

The shaft was designed for torque applied by the prime mover.

$T_{PTO} = (\pi/16) d^3 \tau_{max}$

Where,

T_{PTO} = Maximum torque to be transmitted by PTO shaft of tractor = 4946 kgf-cm

d = Diameter of shaft, cm

τ_{max} = Allowable shear stress = 250 kgf/cm² (after factor of safety)

Therefore,

4946 = (3.1416/16) × d^3 × 250

d^3 = 100.76

d = 4.65 cm or 46.5 mm

Shaft having outer diameter of 65 mm was selected.

Design of Belt and Pulley Arrangement

PTO power of tractor (P) = 27.97 kW

Design power = 27.97 × service factor (Sharma and Aggarwal, 2011)

= 27.97 × 1.2 = 33.5 kW

As the maximum design power ranges between 11-75 kW, belt section 'C' was selected.

Power Transmission from Gear Box to Cutting Unit

Diameters of both the pulleys were determined on the basis of velocity ratio.

Selected speed for cutting unit = 18 m/s

Taking cylinder outer diameter as 110 mm and total length of straight blade as 130 mm.

Diameter of blade tip circle while rotation (D_{b1}) = 370 mm = 0.37 m

Therefore, for achieving peripheral speed of 18 m/sec,

$18 = (\pi \times D_{b1} \times N_b) / 60$

Where,

N_b = Number of rotations of cutting unit per minute, rpm

$N_b = (18 \times 60) / (3.1416 \times 0.37) = 929$ rpm (say 925 rpm)

$D_b / Dg_b = (1 - s) N / N_b$

Where,

D_b = Diameter of driven pulley on cutting unit, mm

D_{gb} = Diameter of driving pulley on gear box, mm

N = Number of rotations of driving shaft per minute, rpm

s = slip factor = 0.01

$D_b / D_{gb} = (1 - 0.01) \times 540/925$

Let the selected diameter of commercially available driving pulley, D_{gb} = 305 mm

Therefore,

$D_b = (0.99 \times 540 \times 305) / 925 = 176.3$ mm

Commercially available 178 mm diameter pulley was selected as driven pulley for cutting unit.

Check for Suitability for Centre Distance

As V-belt drive is not recommended for large distances, check for centre distance was carried out.

Centre distance (C) should be < $3(D_{gb} + D_b)$ (Sharma and Aggarwal, 2011)

Now, $3(D_{gb} + D_b) = 3(305 + 178) = 1449$ mm

Centre distance between driving pulley and driven pulley of cutting unit 1 (C_1) = 760 mm

Centre distance between driving pulley and driven pulley of cutting unit 2 (C_2) = 705 mm

As C_1 (760 mm) and C_2 (705 mm) < 1449 mm

Therefore, selected V-belt drive was suitable as far as centre distance was concerned.

Angle of Contact on Smaller Pulley for Belt Drive Arrangement of Cutting Units

Angle of contact on smaller pulley for belt drive arrangement of cutting unit 1

$= \pi - 2\text{Sin}^{-1}(D_{gb} - D_b) / 2C_1$

$= 180° - 2\text{Sin}^{-1}(305 - 178) / (2 \times 760)$

$= 170.4° = 2.97$ radian > 2.1 radian

Therefore, safe for power transmission.

Angle of contact on smaller pulley for belt drive arrangement of cutting unit 2

$= \pi - 2\text{Sin}^{-1}(D_{gb} - D_b) / 2C_2$

$= 180° - 2\text{Sin}^{-1}(305 - 178) / (2 \times 705)$

$= 169.6° = 2.96$ radian > 2.1 radian

Therefore, safe for power transmission.

In case of use of common belt(s) for power transmission to both of the cutting units, angle of contact on smaller pulleys would be further higher than the calculation made for individual belt drive of each cutting unit.

Power Transmission from Gear Box to Clod Crushing Unit

Diameters of both the pulleys were determined on the basis of velocity ratio.

Selected peripheral speed of top level blades = 8.6 m/s

Taking outer diameter of rotor blade hub as 230 mm and total length of straight blade as 110 mm.

Diameter of clod crusher blade tip circle (top layer) while rotation (D_{c1}) = 450 mm = 0.45 m

Therefore, for achieving peripheral speed of 8.6 m/sec,

$8.6 = (\pi \times D_{c1} \times N_c) / 60$

Where,

N_c = Number of rotations of clod crusher per minute, rpm

$N_c = (8.6 \times 60) / (3.1416 \times 0.45) = 365$ rpm

$D_c / D_{gc} = (1 - s) N / N_c$

Where,

D_c = Diameter of driven pulley on cutting unit, mm

D_{gc} = Diameter of driving pulley on gear box, mm

N = Number of rotations of driving shaft per minute, rpm

s = slip factor = 0.01

$D_c / D_{gc} = (1 - 0.01) \times 540/365$

Let selected diameter of commercially available driving pulley, D_{gc} = 204 mm

Therefore,

$D_c = (0.99 \times 540 \times 204) / 365 = 298.8$ mm

Commercially available 305 mm diameter pulley was selected as driven pulley for clod crushing unit.

Check for Suitability for Centre Distance

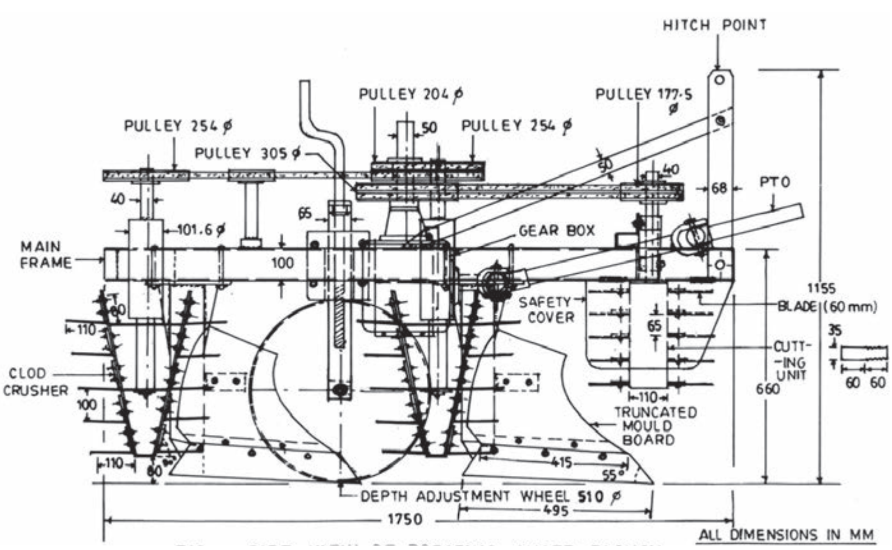
Centre distance (C) should be < $3(D_{gc} + D_c)$

Now, $3(D_{gc} + D_c) = 3(204 + 305) = 1527$ mm

Centre distance between driving pulley and driven pulley of clod crushing unit 1 (C_3) = 510 mm

Centre distance between driving pulley and driven pulley of clod

Fig. 6 Detailed drawing of side view of developed biomass incorporator



crushing unit 2 (C_4) = 785 mm

As C_3 (510 mm) and C_4 (785 mm) < 1527 mm

Therefore, selected V-belt drive was suitable as far as centre distance was concerned.

Theoretical Length of Belt

Length of belt for driving pulley and driven pulley of clod crushing unit 1

$= 2C_3 + (1/2) \times \pi \times (D_c + D_{gc}) + (D_c - D_{gc})^2 / 4C_3$

$= 2(0.510) + 1.57\ (0.305 + 0.204) + (0.305 - 0.204)^2 / (4 \times 0.510)$

$= 1.824$ m

Similarly, length of belt for driving pulley and driven pulley of clod crushing unit 2

$= 2C_4 + (1/2) \times \pi \times (D_c + D_{gc}) + (D_c - D_{gc})^2 / 4C_4$

$= 2(0.785) + 1.57\ (0.305 + 0.204) + (0.305 - 0.204)^2 / (4 \times 0.785)$

$= 2.372$ m

The nearest belt length (C-section) was selected from standard V-belt length tables.

Angle of Contact on Smaller Pulley for Belt Drive Arrangement of Clod Crushers

Angle of contact on smaller pulley for belt drive arrangement of clod crushing unit 1

$= \pi - 2\mathrm{Sin}^{-1}(D_c - D_{gc}) / 2C_3$

$= 180° - 2\mathrm{Sin}^{-1}(305 - 204) / (2 \times 510)$

$= 168.6° = 2.94$ radian > 2.1 radian

Therefore, safe for power transmission.

Angle of contact on smaller pulley for belt drive arrangement of clod crushing unit 2

$= \pi - 2\mathrm{Sin}^{-1}(D_c - D_{gc}) / 2C_4$

$= 180° - 2\mathrm{Sin}^{-1}(305 - 204) / (2 \times 785)$

$= 172.6° = 3.01$ radian > 2.1 radian

Therefore, safe for power transmission.

Fabrication of Biomass Incorporator

The fabrication of different components and integration of various sub-assemblies i.e. cutting unit, truncated mould board plough unit and clod crushing unit was carried out. A depth adjusting wheel having diameter of 510 mm and width of 100 mm was provided to control the working depth of the machine. To reduce the manufacturing cost, components such as gears, pulleys, belts, cutting blades, auger blades etc. were selected from the commercially available components being used in other equipment. Three idlers (130 mm diameter), one for cutting unit and one each for two clod crushing units, were provided on the slack side of the drive for proper tightening of the belts during field operation of the machine. The detailed drawing of side view of developed machine is shown in **Fig. 6**. The detailed drawings of cutting unit and clod crushing unit are shown in **Fig. 7**. A stationary view of developed biomass incorporator is shown in **Fig. 8**. The brief specifications of the machine are given in **Table 1**.

Field Trial of Biomass Incorporator

Field experiments were conducted at research farm of Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana, India (30° 54' 38" N latitude and 75° 48' 45" E longitude). The type of the soil was loamy sand having constituents as 745.9 g kg^{-1} sand, 122.1 g kg^{-1} silt and 132.0 g kg^{-1} clay. S*esbania*

Fig. 7 Detailed drawing of (a) cutting unit (b) clod crushing unit

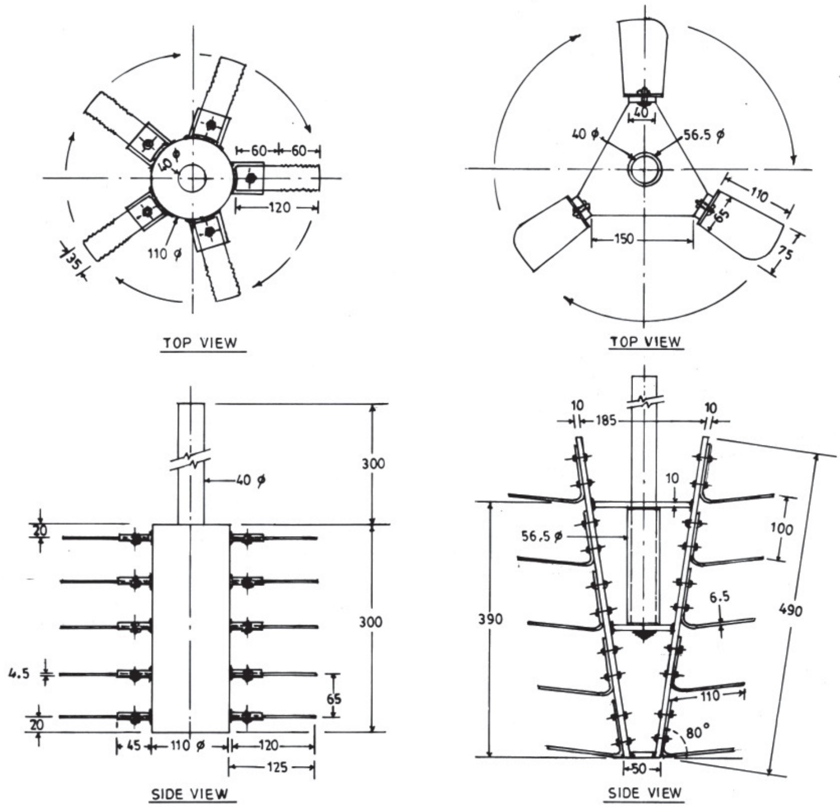


Fig. 8 A stationary view of tractor operated biomass incorporator

aculeata of variety 'Punjab Dhaincha 1' was sown as green manure crop in the first week of May with conventional seed-cum-fertilizer drill, using 50 kg seed per hectare. *Sesbania aculeata* is an indigenous green manure crop having unique ability to flourish in a variety of soil and climate conditions and is widely cultivated in India. Biomass incorporator was operated to incorporate the green biomass at two stages of crop growth i.e. 36 days after sowing (36 DAS) and 50 days after sowing (50 DAS). The various crop and field parameters at different stages of crop growth are given in **Table 2**. A 55 hp tractor, fitted with fuel flow meter, was used to operate the machine at rated engine speed of 2400 rpm producing PTO speed of 540 rpm. A view of the field at crop growth stage I (H1) and machine in operation at this stage has been shown in **Figs. 9** and **10**, respectively whereas view of the field at crop growth stage II (H2) and operational view of machine at this stage has been given in **Figs. 11** and **12**, respectively.

The parameters such as size of cut, fuel consumption rate, soil pulverization index, bulk density index and mixing index were recorded during field operation of the machine. The average size of chopped crop mass is referred as size of cut. After operation of machine, a square meter frame was placed randomly on the operated field at three places. The incorporated biomass was exposed out after carefully removing the layer of soil covering it. The size of cut of green mass was measured with standard measuring tape by taking 50 samples at each place and its average was taken. Fuel consumption rate was measured with the help of flow meter installed in the fuel line of the tractor. Pulverization index was measured by determining the mean mass diameter (MMD) of soil clod by using sieve analysis method (Mehta et al., 2005). Bulk density of surface soil was measured by using standard core cutter method (Mehta et al., 2005). Bulk density index is the percent difference between the soil bulk density before and after the operation of the machine. Mixing index is the percentage of crop mass incorporated in the soil. A square metal frame of 1 m side was used to measure the above-ground crop intensity in terms of weight. Before the machine operation, the crop standing inside the square

Table 1 Specifications of Tractor Operated Biomass Incorporator

S. No	Description of component	Specification
1	Type of implement	Tractor mounted (Three point hitch)
2	Recommended tractor power, hp	50 or above
3	Number of cutting units Height of cutting unit from ground, mm Length of cutting unit, mm Diameter of rotor shaft, mm Number of levels of blades on each unit Number of blades on each level Type of blade	2 280 300 110 5 5 Straight (serrated length 60 mm)
4	Mould board type / material	General type (truncated from rear)/ alloy steel
5	Share Type Size, mm	Slip share 495
6	Frame	Tubular section frame
7	Hitching type Mast height, mm Mast braces, mm (L × W × H)	Category II 1155 970 × 55 × 10
8	Depth wheel Diameter × Width, mm Method of adjustment	510 × 100 Hand screw
9	Hand screw Number of rotor units / shape Size of rotor (without blades), mm Number of levels of blades on each rotor Number of blades on each level Shape and size of blade, mm Direction of rotation Rotor speed, rpm	 Two / conical Top diameter - 260 Bottom diameter - 80 Length - 390 5 3 Trapezoidal section Width b1 - 65 Width b2 - 75 Length - 110 Clockwise as viewed from top Variable (as per PTO speed and transmission ratio)
10	Power Transmission Propeller shaft Drive from gear box to cutting unit and to clod crusher rotor Provision for adjustment	 6 splines V-belt and pulley Three idlers provided (130 mm diameter)
11	Overall dimension, mm (L × W × H)	1750 × 1160 × 1155
12	Weight, kg	465

Fig. 9 A view of field at crop growth stage I

Fig. 10 Field operation of biomass incorporator at crop growth stage I

Table 2 Crop and field parameters

S. No	Parameter	Crop Growth Stage I (36 DAS)	Crop Growth Stage II (50 DAS)
1	Soil moisture content, % (db)	9.47	10.04
2	Initial dry bulk density, g/cm^3	1.313	1.302
3	Average plant height, mm	685.5	1274.0
4	Average above-ground biomass density, q/ha	154	224.63

meter area was cut from the bottom and weighed (W_t). The machine was operated in the standing crop to mix/incorporate it into the soil. After machine operation, square meter was again placed randomly on the operated field and the pieces of the crop which were exposed 1/3rd of their length or more were collected and weighed (W_e). The mixing index was calculated as:

Mixing Index (MI), % = $[(W_t - W_e) / W_t] \times 100$

Results and Discussion

Performance of Biomass Incorporator

The machine was operated at forward speed of 2.10 to 3.4 km/h. The speed of cutting unit of the machine was 925 rpm thereby producing blade peripheral speed of 17.92 m/s. The rotor of the clod crushing unit was operated at 360 rpm thereby producing peripheral speed for topmost blade layer as 8.40 m/s. The field capacity of the machine varied between 0.25-0.28 ha/h while operating machine at forward speed of 3.3-3.4 km/h. There was non-significant change in field capacity of machine while operating machine at crop growth stage II than its operation at crop growth stage I. Machine was operated at an average depth of operation 17.90 cm and evacuated soil mass was sufficient to cover the amount of biomass up to crop growth stage II. No need of further increasing the depth of operation was felt as the quantity of soil mass excavated up to this depth was sufficient to cover the crop mass completely. The average width of cut of the machine was found to be 90 cm. The average size of cut of the green manure crop ranged between 17.05-20.20 cm when machine was operated at crop growth stage I, whereas, average size of cut of the biomass varied from 26.05 to 32.65 cm when machine was operated at crop growth stage II. The fuel consumption rate with the machine varied between 6.66-7.56 l/h at crop growth stage I (36 DAS) whereas it was 7.36-8.31 l/h at crop growth stage II (50 DAS). Soil pulverization index with the machine varied from 5.37 to 9.70 mm. Soil pulverization index was not significantly affected with the change in crop growth stage. The soil bulk density index was found to be 23.31-26.57%. The mixing index with biomass incorporator ranged between 97.08-97.91% at crop growth stage I where as it was 97.07-98.00% for 50 day old crop. No clogging or entanglement of biomass was recorded during operation of the machine at different levels of plant height.

Fig. 11 A view of field at crop growth stage II

Fig. 12 Field operation of biomass incorporator at crop growth stage II

Conclusions

Biomass incorporator was found to be sucessful for efficient incorporation of green manure crop. The machine handles adequate amount of soil mass that is sufficient for proper coverage of chopped biomass. The machine results in well pulverized field and there was no reduction in mixing index value at different stages of crop growth.

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Optimization of Developed Continuous Type Pomegranate Juice Extractor

by

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Abstract

The pomegranate consumption is tremendously increasing due to the development of diversified value-added products and its health benefit among all age groups of consumers. For commercial use, there is no availability of continuous juice extraction, which is drudgery-free at industrial level. To address this major issue, continuous pomegranate juice extractor was designed and fabricated having major components such as feed chute, carrier roller, crushing roller and juice collecting platform with filter. The optimization of the extractor was performed with carrier roller speed (5, 7.5, 10, 12.5, 15 rpm) having highest machine capacity (357 kg/h), extraction efficiency (88%,) with low extraction losses (< 12%) and having a significant effect ($P < 0.05$) with good coefficient of determination analysed using response surface methodology. The comparison performance studies revealed that high juice efficiency in continuous juice extractor (98.3%) compared to batch conventional mixer (48.2%). The physicochemical analysis also proved better results in continuous pomegranate extractor mainly pH (3.23 ± 0.025), TSS (19.13 ± 0.126 0Brix), total sugar (14.80 ± 0.09 %), titratable acidity (0.70 ± 0.04 %), total phenol (0.209 ± 0.008 %) and total flavonoids (22.1 ± 2.3 CE /100 mL).The sensory evaluation using the hedonic scale method revealed that continuous juice extractor (> 8.75) compared to the mixer.

Keywords: Pomegranate fruit; Pomegranate juice; Extraction efficiency; Extraction loss; Machine capacity; Total sugar; Total phenol; Sensory evaluation.

Introduction

Pomegranate (*Punica granatum* L.) fruits are popular worldwide, which belongs to the Punicaceae family. Pomogranate is extensively cultivated in countries like India, Iran, Turkey, Morocco, Afghanistan, China, Greece, Cyprus, Israel, Chile, Portugal and South Africa (Holland et al., 2009, Al-Said et al., 2009, Fawaole and Opera 2013 and Mphahlele et al., 2016,). India is the largest producer of pomegranate fruits at the global level with total production of 2442.39 thousand MT (NHB, 2017). The fresh aril is the edible part of the fruit, which is consumed or either processed mainly contains substantial quantities of acids, sugars, polyphenol and important minerals (Al-Maiman and Ahmad, 2002).

Pomegranate are used for the preparation of fresh juice, drinks, wines, jam and jelly, also for colouring beverage products and flavouring (Fadavi et al., 2006, Mousavinejad et al., 2009 and Holland et al., 2009).

From past 15 years Pomegranate has gained rich source of polyphenols compared to wine and green tea beverages (Gil et al., 2000, Fischer et al., 2013 and Mphahlele et al., 2016). The consumption of pomegranates has much benefit in health contributing more antioxidant capacity that strongly correlates with more concentration and phenolic compounds compositions (Gil et al., 2000, Borochov-Neori et al., 2011, Fischer et al., 2011, He et al., 2011 and Fawole et al., 2013). However, the phytochemicals differ in concentration and are dependent on cultivar types (Shwartz et al., 2009, Tezcan et al., 2009, Gil et al., 2000, Elfalleh et al., 2011 and Fawole et al., 2013).

Recently, juice extraction is been followed by different methods either whole fruit or the separated arils in juice preparation at industrial level (Miguel et al., 2004, Muhacir-Guzel et al., 2014 and Mphahlele et al., 2016). The consumption of pomegranate juice has shown several health benefits reduction of systolic blood pressure in hypertensive patients, decrease of common carotid artery intima-media thickness (Aviram et al., 2004), attenuation of myocardial ischemia and the lipid profile improvement of diabetic patients (Rosenblat et al., 2006). In addition, it is also helpful in curing of atherosclerosis and cardiovascular dis-eases (Al-Jarallah et al., 2013, Aviram et al., 2008 and Hamoud et al., 2014).

During processing of juice, significant effects in safeguarding of color, aroma, and flavor on the quality of the final products is attempted, were as the concentration of fruit juices is an important operations unit in fruit processing. The commercial pressing of pomegranate into juice and its concentration facilitate its handling and storage, enabling its application in the food industry (Maskan, 2006).

Pomegranate is a tropical and seasonal fruit, and its production occurs during August and September. Therefore, many processes such as cold storage, concentration, reducing to paste, or drying are used to conserve pomegranates or their juice (Ashoush et al., 2012). Pomegranate fruits and related juices contain high amounts of water (75-90%), which makes them susceptible to enzymatic and microbial deterioration reactions due to the high enzymatic and microbial activities in water. Thus, extracted juice is concentrated for long-term storage and easier transportation (Kumar, 2015).

Table 1 List of techniques used for pomegranate juice extraction

Sl No	Juice extraction techniques	Pomegranate Fruit modicum	Description
1	Newly developed continuous juice extractor	Whole fruit	The fruit was fed continuously in the roller grooves were in crushed fruit juice were obtained.
2	Electronic mixer	Arils and seed	In this technique manually peeling the fruits, separating the arils from peel. The arils and seeds were blended at a maximum speed using electrical mixer.

In recent decades, many institutions have developed diversified pomegranate value-added products for consumption among all age groups of consumers. The foremost challenge in pomegranate juice extraction is the mechanical peeling of the fruit., as it is time consuming and irritating as the hands get stained due to polyphenols and oxidative enzymes contain in peel (Dhinesh et al., 2016).For commercial use, there is no mechanized machine available which is free from drudgery, faster and continuous juice extraction.

Hence, the present investigation focuses on development and evaluation of the novel continuous pomegranate juice extraction, which is prime requirement to the growers and entrepreneur. Further efforts are also made to evaluate the quality of extracted pomegranate juice. Techno-economic feasibility of the pomegranate juice is also assessed.

Material and Methods

2.1 Raw Material

The freshly matured Pomegranate fruits (cv. Bhagwa) are sourced from Gujarat, India, grown during kharif season (June 2015 - October 2015) was procured from nearby private orchards (21.5222° N, 70.4579° E). The Pomegranate fruits were stored at temperature (7.5 ± 0.5 °C) and Relative humidity (92 ± 3%) before juice extraction from the developed continuous juice extractor (Mphahlele, 2016). Initially, the surface of the fruits was thoroughly washed under tap water and the surface sterilized with 100 ppm chlorine for 5 minutes (Rich, 2003 and Dhumal et al., 2012). The fruits of uniform size, colour and maturity were selected by visual observation for conducting optimized experimental trials.

2.2 Newly Developed Continuous Pomegranate Fruit Extractor

The extractor was developed based on the engineering properties of the cv. Bhagwa pomegranate (Jithender et al., 2017a and Jithender, 2017b). **Fig. 1** shows the

Fig. 1 Continuous type pomegranate juice extractor

Table 2 Parameters considered for performance evaluation of extractor (Olaoye, 2011)

Sl No	Parameters	Formulas
1	Machine capacity (kg/h)	$C_o = W_j / T$ W_j: Weight of juice extracted (kg), T: Total time taken for extraction (h)
2	Extraction efficiency (%)	$E_{ef} = (W_j / J_p) \times 100$ W_j: Weight of juice extracted (kg), J_p : Juice present (kg)
3	Extraction losses (%)	$E_{EL} = [(J_p - J_e) / J_p] \times 100$ J_p: Juice present (kg), J_e: Juice extracted (kg)

major components in the extractor were feeding chute, carrier roller, surgical doctors' blade, crushing roller, waste outlet, juice collection platform, juice filter, driving mechanism, motor and speed controller. The feeding chute is essential part, where the fruit is fed into the carrier roller groove through gravity (Catalano, 2016 & Wettlaufer, 2017). The thickness and length of the surgical doctors' blade was 0.4 cm and 17.5 cm were fixed based on the initial physical properties studies (Jithender et al., 2017a). The two identical rollers carrier rollers and crushing rolls were made of Teflon (Poly tetra fluoro ethylene (PTFE). The juice collecting platform with filter was made of SS material at the centre of platform (Eyeowa et al., 2017).

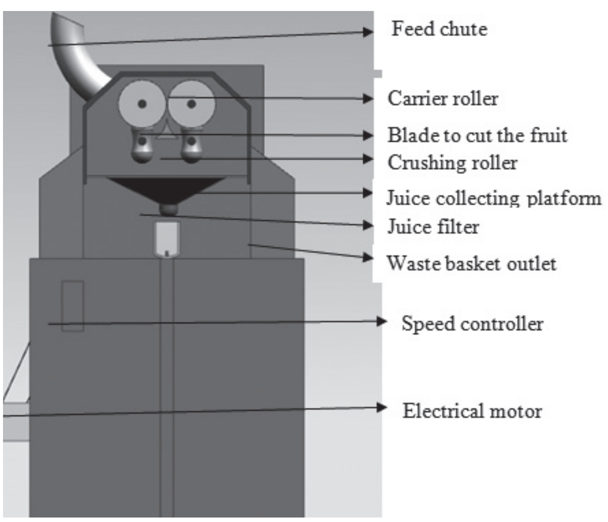
2.2.1 Principle Operation of the Fruit Extractor

The fresh Pomegranates fruit were passed through feed chute from where the fruits fell by gravity into the grooves of carrier roller, where conveying to the cutting blades and are cut into two halves. After cutting the fruits are further conveyed to the crushing rollers which rotate in such a way that the head of crushing roller pierces into the grooves made over the carrier rollers. The arils are this crushed to juice while the peels fall into the wastebasket outlet. The extracted juice is collected and filtered (**Fig. 2**).

2.3 Comparative Juice Extraction Techniques

The experiment was conducted using the newly developed continuous pomegranate juice extractor and study was compared with the conventional methods was electronic mixer juice extraction. The sorted fresh pomegranate was subjected juice extraction as shown in **Table 1**.

Fig. 2 Isometric view of continuous juice extractor



2.4 Performance Evaluation of the Juice Extractor

The carrier roller speed was considered for optimizing the performance of the newly developed juice extractor (Olaoye, 2011). **Table 2** shows the equation considered for evaluating extraction efficiency, extraction loss and machine capacity of the extractor.

2.5 Chemicals

All the chemicals used in the assay were of analytical grade. The reagents used in the experimentation were purchased from Sigma Chemical Co. (USA) and H.B. Chemicals - Offering Microbiology Culture Media (HiMedia) Pvt. Ltd. in Gujarat, India.

2.6 Physicochemical Analysis of Pomegranate Extracted Juice

2.6.1 pH

pH of the pomegranate juice was measured using digital pH meter Model: Adwa AD8000) in triplicates. The probe of pH meter was inserted into extracted juice and the stable reading obtained was considered as the final pH value.

2.6.2 Total Soluble Solids (TSS)

The digital hand held refractometer (Model: PAL-1; Make: Atago, Japan) was used for measuring TSS content. The distilled water was used for calibration of the instrument. A drop of the extracted juice was placed on the sample slot refractometer and data was noted in terms of °Brix (Ranganna, 1991).

2.6.3 Total Sugar

Total sugar content was estimated following the phenol-sulphuric acid method described by Sadasivam and Manickam (1996).

2.6.4 Glucose and Fructose

The glucose and fructose content were determined in pomegranate juice by phenol sulfuric acid method (Nielsen, 2010 and Ismail et al., 2014).

2.6.5 Titrable Acidity

10 ml of pomegranate juice was diluted to 30 ml with distilled water.

Further, 10 mL diluted extracted juice was taken for titration and add 2-4 drops of 1% phenolphthalein indicator. The obtained solution is titrated against 0.1 N NaOH solution (Ranganna, 1991).

2.6.6 Total Phenols

This was determined using the Folin-Ciocalteu reagent (CR) assay according to the method of Singleton et al. (1978). Initially, 5ml of juice was added to 25 ml, 80% methanol in distilled water and was stored at temperature (27 ± 1 °C) for 3h. The blue color was developed using a Folin-Ciocalteu reagent (FCR) in an alkaline medium (20% sodium carbonate) over 90 minutes. The UV-visible spectrophotometer (Model: UV1700; Make: Shimadzu, Japan) was used to measure phenols at absorbance (750 nm).

2.6.7. Determination of Total Flavonoid Content

Total flavonoid content was measured as described by Yang et al. (2009). Catechin (0.025-0.100 mg/mL) was used for the standard curve. The results were expressed as catechin equivalent per 100 mL pomegranate juice (mg CE/100 mL pomegranate juice).

2.6.8. Total Anthocyanins

The total anthocyanins content in the extract from fruits. The samples were diluted by a potassium chloride buffer until the absorbance of the sample at 510nm wavelength was within the linear range of the spectrophotometer (Cecil 2010 UV-visible). This dilution factor was later used to dilute the sample with the sodium acetate buffer. The wavelength reading was performed in two halves and the juice was immediately extracted after 15 min of incubation, four times per sample, diluted in the two different buffers and at two wavelengths of 510 nm and 700 nm (Ismail et al., 2014).

2.7 Sensory Analysis

Sensory analysis was carried out by ten panelists, according to the previous methods (Castro-Vázquez et al., 2009). During the test, samples were presented at room temperature in standard juice-testing glasses. Panelists were placed separately in rooms for unbiased evaluation of sensory attributes. Pomegranate juice was obtained from the developed extractor and electrical mixer were scored from 1 (lowest) to 9 (highest) for color, odor, sweetness, flavor, acidity and overall acceptability.

2.8 Statistical Analysis

Statistical analysis was carried out by using response surface methodology was used to optimize the operating conditions of the developed juice extractor. The independent variable in this experiment was the carrier roller speed. Five levels which are the order of 5, 7.5, 10, 12.5 and 15 rpm of an independent variable were chosen for this study. Data analysis was carried out by using Design Expert Version 11.0.

Fig. 3 Electrical mixer

Results and Discussion

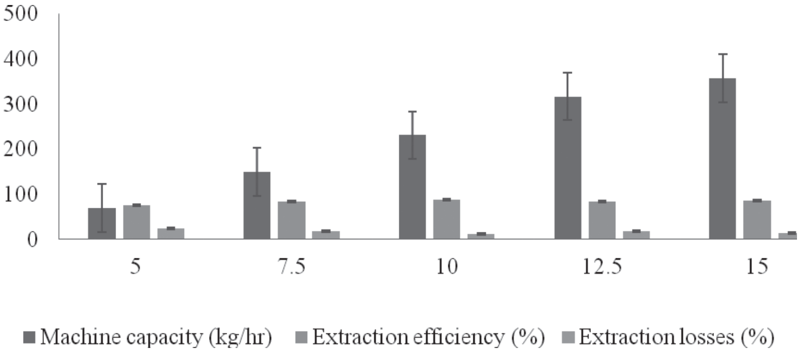
3.1 Optimization of the Developed Pomegranate Juice Extractor

The optimization of the developed pomegranate juice was selected based on the variation of the carrier roll speed with maximum machine capacity and extraction efficiency with minimum extraction loss. The **Fig. 3** shows the average calculated parameters such as machine capacity, extraction efficiency and extrac-

Table 3 ANOVA table for evaluating the effect of carrier roller on the performance of the pomegranate extractor

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Machine capacity (kg/h)					
Corrected Model	342877.482[a]	4	85719.371	3643.643***	.000
Intercept	1514782.694	1	1514782.694	64388.330***	.000
Speed	342877.482	4	85719.371	3643.643***	.000
Error	588.143	25	23.526		
Total	1858248.320	30			
Corrected Total	343465.625	29			
Extraction efficiency (%)					
Corrected Model	542.763[a]	4	135.691	29.114***	.000
Intercept	206681.288	1	206681.288	44345.691***	.000
Speed	542.763	4	135.691	29.114***	.000
Error	116.517	25	4.661		
Total	207340.568	30			
Corrected Total	659.280	29			
Extraction losses: (%)					
Corrected Model	510.996[a]	4	127.749	571.078***	.000
Intercept	8742.640	1	8742.640	39082.309***	.000
Speed	510.996	4	127.749	571.078***	.000
Error	5.592	25	.224		
Total	9259.228	30			
Corrected Total	516.588	29			

Fig. 4 Parameters for continuous type pomegranate juice extractor performance



tion losses with varied carrier speed. **Tables 3** and **4** shows the ANOVA table and empirical model with coded factors. Based on the highest and lowest capacity of machine, the carrier roller speed (10 rpm) was optimized for further evaluation of the physicochemical analysis of the fruit juice.

3.2 Machine Capacity (kg/h)

The carrier roller speed (15 and 5 rpm) resulted the maximum (357 kg/h) and minimum machine capacity (68 kg/h) in extracting of pomegranate juice (**Fig. 4**). The **Table 3** shows the effect of varied carrier roll speed on machine capacity was statistically analyzed and the result obtained to be significant ($P < 0.05$) with a R^2 =0.998. In **Table 4**, the coded variables indicated that machine capacity increases with the increases carrier roller speed. The obtained results should similar to the experiments conducted by Aviara et al. (2013) for multi-fruits.

3.3 Extraction Efficiency (%)

The extraction efficiency was found to be highest (88 %) and lowest (55%) at the carrier speed (10 and 5 rpm) (**Fig. 4**). The obtained results were analyzed and the results found to be similar in case of extractors developed by Olabisi and Adelegan (2015) for citrus fruit juice. However, from the below ANOVA table the speed was statistically significant ($P < 0.05$). The empirical model implies that extraction efficiency increases with increases the carrier roller speed up to 10 rpm to get high extraction efficiency and thereafter with the increment in carrier roller speed extraction efficiency decrease. The higher speed (10 rpm) resulted that extraction time is shortened resulting in the inadequate crushing pressure on the fruit resulting in the lesser extraction efficiency. The type of fruit also is effect on the machine's extraction efficiency which seems to indicate that extraction efficiency is not only dependent on the potential juice content of fruits and vegetables but it could also depend on their texture/hardness. The results obtained were very comparable to the study of Oyeleke, 2007 and Agidi et al., 2013 extraction efficiency showed extraction efficiency of 81-98% and 66%, respectively.

Table 4 Development of empirical model first order equation of the performance characteristics of pomegranate juice extraction

Sl No	Parameters	Empirical model equation
1	Machine capacity (kg/h)	$-127.48 + 39.86 * A - 0.47 * A^2$
2	Extraction efficiency (%)	$-10.55 + 16.70 * A - 0.73 * A^2$
3	Extraction losses (%)	$110.55 - 16.70 * A + 0.73 * A^2$

Where,
A is the for-carrier roller speed (RPM), negative sign indicates the antagonistic effects and whereas the positive sign indicates the synergistic effects.

Table 5 Comparative pomegranate juice extraction techniques

Juice Extraction techniques	Juice extraction yield (%)	Juice extraction cost (Rs/kg)	Machine capacity(kg/h)
Continuous juice extractor	98.3 ± 0.2	0.2 ± 0.01	357 ± 0.2
Electrical mixer	48.2 ± 0.5	16 ± 0.4	4 ± 0.1

3.4 Extraction Losses (%)

The evaluation resulted that at carrier speed (5 and 10 rpm), maximum and minimum loss were 88 % and 12 % respectively. The Table 3 shows the effect of varied carrier roll speed on extraction losses was statistically analyzed and the result obtained to be significant ($P < 0.05$) with a $R^2 = 0.99$. The model represented that the extraction losses increase with increasing the carrier roller speed (**Table 4**). This result is similar to the extraction loss obtained from the evaluation of multi-juice extractor with extraction loss of 2-20% in case of, Olaniyan, 2007, Aviara, 2013 and Adanu et al. (2015).

3.5 Comparative Pomegranate Juice Extraction Techniques

The conventional fruit batch type juice extractor (domestic mixer) and the continuous juice extractor was evaluated for the best techniques in maximum juice extraction. It was found that the conventional batch type juice extraction and the continuous juice extraction yield were around, 48.2 % and 98.3% respectively (**Table 5**). It was noticed that the high juice yield was obtained in continuous juice extractor compared to the batch type of juice extraction. The juice obtained was having high turbidity and clarified juice was obtained.

3.6 Physicochemical Analysis of Extracted Juice

The quality of the juice extracted

from the optimized continuous juice machine and the mixer is shown in the **Table 6**.

The pH of continuous extractor juice and electrical mixer juice were 3.33 ± 0.025 and 3.94 ± 0.046, respectively with both juices being acidic in nature. The pH of pomegranate juice characterizes its acidic taste (Zarei et al., 2011).

The average TSS obtained were 10.50 ± 0.25 and 15.13 ± 0.13 and °Brix, respectively in developed juice extractor and mixer. The sweetness and flavor in the fruit as well as due to decrease in juice acidity and tannin concentration causes the increase in the TSS content (Shwartz et al., 2009; Zarei et al., 2011). The value of TSS in the case of continuous extractor juice was found more than that of electrical mixer juice, indicating that the better quality of juice from continuous extractor juice than the electrical mixer. The lower value of TSS in electrical mixer juice might be due to chances of crushing the seed during grinding in mixer/grinder in the conventional method.

As shown in the **Table 6** that the titratable acidity content which is responsible for the extremely bitter or sour taste of pomegranate juice. This observation was in agreement with those reported in the literature (Mena et al., 2011; Rajasekar et al., 2012; Vardin and Fenercioglu, 2009). As in previous cases here also due to the crushing of seed during extraction in the conventional method, the value of titratable acidity in the juice of conventionally extracted was found less.

The pomegranate juice extracted by developed juice extractor has significantly higher ascorbic acid (11.2 ± 0.3 mg/100g) than in juice extractor by electrical mixer extractor (9.1 ± 0.4 mg/100g). The above results are similar with Ismail et al., 2014 and Thankur, 2016.

The average total sugar of continuous extractor juice and electrical mixer juice was found to be 14.80 ± 0.09 and 9.81 ± 0.04, respectively, Similar to the TSS, the total sugar content of the juice extracted by developed extractor juice was found more than that of conventionally extracted juice, Here also the lower value of total sugar in conventionally extracted juice might be due to a slight amount of seed, crushed during extraction.

Total flavonoid content is in pomegranate juice extracted the order of electrical mixer (42 ± 2 mg GAE/100 ml 52 ± 1 mg GAE/100 ml) less than continuous juice extractor (52 ± 1 mg GAE/100 ml).

The average total phenolic of developed extractor juice and juice extracted with mixture was found to be 270 ± 7 mg/100ml and 230 ± 6 mg/100ml, respectively. In the pomegranate juice, the phenolic content was significantly higher than that of mixer extracted juice. Such variation due to the effect of extraction method on the whole fruits. The rpm of rotating and crushing rollers are might extract phenolic compounds from the rind, which is mixed with juice because pomegranate peel is rich source of phenolic compounds. Several researchers have reported that pomegranate fruit is a rich source of phenolic contents (Artes et al., 2000; Opara et al., 2009; Al Said et al., 2009).

The pomegranate juice content large amount of fructose than the glucose which is reported by Ekþi and Özhamamcý, 2009 and Thakur, 2016. Both the glucose and fructose content were significantly higher in pomegranate juice extracted by developed juice extractor (6.8 ± 0.01%) as that of obtained by electrical mixer (5.4 ± 0.01%). These results are agreed with those obtained by Miguel et al., 2004 and Ismail et al., 2014.

As shown in the **Table 6** that the lowest significant non-reducing sugar percentage was found in juice extracted by developed extractor juice while other contained significant highest amount of non-reducing sugars. These results are in agreement with Ismail et al. (2014) which is found that total sugars and reducing sugars were highest in the juice obtained by blending of seeds while non-reducing sugars was highest in whole fruit juice. These results are similar to those resulted by Thankur, 2016, Ghadge and Jadhav, 2015 and Ismail et al., 2014.

3.7 Sensory Evaluation

The results in Fig.5 shows the average consumer acceptability studies significant differences were detected by the panellists between continuous extractor and mixer extracted juice in terms of colour (8 vs. 6.5), odour (8.5 vs. 7), acidity (8 vs. 5), sweetness (8 vs. 6.5), flavour

Table 6 Physicochemical analysis of extracted juice with continuous type and electrical mixer

Sl No	Chemical analysis	Continuous extractor	Electrical mixer
1	pH	3.33 ± 0.05^b	3.94 ± 0.04^a
2	TSS (°Brix)	10.50 ± 0.25^b	15.13 ± 0.13^a
3	Total sugar (%)	14.80 ± 0.09^a	9.81± 0.04^b
4	Titratable acidity (%)	0.7 ± 0.04^a	0.58 ± 0.03^b
5	Ascorbic acid mg/100g	11.2 ± 0.3^a	9.1 ± 0.4^b
6	Non reducing sugars (%)	0.94 ± 0.01^a	0.92 ± 0.03^a
7	Fructose (%)	6.8 ± 0.01^a	5.4 ± 0.01^b
8	Glucose (%)	6.4 ± 0.1^a	5.8 ± 0.5^b
9	Total anthocyanins (mg/100 ml)	13.1 ± 0.5^a	8.2 ± 0.7^b
10	Total flavonoids (mg GAE/100 ml)	52 ± 1^a	42 ± 2^b
11	Total phenol (mg/100ml)	270 ± 7^a	230 ± 6^b

*Means with the same letter are not significantly different (a = 0.05)

(7.8 vs. 6.3) and overall acceptability (8.1 vs. 6.2), respectively (**Fig. 5**). The number of panellists found the continuous extracted juice good flavour twice than juice extracted with electrical mixer juice. The overall acceptability more in case of continuous type extractor than electrical mixer.

Conclusions

The diversified pomegranate value added products and its health benefit to the consumers attracted all the growers and the industrial people entering in the field of pomegranate processing. Hence, the novel continuous pomegranate extractor for faster juice extraction with drudgery free was developed to provide relief to pomegranate fruit growers, traders and entrepreneurs. The performance studies of the continuous extractor were based on the speed of the carrier roller in extracting the juice, were in 10rpm speed was selected for optimization technique based on the highest machine capacity, extraction efficiency and lowest juice extractor. In future this juice extractor can also be used for extraction of juice from other fruits such as orange, mandarin and lemon.

Practical Applications

- Developed continuous pomegranate juice extractor would be helpful for farmers as well as small entrepreneurs including roadside marketers, can start up small value addition centre and get more remuneration.
- This developed continuous pomegranate juice extractor can be used for commercial use.
- In future this juice extractor can also be used for extraction of juice from other fruits such as orange, mandarin and lemon.

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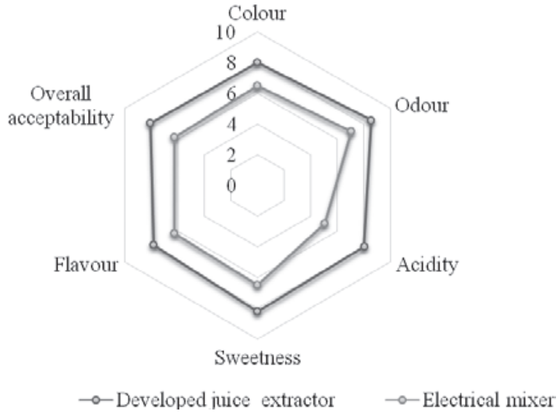
Fig. 5 Sensory evaluation of pomegranate juice extracted with continuous type extractor and electrical mixer



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Analysing Failure of the Government-backed Free Tractor Distribution to Farmers in the Five Agro Ecological Zones in Cameroon: the Case of SONALIKA Tractors

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Abstract

The study aimed at evaluating the main causes of the failure of an agricultural mechanization program in Cameroon despite attempts by the government to improve on the sector with the introduction over 1000 free SONALIKA tractors to farmers in five Agro-ecological zones of Cameroon. Specifically, it was to identify and prioritize the primary causes of breakdowns and propose sustainable management plan. Questionnaires were administered to respondents (tractor operators and mechanics) and data collected was analyzed using SPSS and Microsoft excel. Interviews were carried out to get root causes of breakdown then prioritized using Pareto chart. Organization of root causes was done using ISHIKAWA diagram and a Gantt chart used to make a preventive maintenance plan. Results show five primary causes (Material, Machine, Manpower, Method and Environment) of operational weaknesses of SONALIKA tractors and after prioritizing, three vital few causes were identified; (Manpower, Machine and Environment) that if solved, 90% of the effects will be avoided. Data for external causes showed that the decision to provide tractors and implements was 48% by the Ministry of Agriculture and Rural Development, 30% based on availability. About 54% of operators had access to operator's manual but only 18% used it. Twenty-three percent (23%) of tractor mechanics were available to all tractor operators with most of them being less proficient. There was low affordability (30%) of spare parts in all the zones. Internal causes showed that tractor breakdown was mostly due to broken parts (75%).

Keywords: SONALIKA tractor, maintenance plan, mechanisation, tractor breakdown

Introduction

Agriculture exists as one of the chief sectors in every African economy and plays a central role in achieving development. Farming represents 32% of continental African gross domestic product (GDP) and subsistence farming alone employs over half the population of Sub-Saharan Africa (FAO and UNIDO, 2008)

In Sub-Saharan Africa (SSA) specifically, 65% of farm power is hand power, 25% is animal power, and 10% is engine power meanwhile, in Asia, Latin America, North Africa and the Middle East, the farm power is 25% hand power, 25% animal power, and 50% engine power. The reason behind this low level of agricultural mechanization in sub-Saharan Africa (SSA) include population growth, land scarcity, climate change degrading ecosystems, and under investment in agricultural research, infrastructure, and technology (Mrema et al., 2015)

Sheru et al. (2013) reported that no country has ever successfully made the transition to industrialization without first developing its agricultural sector, yet the agricultural sector in Africa remains stagnantly underdeveloped. The FAO and UNIDO, (2008) stated that countries that have achieved development and industrialization have invested in technology. A similar investment in the mechanization of agriculture in Africa would have an exponential effect on output and continental economic prosperity, as rates of economic return to agricultural research are proven very high. Taking the case of Rwanda, from 2004 to 2014, the government increased investment in the agricultural sector from 3.5% to 7.2%, and as a result, crop production more than doubled (Sheru et al., 2013).

In 2003, the African Union proposed the Comprehensive Africa Agriculture Development Program (CAADP) guide which is used today by the African continent to develop her agricultural sector. The CAADP rests on four pillars: increasing land under cultivation, as about 60% of cultivable land in Africa is not being farmed; linking farmers to markets through innovation in the value chain; increasing the yields of staple foods; and investing more in research and technology to the order of 10% of national public expenditures. Presently, the target for public expenditures spent on agriculture has been attained by 9 of 54 African countries (Sheru et al., 2013)

Most African countries have an economy strongly dominated by the agricultural sector. In some countries, agriculture generates up to 50 percent of the gross domestic product (GDP), and contributes over 80 percent of trade in value and more than 50 percent of raw materials to industries. It provides employment for the majority of Africa's people. Despite this domination, investment in the sector is still grossly low in most African countries FAO, (2011).

The low level of engineering technology inputs in agriculture is one of the main constraints hindering the modernization of agriculture and food production systems in Africa FAO and UNIDO, (2008),. Farm power in African agriculture, especially sub-Saharan Africa, relies to an overwhelming extent on human muscle power, based on operations that depend on the hoe and other hand tools. Such tools have implicit limitations in terms of energy and operational output in a tropical environment.

Past efforts to mechanize African agriculture such as sharing of tractors and their implements have produced mixed results. Compared with other regions, Africa has not had the large-scale investment in agricultural infrastructure, such as irrigation or other inputs needed to intensify crop production. This is partly because Africa is fragmented into relatively small countries, unlike countries such as Brazil, India, or China. Investment in mechanization has been limited to large commercial farms or government schemes. In many cases where governments established tractor hire schemes to serve small-scale farmers, planning was very short term, and management was poorly trained and poorly supported. Such schemes, though relatively few across the continent, failed miserably, denting the image of agricultural mechanization in general (Fonteh, 2007).

The low level of mechanization in Cameroon is still a thorny problem to be solved. Hand tools are highly dominating in most farming systems with approximately 92% in small-scale farming and 72% in the exploitations of great importance and agricultural processing industries (FAO, 2011). The Animal haulage is employed mainly in certain areas, about 13% in the Extreme North, North, Adamaoua and 2% in the North-West (FAO, 2011). In large farms, the majority of the mechanized operations are dependent on the activities of postharvest (42%), and in a less proportion with plowing (15%).

In Cameroun, the actions towards the development of agricultural mechanization are specific and do not lie within the scope of a total reflection. This led the authorities to reflect thoroughly on the way of leading the development of agricultural mechanization vis-a-vis the national challenges as regards improvement of production and agricultural productivity (FAO, 2011).

It is within this framework that the project TCP/CMR/3204 "Formulation of agricultural mechanization strategy (AMS) in Cameroun" was born. Coordinated by the National Centre for Experimentation on Agricultural machinery CENEEMA, and with the support of FAO, this project aimed at assisting the Government of the Republic of Cameroun in the formulation of an Agricultural Mechanization Strategy (AMS) by taking into account all the factors which contribute to its development (FAO, 2011).

Despite all the efforts put in place to improve mechanization, it is still at its floor level in SSA and Cameroon in particular. It can be seen that the reasons for the disappointing performance and low contribution of mechanization to agricultural development have been the fragmented approach to mechanization issues. This can be attributed to poor planning by government agencies, over-reliance on unpredictable or unsuitable, one-off, aid-in-kind or other external mechanization inputs. Lacks of teamwork or coordination within and between government departments and inherent competition with private sector business initiatives in mechanization services have not helped the situation (FAO, 2008).

In order to boast agricultural mechanization in Cameroon, a contract that led to the introduction of 1000 tractors with adequate equipment was signed between the Cameroon and the Indian government. However, due to failures in the proper management of these tractors in the field, most of the tractors have been abandoned on the field.

The main objective of this work was to investigate the reasons for the failure of the agricultural mechanization program in Cameroon in spite of heavy financial and material input from the government.

Material and Methods

2.1 Study Site

This study was carried out in the five agro-ecological zones of Cameroon. Cameroon is characterized by diverse and distinct ecosystems with their respective climates. The country has been organized into five major agro-ecological or agro-climatic zones distinguished by dominant physical, climatic and vegetative features. Cameroon is located in the continent of Africa and covers 472710 square kilometers of land and 2730 square kilometers of water making it the 54th largest nation in the world with a total area of 475440 square kilometers. It is located between latitude 1° 650' and 13° 070' North and between longitude 8° 490' and 16° 190' East.

2.2 Target Population

The study population involved in this project were SONALIKA tractor beneficiaries that the Cameroon government in collaboration with the Indian government gave as subsidies in the form of tractors and their accessories. The tractor beneficiaries in total were 80 in number.

Table 1 Recapitulation of the frequency of primary causes of SONALIKA tractor weaknesses

Primary cause	Designation	Frequency of breakdown occurrence
Environment	Problem link to climatic conditions	25
Machine	Problems link to machine make up	35
Material (product)	Problem linked to product handled by machine	5
Method	Problem link to technology used	15
Manpower	Problem link to users	40

2.3 Sampling Technique and Sampling Size

Since tractor beneficiaries are sparsely distributed all over the country, the sample size was gotten based on a significant representation in order to ease the work. To do this a simple random sampling technique was used. It was calculated using the formulae proposed by Amin and Martin, (2005). The formula holds only when the total beneficiaries in all the zones are known.

$$n = [(z^2 \times p \times q) + ME^2] / [(ME^2 + z^2 \times p \times q) / N] \quad (1)$$

Where:
n = sample size,
α = confidence level (95%),
z = critical standard score (1- α/2),
P = probability of success (0.5),
q = probability of failure (0.5),
ME = marginal error (5%),
N = total population size of tractor beneficiaries (80).

From the equation, we had a sample size of 60 beneficiaries for all the five zones. Since the tractor beneficiaries had different densities in the different zones, in order to have the sample size in each zone without bias, a stratified sampling technique was used to have the sample size of each zone.

2.4 Data Collection

Both open and close questionnaires were given to respondents to give their views on the causes of breakdown, brainstorming with respondents was done to come out with the root causes of breakdown. Data was collected between 2nd March to 23th May 2018 and respondents of the required data were tractor operators and tractor mechanics.

2.5 Data Analysis

The data gotten from the field was analyzed using SPSS (Statistical Package of Social Sciences) version 20 and Excel spread sheet software. Both spread sheets were used to clean for irregularities. The cleaned data was then summarized into descriptive statistics in the form of frequencies and percentages. A qualitative analysis was then done for the different parameters obtained.

Results and Discussion

3.1 Identification and Prioritization of Primary Causes of Breakdown

Data obtained from survey show five primary causes presented in 4M and E (Machines, Methods, Materials, Manpower, and Environment) responsible for the operational weaknesses of SONALIKA tractors and time spent on maintenance.

As seen on **Table 1**, the highest frequency of breakdowns came from user related causes followed by those associated with machine technology. Though all these aspects are highly influential as primary causes of operational weaknesses of tractor breakdown, there was the need to use a maintenance tool to prioritize the causes in order to ease maintainability of these tractors with an objective of increasing the shelf life

Table 2 Categorization of primary causes of tractor breakdown in order of importance

Symbol	Causes	Frequency of occurrence	Percentage (%)	Cumulative frequency
A	Manpower (users)	40	33.33	33.33
B	Machine make up	35	29.17	62.5
C	Environmental conditions	25	20.83	83.33
D	Methods used	15	12.5	95.83
E	Material (product)	5	4.17	100
Total		120	100	

thus improving its productivity and reducing the time spent on maintenance.

3.2 Prioritization of Primary Causes of Breakdown

Table 2 quantifies the frequency of occurrence to come out with the most influential primary causes of breakdown

From the **Table 2**, if the cause 'A' is solved, the problem of tractor breakdown will be avoided at 33.3%. If causes 'A and B' are solved, we will solve the problem of breakdown at 62.5%. Finally, if cause 'A, B and C' are solved, the problem of breakdown would be avoided at 83.33%.

Fig. 1, identifies what is called the "law of the vital few," or more often, the "80:20 rule." Here we are interested in isolating the few important causes that lead to a high effect of breakdown (prioritization). So solving the problem of the vital few causes (Machine make up, Manpower and Environment), we will tackle more than 90% of the effects of breakdown.

In order to better tackle these vital few causes of breakdown, they were categorized into internal (Machine make up) and external (Manpower and environment) causes of tractor breakdown.

3.3 Analysis of the External Causes of Tractor Breakdown

These are causes responsible for the operational weaknesses of SONALIKA tractors but which are not due to the tractor make up.

3.3.1 Educational Background of Tractor Operators and Mechanics in the Five Agro Ecological Zones of Cameroon

Education is the knowledge of putting one's potentials to maximum use (Crowder, 2007). From **Fig. 2**, 44% of operators have primary school level, against 13% who have no formal education. These results can be attributed to the frequent breakdown of tractors as tractor operators can hardly read and understand the manual. It ties with the results of Bhutta, (1997) who says, the literacy status of tractor operators and mechanics may influence understanding about the use of tractors and its associated implements because he can study the operation manual and understand all the instructions. Also, though 20% and 23% respectively have secondary and tertiary level of education, they do not have the knowledge of how to better manage the tractors.

3.3.2 Training Background of Tractor Operators in the Five AEZ of Cameroon

Fig. 3 shows that majority of operators (46%) learnt how to operate tractors from other tractor operators rather than through a formal tractor operating training school such as CENEEMA. This means that different tractor operators would train their subordinates based on their own limited experience producing gaps or lapses in their subordinates

Fig. 1 Pareto diagram prioritizing the primary causes of breakdown

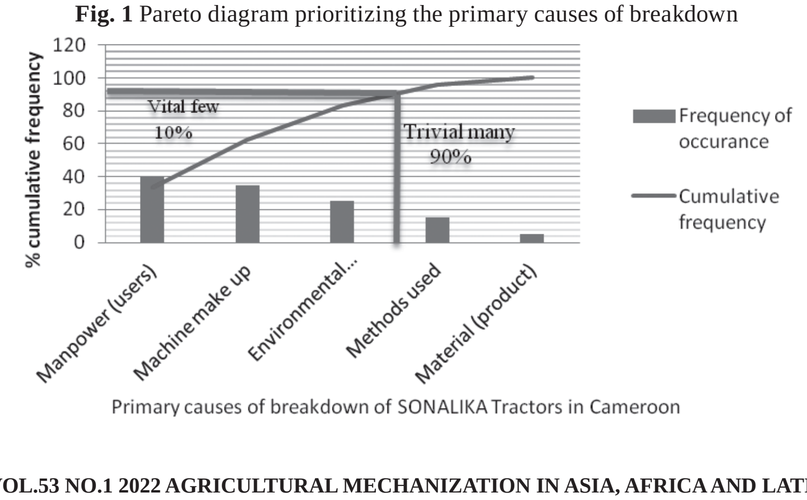


Fig. 2 Educational background of tractor operators and mechanics in the five AEZs of Cameroon

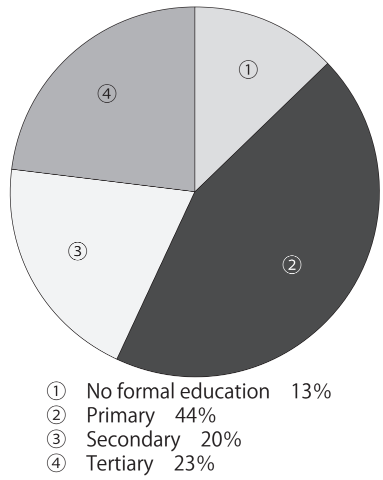
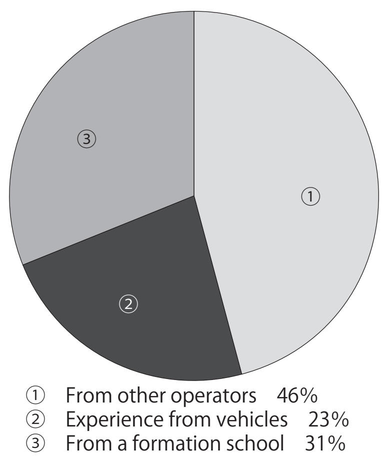


Fig. 3 Training background of tractor operators in the five AEZ of Cameroon



training which is in accordance to (Wehrspann and Jodie, 2003). Also, 23% of operators got their training from other vehicles such as heavy duty trucks. All these high informal training of operators influence greatly on the breakdown of tractors as they do not have a good mastery of the machine

3.3.3 Experience Background of Tractor Operators in the Five AEZ of Cameroon

Fig. 4, shows that 48% of operators have experience of less than 5 years, 22% have experience of 5 to 10 years and 30% have experience of more than 10 years. This shows that a good number of operators are not familiar with the tractors as such they hardly detect a fault when it indicates. When the machines have strange sound or is indicating a fault, they cannot easily identify which later generates into a bigger cause of tractor failure.

3.3.4 Choice of Material to Be Given to Beneficiaries in the Five AEZ of Cameroon

Fig. 5 shows that 48% of the decision to give tractors and their implements came from the ministry of Agriculture and Rural development (MINADER), 30% based on the availability and 22% decision of experts. Since the decision of choice was mostly done by MINADER and the available equipment, without taking into consideration the need of each beneficiary, most beneficiaries had implements that were not compatible with the tractor horse power and their needs. Also, most beneficiaries did not have an insight into the need of tractors for farming as such requested for tractors only without implements. At the end they abandoned the tractors

3.3.5 Issuance of Tractor Operation Guide in the Five AEZs of Cameroon

Tractors operator's manuals are the 'oracle' on proper tractor operation and maintenance. Reading the operator's manual is important because it tells the owner or operator how to set the machine and what part to check before one takes it to

Fig. 4 Experience of tractor operators in the five AEZ of Cameroon

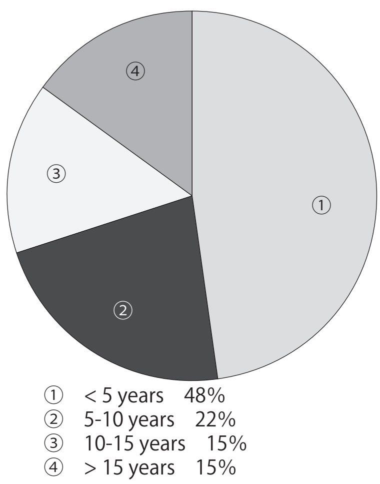


Fig. 6 Issuance of tractor operation guide in the five AEZ of Cameroon

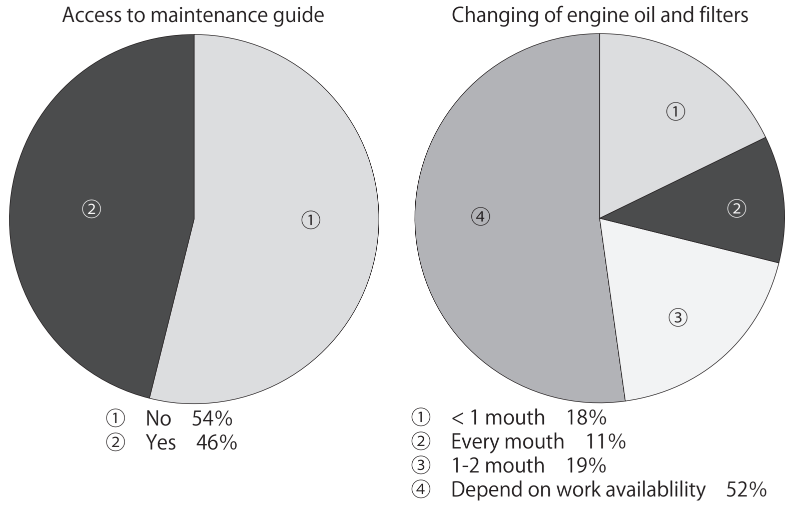


Fig. 5 Choice of material to be given to beneficiaries in the five AEZ of Cameroon

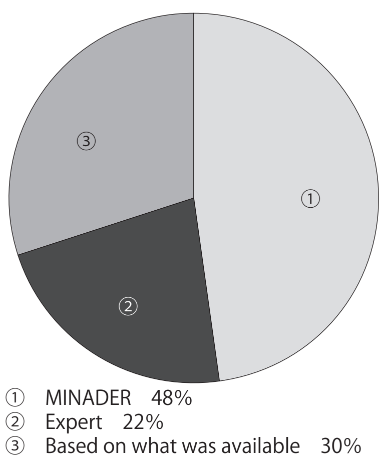
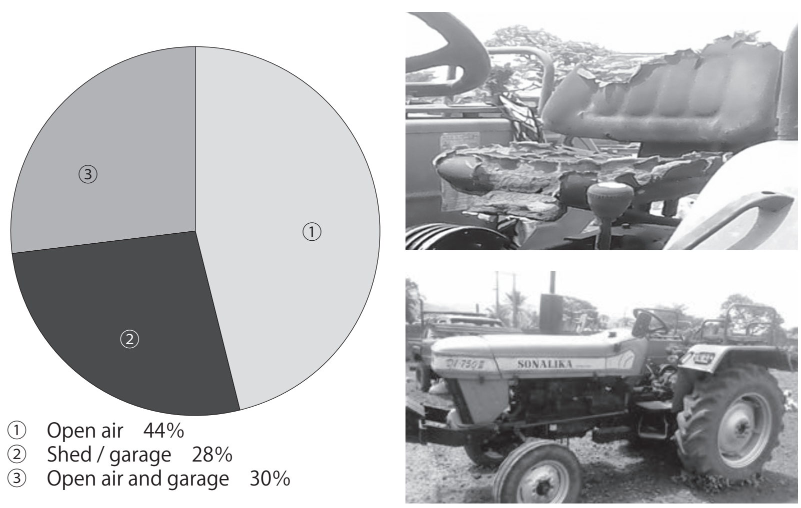


Fig. 7 Availability and proficiency of tractor mechanics in the five AEZs of Cameroon



the field and what type of maintenance to carry out and when to do it (Wehrspann and Jodie, 2003). From survey, operators that have access to operator's guide were 54% from chart 'A' but it was realized that only 18% chart 'B' actually make use of the guide. This shows the impact of illiteracy level of operators. This cause of failure is also justified in 'B' as 52% of operators' only change engine oils and filters depending on work availability.

3.3.6 Tractor Housing After Usage in the Five AEZ of Cameroon

Fig. 7 shows that 44% of the beneficiaries park their tractors in open air, 28% beneficiaries store in both garage and open air and 28% store in sheds. These results explain why most parts get weakened due to excess adverse conditions on tractor parts leading to rusting of parts which is in line with (Wehrspann and Jodie, 2003). The impact is great with these SONALIKA tractors when working or parked in open air as it does not have FOPs to prevent direct sunrays and rain drops. Thus the comfort of operators is not guaranteed.

3.3.7 Availability and Proficiency of Tractor Mechanics in the Five AEZs of Cameroon

Fig. 8 shows that 73% of operators do not have readily available tractor mechanics. Thus services too expensive for few available mechanics that discourages operators form continuously using the tractors once they breakdown. Also, out of the few available 27% tractor mechanics, some are less proficient as they are recycled truck mechanics adapted to handle tractors. This makes them to be limited in their expertise as some breakdowns are usually beyond their know-how leading to abandonment of tractors.

3.3.8 Availability of Tractor Spare Parts in the fFive Agro-ecological Zones

From **Fig. 9** five, we see that the

Fig. 8 Availability and proficiency of tractor mechanics in the five AEZs of Cameroon

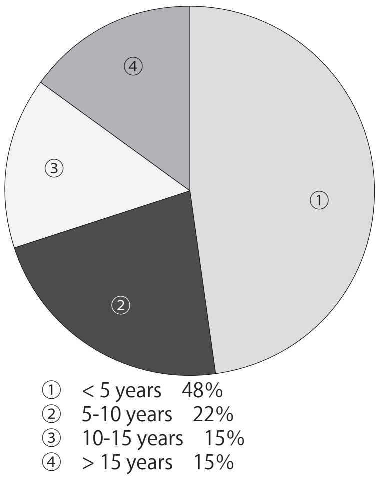
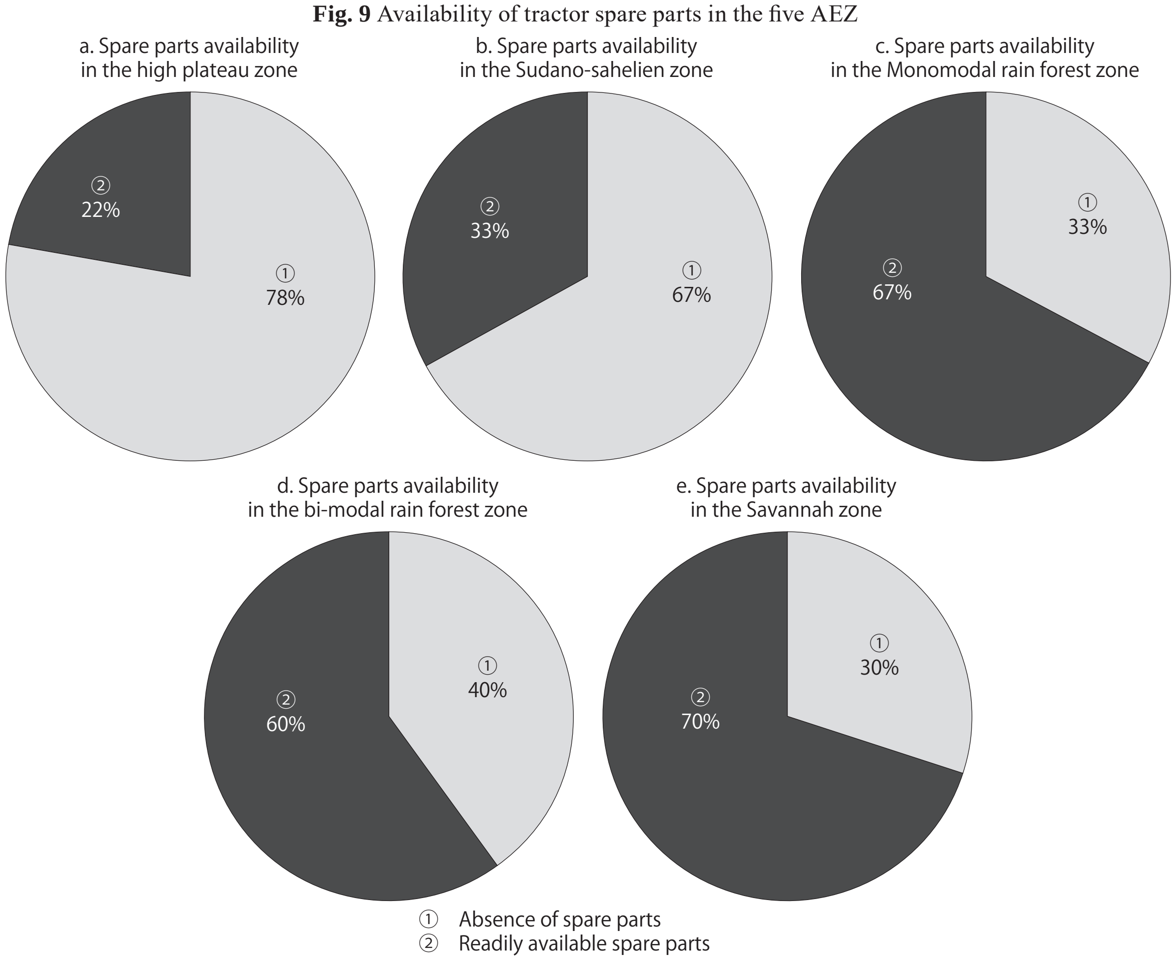


Fig. 9 Availability of tractor spare parts in the five AEZ



availability of spare parts in the High plateau zone is 22%, Sudano-sahelian zone (33%), Savannah zone (30%), Bi-modal zone (60%) and finally Mono-modal zone (67%).

High plateau zone (**Fig. 9a**) has the least opportunity of having spare parts compared to Sudano-sahelien (**Fig. 9b**) and Savanah zone (**Fig. 9e**) despite the fact that it is closer to the only source of spare parts (EMEIL DIESEL). This is because the latter is closer to Chad and Nigeria where they can easily have spare parts.

The highest availability of spare parts is found in the Mono-modal zone (**Fig. 9c**) and Bi-modal zone (**Fig. 9d**) respectively. This is because the only source of spare part is located in this zone and also the assembly park is located there respectively. This gives them the opportunity to have a good mastery of how and where to get spare parts easily

The effects that the absence of spare parts impact on breakdown of tractors in Cameroon is enormous as it forces most operators to abandon tractors getting back into hand tools which though tedious but readily available.

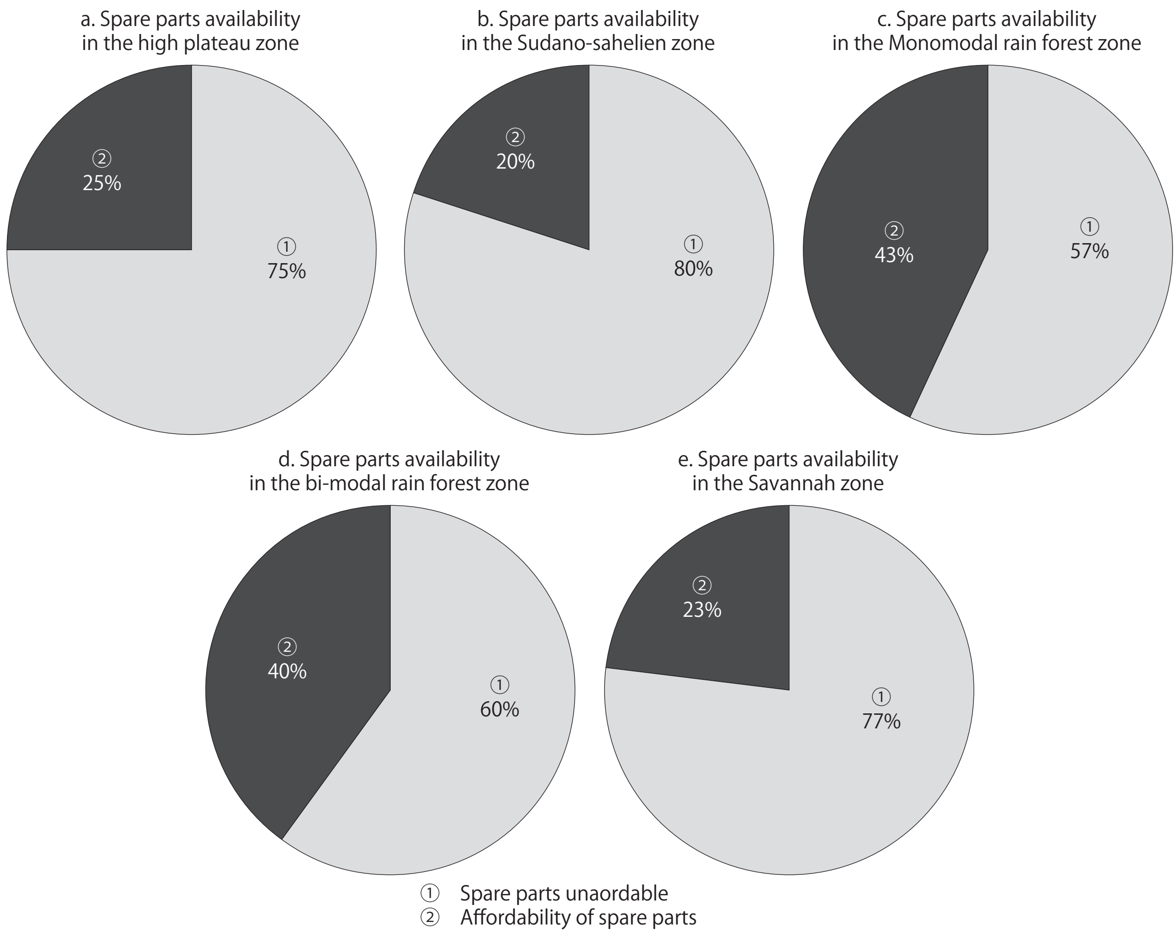
3.3.9 Affordability of Tractor Spare Parts in the Five AEZs

Fig. 10 shows that the ability to buy spare parts in the High plateau zone is 25%, Sudano-sahelian zone is 20%, in the Savannah zone (SZ) is 23%, Bi-modal zone (BMZ) is 40% and finally the Mono-modal zone is 43%.

The Sudano-sahelien zone (**Fig. 10b**) and Savanah zone (**Fig. 10e**) have the least ability to buy spare parts in Cameroon as they have a second option which is Chad and Nigeria. It is followed by High plateau zone (**Fig. 10a**) which also has a low ability to buy spare parts since there is only one supplier who imposes prices on the spare parts. The Bi-modal zone (**Fig. 10d**) and Mono-modal zone (**Fig. 10c**) have a relatively high ability to buy spare parts as they do not incur any extra cost of travelling to the sole supplier for the acquisition of spare parts.

From findings, we realized that there is generally a low ability to buy spare parts in the five zones reasons being that since there is only one supplier of spare parts, they turn to be very expensive and tend on the prices. This scare away most tractor owners and scares from buying spare parts as such look for other alternatives like locally made parts, adapted parts and to a greater

Fig. 10 Availability of tractor spare parts in the five AEZ



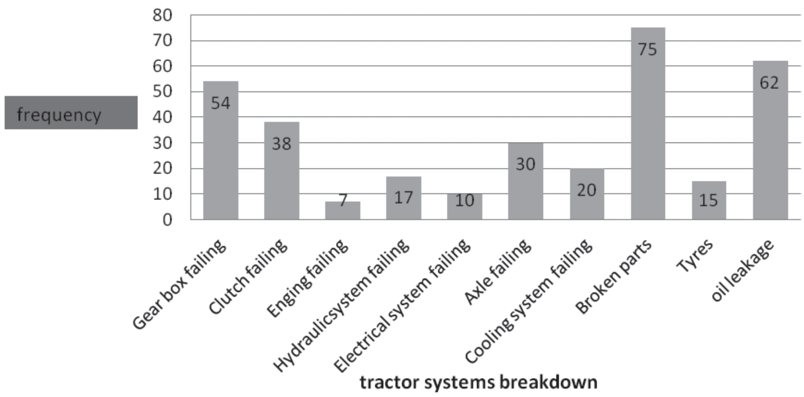
extend prefer to go back into their hand tools thus abandoning tractors.

3.3.10 Accessibility of Tractor Spare Parts in the Five AEZs

Accessibility means having access to something. It refers to the ability for everyone, regardless of disability to access, use and benefit everything within their environment. The various charts in **Fig. 11** give us the discrepancy on the accessibility of spare parts in the different zones;

From the pie charts, those in the sudano-sahelian zone and those in the savannah zone do not have easy access to spare parts in Cameroon thus prefer Chad and Nigeria who are closer to get their spare parts or will prefer to make use of locally made spare parts. Also in the high plateau zone, there is little access to spare parts as Douala is far from the zone thus they make use of locally made materials and where they do not have locally made spare parts, they are compelled to abandon the tractors thus not serving the intended purpose. Lastly the bi-modal and mono-modal rain forest are closer and easily accessible to the source of spare parts.

Fig. 12 Breakdown frequency of various tractor systems

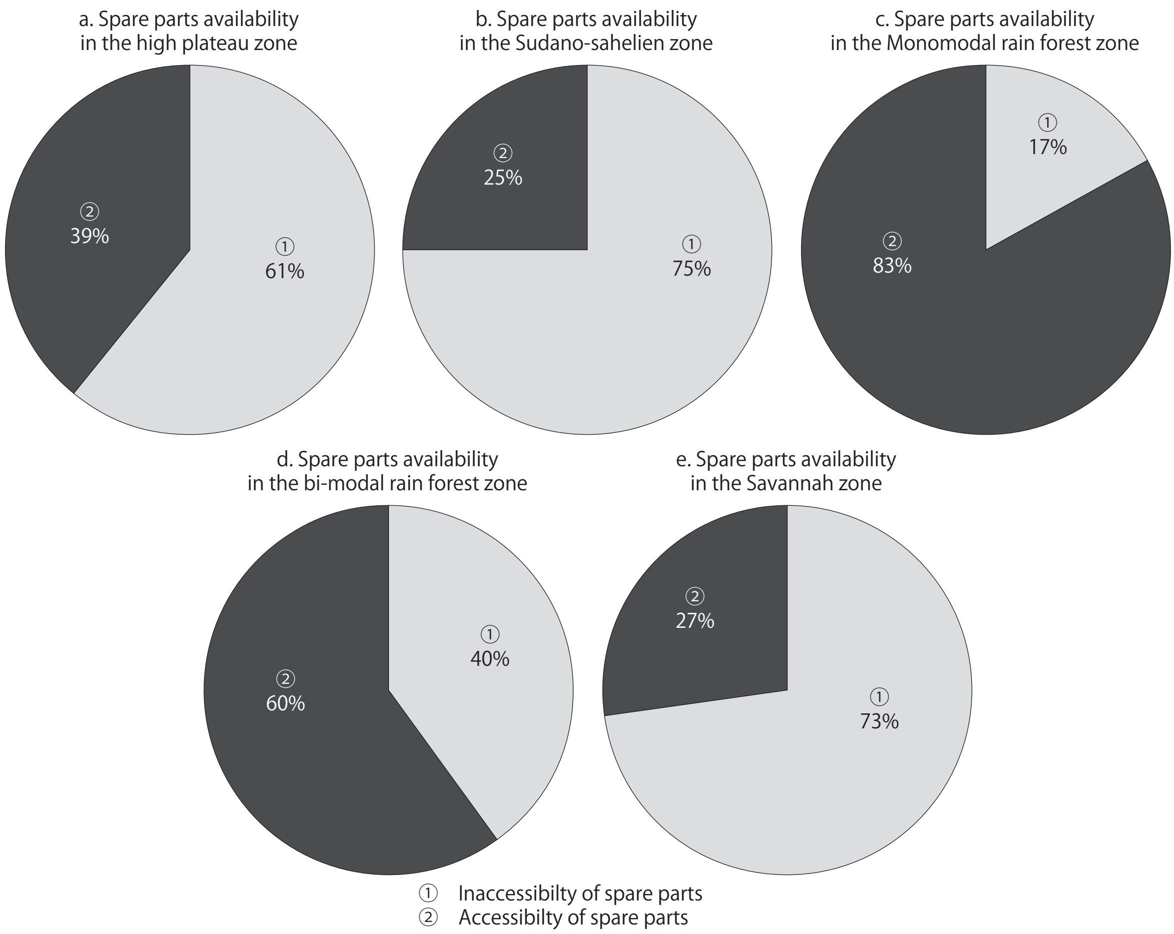


3.4 Identification and Analysis of the Internal Causes of Tractor Breakdown

Out of the three vital few causes of operational weaknesses of tractors obtained from **Fig. 12**, Machine make up is categorized as an internal cause responsible for the operational weakness of these tractors.

3.4.1 Identification of Various

Fig. 11 Accessibility of tractor spare parts in the five AEZs



Tractor Systems That Breakdown Frequently in All the Five Zones

From results obtained in the different zones it was seen that all the zones have almost the same reasons for breakdown with slight differences due to the pedological nature of soils and the types of crops cultivated. **Fig. 12** shows the percentages of breakdown of the different systems of tractors in all the zones of Cameroon.

Fig. 12 shows that most causes of breakdown are broken parts that account for 75%, followed by oil leakages 62%, gear box failure 54%, clutch failure 38%, axle failure 30%, hydraulic failure 17% and other minor causes.

Broken Parts: this is the major cause of breakdown in tractors due to poor quality materials used in the fabrication of parts. These parts mostly do not possess adequate properties that are attributed to materials used in the manufacturing of machine elements. This can be justified with the fact that bolts, nuts, chassis, implements, three-point linkage get broken (**Fig. 13**) when high force is applied which is an indication that the compressive strength and ultimate tensile strength of the material is relatively lower than normal. As such we can say the materials used are mostly made of cast iron since it has a high amount of graphite 2 to 4% that makes it less ductile and very brittle, it compressive strength ranges from 6.3 to 7.1 tons/cm^2 and ultimate tensile strength between 1.26 to 1.57 tons/cm^2 which is far less than that of mild steel which is 4.75 to 25.2 tons/cm^2 and ultimate tensile strength is 5.51 to 11.02 tons/cm^2. This clearly shows that machine elements made of cast iron have a very low ultimate tensile strength thus cannot resist for a long time without breaking which is the reason for frequent broken parts of tractors (Appendix 3) especially the implements that are in contact with the soil and requires much strength for farm operations.

Oil Leakages: it is also another issue that causes tractor breakdown. As oils leak, there is shortage of required amount in the various systems that lead to wears and broken parts due to insufficient lubrication. This is realized from survey that the hoses and clips used in transporting oil to a destination and holding the hoses to prevent leakages respectively are of low quality and have a high tendency of failing frequently thus excessive leaks are seen on the tractors (**Fig. 14**).

Gearbox and Clutch: from survey it was seen that the gears skip at every instance and this is because the spring that blocks the various gears weakens easily and also because

Fig. 13 Showing broken parts of tractors due to poor quality of material: a) Adapted washer, b) Engine support, c) Adapted bolt, d) Engine block support, e) Transmission bar guard, f) Welded mold board plow, g) Broken PTO

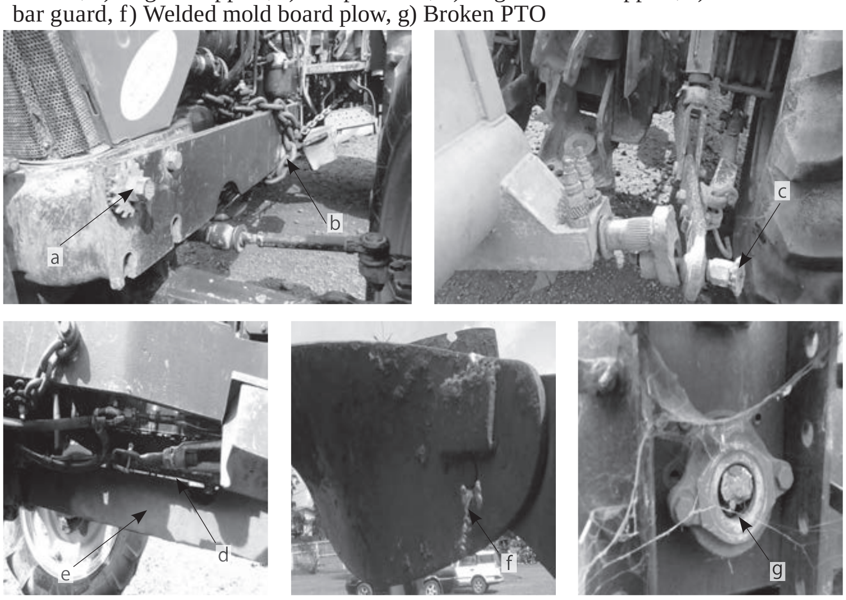


Fig. 14 Oil leakages on tractor and clips holding hoses to prevent oil leaks: a) Hose covered with leaked oil, b) Oil leakage, c) Weakened clips

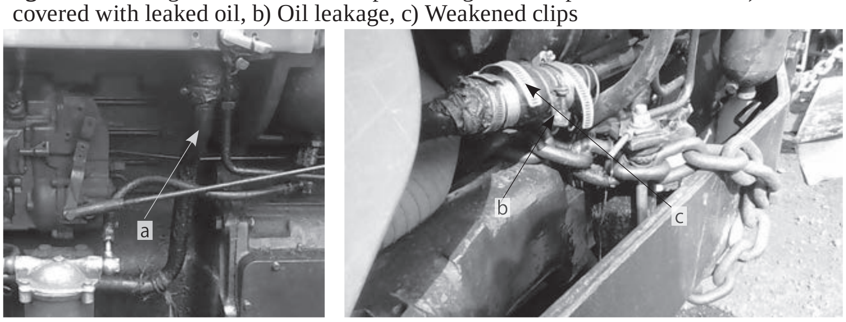
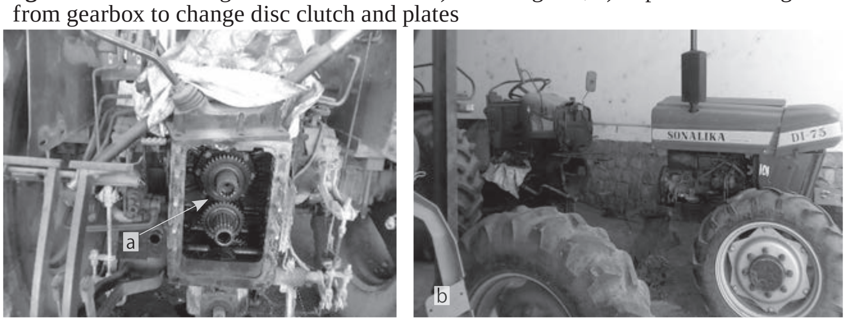


Fig. 15 Illustration of gear box breakdown: a) Broken gears, b) Separation of engine from gearbox to change disc clutch and plates



of misalignment of the transmission shaft. It was also realized that breakdown of gear box is due to the usage of unsuitable gears where not necessary thus leading to failures. There is also frequent breaking of clutch disc and plates that calls the attention of mechanic most often and since they are not readily available and spare parts are scarce it forces most tractor owners to abandon tractors after a short time of usage.

Engine: the engine of the tractor is very robust and does not easily fail the only problem that these engines may fail is shortage of oil due to poor maintenance

The other systems fail due to poor maintenance and operator's knowledge on how to better handle the tractors that lead to their frequent breakdown.

3.4.2 Analysis of the Root Causes of Breakdown of Various Tractor Systems

a) Cause-effect (ISHIKAWA) Diagram for Tractor Breakdown

Fig. 16 ISHIKAWA (cause-effect) diagram tractor breakdown

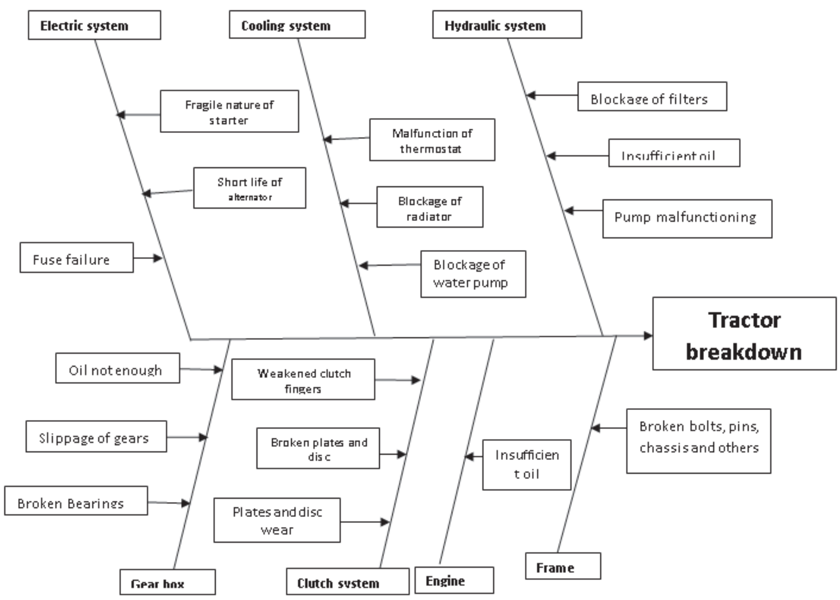
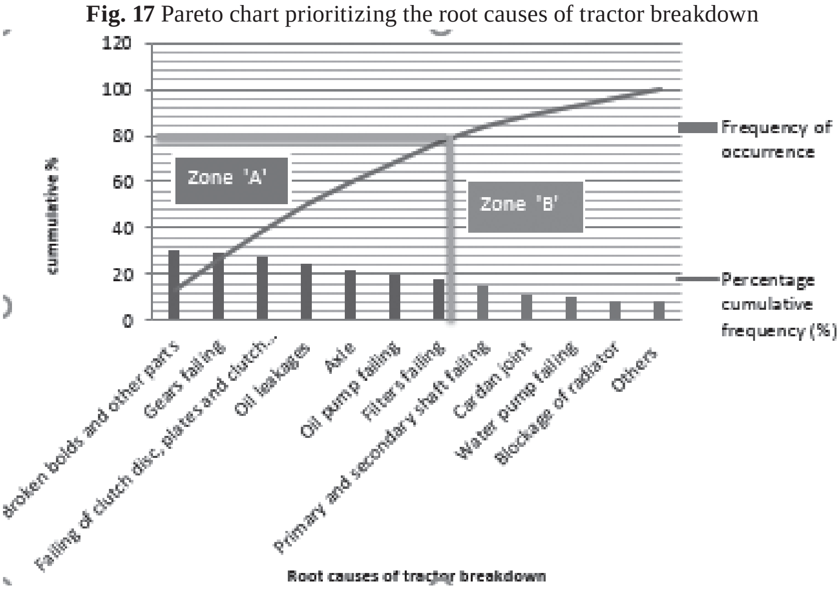


Fig. 17 Pareto chart prioritizing the root causes of tractor breakdown



Ideas collected after interviews, were grouped based on the different tractor systems as main causes and root causes of breakdown where easily visualized using ISHIKAWA diagram. **Fig. 16**;

b) Pareto Chart and Graph

Root causes gotten from the cause-effect diagram can be categorized using Pareto chart starting from the most frequent as seen on **Table 3** below;

Interpretation of chart:

The Pareto chart makes it possible to prioritize causes of breakdown. This principle highlight that some causes are more important than others (Latino, 2006). From the data **Fig. 17**, it is seen that by solving the causes in zone 'A', we would have solved 80% of the problems of tractor breakdown which are the vital few causes of breakdown. The chart also shows the sequence of prioritizing causes to remedy first. If solving the cause of broken parts, we would have solved 33.39% of the effects and if the second, third and fourth causes are solved 80% of the effects will be solve and this will remedy the problem of tractor breakdown.

Since cause-effect (ISHIKAWA) diagram and Pareto (ABC) analysis are maintenance tools that are used to identify root causes of breakdown and prioritization of these causes on what to remedy first respectively. It does not bring out a way to remedy these causes as such management tool is necessary to solve the problems.

3.5 Proposition of a Maintenance Plan for Remedying the Causes of Breakdown

Planning is all about making sure the future happens exactly as you want it to happen. In a nut shell, a maintenance plan is to guide the future actions of the maintenance person in charge so that things are done right on purpose and not by accident. In order to execute a maintenance planning, there are sequences to follow which are;

3.5.1 Maintenance Information Loop

The maintenance information loop describes the flow of maintenance information from the operator to the mechanic and back to the operator and how the various aspects fit together. It is said to be a close loop. The **Fig. 18** illustrates the maintenance information loop as follow;

Explanation of information flow loop:

Fig. 18 shows that as the operator comes back from the field, he tells the maintenance team (mechanic) what signs he has noticed in the field. The maintenance team does a diagnostic to detect the problem by visiting the checklist (a list that carries all the parts of the tractor that are liable to failure). It gives an assurance that all the parts have been diagnose. From here, the list shows whether it is short term maintenance or long term maintenance to be executed. After the execution of the task, the tractor is tested and feedback sent with details of equipment failure to be recorded in the log book for historical reporting purposes. This feedback helps in refining the content of checklist to improve the quality of the preventive maintenance specially to prevent reoccurrence of failures. All information gotten from feedback are put into good use otherwise it is waste of time as it is with this that management report can be created from maintenance report (Dave, 2017).

3.5.2 Propose Maintenance Checklist for Tractors

Interviews and documentaries on the causes and effects that led to failure of tractor parts and identification of the parts is the most time consuming aspect of setting up a PMP. The list of inventory is as seen in **Table 4**;

This list help assures the maintenance teams whether or not they have touched all parts of the tractor thus prevent accumulated failures in other parts of the tractor unknowingly.

Table 3 Hierarchization of the internal causes of tractor breakdown

Root causes	Frequency of occurrence	Percentage frequency (%)	Percentage cumulative frequency (%)
Broken bolts and other parts	30	13.39	13.39
Gears failing	29	12.95	26.95
Clutch disc, plates and clutch fingers fail	28	12.50	38.84
Oil leakages	25	11.18	50.02
Axle	22	9.82	59.84
Oil pump failing	20	8.93	68.93
Filters failing	18	8.04	76.81
Primary and secondary shaft failing	15	6.70	83.51
Cardiant joint	11	4.91	88.42
Water pump failing	10	4.46	92.88
Blockage of radiator	8	3.57	96.45
Others	8	3.57	100
Total	224	100	

3.5.3 Gantt Chart (Scheduling) for Proper Maintenance

The purpose of this chart is to map out what task to be done in parallel and which need to be done sequentially. Scheduling or preventive maintenance (PM) plays a key role in every operation since these will regularly occur and will involve time, energy and workforce to complete (Naybour, 2014). A sample of the schedule is seen on **Table 5**.

After developing a maintenance schedule, proper implementation and adaptation is crucial. It is important that those in charge of the tractors be well familier with the maintenance schedule as they are the core users of the system. Having tractor operators, tractor mechanics and others who are in the entourage of the tractor trained to use the schedule increases the chances of proper functioning of the tractor and reduces time spend on maintenance. Since there are a lot of dynamics in equipment assets, it is important to always analyze the results of the

Fig. 18 Maintenance information loop

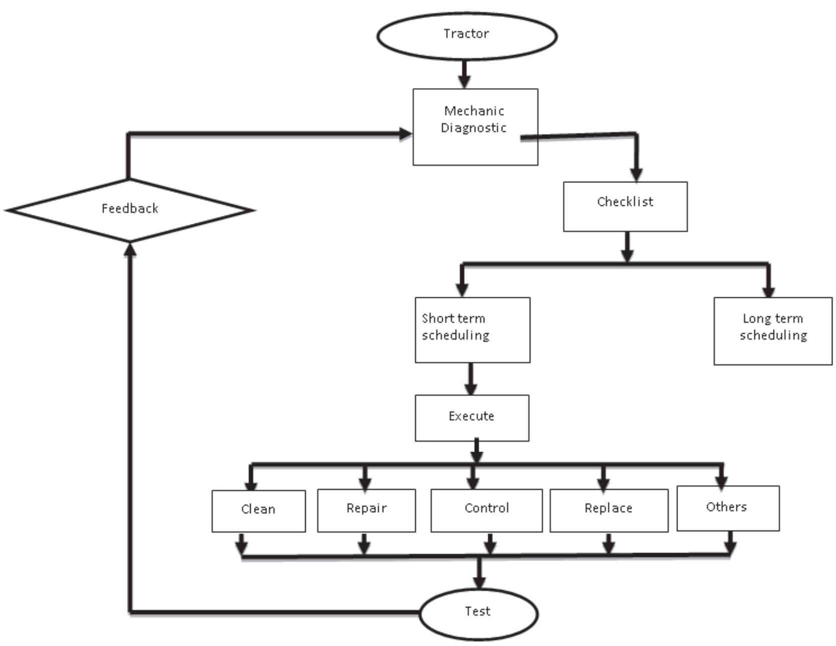


Table 4 Maintenance control checklist for SONALIKA tractors

Name of respondents:	Tractor No... Year..							
Inspection initial date								
Repair date								
Items inspected	OK	NR	OK	NR	OK	NR	OK	NR
Are there any signs of leaks from hydraulics or transmission?								

NR= Need Repairs

Table 5 Proposed preventive maintenance schedule for SONALIKA tractors

Components	Operation	Frequency of operations to be carried out daily and weekly						
		Daily	1st week	2nd week	4th week	6th week	8th week	10th week
Oil	Level	■						
Oil and filters	Change			■				
Belts	Check	■						
Air cleaner oil	Check	■						
Water pump body	Tighten			■				
Pre cleaner	Clean	■						
Fuel tank	Check	■						
Fuel tank	Clean							■
Primary filter	Change				■			
2dary injector	Change					■		

Where indicators represent: ■ = Adjust/ Tighten, ■ = Change, ■ =Check, ■ = Clean, ■ = Level

feedback so as to adjust or improve the schedule when need be. If this routing maintenance is followed properly;

a) It eliminates unexpected replacement and breakdown,
b) It keeps costs down because repairs are not made on emergency basis,
c) It extends the lives of expensive common elements and reduces reserve funds,
d) It stops problems before they occur.

Conclusions and Recommendations

4.1 Conclusions

Based on the methodology used in this study and the results obtained, it can be concluded that:

a. There are five primary causes responsible for the operational weaknesses of SONALIKA tractors in Cameroon which are categorized in 4M and E (Machine make up, Method of handling, Manpower, Materials (product) and Environment).
b. Out of the five primary causes of breakdown, there are three vital few causes which are prioritized and if they are avoided, the problem of operational weaknesses of SONALIKA tractors will be solved by 90%.
c. We see that 54% have access to the operator's manual but out of the 54%, only 18% make use of it and the remaining 79% do not make use of the operator's manual.
d. There is 23% of tractor mechanics who are readily available to tractor operators and 77% of operators who do not have readily available tractor mechanics. Also the proficiency of the readily available tractor operators in relatively very low.
e. There is a general low availability of spare parts in all the five zones accounting for 40%, low affordability of 30% and also a low accessibility of spare parts of 42%.
f. Internal causes of tractor breakdown are broken parts of tractors accounting for 75%, oil leakages account for 62% and gear box accounting for 54%.
g. Operators and tractor mechanics follow a detailed checklist that help to visually inspect all parts of the machine to ensure that there is no accumulation of breakdown unknowingly.
h. The proposed preventive maintenance schedule if well followed up will greatly reduce time spent on maintenance, extend the shelf life of the machine and increase working time of the tractors thus increasing productivity.

4.2 Recommendations

4.2.1 Recommendation for Improvement

a) To the government:

1. Encourage and make it possible for the involvement of private individuals in the importation of SONALIKA tractor spare parts
2. Organise frequent workshops to train and receive feedbacks of tractor's performance
3. Share tractor manuals to most operators and in the language they best master
4. When next tractors are imported emphasis be put on ROPs and FOPs to assure safety and comfort
5. Ameliorate the formation of training schools and programs in the intensive training of tractor operators, maintenance and repairs of tractor
6. Let tractor beneficiaries be aware that only tractors are subsidized and not spare parts so that they can prepare their minds before using the tractors.

b) To SONALIKA tractor providers (international tractor limited)

1. Improvement on the Metallurgy of SONALIKA tractor parts
2. Improve on the availability of spare parts
3. Follow up of their tractors in the field to know their state

c) To beneficiaries /Operators and Mechanics

1. Follow the maintenance manual
2. Provide sheds for the tractors after usage
3. Have a good mastery of the tractor before engaging into it or otherwise get an expert to operate (endeavour to undergo training for perfections in the milieu)

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ABSTRACTS

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

2046

Design Parameters of the Spacer Organs for the Pigeon Pea Sheller (*Cajanus Cajan* L.) GREEN: Ernesto Ramos Carbajal (e-mail: erc670819@gmail.com), Geisy Hernández Cuello, Arturo Martínez Rodríguez, Leidy Burón Mederos, Jeny Pérez Petitón, Omar González Mejía

The objective of this research is to calculate the design parameters of the separating organ of a green pigeon peeling sheller for the production of canned peas. A software and data on the physical-mechanical properties of the pods and grains of green pigeon pea were used for the calculation. As a result, it was obtained that the separator rollers with a diameter of 40 mm will have 2.26 mm of play between them, with an angular speed of the drive roller of 2.01 rad/s and thus achieve a total flow of 14.54 sheaths/s for a productivity of 67.81 kg/h of processed green pigeon peas.

SDGs and Waste Management of Agricultural Production in Egypt

by

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Abstract

Egypt depends on grain in particular for food security achievement. Wheat grains account for the bulk of these grains. The amount of agricultural waste in Egypt ranges between 49.5 to 52 million tons, which can be recycled. The Egyptian government approves a law regulating waste management, which stipulates that a public agency called Waste Management Regulatory Authority (WMRA). The new agency is responsible for organizing, following up, monitoring, and developing everything related to the activities of integrated waste management, and attracting and encouraging investments in this field to ensure sustainable development.

Keywords: Food security, Environmental pollution, Recycling, Investment

Food Security for SDGs

Among all crops cultivated in Egypt, grains are the overwhelming staple, particularly for human consumption. Wheat grain is the most important crop, constituting for 43% of the total cultivated region in 2017 in winter season. Maize and rice are the foremost grown grains in the summer season: in 2017, maize accounted for 38% of summer plantings whereas rice accounted for around 19%. The farming areas of Maize are like to those of wheat, and the wheat-maize farming cycle is common in Egypt. In contrast, rice farming is constrained to the Delta region in the Lower Egypt (**Fig. 1**) (Abdelaal and Thilmany, 2019).

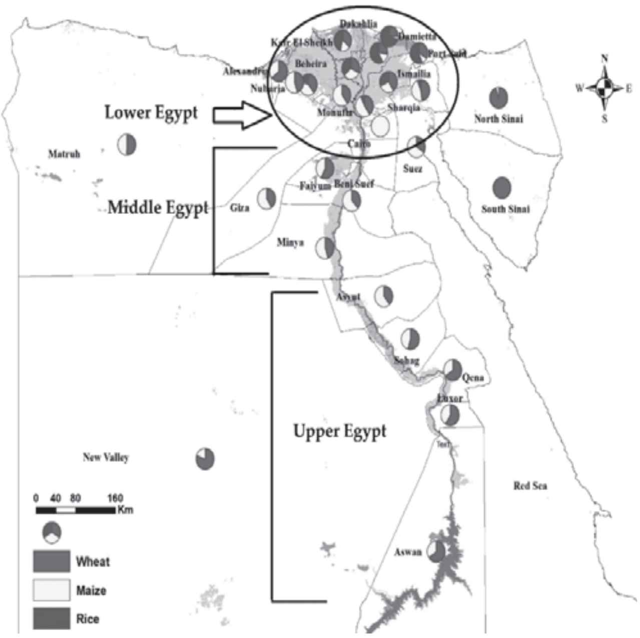
Agricultural Waste Management and Sustainable Agriculture

The amount of agricultural wastes delivered annually in Egypt is from 49.5 to 52 million tons **Table 1**, (MoE, 2020a). This could be able to recycle in different fields as follow:

1. Biogas production (Waste to energy) (EOG, 2020)
2. Non-convolutional forage as silage
3. Organic fertilizers as compost
4. Microbial and bioproduction

So, In September 2019, The Egyptian government approved a law regulating waste management, which stipulates that a public agency called Waste Management Regulatory Authority (WMRA) should be established, with public character. The new agency is responsible for organizing, following up, monitoring and developing everything related to the activities of integrated waste management, and

Fig. 1 Grains area by region, 2017



attracting and encouraging investments in this field to ensure sustainable development (WMRA, 2020).

The amount (**Table 1**), types (**Fig. 2**) and geographical distribution (**Fig. 3**) of agricultural residues delivered from different crops in Egypt show the importance of establishing a potential agricultural waste management system for agricultural sustainable development (MoE, 2020a).

Rice Straw Burning Problem and Black Cloud Phenomena

Rice straw waste management system created by Ministry of Environment

During the previous 20 years, Egyptian people suffered from the black cloud phenomenon that annually appears on autumn synchronizes with the harvest season of rice crop from the beginning of September to the middle of November. The black cloud appearance are due to the increasing of the emissions to the air during the autumn season as a result of agricultural wastes burning, **Fig. 4** and industrial activities emissions synchronized with the changes of the weather conditions associated with the autumn season. Rice straw burning contributes around 42% out of the whole emissions during the season. Small holders are used to burn theses wastes after harvesting to evacuate the land and receive new culturing season, **Fig. 4**.

In an effort against air pollution

Fig. 3 Agricultural residues locations in Egypt (MALR, 2017)

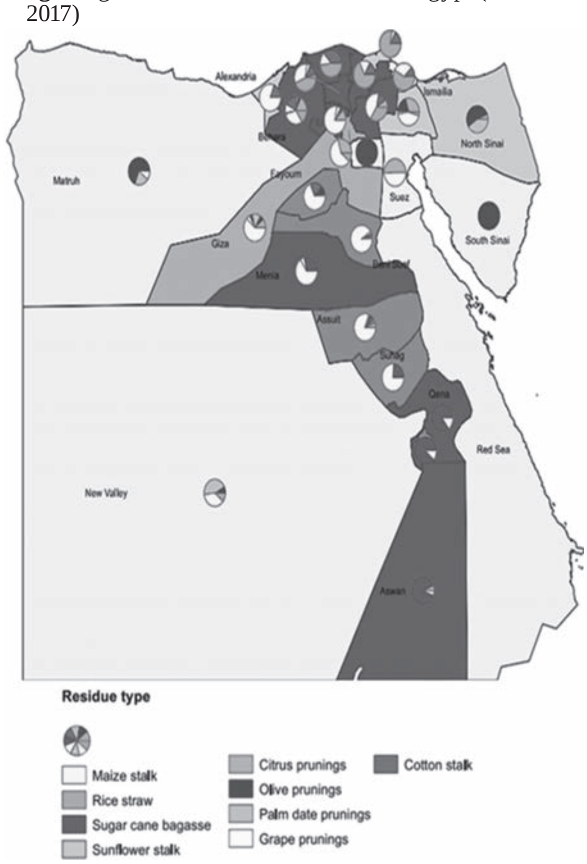


Fig. 2 Classification of crop residue

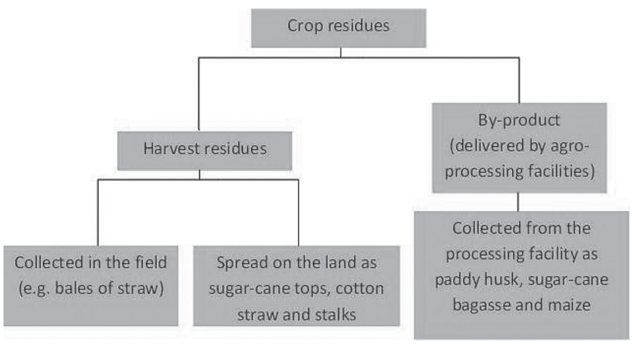


Table 1 Agricultural wastes delivered from different crops in Egypt

No.	Crop type	Wastes amount, ton	No.	Crop type	Wastes amount, ton	No.	Crop type	Wastes amount, ton
1	Rice	5,236,738	18	Dried black-eye pea	0.087	35	Cantaloupe	8,372
2	Corn	20,138,667	19	Green black-eye pea	0.063	36	Pumpkin	44
3	Cotton	1,600,128	20	Dried peas	0.060	37	Potatoes	718,756
4	Wheat	7,901,650	21	Green peas	0.63	38	Citrus	4,098,590
5	Broad Bean	146,859	22	Cabbage	13,135	39	Grape	1,434,666
6	Lentils	381	23	Cauliflower	17,796	40	Banana	1,158,224
7	Chickpeas	5,269	24	Eggplant	114,501	41	Mango	712,537
8	fenugreek	5,622	25	Okra	783	42	Guava	315,281
9	Sugar beet	3,390,048	26	Artichoke	50,862	43	European pear	58,852
10	Linen	153,024	27	Peppers	71,468	44	Apple	629,613
11	linseed	15,066	28	Taro	9,330	45	Pomegranate	106,260
12	Onion	21,772	29	Carrot	26,084	46	Plum	13,616
13	Garlic	5,876	30	Sweet Potato	486	47	Peach	281,119
14	Tomatoes	191,914	31	Strawberry	28,353	48	Fig	176,595
15	Zucchini	6,198	32	Cucumber	18,122	49	Armenian plum	92,444
16	Dried been	2,065	33	Watermelon	32,685	50	Olive	541,790
17	Green been	15.984	34	Armenian cucumber	1		Total	49,551,659

the Ministry of Environment designs a waste management system to prevent rice straw burning to collect rice straw from farmers recycling and be used for animal fodder and furniture manufacturing instead of burning, **Fig. 5**. To ensure the sustainability of the waste management system, the farmers who produce the rice straw crop and the collectors will be the contractors for economic incentive. The real challenge appears in the vast cultivated spaces with rice which reached to 1.8 million feddans. These cultivated areas produce 3.6 million tons of rice straw in six delta-governorates region. According to the final report of the Ministry of Environment in Egypt on the efforts to develop an agricultural waste management system during 2019 by collecting and compressing 2.6 million tons of rice straw **Fig. 5**, which was collected by the people and contractors working under the supervision of the ministry (by providing financial support and equipment support) (MoE, 2020b).

The new system takes into account the environmental, economic and social dimensions, so as to address the problem. With the time, the ministry role changes from the director to supervisor.

The use of the modern technological techniques and the satellite images to follow and control the system on the field, **Fig. 6**. The ministry has also formed a large number of agricultural waste inspection patrols that covers all main axes in delta districts by cars with GPS tracking devices to guide the nearest inspection patrol quickly to the burning site for immediate handling and control and record penalties for violators, (MoE, 2020b).

The amount of sugar-cane residues is 6.8 million tons (Elfeki et al., 2017). In October 2018 (Egypt today, 2018), the ministry of environment has provided 127 agricultural shredders (**Fig. 7**) for supporting the waste management system in different districts as Aswan, Luxor, Qena, Beni Suef, Minya, Assuit, Sohag and Sharqiya. These shredders were manufactured by Arab Organization for Industrialization (Qader factory) (AOI, 2020).

Egypt interests toward agro waste management system which can progress the economic and social issues. The first step is to provide the small owners with shredder machines to recycle these wastes instead of burning.

Fig. 4 On-field rice straw burning to get rid rice wastes after harvesting

Fig. 5 Rice straw collection process as raw material (for chopping) or after pressing in bales for recycling processes

Fig. 6 Rice straw waste management monitoring by satellite

Fig. 7 On-farm shredding the residues of cotton and sugar-cane

Fig. 8 Waste recycling companies locations in Egypt (part 1)

Fig. 9 Waste recycling companies locations in Egypt (part 2)

Fig. 10 Compost production from agricultural wastes

The overall societal effects of agricultural waste management system are increasing overall income, improving food security, reducing greenhouse gaseous emissions, government efforts (enforcement, monitoring, and legalization), and infrastructure building (investment) (MoE, 2020b).

Agricultural Wastes Recycling Products

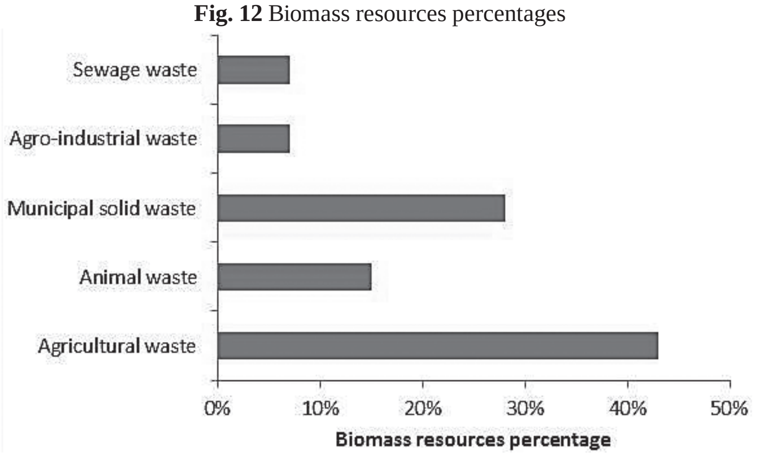
Nowadays Egyptian awareness upsurges about agricultural wastes uses. There are a lot of emerging companies which convert these wastes into a value produce as bio-fertilizers (compost, **Fig. 10**), bio-fuel (**Fig. 13**) and animal feed (silage). The famous companies in Egypt are Egyptian Company for Solid Waste Recycling (Ecaru). Ecaru collects and treats about 500 000 tons/year of agricultural wastes in four governorates, the most famous companies are shown at **Figs 8** and **9**. The agricultural wastes are converted into compost, **Fig. 10**, pellets, animal feed and alternative fuel for cement plants, **Fig. 11** (Ecaru, 2016).

Bioenergy from Agricultural Wastes (Biomass)

Egypt has huge resources of biomass from agricultural waste, **Fig. 12**. About 40% of 50 million tonnes of agricultural wastes produced annually for animal forage, the rest amount being available for energy purposes (equivalent to 5 Mtoe/year). Different biomass technologies have been demonstrated in Egypt as biogas production from agricultural wastes in rural areas. The Bioenergy for Sustainable Rural Development Project (BSRD) (EEAA et al., 2013), led by the Egyptian Environmental Affairs Agency (EEAA), was initiated in 2009 and funded by the United Nations Development Program and the Global Environmental Facility. The project develops and operates 960 biogas units of different sizes in 18 Egyptian governorates. The Bioenergy for Sustainable Rural Development is considering a selling prices regulation for biomass systems similar to that for wind and solar issued by the Prime Minister in October 2014 (EEHC, 2016).

Fig. 11 Alternative fuel to cement plants

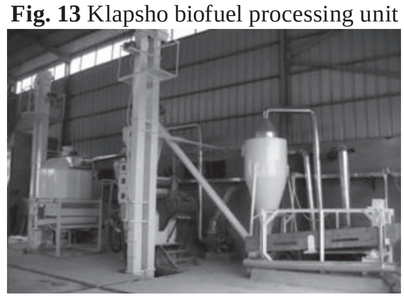
Fig. 12 Biomass resources percentages



Conclusions

Chronic environmental problems resulting from agricultural waste have been afflicting successive Egyptian governments over the past twenty years until the Waste Management Regulatory Authority developed a protocol or strategic plan to eliminate these problems, such as rice straw and sugar cane waste burning. Sustainability has been achieved by recycling rice straw and sugar cane waste to produce other products that have eco-

Fig. 13 Klapsho biofuel processing unit



nomic returns, as well as achieving food security. Under the awareness campaigns about the importance of recycling agricultural waste that the government carried out, this led to the emergence of large investments in this sector, which directed to the emergence of multiple competing companies.

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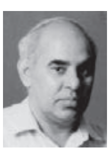
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