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EDITORIAL

The spread of coronavirus infection that began in Wuhan in China quickly propagated to the whole world. The first China, neighboring Korea, Japan, especially Taiwan, etc. have headed gradually to the general economic activities. However, there are regions such as South America and Africa, the infection is still spreading. The whole world is now connected to one, but the coronavirus this time worked to cut those connections. To that end, many stores are closed, many companies ‘economic activities has stagnated.

At first no one could imagine that the coronavirus would cause so much economic damage to the whole world. But half a year later, terrible economical and financial damage has happened. The important thing that became clear this time is that the great numbers of the poor people are dying in these disasters without good medical care. A sufficient medical system is not provided for the poor in many countries, including the United States. There are many people who want to see a doctor but cannot afford to go to the hospital. It is predicted that many similar poor people will die in Africa where infections will escalate from now on.

AMA is designed to make farmers in developing countries to prevent from expansion of the economic disparity between famers and cities and farmers become even slightly rich by the new appropriate agricultural mechanization, and AMA publishing has performed for that purpose by connecting experts of agricultural machinery since 1971. There are various natural disasters on this earth, and farmers have maintained their agricultural production by fighting the natural disasters.

This time the coronavirus divided our world; however gave the big stimulus to agriculture far beyond those natural disasters. Vaccines against the virus should be developed as rapidly as possible and everyone should cooperate so that everyone especially the poor can receive them. Everyone recognized that the coronavirus requires timely operation. Agricultural mechanization helps most needed timely operation for agriculture. Let’s promote the new agricultural mechanization in the world, especially for developing countries.

Yoshisuke Kishida
Chief Editor
April, 2020

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Could Conservation Tillage Farming Be the Solution for Agricultural Soils in Iraq?

by

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Abstract

Soil is the cardinal resource for agricultural crops. Healthy soil will produce healthy plants. Since healthy soil is the important goal for the farmers, they need to select the best tillage system to achieve that goal. There are two main types of tillage systems. Conservation tillage (no-tillage farming) uses agricultural machinery that performs a double function; tillage and seed farming simultaneously. In contrast, conventional tillage farming uses multiple agricultural machines to till and seed the soil. The farmers in the northern governorates of Iraq have used the conservation farming system for a long time. However, the farmers who live in the middle and southern governorates in Iraq use conventional tillage farming. Because most of the farmers in Iraq use the conventional tillage farming method instead of conservation tillage farming to prepare the soil, this paper will briefly explain the advantages and disadvantages for each method. This article might help Iraqi farmers to select one of these two approaches, with the goals of increasing crop yield, saving energy, conserving water, reducing total cost of farming, and guarding the environment against air pollution.

Introduction

Wiedenfeld (2006) referred to conventional tillage farming as the best way to solve agriculture's soil problems. However, Uzun et al. (2012) illustrated that soil problems decreased when they used conservation tillage farming. They found the conservation tillage farming method preferable to conventional tillage farming for many reasons. These reasons were: to increase crop yield, save energy, and reduce the total cost of farming.

Mrabet (2000) found that the conservation tillage farming method produced an average wheat grain yield of 2.47 t/ha. However, when he used the conventional tillage farming, he obtained 2.41 t/ha. The researcher found that conservation tillage farming increased crop yield for three reasons. The first was that the method increased the activity of living organisms causing a new macro system in the agricultural soils. The second reason was that it reduced total phosphorus losses. The last reason was that the method increased the organic matter in the agricultural soil. He concluded that conservation tillage farming proved its ability to increase crop yield.

The power and fuel consumption requirements are affected by the type of tillage equipment design. For example, conservation tillage farming has saved energy (Uzun et al., 2012). Uzun et al. (2012) evaluated two types of tillage farming for agricultural machinery costs. They observed that conservation tillage farming equipment (no tillage farming) required less power and required less fuel compared to the conventional tillage farming equipment. Conservation tillage machinery has a narrower tillage width per row and works soil at a shallower depth. Engineers design conventional tillage equipment for operating at a greater tillage depth than conservation tillage farming. In the middle and southern areas of Iraq, farmers use the conventional tillage farming equipment. The conventional tillage farming equipment includes the moldboard plow, disk plow, rotary plow, and chisel plow. One of the more traditional pieces of tillage farming equipment in the south of Iraq is the moldboard plow. Farmers use a moldboard plow at an average tillage depth of 20 cm. Iraqi soil does not need that tillage depth, so conventional tillage consumes a higher power input than necessary, since average fuel consumption increases gradually as tillage depth increases. The design of conventional tillage farming equipment like the moldboard plow increases the soil resistance or compaction, which increases fuel consumption. Conservation tillage farming machinery requires less power input to prepare soil and seed a crop compared to the conventional farming equipment. This is because of the narrower tillage width per row of the conservation agricultural equipment design. As illustrated above, the conservation tillage farming system saves energy by reducing fuel consumption.

Conservation tillage farming saves water. Soil water holding capacity can be determined by measuring the volumetric water content of the agricultural soil. Malecka et al. (2012) found that volumetric moisture content inside agricultural soil was 12.2% when the researchers used conventional tillage farming. However, when they used the conservation tillage farming Malecka and others found 17.6% volumetric water content in the agricultural soil. Mrabet (2000) conducted a field experiment from 1995 to 1999 at Sidi El Aydi (Morocco) at the experimental station located 50 km south of Casablanca to study the impacts of conservation and conventional tillage farming methods on water consumption. He found a higher rate of water consumption, 277 mm, when he used conventional tillage compared to 271 mm when he used conservation tillage. Soil moisture loss decreased when Mrabet used conservation tillage farming instead of conventional tillage farming. Mrabet concluded conservation tillage farming was better able to save water in agricultural soil than conventional tillage farming.

Conservation tillage farming reduces the total cost of farming. The total cost of farming includes agricultural equipment, maintenance, and fertilizer costs. There are three different kinds of agricultural equipment that farmers use with conventional tillage. The first one is tillage equipment, the second one is cultivator equipment and the third one is seeder equipment. However, farmers using conservation tillage require only a no-till planter. Khakbazan and Hamilton, (2012) conducted a field study to determine the influence of conservation and conventional tillage farming systems on total farming costs. The researchers showed that the total cost of farming was $429 for one hectare when they used the conservation tillage farming system. However, once they used convention tillage farming methods the total cost of farming was $433 for one hectare. The researchers concluded that conservation tillage farming provides the best financial advantage in comparison to conventional tillage farming. This is because conservation tillage farming used one piece of agricultural equipment instead of three pieces of agricultural equipment. This means farmers need more agricultural equipment maintenance when they use conventional tillage farming. Although the cost decrease for conservation tillage from the Khakbazan and Hamilton (2012) experiment was minimal, the longer term benefit of increased soil organic content and water holding capacity is expected to continue to decrease net costs in future years.

For fertilizer purposes (organic matter), Malenko et al. (2012) conducted an experiment in 1999 at the University of Life Science, Poland on a loamy soil. The aim of the research was to verify the impact of conservation and conventional tillage farming systems on the physical and chemical properties (organic matter) inside the soil. The availability of the organic matter was 10.18 grams for each kilogram of soil in the first few centimeters of the soil depth (1 to 5 cm) when the researchers used conservation tillage farming. However, when they used conventional tillage farming for the same soil depth, they obtained 8.07 g/kg of soil. They concluded that organic material contained inside soil increased when they used conservation tillage instead of conventional tillage. Farmers will be able to decrease fertilizer application levels when they use conservation tillage. In that case, the conservation tillage farming system reduces total cost farming.

Conservation tillage farming reduces air pollution. Conservation tillage farming is different from conventional tillage farming in terms of carbon dioxide emission. Soane and others (2012) conducted a study in Denmark between conservation and conventional tillage farming systems and their effects on air pollution. They found carbon dioxide emission was 127 kg for each hectare when they used conservation tillage machinery. Meanwhile, with conventional tillage emissions were 263 kg of carbon dioxide per hectare. In other words, if farmers prepare the soil for farming by using conventional tillage farming, they will use the three agricultural types of machinery (chisel plow, cultivator, and planter). However, when farmers use a conservation tillage farming method, they will use only one piece of machinery to prepare the agricultural soil and use less fuelthus emitting less carbon dioxide from the engine. However, farmers require more fuel to operate conventional tillage so emission of carbon dioxide is greater. This example proves the advantage of conservation tillage farming to guard our environment from air pollution.

In cool wet climates or years some seedling diseases are made worse by conservation tilling (Dill-Macky and Jones 2000). This is not likely in Iraq.

The conservation tillage farming method (no-tillage) saves energy, water, the cost of farming, and the environment compared to conventional tillage farming. The advantages of using conservation tillage farming (no-tillage) are greater than using conventional tillage farming method in preparing the soil. The University of Baghdad is the leading agricultural research institution in Iraq. Currently, there are no government programs to encourage conservation tillage. We recommend that farmers in Iraq use the conservation tillage farming method (no-tillage).

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EVENT CALENDAR

With the COVID-19 virus being declared a pandemic by the WHO, Various events and international conferences have been canceled or postponed. Please note that the schedule may change.

2020

◆ ASAEB 2020 Annual International Meeting [Virtual Evant]
July 13-15
www.asaeb.org/

◆ EIMA International [Degital Preview]
November 11-15
www.eima.it

2021

◆ EIMA International [The Ivent]
February 3-7, Bologna, ITALY
www.eima.it

◆ SIMA
February 21-25, Paris (Nord Villepinte), FRANCE

◆ 5th CIGR International Conference 2020
May 10-14, Quebec, CANADA
www.cigr2020.ca/

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Design, Development and Testing of 4-Row Tractor Drawn Gladiolus (*Gladiolus Grandiflorus* L.) Planter for Uniformity in Corm Spacing

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Abstract

A tractor drawn 4-row gladiolus planter with cup type metering device was designed and tested in actual field condition. The planter was tested for three levels of corm spacing that of 15, 20 and 25 cm and four levels of forward speed that of 1.0, 1.5, 2.0 and 2.5 km/h. Corm spacing, coefficient of uniformity, missing and multiple index, quality of feed index and mechanical damage were measured as performance indicators. The field result indicated that the planter was able to place the corms at required nominal spacing with variations of 2.18 cm. Average missing and quality of feed indexes were observed as 3.48 and 96.52% respectively with no multiples. The performance of the planter was observed better for wider nominal spacing at lower forward speed. The field capacity of the planter was found as 0.103 ha/h with an observed field efficiency of 76.57%.

Introduction

India is the second largest country in the world next to China in terms of area under flower crops with an area of 2.49 Mha during 2014-15 (Anonymous, 2015). Gladiolus (*Gladiolus grandiflorus* L.) is one of the most popular cut flowers grown in the country for its elegant spikes. It is available round the year because of its wide adaptability under various agro-climatic zones of the country. Commercially, the gladiolus is propagated through its corms that are planted 8-10 cm deep for both the quality cut flowers and corm production. Planting of gladiolus corms is performed manually, in general, by marking the furrow lines, placing corms at required spacing and thereafter covering it with soil by narrow spade. This operation is very tedious, time consuming and results in low work rate. Thakur (2016) has reported total human labour requirement in Gladiolus cultivation to about 322 man-days. Considering the huge labour demand and low work rate, mechanizing the planting operation is of utmost importance. A two-row saffron corm planter was designed and developed by Rad (2006) with cup type metering device that was able to plant the corms 15 cm deep at a row spacing of 22 cm without damaging the corms. Gulati and Singh (2003) designed and developed a manually operated potato planter with belt in cup type metering device. The effective field capacity of the planter was 0.50 ha/day with 0.50 percent missing. Bakhtiari and Loghavi (2009) developed and tested a tractor-mounted precision planter for planting garlic (*Allium sativum* L.) cloves on each raised bed. The planter was capable of planting 220,000 plants/ha at a depth and spacing of 12.3 and 22.7 cm, respectively. Miss index, multiple index and seed damage were found as 12.23, 2.43 and 1.41%, re-

Fig. 1 Prototype of 4-row Gladiolus planter

spectively. A number of planters are available commercially but no suitable planter is available for planting of gladiolus corms. Considering the importance and non-availability of a suitable planter, the work was initiated to design, develop and test the same for uniformity in corm spacing.

Materials and Method

A prototype of 4-row gladiolus planter (**Fig. 1**) was designed and developed for planting of gladiolus corms. The major components of the planter are frame, furrow opener, hoppers, metering mechanism, power transmission, depth regulating wheel and hitch system. The design details and criterion are discussed as under:

Design of frame: A rectangular hollow frame, overall length and width as 1,800 and 600 mm respectively, was selected. The frame was designed considering it as a beam with fixed ends and subjected to both bending and twisting moments. Maximum bending moment (M_I) at the centre of beam (**Fig. 2**) due to weight of 150 kg (1471 N) corms filled at a time in the hopper was determined as 661.95 N-m by using Equation 1.

$M_I = R_A \times (L / 2)$ [1]

Where, M_I = Bending moment, N-m; R_A = Reaction at ends, 735.50 N and L = length of the beam, 1.80 m. Considering **Fig. 3** and assuming that all the 4-furrow openers are experiencing equal draft force of 0.918 N, therefore, reactions (R_1 and R_2) at the end of beam would be equal and was determined as:

$R_1 + R_2 = 4 \times 0.918 = 3.672$ kN

By symmetry,

$R_1 = R_2$, therefore $R_1 = R_2 = 1.836$ kN

Therefore, maximum bending moment (M_2) due to draft force could be determined by taking moment, at section x-x, as:

$M_2 = (1.836 \times 0.90) - (0.918 \times 0.45) - (0.918 \times 0.15) = 1.102$ kN

Therefore, equivalent bending moment (M_b) would be determined as:

$M_b = \sqrt{(0.662)^2 + (1.102)^2} = 1.29$ kN-m

Maximum torsional moment (M_t) transferred on the beam due to draft force would be:

M_t = Number of furrow openers × Draft on each furrow opener × Lever arm = 4 × 0.918 × 0.58 = 2.13 kN-m

Considering maximum shear stress failure theory, the equivalent torsional moment (T_e) was determined as 4.11 kN-m by Equation 2 as:

$T_e = \sqrt{(K_b M_b)^2 + (K_t M_t)^2} = 1.29$ kN-m [2]

Where, M_b = Equivalent bending moment, 1.29 kN-m, M_t = Maximum torsional moment, 2.13 kN-m, K_b and K_t are shock factors. Thus the values as 2 and 1.5 were adopted respectively, for minor shock.

As the beam is subjected to stresses due to torsional moment, the maximum torsional shear stress (τ_{max}) was determined by Equation 3 as:

$\tau_{max} = T_e r / J$ [3]

Where, τ_{max} = Designed stress of the material, N/m^2 ; T_e = Equivalent torsional moment, N-m; r = Distance of edge from the centre of the beam i.e. a/2, m and J = Polar moment of inertia of the cross-section, m^4.

The value of τ_{max} was determined by Equation 4 as 208.33 MPa by considering the allowable yield stress (S_y) for MS as 250 MPa and 1.2 as factor of safety (F_oS).

$\tau_{max} = S_y / F_oS$ [4]

Now substituting the values in Equation 3, the value of outer and inner dimensions (“a” and “b”) of frame was determined as 45.53 and 35.53 mm respectively. However, standard size of hollow square pipe with outer and inner dimensions of 50 and 40 mm, respectively, having 5 mm thickness was selected for fabrication of the frame.

Furrow opener design: Four numbers of ridgers fitted with 580 mm long shank, attached to fore bar of the frame, was fabricated to open furrow lines. The length and width of ridger was selected as 145 and 170 mm, respectively to obtain required width of furrows. Reversible shovels, 200 mm long at rake angle of 22° for minimum draft, were fitted to form V-shape furrows. The furrow opener shank was designed by assuming maximum working depth of 10 cm. Since, the planter would operate in well prepared soil, therefore, maximum unit draft in silty-clay- loam soil (sand-silt-clay as 36.2-47.6-16.2%) was assumed as

Fig. 2 Weight of the corms acting on the frame

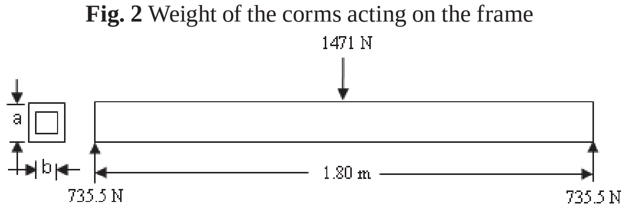
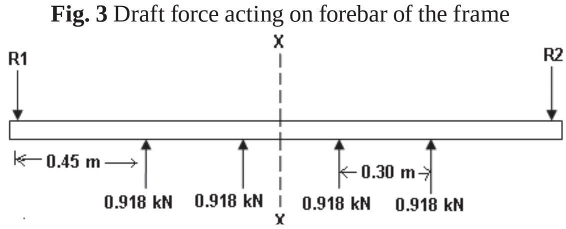


Fig. 3 Draft force acting on forebar of the frame



0.054 N/mm^2. The draft force acting on each furrow opener was determined as:

Draft per shank = Furrow x-section, mm^2 × unit draft, N/mm^2 of soil = 0.918 kN

Bending moment (M) = Draft × length of shank = 532.44 kN-mm

The section modulus of the shank could be determined by using flexural equation. Bending stress (f_b) induced in the ridger shank can be expressed as:

$$f_b = 6M / bh^2 \quad [5]$$

Where, f_b = allowable bending stress, 0.099 kN/mm^2 (970 kPa) for MS; M = bending moment, kgf-cm; b = thickness of the section, cm and h = breadth of the section, cm. Assuming h = 3 b and substituting the value in Equation 5, thickness (b) and breadth (h) of shank was determined as 15.31 and 45.93 mm respectively. Therefore, MS flat of standard size, 16 × 50 mm, was selected for fabricating the shank of the furrow opener.

Hopper design: There are two hoppers, main and feeding hopper, provided on the gladiolus planter. Main hopper, 150 kg capacity with trapezoidal shape, is common where as individual feeding hoppers, 5 kg capacity, for each row have been provided to feed the cups of metering device. The hopper capacity was decided keeping in view the minimum weight on the planter frame, number of refills and unproductive time. The volume of gladiolus corms, Vg, was determined as 0.254 m^3 by using Equation 6.

$$V_g = W / \rho \quad [6]$$

Where, W= weight of the gladiolus corms, 150 kg and ρ = bulk density of gladiolus corm, 590 kg/m^3 (Singh et al., 2015). The designed volume of hopper should be the same or little more. The hopper (**Fig. 4**) consisted of upper section of rectangular shape (V_1) and bottom section of trapezoidal shape (V_2).

Volume (V_1) = length, m × width, m × depth, m = 0.162 m^3

Volume (V_2) was determined as 0.101 m^3 by Equation 7 as:

$$V_2 = ½[A_1 + A_2] \times h_1 \quad [7]$$

Where, A_1 = top area of bottom section 0.806 m^2, A_2 = base area of the bottom section, 0.202 m^2, h1= depth of bottom section as 0.20 m. Hence, the total volume (V) of the hopper was computed as 0.262 m^3. The volume of hopper as calculated was observed 3.14% higher than the volume of gladiolus corms, therefore, the designed dimensions of hopper was found appropriate. The hopper wall inclination was kept 45° i.e. higher than angle of repose of gladiolus corms.

Thickness of hopper sheet (t) was designed considering the maximum bending moment (BM_{max}) developed in the wall by using Rankine's Equation 8 as 1689 kg-mm.

$$BM_{max} = [\rho h_3^2 b_2^2 \cos\theta_1] / 8 \quad [8]$$

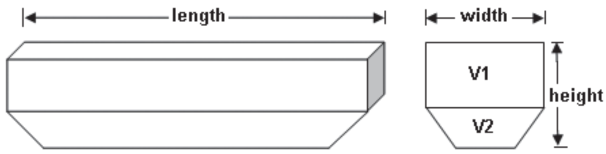
Where, ρ = bulk density of the gladiolus corm, 590 kg/m^3, h_3 = total height of main hopper, 0.40 m, b_2 = maximum width of hopper, 0.45 m and θ_1 = angle of repose of corms, 45 deg. Sheet thickness was found as 1.58 mm by determining the maximum shear stress and moment of inertia using Equation 9.

$$fs_{max} = [BM_{max}Y] / I \text{ and } I = (h_3t^3) / 12 \quad [9]$$

Where, fs_{max} = Maximum allowable shear stress, 9.8 kg/mm^2 (950 MPa) for MS sheet, Y = distance of the outer stress fiber from the neutral axis, t/2 mm and I = moment of inertia, mm^4. However, for safer design and ease of availability, 2.5 mm thick MS sheet was selected. The feeding-hopper was also designed in similar manner.

Metering mechanism: Cup-feed type metering device was selected for singulation and placing of the corms into the furrow lines. The diameter and depth of the cups were selected as 50 × 25 mm respectively based on average size of corms. The cups were fitted on a roller chain of length 130 cm. Four such units were fabricated, one for each row, for the planter. Each roller chain had 13 numbers of cups fitted at a spacing of 100 mm apart. Spacing between the successive cups was decided on the basis of preliminary trial.

Fig. 4 Main hopper of the planter



Power transmission: MS lug wheel with diameter 310 mm and 100 mm lug height fitted with 30 numbers of teeth sprocket was used to drive a primary shaft having three sprockets with 30, 18 and 11 numbers of teeth to obtain the required corm spacings of 15, 20 and 25 cm. Another, fourth sprocket with 11 numbers of teeth fitted on primary shaft drives similar size of sprocket fitted on a secondary shaft which in turn drives the metering unit shaft through again a similar size of sprocket.

Determination of sprocket size: Various sizes of sprockets were selected, based on gear ratios, to meet the required spacings of 15, 20 and 25 cm. The gear ratio was determined by Equation 10.

$$SR_{gf} = [D_g S_c] / [D_{fs} S_g] \quad [10]$$

Fig. 5 Testing of prototype in experimental field

Where, SR_{gf} = speed ratio between drive wheel to primary shaft sprockets, D_g = effective diameter of the ground drive wheel, 40 cm; S_c - spacing between the cups of metering unit, 10 cm ; D_{fs} - pitch circle diameter of feed drive-shaft sprocket, 10 cm and S_g - required corm to corm spacing (15, 20 and 25 cm). Substituting the values in Equation 10, the speed ratios were found as 2.67, 2 and 1.6 respectively for 15, 20 and 25 cm corm spacings. The number of teeth (T_2) required for above speed ratios, with 30 numbers of teeth (T_1) on drive wheel sprocket, was determined by Equation 11 as 11, 15 and 18 teeth.

$$T_2 = T_1 / [SR_{gf}] \quad [11]$$

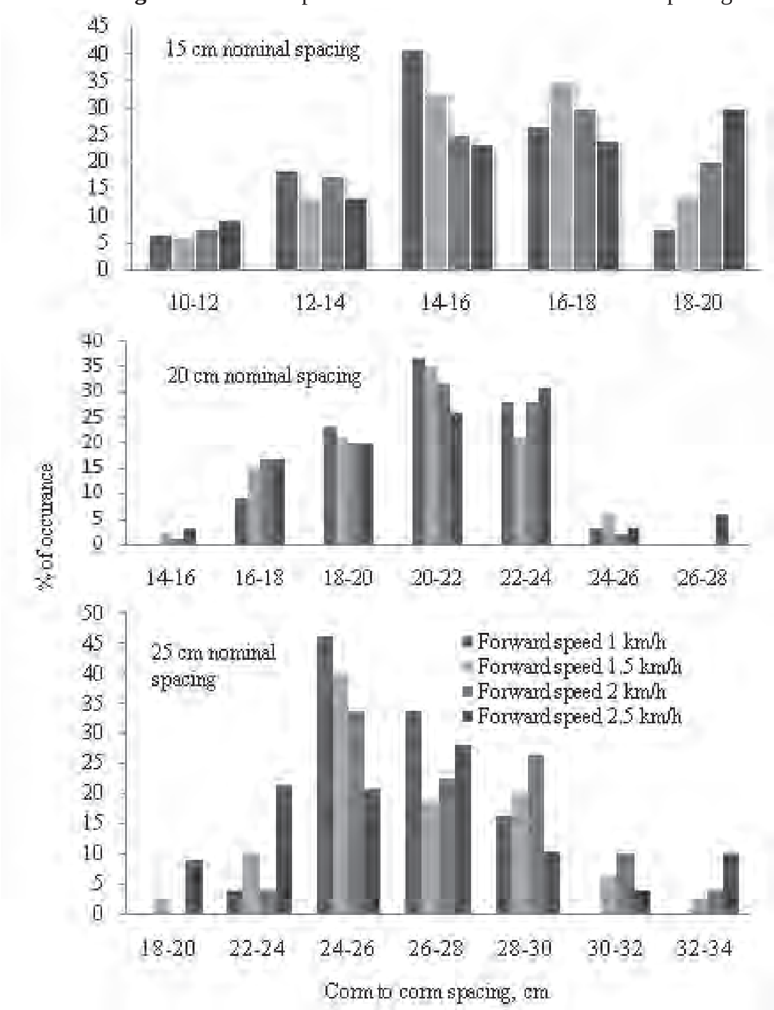
Depth regulating wheel: Two numbers of wheels, one at each side of the planter, with 400 mm diameter and 100 mm face width, was provided to maintain uniform planting depth and also to support the weight of the planter. The depth of planting can be varied by adjusting the depth wheel.

Hitch system of category-II was fabricated, with MS flat of size 100 × 12 mm, conforming to Indian Standard (IS-4468-1997). The mast height and lower hitch span was kept 610 and 685 mm, respectively, for hitching the planter with tractor.

Performance Evaluation

Planter was evaluated in fine prepared seedbed (**Fig. 5**) having length and width of each test field as 20 m × 2.5 m respectively. Four levels of forward speed (1, 1.5, 2 and 2.5 km/h) and three levels of nominal spacing (15, 20 and 25 cm) were considered for performance evaluation. Each experiment was replicated five times to minimize the experimental error. Missing index (MISS), multiples index (MULTI), quality of feed index (QFI) and precision index (PREC) were determined as performance indicators as suggested by Singh et al. (2014); China et al. (2016) and Singh and Mane (2011). Variation in observed spacing was analyzed by determining standard deviation (SD), coefficient of variation (CV) and coefficient of uniformity (CU). The significance of the data was analyzed by using 2-way Completely Randomized Design (CRD).

Fig. 6 Distribution pattern of corms at various nominal spacings



Results and Discussion

Distribution and spacing of corms for three nominal spacings (15, 20 and 25 cm) and four forward speeds (1, 1.5, 2 and 2.5 km/h) indicated that the planter was able to drop majority of the corms within the required nominal spacing (**Fig. 6**). The placement of corms was observed more accurate at lower forward speeds and wider nominal spacing as indicated by lower values of standard deviation (**Table 1**). Similar result was reported by Panning et al. (2000). This may be due to proper self-filling of metering cups at lower forward speeds due to lower linear speed of cups. At forward speed of 2 and 2.5 km/h, the placement of corms was at wider spacing than the required spacing. At nominal spacing of 25 cm and lower forward speeds between 1-1.5 km/h, about 40-46% corms were placed at an average observed spacing of 25 cm. This may be due to more time available for self-fill of the cups leading to higher accuracy. The mean observed spacing and lower value of standard deviation also indicated better accuracy in corm placement i.e. quite closer to the required nominal spacings.

Coefficient of variation was found lowest (7.68 to 8.87) for above mentioned speeds and nominal spacing. Statistical analysis (**Table 2**) indicated significant effect of forward speed and theoretical space setting on observed corm spacing.

Coefficient of uniformity in placing the corms at required nominal spacing (**Table 3**) was found to increase with increase in nominal spacing and it decreased with increase in forward speed of operation and vice versa. The value was observed highest as 97.21% for 25 cm nominal spacing at forward speed of 1 km/h. This may be due to sufficient time available for self-fill of cups. Another reason may be due to smooth operation and lesser field vibration transferred to planter at lower speed. Statistical analysis (**Table 2**) showed significant effect of nominal spacing and forward speed of operation on coefficient of uniformity at 5 percent significance level. The lower value of precision (PREC), less than 10%, indicated better uniformity as reported by Katchman and Smith (1995). The ratio of mean to nominal spacing was also observed closer to 1.0 indicating observed corm spacing closer to the required nominal spacings.

Missing and multiple indexes result indicated minimum MISS percentage at lower forward speed and for higher nominal spacing and vice-versa (**Table 3**). The reason could be due to proper self-filling of cups because of more time available and probably due to less field vibration. The result was found in accordance with the findings of previous researchers (Bozdoğan, 2008 and Panning et al., 2000). Theoretical space setting and forward speed had significant effect on missing percentage (**Table 2**). Result of multiple index (MULT) indicated that none of the corms dropped at a spacing ≤0.5 times the nominal spacing.

Quality of feed index (QFI), a measure of the percentages of single seed drop, ranged between 92.4 and 99.2% (**Table 3**). In general, QFI increased with increase in nominal spacing and decreased with increase in forward speed of operation. The reason for higher QFI is due to less MISS and no MULT indexes. This indicated that none of the corms dropped at spacing ≤0.5 times the nominal spacing. The minimum value of QFI was observed 92.4% which is much higher than the suggested limit (Katchman and Smith, 1995) of ≥85% which indicated that more than 92 out of every 100 drops was a single corm.

Mechanical damage was observed nil (**Table 1**) at lower forward speeds of 1.0 and 1.5 km/h for all the nominal spacings. Maximum visible damage of 1.48% was observed for 15 cm nominal spacing at 2.5 km/h forward speed which may be due lesser time available for the corms to fit into the cups. Another reason could be due to accumulation of the corms at the bottom of the hopper. However, the visible mechanical damage was observed within the acceptable limit of 5%.

Conclusions

Based on experimental result, the performance of the gladiolus planter was observed better at lower forward speed of 1.0-1.50 km/h and for wider nominal corm spacing of 25 cm. The coefficient of uniformity was found the highest (96.37-97.21%) with no mechanical damage to the corms. Missing percentage was lower for lower forward speed and wider nominal spacing with no multiples. The quality of feed index was observed more than 92.4%. The designed palnter could be used for planting of gladiolus corm to reduce the human drudgery involved in planting operation.

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Table 1 Observed corm spacings at various forward speeds and nominal spacings

Forward speed, km/h	Nominal spacing, cm	Mean observed spacing, cm	Standard deviation	Coefficient of variation	Mechanical corm damage, %
1.0	15	15.06	1.56	10.36	0
	20	20.72	2.04	9.86	0
	25	26.13	2.01	7.68	0
1.5	15	15.10	1.68	11.11	0
	20	20.40	2.20	10.78	0
	25	26.37	2.34	8.87	0
2.0	15	15.06	1.71	11.33	0.26
	20	20.27	2.21	10.54	0.20
	25	25.86	2.35	9.09	0
2.5	15	14.90	2.07	13.88	1.48
	20	20.22	2.40	11.88	1.20
	25	25.58	3.53	13.79	0.76

Table 2 Analysis of variance (f-values) for various parameters

Source	Observed corm spacing	Coefficient of uniformity	Missing percentage
Nominal spacing (W)	11,430.54**	42.96072**	5.613054**
Forward speed (S)	10.65116**	35.57704**	20.26884**
Interaction (W × S)	3.038760*	3.927493**	0.3667444^{NS}

**highly significant at P ≤ 0.05, NS - not significant

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■■

Table 3 Performance indices of Gladiolus planter

Forward speed, km/h	Nominal spacing, cm	Measures					
		CU, %	PREC, %	Ratio of mean/ nominal spacing	MISS, %	MULT, %	QFI, %
1.0	15	93.06	8.36	1.004	2.0	0	98.0
	20	94.61	8.06	1.036	1.8	0	98.2
	25	97.21	6.88	1.045	0.8	0	99.2
1.5	15	92.42	8.31	1.007	2.8	0	97.2
	20	93.88	8.38	1.020	2.4	0	97.6
	25	96.37	7.47	1.055	1.4	0	98.6
2.0	15	91.53	5.93	1.004	5.4	0	94.6
	20	92.5	6.94	1.014	3.6	0	96.4
	25	95.65	6.49	1.034	2.6	0	97.4
2.5	15	87.53	6.28	0.993	7.6	0	92.4
	20	89.5	5.88	1.011	6.0	0	94.0
	25	90.3	8.39	1.023	5.4	0	94.6

Design and Development of Power Operated Walking Type Weeder

by

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Abstract

Delay in weeding operation reduces the crop yield and consequently the net returns of vegetable production. Therefore, a power-operated walking type weeder for vegetable crops was designed, developed and fabricated in Faculty of Agricultural Engineering, Indira Gandhi Agricultural University, Raipur, India. A petrol start - kerosene run 2.20 kW engine was used as a prime mover. The power transmission from the engine to the cutting tool was provided by means of V belt-pulley, worm gear and chain-sprocket. Speed reduction from 3,000 rpm in the engine to 22 rpm in traction wheels was obtained in three stages. In first stage speed reduction from 3,000 rpm to 750 rpm was obtained by double groove pulley (size 76.2 mm to 304.8 mm). Worm and gear were responsible for second stage reduction. The ratio of worm gear wheel was 30:1 so the speed becomes 25 rpm. Third or final speed reduction was done by chain and sprockets. Two traction wheels were provided. A clutch system before the final drive was provided for easy turning during operation either right or left. The track width of power weeder was adjustable between 0.4 to 0.9 m so that it could cover weeding of the wide range of vegetable crops. A depth control, as well as transport wheel, was provided at the rear end of the machine. Two types of soil cutting tools viz. double point shovel and helical cage roller were designed for weeding operation. During the field-testing of weeder in chili crop, the field capacity was found to be 0.12 ha/h, weeding efficiency 89 % and operational cost Rs. 925/ha. (1 US $ ≈ 72 Rs.)

Introduction

Weeding is one of the most difficult tasks in vegetable cropping that accounts for a major share in the cost of crop production. An analysis revealed that one-third cost of cultivation was being spent on weeding alone. Mechanical weed control not only eradicates the weeds but also makes the soil surface loose, ensuring better soil aeration and water holding capacity. Tajuddin (2006) designed, developed and tested an engine operated weeder with 2.2 kW petrol start kerosene run engine. The rated speed of 3300 rpm at load was reduced to 60 rpm of the ground wheel by a belt-pulley and sprocket-chain mechanism. A sweep type weeding blade was designed for structural strength. The effective field capacity 0.10 ha/h, fuel consumption rate of 0.60 to 0.75 L/h, depth of operation 37 mm, field efficiency 85.7%, weeding efficiency 85.8% were found. The initial cost of weeder is Rs. 20,000 and cost of operation Rs. 580/ ha was found. Niyamapa and Chertkiattipol (2010) designed three prototype rotary blades to reduce the tilling torque, impact force and specific tilling energy and tested in a laboratory soil bin with the flat tilling surface. Experiments with the prototype rotary blades and Japanese C-shaped blade were carried out at forward speeds of 0.069 and 0.142 m/s and at rotational speeds of 3.30, 4.79, 6.11 and 7.65 m/s by the down-cut process in clay soil. Ojomo et al. (2012) conducted a study on machine performance parameters by developing and evaluating a motorized weeding machine for the effect of moisture content (10%, 13% and 16%) and the type of cutting blades (Flat, spike tooth and curved blade) on the machine efficiency, quality performance efficiency, percentage of uprooted weeds and percentage of partially uprooted weeds. At 16% soil moisture content, the spike tooth blades gave the best machine efficiency of 94%, and quality performance efficiency of 84%. Hegazy et al. (2014) developed a power weeder for maize crop with modified vertical blades which were mounted on a circular rotating element on its horizontal side; the motion was transferred to blades units by the amended transmission system. The effect of weeder forward speeds, depth of operation, number of blades and soil moisture content on fuel consumption, plant damage, weeding index, effective field capacity, field efficiency, the energy required per unit area and total cost were studied. The results showed that the minimum value of fuel consumption was 0.546 L/h and recorded by using two blades with 1.8 km/h weeder forward speed at depth of operation ranged from 0-20 mm and soil moisture content 16.18 %. Due to the higher labour wages and unavailability of agricultural labour for weeding operation and this fact has created the requirement of a small power weeder which should be light in weight, cheap and easy to move across the fields. Keeping all the above points in view the work on design and development of power operated walking type weeder has been undertaken.

Materials and Methods

The various factors involved in the design were operational safety, ease of construction, ergonomic consideration and cost of the machine. The emphasis has been given on ease of operational adjustments with minimum maintenance. The machine can be divided into three main components, that are power source engine, transmission gearbox and soil working tools.

Chassis

A chassis was made of MS flat to hold power unit transmission box and other units. Consideration was made that the chassis is light in weight, yet strong enough to withstand the imposed locating during field operation with appropriate material. The box section was selected for the toolbar. For determination of the size of box sections following assumptions were made:

1. The depth of cutting: 0.05 m
2. Width of cutting tool: 0.035 m
3. Ground clearance: 0.25 m
4. Number of cutting tools: 5
5. The range of Row to row spacing of vegetable crop: 0.40-0.90 m
6. Soil resistance: 68670 N/ m^2 (For sandy loamed and clay loam soil, Devanani, 1991)

   Draft per tine = Soil resistance × Furrow cross - section area = 68670 × 0.00175 = 120.17 N

The toolbar is subjected to torsion and bending moment due to the induced draft. Five tines were arranged in toolbar, the design is based on stress produced on the bar.

Total draft for 5 tine = 120.17 × 5 = 600.85 N

Design draft value = 600.85 × 4 (Factor of safety for agricultural implements 4) = 2403.45 N [1]

Total torque (T) on the toolbar = Design draft × Ground clearance = 150.2 Nm

In addition to torque bending moment would also be produced. The toolbar can be taken as a simply supported beam on the chassis.

The max bending moment (M)

$B.M_{max} = Wl / 4$ [2]

Where, W = total Force on chassis = 2403.40 N

Total length (l) = 0.5 m

$B.M_{max}$ (M) = 300.42 N-m

Equivalent torque due to torsion and bending moment

$Te = (M^2 + T^2)^{0.5}$ [3]

Where, Te = Equivalent torque

M = Maximum Bending moment

T = Torque on the toolbar

Te = 335.49 Nm

The maximum shear stress developed on the toolbar can be obtained by using the tensional formula

$f_s / R = T / J$ [4]

Where

f_s = Shear stress at any section

R = Distance of the Section from neutral axis

T = Equivalent torque produced

J = Polar moment of inertia

For MS angle section Ultimate stress of selected material = 360 N mm^{-2}.

Design stress (working stress) = Ultimate stress / Factor of safety = 360 / 4 = 90 N/ mm^2

Maximum working stress of 360 N/ mm^2 at the center of tool frame

$J = [\pi / 32] \times d^4$

$R = d / 2 = d^4 / 9.6$

Where

d = width of the section in mm

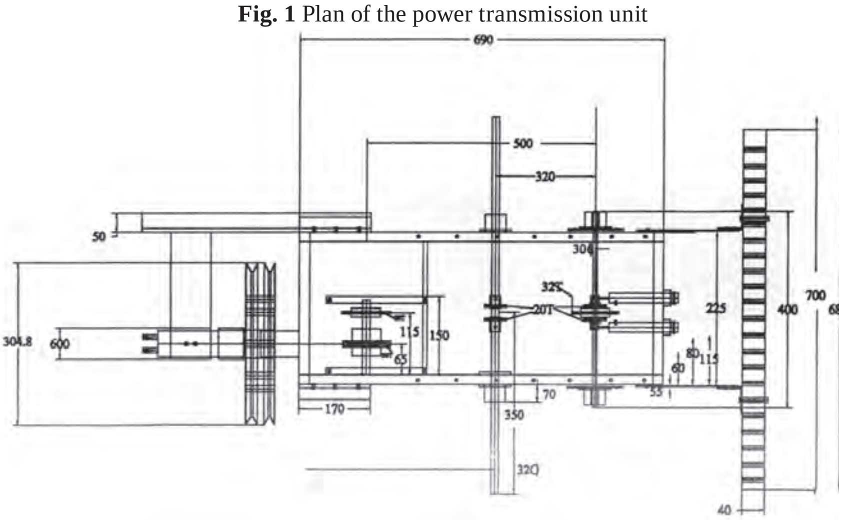
Substituting above values putting in equation 4, we get

d = 28.9 mm

$90 / [d / 2] = 335490 / [d^4 / 9.6]$

Thus on the basis of calculations

Fig. 1 Plan of the power transmission unit



toolbar was to be made of angle section each side measuring more than 28 mm.

Selection of Power Source (Engine)

The capacity of the engine can be decided on the basis of draft requirement, and availability of engine.

Total draft = 2403.4 N (as calculated in Equ. 1)

Maximum operational speed of power weeder = 2.5 km/ h

Power = [draft (kg) × speed (m/min)] / 4500 = 1689 W = 1.7 kW [5]

In view of sudden resistance offered by the soil, engine selected was of 3 hp (2.24 kW), 3000 rpm S.I. engine petrol start and kerosene oil run type.

Power Transmission

The design of power transmission system was such that the power transmitted from engine to final drive of power weeder was with minimum loss in power. Plan of the transmission unit is shown in **Fig. 1**. The speed reduction is provided in three stages, by belt driven, gear drive and chain. Velocity ratio and rpm in various stages are given below:

1st stage VR = 4, V-belt drive (3000-750)

2nd stage VR = 30 gear drive (Worm Gear) (750-25)

3rd stage VR = 1.19, chain drive (roller chain) (25-22)

Let D be pulley diameter of the input shaft

$N_1 \times d = N_2 \times D$

Where

N_1 = Engine speed in rpm, 3000

d = Engine pulley diameter in m, 0.0762

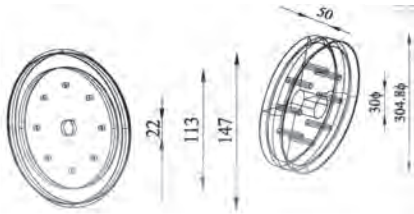
N_2 = worm speed in rpm, 750

D = 0.3048 m

Design of Cone Clutch

The function of the clutch was to engage or disengage transmission of power. Cone clutch was designed by following empirical rules. This cone clutch was the primary dry type clutch, which initially transmitted the power to the machine and could be engaged or disengaged with the help of a large pulley. This arrangement could be operated with the help of the spring-loaded type lever system. Cone clutch is shown in **Fig. 2**.

Fig. 2 Isometric view of cone clutch and pulley



Power to be transmitted = 2.2 kW

Number of rev. per minute of shaft = 750

Maximum stress = 101.34 N/mm^2 (Taking factor of safety = 4)

Working or design stress = 101.34 / 4 = 25.34 N/mm^2

$\therefore d^3 = 16T / \pi f_s$

Co-efficient of friction (clutch friction material - hair belt) μ = 0.3

Mean radius of cone clutch = 0.065 m

Calculation of Outer Radius & Inner Radius of Cone Clutch

The standard semi angle of the cone clutch is 14° = 0.24 radian

So outer radius of cone clutch = r + 2 tan α = 73.5 mm

Inner radius = r − 2 tan α = 56.47 mm

$T = [\pi f_s d^3] / 16$

The diameter of the shaft on which clutch mounted Let 'd' be the diameter of the shaft, Where

T = Torque, N mm

f_s = Working stress = 25.34 N mm^{-2}

N = Shaft rpm = 750

Power requirement (P) = [2πNT] / 60 = 28010 N mm [6]

Putting value of T in equation

$T = [\pi f_s d^3] / 16$

$\therefore T = [60 \times 2200] / [2 \times 3.14 \times 750]$

d = 14.27 mm [7]

A Shaft of 22 mm diameter was taken considering the point of safety because of use of a heavy pulley. The material selected for shaft was MS C 45. The proportion for worm and worm gear are given in **Table 1** and **2**.

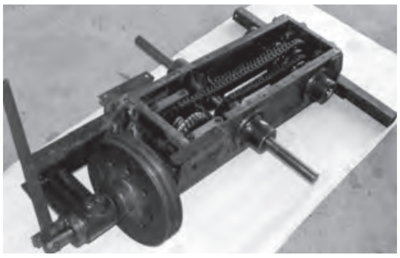
Table 1 Proportion for worm

S. No.	Particulars	Single / Double threaded
1	Normal pressure angle (λ)	14.5°
2	Lead angle (Φ)	16°
3	Pitch circle diameter for worm integral with the shaft	2.35 Pc + 10 mm
4	Pitch circle diameter for worm bored to fit over the shaft (Dow)	2.4 Pc + 28 mm
5	Maximum bore shaft (D)	Pc + 13.5 mm
6	Hub diameter	1.66 Pc + 25 mm
7	Depth of teeth (h)	0.686 Pc
8	Addendum (a)	0.318 Pc
9	Pitch circle diameter for worm (Dw)	3 Pc
10	Face length (lw)	Pc (4.5 + 0.02 n) n = No. of starts

Table 2 Proportion for worm gear

S. No.	Particulars	Single / Double threaded
1	Normal pressure angle (λ)	14.5°
2	Outside diameter (D_{OG})	D_G + 1.0135 Pc D_G = pitch circle diameter of the worm gear
3	Throat diameter (D_T)	D_G + 0.636 Pc
4	Face width (b)	2.38 Pc + 6.5 mm
5	Radius of gear face (R_f)	0.882 Pc + 10 mm
6	The radius of gear rim (Pr)	2.2 Pc + 14 mm

Fig. 3 A developed gearbox with a cone clutch



Axle

An axle similar in shape to the shaft in a stationary/rotating machine element and is used for the transmission of bending moment only. It acts as a support for some rotating body such as hoisting drum, a car wheel or a rope sheave.

Maximum power actually required kW = 1.7

rpm of the axle = 22

working or design stress = 25.34 N/mm^2

$P_a = [2\pi NT] / 60$

Where,

P_a = Actual required power of the engine in Watts

T = Torque N.m

N = rpm of axle

T = 737.90 N.m = 737900.19 N.mm

The same material was selected for axle MS C45. Values of stresses are the same as previous

$T = [\pi f_s d^3] / 16$

where,

T = torque.

f_s = maximum shear stress

d = diameter of axle

$d^3 = [16 \times T] / [\pi \times f_s]$

d = 32 mm [8]

The diameter selected for axle was 32 mm. Keyway on the axle was provided to adjust the track width of various wide spacing vegetable crops. By this way, the track width was adjusted from 0.40 to 0.70 m. Four bearings, ISO 6206 were also selected as per the axle diameter. A developed gearbox with cone clutch is shown in **Fig. 3**.

Fig. 5 Tool carrier frame with reversible type shovel

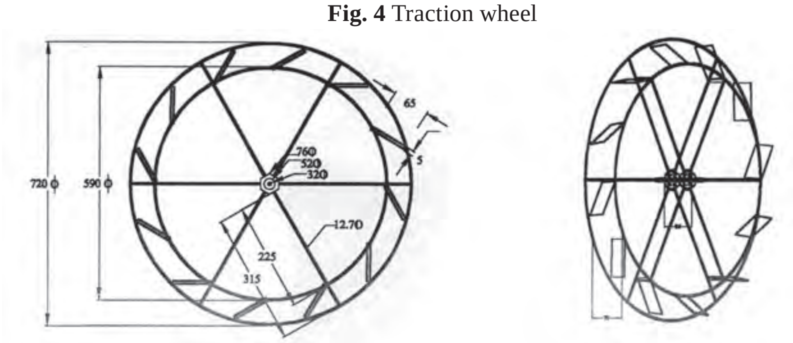
Traction Wheel

Traction wheel or ground wheel was the main component of the power weeder. The ground clearance was kept at 0.25 m to facilitate easy movement of the machine in the standing vegetable crops. Two traction wheels are made of two different diameters (0.72 m and 0.59 m) of MS C 45 rod. The height and thickness of lug were kept as 65 mm and 5mm respectively. For considering smooth operation and self-cleaning ability of the ground wheel, lug angles were decided on the basis of previous studies conducted by Panwer (1999). The length of lug was kept as 70 and 80 mm with 30° lug spacing. Average values of 12 lugs at 30° pitch were selected for power transmission to the ground wheels (**Fig. 4**).

Soil Working Tools (Cutting Tools)

In the soil working a cutting force acts on the working tools. This force was a resultant of the forces due to elastic, plastic and other deformations of the soil, the force of friction between the soil and the working tool, the force due to friction between the working tool and unworked soil on the arc of cutting and so on (Yatsuk et al. 1982). In order for cutting to takes place, a system of forces must act upon the material (weeds) in such a manner as to cause it to fail in shear. This shear failure is almost invariably accompanied by some deformation in bending and compression, which increases the amount of work required for the cutting operation (Bainer et al. 1960). If the material being cut uprooted and crushed is adequately supported and was relatively strong in bending the material it may transmit the force required to oppose cutting element. The weeds to be cut with this machine (Meliotus indicia, Echinochloa crur galli sorghum, Datura, Motha, Moong, Suspenieq) and small plants were not that strong enough to oppose the cutting force. A frame was fabricated with the help of M.S. angle 35 × 35 × 5 mm in a rectangular shape with length 0.5 m and width 0.3 m. A ground wheel was attached with the frame for transporting.

Fig. 4 Traction wheel



Reversible Type Shovel

The soil-working component used in the machine was a cultivator fitted with tines having shovels as cutting tools. The cultivator stirs the soil and breaks the clods. The tine is made of mild steel flat having carbon content ranging from 0.15 to 0.25%. An MS flat of 40 × 10 mm size was used for tines. The shovel used was of the reversible type. The width of the shovel was 35 mm and 5 mm thickness having carbon content ranging from 0.5 to 0.6%. The thickness of the shovel ranged between 3.15 to 5.00 mm. The cutting angle varied in the range of 15o to 20°. The shovels were fitted to the tines with M6.32 TVS nut and bolt as shown in **Fig. 5**.

Cage Roller

It was a roller consisting of a cage of steel blade arranged so as to form the shape of the cylinder. This type of roller was also mounted on field forage harvester to perform simultaneously three operations namely harvesting, chopping and blowing into wagons. These rollers were provided with seven spiral shaped knives on a revolving cylinder which looks something like the rotary cage roller as shown in **Fig. 6**.

The knives can be sharpened without being removed from the cylinder. While sharpening the blades with a grinder, care should be taken not to spoil the bevel of the edge and avoiding excessive grinding. Changing the speed of the feed rolls provided adjacent to the shear blade changes the length of the cut. The chopped material (green manure) falls into the field and mixed with soil.

Theoretical length of cut (TLOC)

$$= \{\pi(D_u \times N_u + Dl \times N_l) / Z\} / N \times K \quad [9]$$

Where,

D_u, D_l = diameter of upper and lower feed rolls in mm.

N_u, N_l = Speed of upper and lower feed rolls in rpm.

N = cutter head speed in rpm.

K = Number of knives on the cutter head.

Z = Number of feed rolls.

If the diameters of the upper and lower rollers and there speeds being the same the above equation will be as follows.

$$= \pi\{(527.2 \times 47) / (21 \times 7)\} = 529.54 \text{ mm} = 0.529 \text{ m}.$$

The prototype of walking type power weeder is shown in **Fig. 7**

Results and Discussion

Developed power operated weeder was evaluated in the research and farmer's fields for weeding operation of chili, turmeric and maize crops (**Fig. 8**), sown in the row spacing from 50-90 cm.

Field Performance Test of Power Operated Weeder

The overall performance of the machine was evaluated on the basis of field capacity, field efficiency, weeding efficiency, the percentage of plant damaged, labour requirements, energy consumption, and operational cost. The average effective field capacity shown by the power weeder was 0.130 ha/h. In spite of the high field capacity, the power weeder had low field efficiency because of turning losses and cleaning of the weeding tines, which got choked due to, uprooted weeds and mud. The field efficiency was 75%. The weeding efficiency was 89.4%. Plant damaged during the weeding operation of the power weeder was found to be 5%. However, it could be minimized if the operator develops a skill to move the machine properly in the forward direction in between the rows. In power weeder, the average time loss at headland was 25 s. The total time loss was 3 h/ha. It was due to turning and time-to-time aligning of the cutting tool, tightening of the bolts and unclogging weeds. The average speed of operation was found to be 2.52 km/h. Fuel consumption was measured by top up method. Fuel consumption of the power weeder during weeding operation was 0.85 L/h.

Conclusions

Petrol start -kerosene run 2.20 kW engine operated walking type weeder was designed, developed and performance evaluated. On the basis of information secured through the study following conclusions could be inferred.

1. The field capacity of the weeder was found as 0.12 ha/h with field efficiency as 75% and weeding efficiency as 89%.
2. The fuel consumption of weeder was 0.85 L/h and the cost of weeding was found Rs. 925 / ha.
3. Overall working of the weeder was found to be satisfactory, trouble-free and smooth. There were no breakdowns and the accidental incident was observed during operation.

Acknowledgment

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Fig. 6 View of cage roller for weeding operation

Fig. 7 Developed walking type power weeder

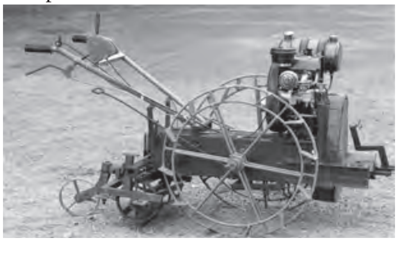

Fig. 8 Weeding operation by walking type power weeder

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ABSTRACTS

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

1703

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

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

1716

Design and Development of Vertical Loading Mechanism for Indoor Single Tyre Test Carriage: Manish Kumar, K. P. Pandey, Satya Prakash Kumar

The present study was undertaken to upgrade the existing traction laboratory of Agricultural and Food Engineering Department of IIT Kharagpur for reduction in drudgery and easy operation. A vertical loading mechanism using hydraulics was designed to apply additional normal load up to 25 kN on wheel axle and remove 13 kN load from the initial load. The circuit used for apply force consists of fixed displacement pump, a 3-way, 4 port directional control valve, a relief valve and a double acting cylinder. Load transducer based on proving ring for 40 kN load bearing capacity was developed. The ring was calibrated to get relationship of voltage and load. The calibration was taken both tensile and compression modes. Vertical loading mechanism by hydraulic loading was validated in both static and dynamic conditions. Validation of hydraulic normal loading was done with test tyres under static and dynamic conditions. The vertical load was varied from 7.85 kN to 10.30 kN using hydraulic loading mechanism under both static and dynamic conditions. A bias-ply tyre and a radial-ply tyre, each of 13.6 × 28 sizes, were selected under this study in soft soil conditions. The soil cone index was maintained between 0.6 to 0.8 N/mm^2. Under static condition, the data show that the maximum load which could be added was 4.75 kN and the corresponding retracted load at the same pressure was 4.69 kN. There was only 3% difference in ring transducer and pan balance reading under dynamic condition, an average of 1.02% to 6.26% difference in load during entire length of travel w.r.t initial load was found for both bias and radial ply tyre under different pull upto 20% slip. There was no significant difference was found between initial vertical load and average vertical load during travel as p-value (calculated probability) was found 0.30 (> 0.05) using t-test available in SAS 9.3.

Optimization of Parameters of Axial Flow Paddy Thresher

by

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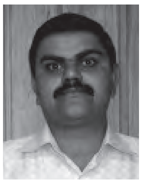

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Abstract

An axial flow thresher was modified to maintain the seed quality in terms of broken grains. The machine got fabricated from local market and its performance was studied on paddy PR-118 to ascertain the effect of louver angles, peripheral speed and feed rate on threshing efficiency, cleaning efficiency, broken grains, grain output, rate of crop flow, non-collectable loss and power requirement. The louver angles, peripheral speed and feed rate had a significant effect on grain damage during the paddy threshing. The broken grains varied from 0.11 to 2.48%. The broken grains were decreased with increase in louver angles from 10° to 15° but further increase in louver angles from 15° to 20°, the broken grain was increased. The similar trend was obtained for threshing efficiency. The rate of crop flow increased with increase in louver angle. Grain output was found to be in the range of 319 to 555 kg/h for the feed rate of 1.5 to 2.5 t/h. The power requirement decreased with increase in louver angles. Similarly non collectable loss decreased with increase in louver angles. The optimum values for broken grains, threshing efficiency, cleaning efficiency, Retention time, power requirement, grain output, rate of crop flow and non-collectable loss was 0.11%, 98.6%, 97.27%, 5.09 seconds, 12.86 kW, 543.13 kg/h, 5.24 q/h and 0.01% respectively. (q (quintal) = 100 kg).

Introduction

Threshing is one of the most important operations which can affect the quantitative and qualitative losses of grains. Efforts to reduce grain damage while increasing capacity have resulted in the development of axial flow threshing mechanism. Axial flow threshers developed at International Rice Research Institute (IRRI) in the 1970s have been adopted and widely disseminated throughout Asia. The designs have also been modified by IRRI to serve as multi crop thresher for different capacities (Gummert et al., 1992).

The performance of threshers developed at IRRI have been extensively tested and evaluated by researchers in India and adjoining countries (Anonymous, 1978). A large number of axial flow threshers are manufactured in India by local manufacturers and majority of these threshers are based on IRRI design. These have been improvised by State Agricultural Universities (SAUs) and local manufacturers for the better performance of thresher to suit local varieties of cereals. Majority of the threshers manufactured in India by local manufacturers are manufactured in Punjab and are supplied throughout the country for threshing paddy and other crops. In existing threshers grain losses to the tune of 4.49% have been observed (Anonymous, 2011). Till today these fail to achieve the internationally acceptable loss level of 1% for threshing cereals (Anonymous, 2001). Grain damage in axial flow threshers, reflects the improper design of threshing mechanism especially louvers which results in back feeding through the feed opening and over threshing (Gummert et al., 1992). The over threshing of crop in threshing unit can be reduced by reducing back-feeding of crop and its retention time. Also the power requirement for thresher varies with the louver angles. The variation in the power requirements for the different speeds and concave clearance were observed to be small as comparison to those for louver angles (vane angles), feed rates and moisture contents (Harrison, 1991). Thus adjustment on louver angles, affects the performance of an axial flow thresher considerably. Thus, studies were conducted to determine and select the appropriate parameters as louver angles, peripheral velocity of threshing cylinder and feed rate for reducing grain damage and producing a better quality of grain in threshing operations.

Materials and Methods

Thresher

A3D model of modified axial flow thresher was developed using CAD software. Then machine was fabricated from local market and their performance evaluation was carried out (**Fig. 1**). It mainly consists of main frame, threshing drum, concave, separating and cleaning unit and power drive unit. The threshing drum operates on the principal of axial flow movement of the material with the help of louver angles. The threshing drum was closed type and fixed with 40 flat spikes in 8 rows, each row had 5 spikes in staggered fashion. The diameter and length of threshing drum was 460 and 1260 mm respectively.

Fig. 1 Modified axial flow thresher

Crop

Paddy PR-118 variety, grown with the standard agronomic practice as laid down in Package of Practices for Kharif crops at Punjab Agricultural University, Ludhiana, Punjab, India during Kharif season, was taken for the study. The crop used for the test run was harvested by self-propelled reaper. After the crop harvesting, the bundles were placed in stack to maintain moisture content in one range. The moisture content of straw and grain through the experiment varied in the range of 15 to 20% and 10 to 11% respectively.

Evaluation Procedure

The performance evaluation of modified axial flow thresher was carried out to determine the effect of louver angles, peripheral speed and crop feed rate on threshing efficiency, cleaning efficiency, broken grains, power requirement, retention time, rate of crop flow and non-collectable loss. For this study, three louver angles, three peripheral speeds and three feed rates were used. The three levels of cylinder peripheral speeds were 18.68, 22.0 and 25.3 m/s respectively. The thresher was powered by tractor P.T.O. and the speed was adjusted by tractor engine throttle. Three levels of feed rates 1.5, 2.0 and 2.5 t/h were considered for experiment and were attained by varying the time of feeding the crop in the cylinder. The number of louver angles was seven and spacing between them was kept 120 mm. the three levels of louver angles were 10°, 15° and 20° respectively. The concave clearance between threshing drum and concave was fixed at 25 mm. Three levels of Louver angles (10°, 15° and 20°), three levels of peripheral speed (18.68, 22.0 and 25.3 m/s) and three levels of feed rate (1.5, 2.0 and 2.5 t/h) were taken as independent variables for the experiment (**Table 1**).

The effect of three independent parameters on threshing efficiency, cleaning efficiency, broken grains, grain output, rate of crop flow, non-collectable loss and power requirement was studied. The thresher was operated through tractor PTO and power was transmitted to the threshing drum by V-belts. Tachometer was used for recording peripheral speed of threshing cylinder. The crop was weighted on a weighing balance. The grains collected for determining losses were weighed on electronic balance.

Plan of Experimentation

The mature dried crop which was harvested 2-3 days prior to threshing was manually fed into the thresher. The duration of test run for collecting samples was 20 seconds. The feed rate was measured by feeding crop bundles each of 10 kg weight, with respective to corresponding time. The experiment was started after stabilizing the feed rate by using 3 bundles as free run. The power requirement was calculated by using torque transducer. Retention time of crop inside the axial cylinder was measured by noting the feeding time of colored crop bundle and their exit time from

Table 1 Specifications of independent parameters used for evaluation

S. No.	Description	Level	Values		
1	Louver Angles, ° (degrees)	3	10°	15°	20°
2	Peripheral speed (PS), m/s	3	18.68	22.0	25.3
3	Feed rate (F), t/h	3	1.5	2.0	2.5

Table 2 ANOVA for the paddy threshing unit performance

Source of Variation	d.f.	F-Ratio							
		Threshing Efficiency	Cleaning Efficiency	Broken grains	Retention time	Rate of crop-flow	Grain output	Power requirement	Non-collectable loss
PS	2	4.55*	6.98*	564.44*	11.74*	6.15*	2.56	57.88*	56.69*
F	2	2.92	2.90	6.75*	.00	26.41*	22.55*	21.03*	6.33*
PS × F	4	0.12	-.02	1.94	.00	.58	0.33	0.17	0.22
LA	2	5.62*	3.96*	8.48*	71.86*	36.63*	0.26	26.53*	9.86*
PS × LA	4	0.21	0.39	2.81*	0.50	1.25	0.16	0.41	1.00
F × LA	4	0.12	0.00	0.28	0.01	1.50	0.10	0.03	0.23
PS × F × LA	8	-0.04	0.03	0.14	0.11	0.31	0.08	0.09	0.098
Error	54								

* Indicate significant at 5% level of confidence

threshing cylinder. Based on this retention time, the rate of crop flow was calculated. Factorial design in CRD had been used to analyze the experimental data statistically. The samples were taken from grain outlet for determining the percent un-threshed, broken percentage and cleanliness of the grains. Sieve overflow was collected and re-threshed at the end of experimentation. The straw was also collected for one minute from aspirator outlets and the grain recovered from this outlet was termed as non-collectable loss. The un-threshed grains from grain outlet were separated, weighed and expressed as threshing efficiency. The unwanted material from clean grains was separated, weighted and expressed as cleaning efficiency.

Results and Discussions

Threshing Efficiency

Fig. 2 shows that the effect of louver angles on threshing efficiency at different peripheral speed and feed rates. The results indicated that the threshing efficiency was between 97.9 to 99.65% for the range of variable studied. The threshing efficiency was decreased with increased in louver angle from 10° to 15° but further increase in louver angle from 15° to 20° threshing efficiency increased for all peripheral speed and feed rates. The minimum threshing efficiency was found for the louver angle of 15°. Peripheral speed and louver angles significantly affected the threshing efficiency at 5% level (**Table 2**). Threshing efficiency increased with increase in peripheral speed. The effect of feed rate on threshing efficiency was non-significant at 5% of significance, however the threshing efficiency was found to be increased with an increase in feed rate.

Cleaning Efficiency

The information has been plotted in **Fig. 3**. Statistical analysis revealed (**Table 2**) that the effect of peripheral speeds and louver angles on cleaning efficiency were significant at 5% confidence level. Effect of feed rate on cleaning efficiency was found to be non-significant, however cleaning efficiency decreased with the increase in feed rate. The louver angles played significant role in increasing the cleaning efficiency. The trend of curve shows that the cleaning efficiency increased with increase in louver angles. Similarly, cleaning efficiency was found to be increased with the increase in peripheral speed. The maximum cleaning efficiency was observed at louver angle of 20° and minimum cleaning efficiency was observed at louver angle (LA1: 10°) for all peripheral speeds and feed rates. On overall average basis 97.48, 98.02 and 98.24% cleaning efficiency were obtained at louver angles 10°, 15° and 20° respectively.

Fig. 2 Effect of louver angles on threshing efficiency at different peripheral speed and feed rates

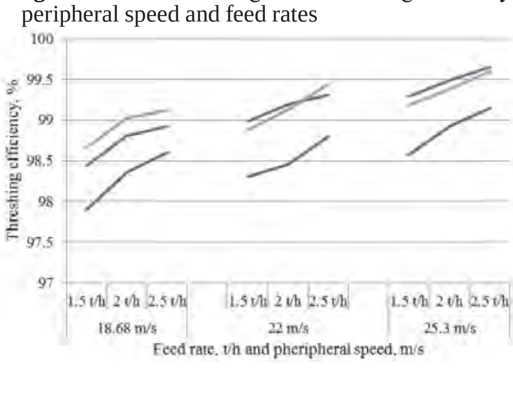


Fig. 3 Effect of louver angles on cleaning efficiency at different peripheral speed and feed rates

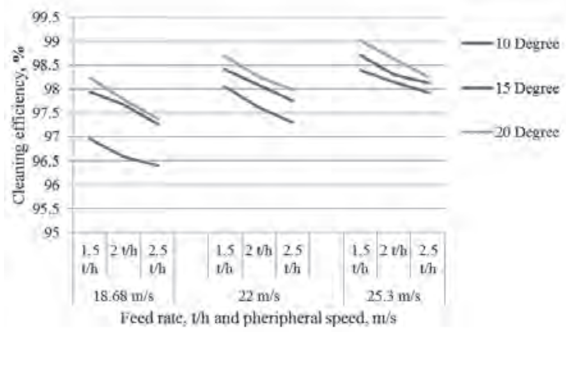


Table 3 Interaction between peripheral speed and louver angles on broken percentage

	PS1	PS2	PS3
LA1	0.151	0.714	2.324
LA2	0.112	0.416	1.887
LA3	0.118	0.483	2.324

Broken Grains

The treatment combination means of percentage of broken grains collected in different outlets were calculated and have been plotted in **Fig. 4**. Statistical analysis revealed (**Table 2**) that the effect of peripheral speeds; feed rate and louver angles on percent of broken grains were significant at 5% confidence level. It was observed that the percentage of broken increased with increase in the peripheral speed. It might be due to rise in extent of impact at higher level of cylinder rotation speed. The interaction between peripheral speeds and louver angles was significant at 5% confidence level (**Table 3**). Factor means depict that minimum broken grains were obtained at louver angles of 15° followed by 20° and 10°. This clearly indicates superiority of louver angle 15 in terms of broken grains. The effects of peripheral speed on broken grains were significantly different for all louver angles. The lower peripheral speed (510 rpm) and louver angle (LA2: 15°) exhibited minimal damage of 0.112%. The maximum broken grain of 2.324% was observed at peripheral speed (690 rpm) and louver angles (10° & 15°). Percent of broken grains initially decreased with an increase in louver angle from 100 to 150 and then it slightly increased with further increase in louver angles from 15° to 20°.

Retention Time

The data on retention time of crop in the axial flow cylinder were recorded and plotted in **Fig. 5**. Statistical analysis revealed (**Table 2**) that the effect of peripheral speeds and louver angles on retention time were significant at 5% confidence level. The effect of feed rate on retention time was found not significant. The retention time were decreased with increasing the louver angles and peripheral speed. In these set of curves it was observed that, there was no clear trend with the effect of feed rates on retention time. On the overall average basis 6.79, 4.64 and 3.55secondretention time were obtained with louver angles LA1, LA2 and LA3 respectively. As increased the louver angles, the retention time was decreased. It could be due to increase in axial movement of crop inside the threshing cylinder due to increase in louver angles. The retention time was observed to be maximum 7.38second at louver angles LA1 and peripheral speed PS1. The retention time for the louver angle LA3 and peripheral speed PS3 was found to be minimal 2.92 second.

Rate of Crop Flow

The data on rate of crop flow inside the axial flow cylinder were calculated based on the retention time of crop as affected by the study variables namely peripheral speed, crop feed rate and louver angles. Statistical analysis revealed (**Table 2**) that the effect of peripheral speeds; feed rate and louver angles on rate of crop flow were significant at 5% confidence level. The effect of study variables on rate of crop flow were presented graphically in the **Fig. 6**. The trend of curve shows that the rate of crop flow was increased with the increase in louver angles. It could be due to the increased in crop flow inside the axial flow cylinder with the increase in louver angles. The peripheral speed and feed rate also played significant role in increasing the rate of crop flow. The factor means depict that the rate of crop flow was increased with the increased in peripheral speed, feed rate and louver angles. The maximum value of rate of crop flow was 9.42 q/h at peripheral speed PS3, feed rate F3 and louver angles LA3. Also, the minimum value of rate of crop flow was 2.03 q/h at the peripheral speed PS1, feed rate F1 and louver angles LA1.

Grain Output

The grain output for paddy threshing at different peripheral speeds, louver angles and feed rates were recorded. The trend curve for grain output as affected by study variables namely peripheral speed, crop feed rate and louver angles were presented in the **Fig. 7**. The data on grain output was statistically analyzed and represent in **Table 2**. Statistical

Fig. 4 Effect of louver angles on broken grains at different peripheral speed and feed rates

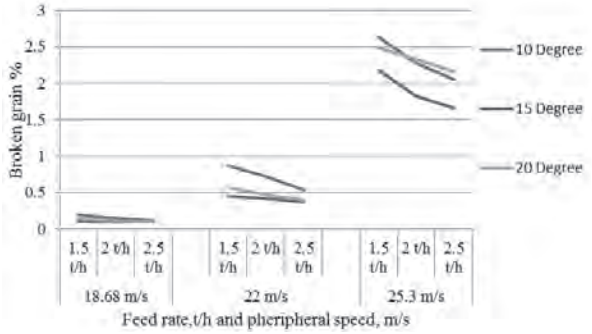
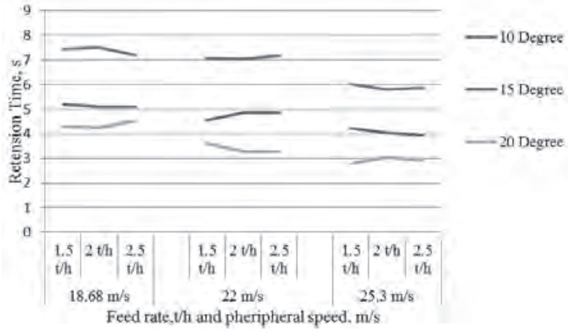


Fig. 5 Effect of louver angles on retention time at different peripheral speed and feed rates



analysis revealed that the effect of feed rate on grain output was significant at 5% confidence level. Grain output was found to be increased with the increase in feed rates.

The factor means depict that the grain output was found to be 365.63, 456.75 and 541.06 kg/h for the feed rates 1.5, 2.0 and 2.5 t/h respectively. The effect of peripheral speed and louver angles on grain output was found not significant. The maximum grain output of 541.06 kg/h was observed at the feed rate 2.5 t/h and minimum grain output of 365.63 kg/h was found at feed rate 1.5 t/h. There were no significant effects of peripheral speed and louver angles on grain output.

Power Requirement

The power requirement as affected by the study variables namely peripheral speed, crop feed rate and louver angles was recorded. The power requirement for paddy threshing at different peripheral speeds, louver angles and feed rates was graphically presented in **Fig. 8**. Statistical analysis revealed **Table 2** that the effect of peripheral speeds, feed rate and louver angles on power requirement were significant at 5% confidence level. The factor means for peripheral speed and feed rate depict that with increasing the peripheral speed and feed rate, the power requirement was found to be increased. On overall average 11.8, 13.52 and 15.91 kW power requirement was observed at peripheral speed of PS1, PS2 and PS3 respectively, which clearly indicates the superiority of PS1 in terms of power requirement. The power requirement was found to be decreased with the increase in louver angles. Factor means depict that on overall average basis 15.2, 13.62 and 12.41kW power requirement was observed at louver angles LA1, LA2 and LA3 respectively. This clearly indicates superiority of louver angles LA3 in terms of power requirement. The power requirement was found to be maximum 19.1 kW at the peripheral speed PS3, feed rate F3 and louver angle LA1. Also, the power requirement was found to be minimum 9.09kW at the peripheral speed PS1, feed rate F1 and louver angle LA3.

Non Collectable Loss

The non-collectable loss includes the grains which were blown through the aspirators. The grains from sieve overflow and underflow were generally re-threshed; therefore they were not including in non-collectable losses. Data on fraction of blown grains were collected in aspirator outlets as affected by the study variables namely peripheral speed, crop feed rate and louver angles was recorded. Statistical analysis revealed (**Table 2**) that the effect of peripheral speeds; feed rate and louver angles on non-collectable loss were significant at 5% confidence level. The effect of study variables on non-collectable losses were presented graphically in the **Fig. 9**. The factor means depict that the non-collectable loss was rapidly increased with an increase in peripheral speed. The non-collectable loss was found to be decreasing order with the increase in feed rates. Similarly, the louver angles had significant effect in reducing the non-collectable loss. The non-collectable loss was decreased with increase in louver angles. Factor means depict that minimum non collectable loss was observed at louver angles LA3 followed by LA2 and LA1. The non-collectable loss of 0.24% was found to be maximum at peripheral speed PS3: 690 rpm, feed rate F1: 1.5 t/h and louver angle LA1: 10°. Also the minimum non collectable loss of 0.01% was observed at peripheral speed PS1: 510 rpm, however this loss was negligible.

Conclusions

A modified axial flow threshing system comprised of adjustable louver angles was introduced. This study indicated that louver angles has great influence on axial flow thresher performance for controlling grain damage, decrease power requirement and amplified the rate of crop flow. During the process of study the fallowing conclusions were drawn.

1. The louver angles, peripheral speed and feed rate have a significant effect on grain damage during the paddy (PR-118) threshing. The broken grains were decreased with increase in louver angle from 10° to 15° but further increase in

Fig. 6 Effect of louver angles on rate of crop flow at different peripheral speed and feed rates

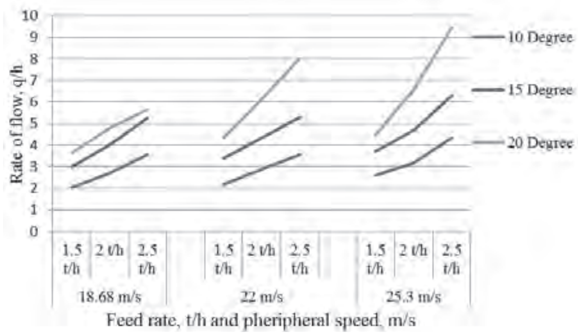
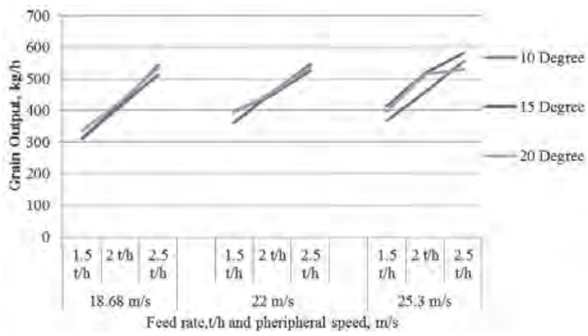


Fig. 7 Effect of louver angles on grain output at different peripheral speed and feed rates



louver angle from 15° to 20°, the broken grain was increased. Also the broken grains were rapidly increased with the increase in peripheral speed and it slightly decreased with increase in feed rate.

2. The louver angles and peripheral speed have a significant effect on threshing efficiency. The threshing efficiency was found to be decreased with increase in louver angle from 10° to 15° but further increase in louver angle from 15o to 20°, it was increased. Also the threshing efficiency was found to be increasing order with increase in peripheral speed. There was no clear trend for the effect of feed rate on threshing efficiency.
3. The louver angles and peripheral speed have a significant effect on cleaning efficiency. The cleaning efficiency was found to be in increasing order with the increase in peripheral speed and louver angles. It also slightly increased with increase in feed rate.

4. The retention time of crop inside the threshing unit was varied from 7.5 to 3.0 second. The louver angle and peripheral speed has significant effect on retention time. The retention time decreased with increase in louver angle and peripheral speed.

5. The rate of crop flow was observed in the range of 2.03 to 9.4 q/h. The louver angle, peripheral speed and feed rate have significant effect on rate of crop flow. The rate of crop flow increased with increase in louver angle, peripheral speed and feed rate.
6. Grain output was found to be in the range of 319 to 555 kg/h for the feed rate of 1.5 to 2.5 t/h. The feed rate has significant effect on grain output.
7. The power requirement varied in the range of 9.0 kW (12 hp) to 19 kW (25.5 hp). The louver angle, feed rate and peripheral speed have significant effect on power requirement. With increasing the peripheral speed and feed rate, the power requirement was found to be increased. On overall average 11.8, 13.52 and 15.91 kW power requirement was observed at peripheral speed of PS1, PS2 and PS3 respectively. The power requirement was found to be decreased with the increase in louver angles. On overall average basis 15.2, 13.62 and 12.41 kW power requirement was observed at louver angles LA1, LA2 and LA3 respectively.
8. The non-collectable loss decreased with increase in louver angles and feed rates but it rapidly increased with increase in peripheral speed.

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Fig. 8 Effect of louver angles on power requirement at different peripheral speed and feed rates

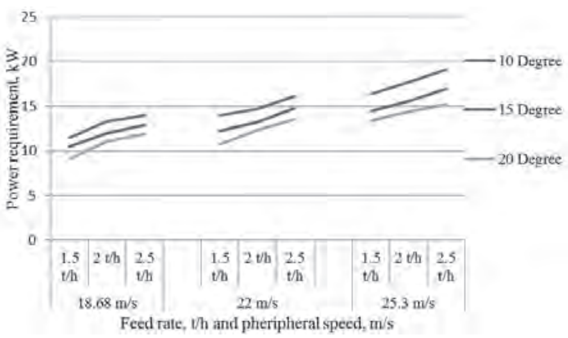
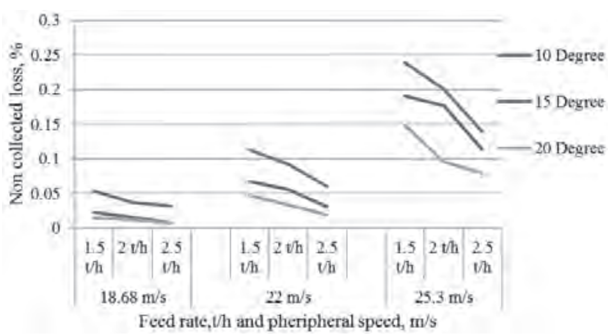


Fig. 9 Effect of louver angles on non-collectable loss at different peripheral speed and feed rates



Measuring Spray and Spray Deposition on Plant and Unwanted in Field Under Iraqi South Conditions

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Abstract

A field study was conducted in Al Qurnah city located in the south of Iraq to measure spray and spray deposition on a soil surface, corn plant, and unwanted to weed control using a herbicide product. A Knapsack sprayer utilized in this study with a Flat Fan nozzle mounted on the rod. Three blocks and three plant densities were carried out in this study. A completely randomized experiment was conducted using split plots. Spray applications were applied at 2 bar and nozzle height of 50 cm and with an average worker speed of 0.15 $m.s^{-1}$. Spray deposition was measured at three levels on both of plant and unwanted and with one location on the soil surface. The main results of this study showed that volume median diameter with ranging between 112.77 and 182.53 m. The results also appeared a sensitive spray deposition and spray impacted with plant and unwanted density. Higher spray deposition and spray impacted observed on the top and middle level of unwanted plant 0.029 and 0.021 $\mu L.cm^{-2}$ respectively compared to bottom level, corn plant and soil surface. In additions, maximum spray impacted on an unwanted plant was 12% with high unwanted plant density compared with small densities of 8.3%. Higher biological efficacy found with Prickly alhagi with no significant differences with al hali weed. Improving spray deposition and spray impacted can be attained by obtaining at a nozzle spray distance of 50 cm from the intended target. The results of this study will be contributing to knowledge and highlight amount of pesticides that deposit on different locations at the time of spraying applications to improve crop protection product.

Keywords: Spray deposits, spray impacted, volume median diameter, unwanted plant

Introduction

Crop protection product (CPP) is one of the fundamental measures agriculture production, and it is especially more important for quality and sufficient yields of crop. After planting crops, there are different problems found related to crop protection as pests, diseases, and unwanted plants. They attack intended plants and cause yield and quality losses (Aktar et al., 2009). During spraying application of crop protection using chemical products, there is an important point to study the exact amount and uniformity of spray that deposit on and off-intended area (Syngenta, 2017). At the last decades, agricultural sprayers already increased the efficiency of plant protection by improving spray application as electing a suitable nozzle height, operating pressure, and nozzle size to reduce the rate of pesticides that enter the soil and move away by air action. In additions, to increase spray deposition on the site. Spray deposition on both of on plant and unwanted is considered a complex problem and it is an important issue to evaluate spray application methods (Fox et al., 2001). It is dependent on several factors as equipment design, properties of the leaves surface, wetting of leaves, application methods and metrological conditions. The main parameters related in spray deposition are spray quality as droplet size, volume median diameter, and both of unwanted and plant density (Nordbo et al., 1995; Breakman et al., 2009; Souza et al., 2017).

There are two methods for characterization spray deposition, firstly, by measuring the amount of liquid retained on the surface of the plant intended and, secondly. The percentage of deposit covered of plant surface. Spray deposition on the target area affected by the changes of spray quality. The finest droplet sprays in size are deposited in more efficiently on the surface of the plant intended than the largest droplet size. In additions, reducing in spray deposit on the target is with the low droplet number density per unit volume. Also, Spray impacted closed to spray deposition. Spray impacted on the target zone is more important issue especially for contact action herbicides and has a different impact on the performance of herbicide. Several studies have considered various ways to measure spray deposits and spray impacted on the collectors (Wolters et al., 2008; Foque and Nuyttens, 2011; Zhu et al., 2011). Quantity sprays deposition that is deposited on the collectors according to (ISO 24253-1, 2015). There are never studies in Iraq about pesticide applications to know portion of each part of the plant from pesticides applied are released to non-target. Also, most of the Iraqi farmers have not any information about nanoparticles spray during agricultural spraying.

Fig. 1 View side of knapsack sprayer

The objectives of this work were to:

1. Quantify spray droplet distribution that deposit on plant, unwanted, and soil surface at different locations.
2. Measure actual amount of spray impacted on the target site.
3. Maximize spray deposition on unwanted plant parts to determine best control.
4. Determine how plant and unwanted density can be affected in spray deposition and spray impacted.

Materials and Methods

An experimental study was performed on a farm located in Al Qurnah city in the east of Basrah at 30.935467N and 47.457006E. The experiment was carried out in September 2017 on a corn plant. The spray deposition, droplet size, volume median diameter and spray impacted were quantified on the top, middle, and bottom of both of plant and unwanted and on the soil using white card papers. The tracer BSF is recommended for quantitative spraying on the target. The spraying applications were done when the corn plant with approximately 60-70 cm tall and of 17-20 cm an unwanted plant. The experimental design was set up in randomized blocks using spilt plots with three replications. The dimensions of each block were 3 × 3 m (width × length) respectively.

Herbicides applications are made within 35 days after emergence of corn plant. Each corn plant and unwanted, randomly selected within the spraying swath.

Corn Plant and Unwanted Density

The number of certain corn plant and unwanted in a particular area are determined by counting the number of individual both of corn plant and unwanted in a separate case in uniformly size sample growth per unit area (plant/ha). Corn plant was planted between two rows distance of 75 cm and the distance between plants in the same row was 15, 20, and 25 cm.

Knapsack Sprayer Settings

Spraying applications were used with knapsack sprayer 16 liters capacity as shown in **Fig. 1**.

Nozzle distance fixed at 50 cm height above the unwanted plant. A driving operater speed was of 0.15 $m.s^{-1}$.

Nozzle Characteristic

Flat Fan nozzle was used in this study to provide spray coverage and spray deposition. Nozzle flowrate was of 0.66 $L.min^{-1}$ at 2 bar of operating pressure. This nozzle was selected based on the application volume, within the recommended pressure range.

Metrological Conditions

Metrological conditions data including air temperature, relative humidity, wind speed, and wind direction was recorded at the test site. A summary of weather conditions during spray treatments was described in **Table 1**.

Table 1 Weather conditions at time of application

Time period	temperature		Relative humidity, %	Wind speed, $m.s^{-1}$	Wind direction
	Max °	Min °			
06:00-06:30 AM	38	32	25	2	North

Spray Deposition and Spray Impacted

Spray deposition and spray coverage at three different locations on the corn crop and unwanted plant (top, middle, and bottom) and on the soil surface using white card papers. WCPs have been used in many studies as a tool for quickly providing a cheap evaluation of both of spray deposition and spray impacted. After completion of spray drying, WCPs were gathered and scanned at 600 dpi.

Herbicides and Doses Tested

Two types of herbicides were applied in this study: Chevelier (Metsulfuron-methyl 1 $g.L^{-1}$) +Topek Janta (Clodinafop-propargyl 2.5 $ml.L^{-1}$)

Field Experimental Procedures

An experiment was conducted in corn field in September 2017 and involved randomly selected rows (approximately 0.032 ha). Corn plant had an average height of 65 cm, and an unwanted plant was 18.5 cm. Amount of spray deposition, spray impacted, droplet diameter and volume median diameter measured on white card papers. White cards papers dimensions were of (8.5 cm × 5 cm) length and width respectively. These papers were positioned horizontally on the ground for measuring ground deposit, and three locations on corn plant, unwanted on the top, middle and bottom **Fig. 2**. The collectors were placed at random plants and unwanted at three locations and on the ground. When the spraying application for any block is finished, the collectors were collected and placed inside of containers until scanner its.

Two types of herbicide were applied at the same volume for all blocks applications. Blocks were made with the same nozzle for this study. Spot sizes on the white card papers were measured with Image J software®. The number of spot size that recorded on each paper was varied depending on the location of a collector. The use of WCPs to collect spray droplets and spray deposition from the different locations on the soil, corn plant, and unwanted in the top, middle, and bottom using fluorescent dye to collect. The swath-width sprayed was at least 0.42 m. A minimum of 3 replications was made in time and place along of the blocks in the field during the spraying applications. This procedure produced a total of 72 white card papers. After the droplet that impacted on the collectors had dried, the collectors marked and saved in box until analysis. WCPs analyzed by using image j software® for measuring droplet size, spray deposition, and spray impacted. Biological efficacy of herbicide deposition on unwanted was evaluated after one month of spraying.

Fig. 2 View picture of the test and spray deposition locations

Statistical Analysis

Data of spray droplet sizes, spray deposition, and spray impacted were analyzed using ANOVA table ($p < 0.05$).

Results and Discussions

Effect of volume median diameter

As shown in **Figs. 3, 4**, and **5** volume median diameter on white card papers has affected significantly for all sampling that located on soil, plant and unwanted at different locations. Higher volume median diameter values were found in the top collectors that located on an unwanted plant of 186 µm compared to other locations. Lower volume median diameter values were measured on the bottom of plant and soil 132.4 and 1132 µm respectively.

Also, as shown in the figures above, The results demonstrated

Fig. 3 Effect of plant density on volume median diameter at different blocks- soil surface

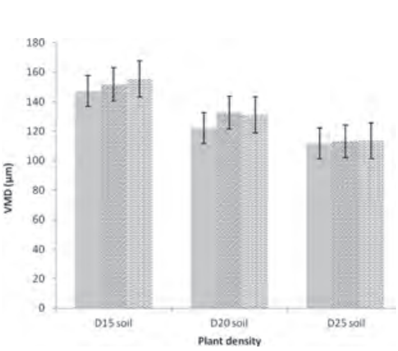


Fig. 4 Effect of plant density on volume median diameter at different blocks- corn plant

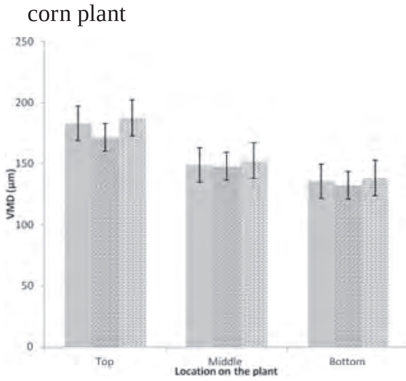


Fig. 5 Effect of plant density on volume median diameter at different blocks- unwanted plant

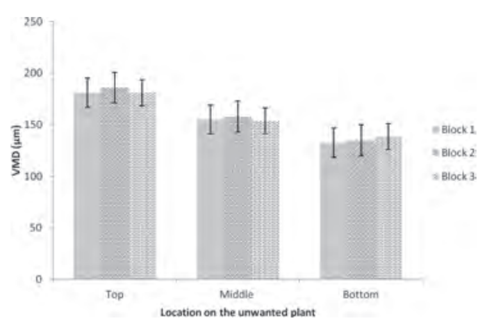


Fig. 6 Effect of plant density on spray impacted at different blocks- soil surface

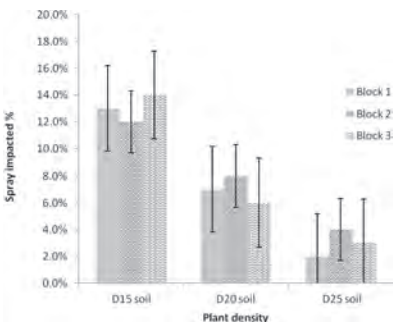


Fig. 7 Effect of plant density on spray impacted at different blocks- corn plant

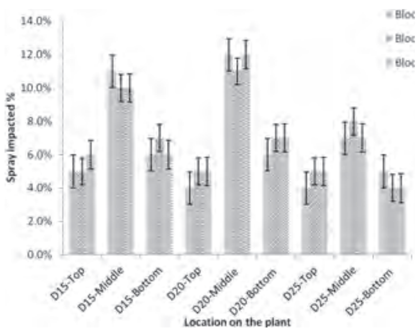
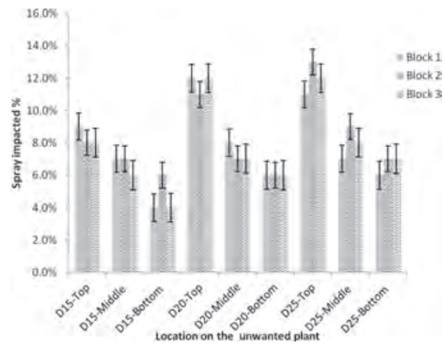


Fig. 8 Effect of plant density on unwanted spray impacted at different blocks

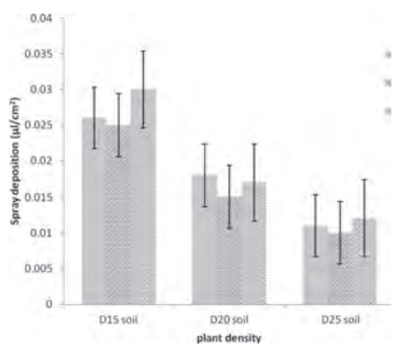


there are no significant differences between blocks in volume median diameters for all data that collected from the soil surface, plant, and unwanted at different locations.

Effect of Spray Impacted:

Spray impacted results in % for different locations on soil, plant intended and unwanted plant are presented in **Figs. 6, 7**, and **8**. Results showed significant differences in spray impacted. Higher spray impacted observed on unwanted plant on the top location of 12% than other treatments. Also, results indicated spray impacted inside both of plant and unwanted showed that the spray impacted decreased with plant and unwanted density. The decreased in spray impacted of white card papers was shown at each block with increasing plant and unwanted plant density. Results also indicated no significant differences in the blocks in spray impacted values for all data collected from soil, plant, and unwanted at different locations.

Fig. 9 Effect of plant density on soil spray deposition at different blocks



Effect of Spray Deposition

As shown in **Figs. 9, 10**, and **11** the results for herbicide spray deposition showed significant differences among spray deposition on soil surface, plant, and unwanted plant densities. Results also induced reduce in ground deposition when increasing in the density of both of plant and unwanted. More herbicide deposition observed on the top of unwanted plant 0.029 µL.cm^{-2} than the other locations of plant and soil surface. The portion of Spray deposition was also compared between different parts of the plant and unwanted plant, while spray deposition did not appear any differences in the blocks for soil surface, plant, and unwanted plant.

Relation Between Spray Deposition and Biological Efficacy

As shown in **Fig. 12** biological efficacy of herbicide treatment to kill different types of unwanted plant found with corn plant. Higher biological efficacy observed with Prickly alhagi with no significant differences with al hali weed. On the other hand, a reduction in biological efficacy was appeared in some type of weed types.

Fig. 10 Effect of plant density on corn plant spray deposition at different blocks

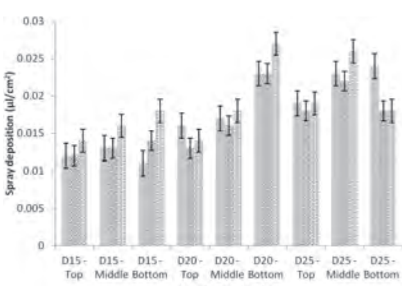


Fig. 11 Effect of plant density on unwanted spray deposition at different blocks

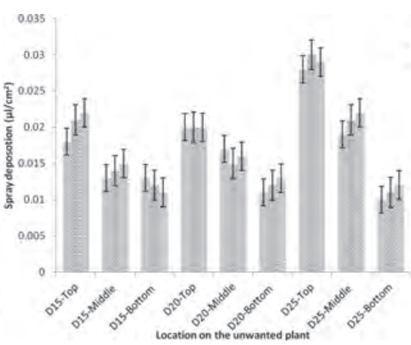
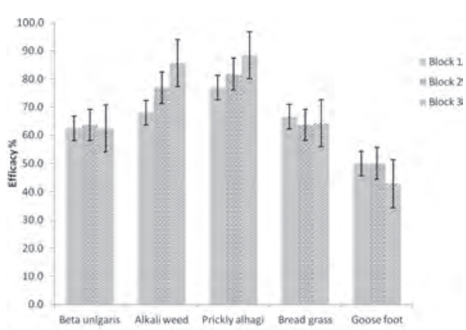


Fig. 12 Biological efficacy of herbicide on unwanted plant types at different blocks



Conclusions

In this study, three parameters were studied as volume median diameter, spray deposition, and spray impact collected on the white card papers from three locations on soil surface, corn plant, and unwanted. Larger values of volume median diameter, spray deposition, and spray impacted observed on the top of unwanted location than other treatments. Increasing of the variation in spot droplet diameter showed with increasing in the size of large spot. Increasing understanding of spray quality as droplet size, volume median diameter involved in the different stages on both of plant intended and unwanted plants and has delivery results in significant differences in herbicides applications. Higher spray deposition and spray impacted observed on the top of unwanted than other locations. Also, lower spray deposition and spray impacted of herbicide amount measured on the top of corn plant and soil surface especially with increasing of plant and unwanted density. According to above mentions, it is an important point to orient nozzle spray on the target for improving spray deposition, spray impacted, and volume median diameter. The results also showed higher biological efficacy with Prickly alhagi with no significant differences with al hali weed. On the other hand, a reduction in biological efficacy was appeared in some type of weed types like goose foot.

Acknowledgement

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Current Situation and Perspectives for Soybean Production in Amur Region, Russian Federation

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Abstract

Soybean production was analysed in the Amur Region of the Russian Federation which is considered the national leader in the agricultural sector. The objectives were to clarify issues in current soybean production and explain ways to enhance the efficiency of soybean cultivation. Results indicated that the main problem is low soybean yield because of a lack of financial resources that hinders the development of cultivation technologies and local farmers' capabilities to purchase advanced agricultural machinery. The Region has unpredictable weather conditions and systematic soil waterlogging that causes additional expenses for farmers. It was concluded that the primary improvements included developing a government subsidy program and promoting the application of new technologies.

Keywords: Amur Region, soybean, yield, agriculture machinery

Introduction

The predominance of soybean over other field crops is due to the biochemical composition of the seeds (Tokarev, 1991). Soybean proteins are closest to animal proteins. Therefore, soybean is considered one of the solutions to protein deficiency problems in the world and as the most high-quality and low-cost food for humans. In the 1930s academician N.I. Vavilov proposed a soybean program aimed to overcome protein starvation in the USSR (Resnik, 1968).

After the collapse of the USSR and the decline in agriculture, the need for soybean production has increased again. In 2000, protein deficiency in the nutrition of the Russian population exceeded 1 million tons. A government program was developed and approved, in which soybean was designated as a pivotal crop to solve nutritional problems in the country (Antonova, 2016).

In recent years, Amur Region has promoted soybean production as a basis of industrial development (Rosstat, 2016). To improve soybean production, a compound logistics centre as well as processing complexes and storage facilities are required. It is necessary to maintain a stable system of crop rotation, oriented to the share of grain and fodder crops which contributes to the development of livestock. There is also a need to sow crops in the northern parts of the Region to expand production acreage. Cold climatic conditions are increasingly recognised as a problem in the north and impose severe limitations. This issue is typical throughout Russia and selection of new varieties of soybean suitable for cold conditions is a goal to overcome these restrictions (Far Eastern State Agrarian University 2002).

Soybean yield depends on the suitability of varieties for specific conditions. There is also a need to develop and introduce new technologies, expand and update agricultural machinery and improve competitiveness and personnel qualifications.

Similarly, attention should be paid to issues of resource conservation and the preservation of the structure of sown areas for soil fertility (Antonova, 2016).

This study aimed to clarify the current situation on soybean production in Amur Region, as well as explain ways for solving present issues. Increased soybean production is a significant trend in the agricultural sector of Amur Region. Currently, scientific activities are aimed at improving soybean cultivation technologies. Institutions and educational establishments are trying to solve the problem of low soybean yield and increase the development level of cultivation technologies.

Fig. 1 Study site in the Amur Region, Russian Federation

(a) Amur Region

(b) Soybean planting map

Materials and Methods

Amur Region is a federal subject of Russia, located in the upper and middle Amur River basin, about 8,000 km east of Moscow (**Fig. 1a**). The Amur River provides a natural border with China to the south. The Region borders the Republic of Sakha in the north, Chita Region in the west, and the Jewish Autonomous Region and the Khabarovskii Region in the east (**Fig. 1b**). Amur Region has about 40% of the agricultural land and over 50% of the arable land of the whole Far Eastern Region. Three major soybean growing areas can be determined-northern, central and southern (Antonova, 2016).

The data for this study were taken from statistical government reports of Amur Region and the State Statistical Service of Russia for 2010-2016. The analysis is based on a study of relevant documents: government regulations, government programs related to the agricultural sector and official statistics.

Results and Discussion

The agricultural sector is positioned as a leading sector of the local economy. The sown area of Amur Region was 1.165 million hectares, of which 72% was soybean (Amurstat, 2015). The primary area of soybean planting was concentrated in the south, in the Mikhailovskii and Tambovskii districts where more than 100,000 hectares was sown. The central area accounted 35% of total soybean plants, and the leading production districts were Oktiabrskii and Serishevskii. Only 3.5% of soybean crops were found in the north, concentrated mainly in the Mazanovskii district (**Table 1**).

Most soybean crops (64%) were produced by agricultural corporations, and 36% were produced by private (peasant) farms and individual entrepreneurs. From year to year, this proportion varied slightly.

For several decades, soybean has been the main crop in Amur Region, gradually capturing more acreage. The rapid expansion of soybean acreage excludes other crops from

Table 1 Soybean yield and acreage by areas in Amur Region (Source: Amurstat, 2016)

Area	District	Planting acreage (ha)	Soybean yield (ton/ha)
South	Arkharinsky	32,790	1.30
	Belogorsky	84,133	1.11
	Blagoveschensky	45,640	1.20
	Ivanovsky	82,044	1.16
	Konstantinovsky	81,132	1.24
	Mikhailovsky	109,929	1.24
	Tambovsky	114,968	1.27
Central	Bureysky	21,910	1.36
	Zavitinsky	29,147	1.09
	Oktyabrsky	94,196	1.44
	Romnensky	52,165	1.33
	Svobodnensky	22,065	1.01
	Seryshevsky	83,774	1.21
North	Zeisky	462	0.45
	Magdagachinsky	1,330	1.66
	Mazanovsky	24,765	1.00
	Selemzhinsky	0	0
	Skovorodinsky	525	0.75
	Tyndinsky	0	0
	Shimanovsky	3,925	0.90

Fig. 2 Dynamics and ration of acreage crops in Amur Region (Source: Amurstat, 2016)

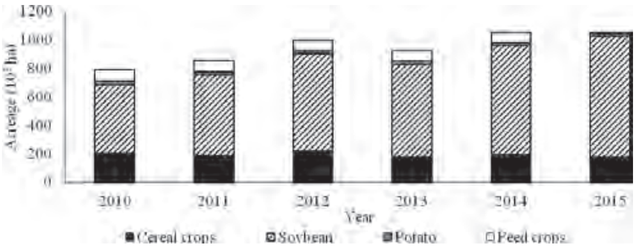
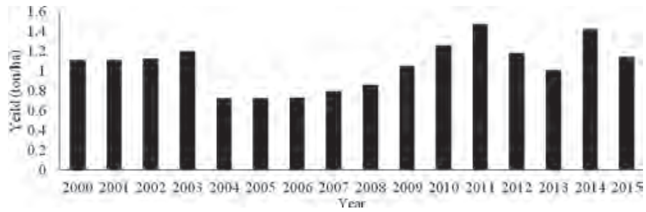


Fig. 3 Dynamics of soybean yield in Amur Region (Source: Amurstat, 2016)



crop rotation. In 2010-2015, the area under grain crops reduced by 1.1 times, potatoes by 1.2 times, and fodder crops by 18 times, while the area under soybean increased by 1.8 times and now occupies 75% of arable land (**Fig. 2**). This expansion leads to crop contamination, disease and damage, detrimental consequences for soil fertility and low crop yields (Amurstat, 2015).

Despite the growth of soybean acreage, soybean yields have remained at similar levels over the last 15 years (**Fig. 3**).

Soybean yield is one of the leading factors affecting production profitability. In general, the average yield of 1.3 tons per hectare is low throughout Amur Region, although in some areas, yields are 1.7 tons per hectare. This is well below the world's leading average soybean production of 2.7-2.9 tons per hectare (Rosstat, 2015). Over the past five years, the acreage of soybean crops has increased in Amur Region (**Fig. 4**), because of higher demand.

Harvests in the north of Amur Region were affected by an unfavourable climate. Currently, the primary task of the Soybean Breeding Institute is to provide a highly productive variety with a stable annual yield, resistant to diseases and unfavourable conditions (Tilba, 2003). In the moderately cold conditions of Amur Region, varieties of the northern ecotype (morphotype) were bred, adapted to local soil and climatic conditions. There are indeterminate and determinate growth types, with narrow medium-sized leaves, slightly branched, faintly responsive to long daylight hours, with 38%-43% seed protein content and 18%-23% oil. Despite the scientific potential for soybean with high yields, the actual yield is often 2-3 times lower than the potential yield (Sinegovskaya, 2014).

The domestic soybean production has increased with the expansion of acreage (**Fig. 5**). Over 15 years, the sown area increased five-fold, although this value is still too low to meet the needs of consumers. Seven Regions accounted for 80% of soybean crop production (**Fig. 5**).

The Far Eastern district is the primary Russian soybean supplier to China (**Fig. 6**). The volume of export increased over the past three years by seven times regarding value and by 5.6 times in quantity. This growth reflects the strengthening of the Russia-China agricultural relationship, as well as the abolition of export customs duties on soybean.

China is the leading importer of soybean crops, and its share has increased from 34% to 63% of world imports (Antonova, 2015). The demand for soybean in China continues to grow. Increased cooperation between Russia and China in agriculture is part of the intensification of the partnership between these two countries. Strengthening of relations was influenced by the signing in 2015 of 35 joint documents that have created an institutional framework for bilateral cooperation in various fields. The Russian market consists of two localised markets: one in the European part (Central and Southern Federal districts) and one in Asia (Far Eastern and Siberian Federal districts). In the future, growing demand for soybean from China will lead to the greater isolation of Far Eastern manufacturers (Antonova, 2015).

Agricultural Machinery

In recent years, machinery updates have lagged both with tractors and combine harvesters, due to the budget constraints of the small farm enterprises that prevail in Amur Re-

Fig. 4 Dynamics of soybean acreage by zones in Amur Region (Source: Amurstat, 2016)

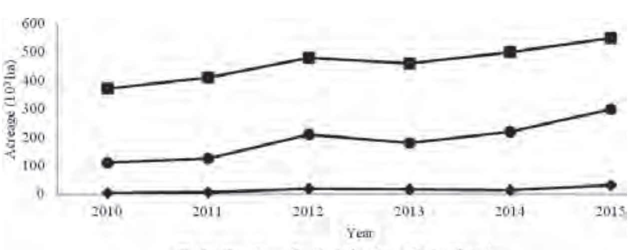
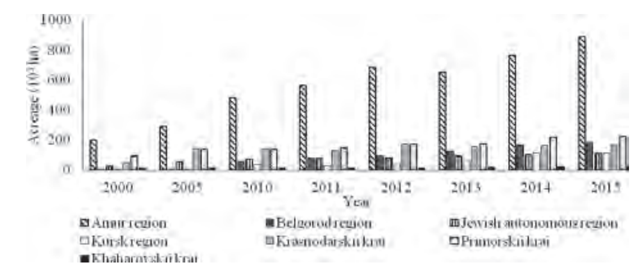


Fig. 5 The acreage under soybean cultivation in the Russian Regions (Source: Ministry of Agriculture in Russia, 2016)



gion. Geographically, tractors were distributed as follows: 2365 units (60.3%) in the south; 1311 units (33.4%) in the central area; and 248 units (6.3%) in the north. Older tractors (over ten years) make up 50% of machines, including 50.1% in the south, 48.4% in the central area, and 57.7% in the north (**Table 2**).

In 2016 the following types of tractors were in use: 40% were MTZ (models with wheels); 20% were crawler tractors DT-75M (66.2 kW) and DT-175 (125 kW); 6% were T-150/150K (120 kW); 12% were K-700/701 (160 kW); 2% were K-744 (220 kW); 2% were “Versatile” and 18% had other modifications. More than 70% of tractors were wheeled because of the absence in the market of models of crawler tractor with high reliability and at a reasonable price.

Combine harvester units were updated more often. In 2016, farmers had 2,356 units of combine harvesters. Of these, 1,376 units (58.4%) were in the south, 856 units (36.3%) in the central area, and 124 units (5.3%) in the north (**Table 3**). On average, 59.7% of the units were less than ten years old.

In recent times, the cost of crawler machines has been higher than wheeled machines. The price of harvesters affected the cost and efficiency of harvesting, as well as overall farm profitability. Due to these circumstances, the John Deere 1075 harvester occupied a leading position in Amur Region, with the experimental version of the combine Yenisei 958R in second place. Third place was occupied by Vector RSM 101. Due to the high cost, more productive combines such as the KZR-10 Palesse, Medion 310 and Mega 204 were not as common. The characteristics of the most common combines are given in **Table 4**.

Most combine harvesters were not adapted to soil conditions in Amur Region. Crops are harvested, as a rule, during months when soils are waterlogged. Due to the climatic features of the Far Eastern Region, over 95% of arable land is subjected to waterlogging. This factor is aggravated by regional soils composed of heavy clay loams, including dominant brown podzolic soil and meadow gley soils in Amur Region (Kashpura, 1964).

Fig. 7 shows that high humidity reduced the coefficient of internal friction and cohesion of soil, decreasing the ability of the soil to resist load shear. Therefore, the resistance to motion coefficient increased. The traction properties of crawler and wheeled machines are determined by the coefficient of adhesion and the coefficient of internal friction of the soil. Crawler treads have higher patency and resistance to slipping than a wheeled chassis due to the larger area of contact with the soil surface and the distribution of the impact on the soil (Emelyanov, 2013).

There is current research aimed at improving the crawler system and eliminating the drawbacks that restrain the further mechanization of harvesting and other technological processes in the plant growth of the Far East. Based on the research experiments of Far Eastern State Agrarian University, we analysed the current crawler chassis found in Amur Region (**Fig. 8**).

The Institute conducted experiments on the combine harvester

Table 2 Tractor numbers and ages in Amur Region (Source: Ministry of Agriculture in Amur Region, 2016)

Area	Total (units)	More than ten years old		Less than ten years old	
		(units)	(%)	(units)	(%)
South	2,365	1,186	50.1	1,179	49.9
Central	1,311	634	48.4	677	51.6
North	248	143	57.7	105	42.3
Total	3,924	1,963	50.0	1,961	50.0

Table 3 Combine harvester numbers and ages in Amur Region (Source: Ministry of Agriculture in Amur Region, 2016)

Area	Total (units)	More than ten years old		Less than ten years old	
		(units)	(%)	(units)	(%)
South	1,376	522	37.9	854	62.1
Central	856	373	43.6	483	56.4
North	124	54	43.5	70	56.5
Total	2,356	949	40.3	1,407	59.7

Fig. 6 Dynamics of soybean exports from the Far Eastern Regions of Russia to China (Source: Federal Customs Service of Russia, Customs Statistics of Foreign Trade, 2016)

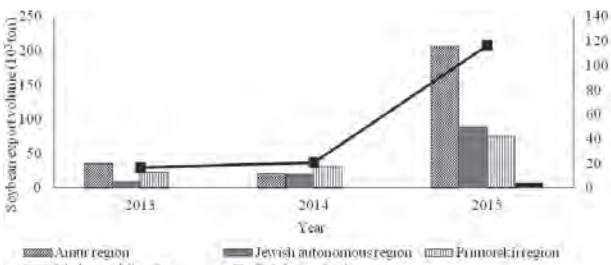


Fig. 7 Dependence of angle of internal friction and soil cohesion on humidity and structural condition (Source: Far East State Agrarian University, 2013)

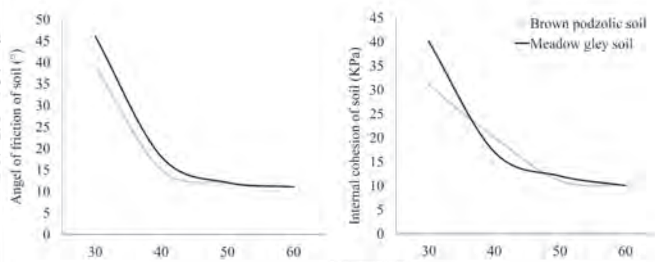


Table 4 Typical combine harvesters used in Amur Region (Source: Ministry of Agriculture in Amur Region, 2017)

Specifications	Models of combine harvester						
	Yenisei 1200 RM	John Deere 1075	Yenisei 958R	Vector RSM 101	KZR-10 Palesse	Medion 310	Mega 204
Price (USD)	31,000	37,000	41,500	42,000	74,230	100,000	115,000
Cutting width (m)	7	6	7	8.6	6	7.5	7.5
Power (kW)	110	110	135	155	195	150	150
Efficiency (ha/h)	1.52	2.44	1.92	2.82	2.75	2.85	3.1
Suspension type	crawler	crawler/ wheeled	crawler	wheeled	wheeled	wheeled	wheeled

Yenisei-1200R with two metal crawler chassis (KSP-01, KSP-80) and two reinforced rubber crawler chassis (TGR-3, TGR-4). The advantages of the TGR-4 reinforced rubber crawler chassis include an increase in physical and ecological patency on soils with low load bearing capacity and a reduction of the maximum pressure and compacting effect on the soil.

In waterlogged soil conditions, preference should be given to using reinforced rubber crawler chassis. Wheeled combines and transport have difficulty in moving around fields and performing technological processes when there is excessive soil moisture. The combine harvester Yenisei-1200 on the crawler chassis is recommended for use harvesting soybean in the Far East, as shown by research from the leading Institute of Amur Region.

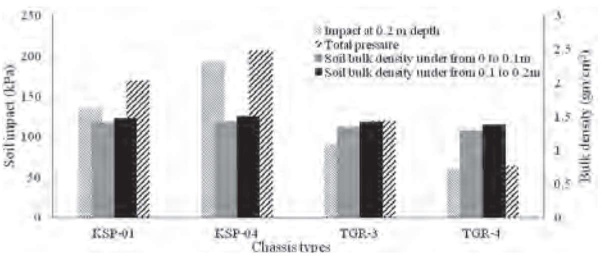
A general deterioration in economic conditions and uncertainty in the marketplace coupled with increased interest rates, unstable exchange rates, and political challenges limit sector development. The government is attempting to stimulate investment in capital purchases by offering various subsidies for strategically essential subsectors.

Government Program on Agriculture

The government has developed a program to help the progress and to solve problems which are hindering increases in soybean production. The focus has been on subsidising rural farms and improving agriculture development of Amur Region and economic relations with foreign countries.

The government program, approved in 2013, has stimulated Russian production of agricultural equipment by offering subsidies to local equipment producers. The program provides for the comprehensive development of all sectors and sub-sectors, as well as fields of activity for agro-industrial complexes. Agriculture production is the leading sector of the economy in Amur Region, underpinning the agro-food market, food and economic security, employment and settlement potential of rural areas. The government program defines the objectives, tasks and development directions for agriculture and food processing industry. Financial support and implementation mechanisms, as well as indicators of their effectiveness, in Amur Region, are provided by state programs (Antonova, 2016). In 2015 the Russian Federation Ministry of Agriculture allocated US$7 million to the regional budget. This action allows farmers to increase total machinery units and expand their farmlands. Government assistance with subsidies has improved the agricultural machinery situation, thereby giving a boost to agriculture production. The absolute value of soybean production reached US$680 million in 2016. With an increase in incoming funds, farmers will be able to spend additional revenue on improving farms.

Fig. 8 Tests of impact on the soil of the combine harvester Yenisei-1200R with metal crawlers and reinforced rubber crawler chassis (Source: Far East State Agrarian University, 2013)



Conclusions

In this paper, soybean production was considered in the major Russian agricultural area, Amur Region. Over the last 15 years, increases in the intensity and efficiency of the grain industry were achieved by profound qualitative and quantitative changes in soybean production of Amur Region. More in-depth government assistance and intervention in agriculture is required to increase production further. Government subsidies allowed a growing number of machines on small farms which enabled farmers to cultivate additional land. Therefore, increases in production came from expanding sown areas instead of improving quality and yield.

However, farmers are faced with variable natural conditions like as drought or high precipitation which leads to excessive soil moisture every year. Therefore, Amur Region is an area where farming is risky. Local researchers are developing appropriate machine technologies for Amur Region conditions. Soil waterlogging is one of the reasons for low yield. Wheeled machines are not suitable for working on most lands in the fall season which leads to late harvesting and crop loss.

This paper showed that to increase economic efficiency production and processing of soybean a comprehensive approach is needed. It is not sufficient to expand arable lands using more machine units or to follow farming methods from the former USSR, which in the case of treatment and cultivation systems, have not significantly changed. New technologies are needed for the development of agriculture in Amur Region. It is essential to raise level and quality of soybean production to meet the growing demand from foreign consumers. Problems can be solved by introducing a new soybean cultivation technology based on an economically justified crop rotation system and by modifying farm machinery, given aspects of soil and climate conditions. Current solutions to deal with waterlogged soil are to provide farmers with crawler machines with high patency and to alter their machines with newly developed technologies. Moreover, it is necessary apply precision farming which helps to monitor and analyse farmlands more clearly and precisely.

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■■

Development and Evaluation of Rasp Bar Mechanism for the Extraction of Onion (*Allium Cepa* L.) Seeds

by

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Abstract

For the sustainable production of onions quality planting materials are required. The conventional method of onion seeds extraction process such as threshing and cleaning affect the germination of onion seeds and pose problems to the farmers. To overcome these problems, an onion seed extractor was designed based on rasp bar mechanism. The objective of the present study was to find the optimum machine parameters for the efficient threshing of onion umbels and to extract the onion seeds. An onion umbel thresher was field tested and machine parameters optimized were a feed rate of 35 ±1 kg/h, two number of rasp bars on the threshing cylinder, peripheral speed of 2.5 m/s, concave clearance of 7.5 mm and cleaning air velocity of 2.4 m/s, which recorded 73.64% cleaning efficiency, 8.23% seed loss and 82% seed germination.

Introduction

Onion (*Allium cepa* L.) is an important cool season vegetable crop. It is highly export-oriented crop and earns more foreign exchange. Though, India produces a significant quantity of onions, production is irregular, and is not sufficient enough to meet the demands of both the domestic consumption and export requirements. In general, onion is propagated through bulbs however, propagation and cultivation of onion through seeds is preferred for many reasons such as higher yield, larger and uniform sized bulbs and less chance of occurrence of diseases. The onions bulbs produced using the seeds are highly suitable for the export purpose. Onion seed production is widely adapted to temperate and subtropical regions. There are two methods of seed production. Seed to seed and bulb to seed methods are in practice for onion seed production. Quality and yield of onion seed could be increased by use of large size bulbs with wide spacing (Asaduzzaman et al., 2015). According to onion seed traders, more than 30% increase was observed in the adoption of hybrid onion CO (On) 5 (Pandiselvam et al., 2014).

The onion seed producing farmers face many practical difficulties during the extraction of onion seeds. The matured umbels are identified based on the seeds inside the capsules when it becomes black and 20 to 25% seeds are exposed to outside and are harvested along with the 3 - 5 cm of stem attached. The harvested umbels are spread on the cement floor to avoid the attack of mold and for uniform drying. This method not only prevents loss of seed but also avoids the admixture of seeds and small stones and/ or soil particles. The dried umbels are threshed by beating with sticks and trampled under tractor tyres and cleaning is done by manual sieving of threshed material and dipping in the water. The conventional method of onion seed production is shown in **Fig. 1**.

The manual operation is labour intensive, tedious, hazardous to health, time-consuming and requires 6-8 days for completing the process (Pragalyaashree and Kailappan, 2014). The onion seeds are subjected to external force leading to damage of the seeds causing whitening of the seed coat. Cracked seed coat hastens fungal infection which can lead to seed deterioration finally causing low seed germination and vigor index. Hence, the post-harvest operations are imperative to maintain the quality and minimize the seed losses (Rajesh et al., 2016; Preetha et al., 2016; Pandiselvam et al., 2015).

The objective of the present study was to find the optimum machine parameters [four different numbers of rasp bars (2, 3, 4 and 8 numbers), three different feed rates (25 ±1, 30 ±1 and 35 ±1 kg/h), two levels of peripheral speeds (2.5 and 3.3 m/s), two levels of concave clearances (6.5 and 7.5 mm) and four levels of cleaning air velocities (1.9, 2.2, 2.4 and 2.8 m/s)] for efficient extraction of onion seeds from the umbels.

Materials and Methods

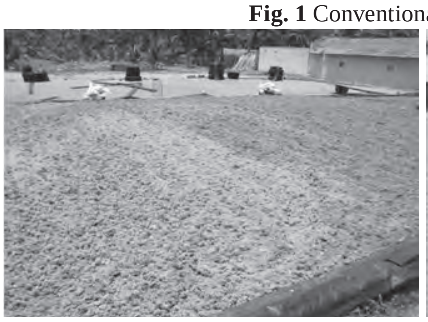
Raw Material

The umbels (CO (On) 5) were obtained from the experimental farm of J.Krishnapuram, Coimbatore district, Tamil Nadu. The experiments were carried out at fixed moisture content of onion umbels (10.86% d.b).

Preliminary Studies on Threshing of Umbels

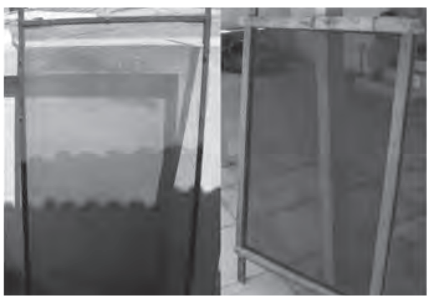
The preliminary studies were carried out to select the suitable threshing cylinder type and concave size. Among the five different types of threshing cylinders used for threshing of agricultural crops, hammer mill type and angle bar cylinder type were not considered due to the high impact forces developed during threshing and delicate and soft nature of the umbels. The wire loop, peg tooth, and rasp bar cylinders were considered for testing and found that the rasp bar type threshing mechanism gave encouraging results in terms of less seed damage and higher cleaning efficiencies as compare to peg tooth type and wire loop threshing cylinder.

Fig. 1 Conventional method of onion


(a) Sun drying of matured umbels


(b) Turning of umbels for uniform drying


(c) Conventional method of threshing by treading with tractor


(d) Local gadgets used for cleaning


(e) Cleaning of threshed onion umbels by hand sieving


(f) Cleaning of onion seed by water dipping


(g) Sun drying of onion seed after cleaning by water dipping

(h) Packaged onion seed

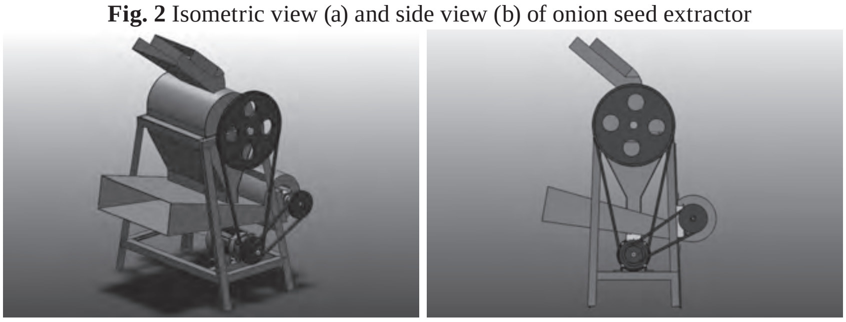
Fabrication of Rasp Bar Type Thresher

The onion seed extractor was designed to work on the principle of abrasive and impact actions from rasp bar. A lab model thresher developed with eight numbers of helically shaped rasp bars with different components namely, feeding chute, threshing drum, circular concave, blower, trash outlet, seed outlet, mainframe and power transmission system with the prime mover (**Fig. 2**).

This machine was designed and developed at Tamil Nadu Agricultural University, Coimbatore, India, for extraction of onion seeds. The dimensions of the rectangular frame were 450 × 330 × 750 mm. The frame of the machine was made of 40 × 40 × 6.3 mm MS angle. The threshing drum was rasp bar type, 300 mm long and 150 mm diameter. Eight teak wood strips, 38 mm wide and 305 mm long, were arranged in the opposite position on the threshing drum surface, which provided soft impact and abrasive action to make the umbels into the flowers and release the seed from flowers. The threshing drum was made such that 2, 4, 6 and 8 numbers of rasp bars can be attached on the threshing cylinder and tests can be conducted for performance evaluation of thresher.

The shaft of the drum was made of a round bar of 32 mm diameter and 660 mm long. The feeding chute of trapezoidal shape was fabricated from 20 gauge mild steel sheet. The concave of the threshing chamber (bottom portion) was made with mild steel sheet having 3 mm holes and 6 mm clearance from center to center. A clearance of 6.5 mm was maintained between the concave and the tip of the rasp bar. By placing

Fig. 2 Isometric view (a) and side view (b) of onion seed extractor



(a) (b)

Table 1 Effects of numbers of rasp bars, feed rates, concave clearances and cleaning air velocities on cleaning efficiency at 2.5 m/s peripheral speed of threshing cylinder

No.*	Feed rate (kg/h)	Concave clearance (mm)	Cleaning efficiency (%) Cleaning air velocity (m/s) 1.9	2.2	2.4	2.8
2	25	6.5	58.78	61.42	76.88	79.63
2	25	7.5	58.46	60.23	74.76	79.18
2	30	6.5	57.22	59.35	75.64	77.53
2	30	7.5	56.16	58.24	74.16	76.98
2	35	6.5	52.63	59.12	73.89	74.87
2	35	7.5	52.32	58.13	73.64	74.56
3	25	6.5	58.92	62.58	78.45	79.89
3	25	7.5	58.23	62.51	76.24	78.86
3	30	6.5	57.39	62.38	77.13	77.79
3	30	7.5	56.27	61.87	76.05	77.43
3	35	6.5	55.35	60.54	75.64	76.89
3	35	7.5	55.16	59.86	75.38	75.99
4	25	6.5	60.15	64.76	77.93	80.16
4	25	7.5	58.69	63.26	76.55	79.82
4	30	6.5	60.12	62.53	77.31	79.94
4	30	7.5	59.93	61.89	76.98	78.96
4	35	6.5	59.76	61.52	76.87	78.57
4	35	7.5	58.11	60.97	75.36	78.35
8	25	6.5	62.93	66.78	79.85	82.94
8	25	7.5	62.18	66.32	79.32	82.56
8	30	6.5	61.12	65.34	78.47	81.59
8	30	7.5	61.18	64.78	77.68	81.05
8	35	6.5	60.49	65.23	78.22	80.35
8	35	7.5	60.38	63.97	76.93	79.86

* Numbers of rasp bars on threshing cylinder

Table 2 Effects of numbers of rasp bars, feed rates, concave clearances and cleaning air velocities on cleaning efficiency at 3.3 m/s peripheral speed of threshing cylinder

No.*	Feed rate (kg/h)	Concave clearance (mm)	Cleaning efficiency (%) Cleaning air velocity (m/s) 1.9	2.2	2.4	2.8
2	25	6.5	59.87	62.38	77.84	80.43
2	25	7.5	59.62	61.53	76.14	80.18
2	30	6.5	58.43	60.35	75.96	78.64
2	30	7.5	57.29	59.74	75.21	77.59
2	35	6.5	54.36	59.42	74.92	76.82
2	35	7.5	53.82	58.92	74.23	76.18
3	25	6.5	60.98	63.58	79.65	81.74
3	25	7.5	62.31	63.36	78.84	79.91
3	30	6.5	60.57	62.38	78.53	78.59
3	30	7.5	58.49	62.08	77.78	78.13
3	35	6.5	57.45	61.76	76.94	77.69
3	35	7.5	56.59	60.94	76.58	76.99
4	25	6.5	63.25	65.91	80.03	82.26
4	25	7.5	62.49	64.58	79.65	81.79
4	30	6.5	61.12	63.28	78.58	81.14
4	30	7.5	59.98	62.78	77.98	80.67
4	35	6.5	59.86	61.13	76.87	79.89
4	35	7.5	58.35	60.99	76.46	79.32
8	25	6.5	63.84	68.82	81.11	83.96
8	25	7.5	63.28	67.43	80.32	83.56
8	30	6.5	62.12	66.31	79.98	82.62
8	30	7.5	61.83	66.01	78.85	81.73
8	35	6.5	60.96	65.83	78.56	81.28
8	35	7.5	60.58	64.26	77.54	80.51

* Numbers of rasp bars on threshing cylinder

the iron slices between the rasp bar and threshing drum, the clearance was changed by 6.5 and 7.5 mm and experiments were conducted.

A radial flow centrifugal type blower with four fan blades (304.8 × 50.8 mm) mounted on a 32 mm diameter shaft and supported by pillow block bearings was fabricated from 18 gauge MS sheet. An airflow control device was made from 18 gauge thick MS sheet. The seed outlet chute was 680 mm in length, 115 mm in width and 200 mm in depth was made up of 18 gauge MS sheet and fixed below the blower unit at an inclination of 38° for easy flow of cleaned seed.

A 2 hp single phase AC motor operating at 1,440 rpm was used to drive threshing cylinder and blower using V-belts through pulleys arrangement (**Fig. 3**). The motor was mounted on the base of mainframe. A driven pulley of 365 mm diameter was mounted on the threshing cylinder shaft. The threshing cylinder and blower were connected by a V-belt and operated at 870, 980, 1,050, and 1,320 rpm to get the desired air velocities of 1.9, 2.2, 2.4 and 2.8 m/s from the blower. The engineering diagram of onion seed extractor is shown in **Fig. 3**.

Evaluation of Thresher Performance

Experiments were conducted with rasp bar type thresher by changing the feed rates (25 ±1, 30 ±1 and 35 ±1 kg/h), numbers of rasp bars on the threshing cylinder (2, 3, 4 and 8 numbers), peripheral speeds (2.5 and 3.3 m/s), concave clearances (6.5 and 7.5 mm) and cleaning air velocities (1.9, 2.2, 2.4 and 2.8 m/s).

Fig. 3 Engineering diagram of onion

As the machine attains the selected speed, the umbels were fed into the feed hopper and operated at desired air flow rate. The thresher was operated continuously and at one point of time, trays were inserted simultaneously at all outlets and the materials were collected exactly for five min. The materials were analyzed

Table 3 Effects of feed rates, numbers of rasp bars, concave clearances and cleaning air velocities on seed loss at 2.5 m/s peripheral speed

No.*	Feed rate (kg/h)	Concave clearance (mm)	Cleaning efficiency (%)			
			Cleaning air velocity (m/s)			
			1.9	2.2	2.4	2.8
2	25	6.5	2.67	3.88	6.64	13.92
2	25	7.5	2.32	3.72	6.52	13.46
2	30	6.5	3.48	4.57	7.85	14.23
2	30	7.5	3.29	4.42	7.23	13.98
2	35	6.5	3.73	5.86	8.74	15.76
2	35	7.5	3.54	5.23	8.23	14.63
3	25	6.5	2.83	3.92	7.24	14.24
3	25	7.5	2.79	3.63	6.62	13.87
3	30	6.5	3.86	4.84	7.89	14.66
3	30	7.5	3.68	4.52	7.67	14.28
3	35	6.5	3.98	5.79	9.24	16.42
3	35	7.5	3.92	5.62	8.62	15.33
4	25	6.5	2.98	4.16	7.83	14.64
4	25	7.5	2.81	3.97	7.14	13.93
4	30	6.5	3.97	5.32	8.21	14.82
4	30	7.5	3.76	4.78	7.94	14.69
4	35	6.5	4.18	5.94	9.98	16.58
4	35	7.5	4.12	5.65	9.36	16.37
8	25	6.5	3.59	4.87	7.88	15.88
8	25	7.5	2.99	4.29	7.72	14.38
8	30	6.5	4.64	5.34	9.34	16.72
8	30	7.5	3.95	4.89	8.36	16.26
8	35	6.5	4.87	6.96	10.79	18.94
8	35	7.5	4.16	5.78	9.67	16.89

* Numbers of rasp bars on threshing cylinder

Table 4 Effects of feed rates, numbers of rasp bars, concave clearances and cleaning air velocities on seed loss at 3.3 m/s peripheral speed

No.*	Feed rate (kg/h)	Concave clearance (mm)	Cleaning efficiency (%)			
			Cleaning air velocity (m/s)			
			1.9	2.2	2.4	2.8
2	25	6.5	2.78	4.62	7.14	15.56
2	25	7.5	2.51	4.15	6.83	14.92
2	30	6.5	3.96	4.97	7.93	14.53
2	30	7.5	3.72	4.65	7.48	14.18
2	35	6.5	4.26	5.99	8.99	16.87
2	35	7.5	3.94	5.82	8.54	15.74
3	25	6.5	3.12	4.96	7.84	15.24
3	25	7.5	2.87	4.57	7.21	14.96
3	30	6.5	3.97	5.14	8.19	14.79
3	30	7.5	3.72	4.85	7.86	14.48
3	35	6.5	4.38	5.98	9.84	17.65
3	35	7.5	4.16	5.74	9.23	16.33
4	25	6.5	3.18	4.86	8.17	15.76
4	25	7.5	2.95	4.11	7.87	15.46
4	30	6.5	4.19	5.74	8.89	15.12
4	30	7.5	3.87	5.06	8.36	14.83
4	35	6.5	4.59	5.98	9.98	17.84
4	35	7.5	4.23	5.86	9.69	17.32
8	25	6.5	3.87	4.94	8.28	16.58
8	25	7.5	3.28	4.63	7.95	15.83
8	30	6.5	4.89	5.92	9.98	17.94
8	30	7.5	4.26	5.39	9.02	17.34
8	35	6.5	5.27	7.58	11.12	19.83
8	35	7.5	5.04	6.71	10.43	17.54

* Numbers of rasp bars on threshing cylinder

and data recorded. The tests were replicated three times and the average values were recorded.

The seed extractor performance in terms of cleaning efficiency and seed loss were calculated using the following equation.

Cleaning efficiency (%) = [H / (H + B)] × 100 [1]

Seed loss (%) = [C / (H + C)] × 100 [2]

Where,

B - weight of trash collected at the seed outlet, g

C -weight of seed collected from the trash outlet as seed and seed in flowers, g

H - weight of seed collected at seed outlet, g

Germination Test

Germination test was conducted according to International Seed Testing Association (ISTA, 1999). Three replicates of 75 seeds were placed between two layers of pre-wet germination papers in germinator and the temperature and relative humidity was maintained at 20 °C and 95%, respectively, for 12 days. The germination (%) was expressed on the basis of normal seedlings (Agarwal, 2008).

Germination n, % = [N_g / N_T] × 100

Where,

N_g = Number of germinated seeds,

N_T = Total number of seeds planted

Statistical Analysis

The performance of the thresher was analyzed using a factorial RBD experimental design with three replications in each treatment using Agres software (ver. 7.01, Pascal International Software Solution, Boston, USA). Comparison between treatment means was done by LSD at five ($P \leq 0.05$) and one ($P \leq 0.01$) per cent significance level.

Table 5 Effects of peripheral speeds, numbers of rasp bars on threshing cylinder, feed rates and concave clearances on germination of onion seed

Numbers of rasp bars on threshing cylinder	Feed rate (kg/h)	Concave clearance (mm)	Cleaning efficiency (%)	
			Cleaning air velocity (m/s)	
			2.5	3.3
2	25	6.5	92	88
2	25	7.5	94	90
2	30	6.5	94	90
2	30	7.5	96	92
2	35	6.5	98	94
2	35	7.5	100	98
3	25	6.5	86	84
3	25	7.5	88	86
3	30	6.5	90	86
3	30	7.5	92	90
3	35	6.5	94	92
3	35	7.5	96	94
4	25	6.5	84	82
4	25	7.5	88	84
4	30	6.5	88	84
4	30	7.5	90	86
4	35	6.5	92	86
4	35	7.5	94	88
8	25	6.5	82	80
8	25	7.5	86	82
8	30	6.5	86	84
8	30	7.5	88	84
8	35	6.5	90	86
8	35	7.5	92	88

Results and Discussion

Effects of feed rates, numbers of rasp bars on threshing cylinder, peripheral speeds concave clearances and cleaning air velocities on cleaning efficiency

The effect of feed rates, numbers of rasp bars, peripheral speeds, concave clearances and cleaning air velocities on the cleaning efficiency of onion seed extractor is shown in **Tables 1** and **2**. The maximum cleaning efficiency of 83.96% was obtained at the peripheral speed of 3.3 m/s, eight numbers of rasp bars, concave clearance of 6.5 mm, feed rate of 25 ±1 kg/h and cleaning air velocity of 2.8 m/s (**Table 2**), whereas a minimum cleaning efficiency of 52.32% was obtained at the peripheral speed of 2.5 m/s, two numbers of rasp bars, concave clearance of 7.5 mm, feed rate of 35 ±1 kg/h and cleaning air velocity of 1.9 m/s (**Table 1**). The cleaning efficiency increased with increase in peripheral speed from 2.5 m/s to 3.3 m/s and increase in numbers of rasp bars from two to eight on the threshing cylinder. An increase in peripheral speed or numbers of rasp bars increased the impacts and rubbing action on onion umbels per unit rotation. Thereby, the opportunity for all the onion umbels to undergo threshing effects at a low feed rate and a number of fine particles production (florets and umbels parts) are higher, which is blown at low air velocity leads to increase in cleaning efficiency. These findings are in line with Pandey and Stevens (2016), Munusamy et al. (2015) and Sinha et al. (2009) and for gram, onion umbels and chickpea thresher, respectively.

The important observation made from the **Tables 1** and **2** is irrespective of cleaning air velocities, feed rates, numbers of rasp bars, clearances and peripheral speeds studied, all the combinations recorded a cleaning efficiency between 52.32 and 83.96%, only. The broken flower parts has the same terminal velocity of onion seed, which posed difficulties to separate broken flower parts from onion seed and made cleaning inefficient.

The data were analyzed statistically and reported in **Table 6**. From the ANOVA table, it is observed that numbers of rasp bar, feed rate, and cleaning air velocity were significant at one per cent level ($P \leq 0.01$) and concave clearance was significant only at five per cent ($P \leq 0.05$) level. Two factors interactions (rasp bar × cleaning air velocity, feed rate × clearance and feed rate × cleaning air velocity), three factors interactions (cleaning air velocity × clearance × rasp bar, feed rate × clearance × cleaning air velocity and feed rate × rasp bar × cleaning air velocity) and four factors interaction (rasp bar × feed rate × clearance × cleaning air velocity) were significant at one percent ($P \leq 0.01$) level. Two-factor interactions like concave clearance × cleaning air velocity and three factors interaction feed rate × clearance × rasp bar were significant at five percent ($P \leq 0.05$) level.

Effects of Numbers of Rasp Bars on Threshing Cylinder, Feed Rates, Peripheral Speeds and Concave Clearances on Seed Loss

The effects of numbers of rasp bars, peripheral speeds, feed rates, concave clearances and cleaning air velocities on seed loss are shown in **Tables 3** and **4**. From the Tables, it is observed that the seed loss was more at the higher peripheral speed of 3.3 m/s, as compared to 2.5 m/s at all clearance studied. This may be observed due to the rate of high energy transfer from rasp bar to onion umbels in the threshing chamber causing more shearing and impact force on the umbels between rasp bar and concave. Hence, the quantity of broken seed increased at higher peripheral speed, which leads to more seed loss at lower cleaning air velocity. Similar results were found during threshing of gram (Pandey and Stevens, 2016), chickpea seed crop (Sinha et al., 2009), cassava (Kailappan et al., 2005) and sunflower (Sudajan et al., 2005).

Higher clearance of 7.5 mm recorded minimum seed loss of 2.32% at 25 ±1 kg/h feed rate, 2.5 m/s peripheral speed and 1.9 m/s cleaning air velocity (**Table 3**) and maximum seed loss of 17.54% at 35 ±1 kg/h feed rate, 3.3 m/s peripheral speed and 2.8 m/s cleaning air velocity (**Table 4**). In the case of 2.32% seed loss, the majority of the seed collected from the blower outlet were broken seed only. The feed rate of 35 ±1 kg/h, peripheral speed of 3.3 m/s, eight numbers of rasp bars and concave clearance of 6.5 mm recorded the maximum seed loss of 19.83% (**Table 4**). The rise in seed loss at higher feed rates observed may be due to more material passed through the cleaning zone had low retention time for effective separation, which leads to an outflow of some threshed seed with flower parts through blower outlet.

From the ANOVA data (**Table 6**), it is observed that the single factors and their interactions were significant at one percent ($P \leq 0.01$) level except rasp bar × cleaning air velocity × feed rate and rasp bar × feed rate × clearance × cleaning air velocity were significant at five percent ($P \leq 0.05$) level.

Effects of Feed Rates, Numbers of Rasp Bars, Peripherals Speeds and Concave Clearances on Seed Germination

The effects of numbers of rasp bars on the threshing cylinder, peripheral speeds, feed rates and concave clearances on seed germination is shown in **Table 5**. The feed rate of 25 ±1 kg/h, concave clearance of 6.5 mm, peripheral speed of 2.5 m/s with two numbers of rasp bars recorded 92% seed germination and eight numbers of rasp bars recorded 82% seed germination. For the same experiment (25 ±1 kg/h feed rate, 2.5 m/s peripheral speed) increase in concave clearance from 6.5 to 7.5 mm, the seed germination increased to 94% for two numbers of rasp bars and 86% for eight numbers of rasp bars. The decrease in germination percent-

Table 6 Analysis of variance for the effects of different combinations of cleaning air velocities, numbers of rasp bars, feed rates and concave clearances on seed loss during threshing of onion umbels

Source	df	Cleaning efficiency	Seed loss	Germination
		F	F	F
Experiment	95	420.9263**	19,701.2264**	271.4681**
Air velocity (V)	3	1,667.7518**	60,090.7716**	468.3930**
Rasp bar (R)	3	159.6164**	1,966.0755**	613.0105**
Feed rate (F)	2	43.3136**	24,780.1555**	163.6632**
Clearance (C)	1	33.2584*	7,038.4086**	166.3750**
V × C	3	32.6574*	45.4143**	3.5509**
F × V	6	318.4449**	446.6996**	18.6250**
R × F	6	6.3812 NS	93.4156**	1.3750 NS
F × C	2	363.0102**	147.9010**	1.3750 NS
R × C	3	9.3218 NS	32.6009**	23.4632**
R × V	9	58.5798**	83.9218**	19.6667**
R × F × C	6	30.0774*	30.2899**	8.7158 **
F × C × V	6	303.9171**	92.2623**	18.6250**
R × C × V	9	156.0410**	37.6507**	9.0000**
V × R × F	18	105.2780**	25.3858*	15.6667**
V × F × C × R	18	315.9846**	27.9467*	9.0000**
TOTAL	191	206.4959	9,799.0398	89.8951

** Significant at $P \leq 0.05$, * Significant at $P \leq 0.01$, NS-Non significant age with increasing numbers of rasp bars may be due to the fact that as the numbers of rasp bars increased, the number of seed in contact with rasp bars increased per unit rotation and unit time. Therefore, more impact and rubbing action of rasp bars on seed coat resulting in cracked seed coat and internal injury to the seed, which decrease the germination percentage. The seed coat has a critical role in the longevity of seed (Mohamed-Yasseen et al., 1994).

The two numbers of rasp bars, concave clearance of 7.5 mm, peripheral speed of 2.5 m/s and feed rate of 35 ±1 kg/h recorded the maximum germination of 100% (**Table 5**). This may be due to reduced impact and rubbing forces directly on seed under higher clearance (7.5 mm). Similar results were observed and reported in threshing of sun flower (Sudajan et al., 2002) and chickpea seed (Sinha et al., 2009).

The data collected on the effects of machine parameters on percentage germination of onion seed were analyzed statistically and reported in **Table 6**. From the table, it is observed that the single factors, two factors interactions (rasp bar × peripheral speed, feed rate × clearance, rasp bar × feed rate and rasp bar × clearance), three factors interactions (rasp bar × feed rate × clearance, feed rate × clearance × peripheral speed, rasp bar × clearance × peripheral speed and peripheral speed × rasp bar × feed rate) and four factors interaction (rasp bar × clearance × peripheral speed × feed rate) were significant at one per cent ($P \leq 0.01$) level.

Conclusions

The optimum peripheral speed for extraction of onion seed was found to be 2.5 m/s at feed rate of 35 ±1 kg/h. Among the two concave clearances studied, 7.5 mm clearance recorded the highest seed germination of 100% with two numbers of rasp bars, 2.5 m/s peripheral speed at 35 ±1 kg/h feed rate. Thus, this study summarized that rasp bar type threshing mechanism was more efficient than conventional methods used for extraction of onion seeds. In addition, further study related to introduce a new peg tooth type pre thresher to separate all the florets and a suitable concentric rotating type self cleaning cylindrical sieves to separate the over size and under size impurities from onion seed to improve cleaning efficiency should be conducted.

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Design and Development of Low Cost Multi-Row Manual Jute Seed Drill

by

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Abstract

A new jute sowing machine has been developed with special design technique. It meets all the requirements for jute seeding with metering and adjustable distances between seeds and rows. It uses horizontal axis rotating conic section seed box-cum-seed dispenser with seeds always in motion. The chance of blockages of seeds dispensing holes is almost nil. The special design of the seed-dispenser makes the machine very light weight, low cost and very simple to operate at very low operating cost. The machine has been tested in the fields and found fully satisfactory. It requires only one man or woman to operate and use it without any mechanical power or fuel cost. It continues to drop the seeds till almost all the seeds in box are used. The seed rate of the seed drill was 2.50-2.75 kg/ha in farmers' fields which is lower than recommended in traditional practice of 6-7 kg/ha. The average number of seeds dropped per square meter area was 124. The average effective field capacity, average field efficiency and average draft requirement of the seed drill was found as 0.17 ha/h, 88.74% and 75.16 N respectively.

Introduction

It may be worthwhile to mention that Asia Pacific region which is mainly responsible for growing exportable jute uses mostly the traditional cultivation technologies. It is a fact that jute when grown in line yield more and their cultivation cost reduce drastically if improved mechanical methods are used for intercultural operations as with other crops. In spite of this row sowing of this crop did not get momentum due to non availability of proper seeding implements commensurate to the economic and social status of the farmers of the area.

Jute is mainly grown as cash crop in eastern and north-eastern states. West Bengal contributes the maximum area to the tune of 73% of the country's total jute area and about 82% of the country's jute production. The total area under jute cultivation in India is about 0.8 million hectare (Shambhu, 2014). Jute is mainly grown by small and marginal farmers with scanty resources (Shambhu and Nayak, 2014). Traditionally jute is sown by broadcasting by the farmers but the research institutes has established that line sowing instead of broadcasting increases yield by 10-20%, it simultaneously save seed by about 50 %, reduces labour requirement, by more than half in weeding and thinning and also facilitates others post sowing operations such as fertilizer applications, plant protection measures, irrigation, inter row cropping and harvesting (Anonymous, 1991; CRIJAF 1991-92, Shambhu et al., 2013). Sowing by hand dispersion (Broadcast) leads to irregularity in plant growth, besides problems in weed control which in turn leads to heterogeneity in the size of the fibre. The sowing density depends on the type, varies from 8 to 15 kg/ha (Maiti, 1997). Sowing in furrow is recommended to ensure greater efficiency in the intercultural practice and reduce cost of cultivation. (Maiti, 1997). A seeder of good performance can reduce jute seed requirement by about 50% and increase fibre yield by about 15% (Alam, 1990). Jute grown in rows paves the way for using weeding equipment which makes air available at root zone. Generally 75-80% of the emergent seedlings are removed at thinning in traditionally sown jute (Shambhu et al., 2013). Labour requirement for weeding and thinning of broadcast planted jute amounts to 1400 man-hours per hectare (about 41%) of total man labour required for producing the crop (Dempsey, 1975). The single heaviest item of expenditure in growing jute broadcast is weeding and thinning, which is done entirely by hand labour and absorbs about half of the total cost of production per acre. Jute is being a labour intensive crop, and with steadily increasing labour wages the cost of cultivation is increasing (Annual report CRIJAF - 1951-52, 1991-92).

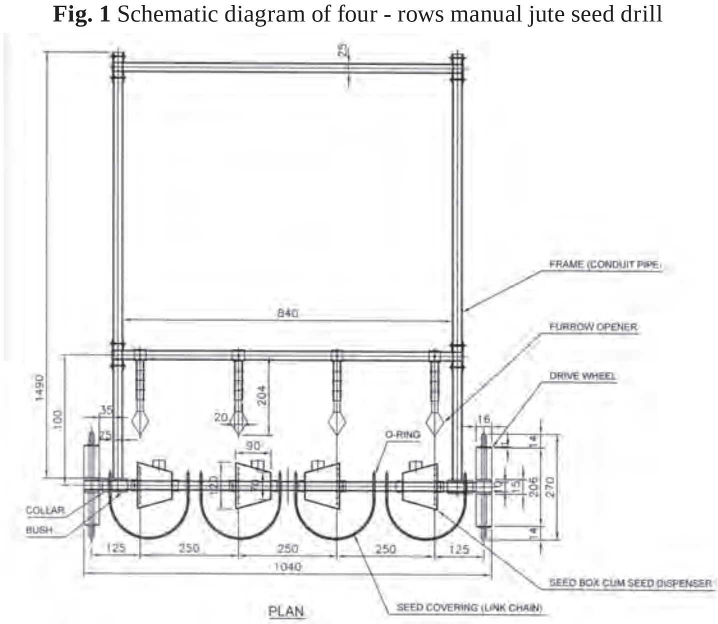
Agriculture mechanization has been recognized as an integral part of agricultural development for improving productivity. Agricultural development involves the availability and use of implements and power units by farmers either as individually owned or available on hire basis. The economic progress of a nation directly depends upon availability of power and its fruitful utilization. In West Bengal about 95% of land owners fall in the category of marginal and small holdings (Shambhu, 2007). Such farmers neither can afford to purchase tractor nor can they afford its economic use, individually at their farms. Tractor is not suitable for small and scattered land holding because it gives low field efficiency. It is need of introducing improved implements on small size land holding to be operated manually. Various seed drills available in the market were tried out, but none was found suitable, as the seeds of jute are very small, light and more or less angular in shape.

Therefore, a low cost, high field capacity and light weight manually operated matching implement was developed to make it acceptable to the jute farmers.

Materials and Methods

The following criteria were considered in designing the best jute seed metering/ dispensing device and drill frame; were (a) simplicity of fabrication (b) field performance (c) portability (d) cost of seed drill and cost of seed sowing and (e) source of power available for jute farm. To design seed metering/ dispensing device and shape and size of seed box of seed drill, physical and morphological parameters like length, breath, thickness, bulk density, test weight and angle of repose of jute seed was determined in the laboratory. *Corchorus Olitorius* jute seed (JRO-524) was used during laboratory condition as well as field test condition.

Fig. 1 Schematic diagram of four - rows manual jute seed drill



Laboratory Test

Seed rate of seed drill at normal speed of sowing was calibrated as per IS 6316 test code (Anonymous, 1993). For calibration, the seed drill was jacked up and supported on its frame so that the wheels were free to rotate. A plain cloth was laid under each seed dispenser for collection of seeds. The seeds were cleaned and seed box-cum- seed dispenser of the drill was filled with cleaned seeds. The ground wheel of the drill was rotated manually for 100 revolutions at normal working speed and seed collected were weighted.

Uniform placement of seeds along the line is one of the important factors which affect the crop growth and thus the yield. Uniform placement of the seeds by the seed drills depends on their metering devices. Therefore the design of metering devices is one of the most important aspects of seed drills. Variation in dropping of seeds through different dispensers and evenness/ uniformity of seed distribution in rows were also studied as per IS 6316 test code (Anonymous 1993). The uniformly seeds placement in the soil along the line was evaluated by using the following equation.

$$S_e = 100\,(1 - d / a) \quad [1]$$

Where,

S_e = seed distribution efficiency of the seeding device.

d = average numerical deviation of number of seeds per meter length of row from average number of seeds per meter length.

a = average number of seeds per meter length of row.

Mechanical damage imparted to the seeds by the metering mechanism was also determined as per BIS test code in the laboratory.

Field Performance Test

Field performance tests were conducted at the CRIJAF experiment field and at the farmers' field to evaluate the performance of seed drill for jute crop. The soil at the experimental site was sandy loam having sand, silt and clay in the ratio of 74.80, 13.30, and 11.90% respectively. The test was replicated thrice in the plot size of 50 × 10 m. The performance parameters like speed of operation, depth of seed placement, effective field capacity, field efficiency, draft force, and plant population per square meter after emergence were determined. Plant population per square meter area was taken at number of places. Ease of operation and adjustment was also studied in field.

Design Consideration

Constructional Descriptions of the Seed Drill

The design of the machine (**Fig. 1**) is so simple that it can be fabricated with locally available materials like mild steel sheet, mild steel rod, M.S. conduit pipe, link chain and nut bolt. The different functional parts made with these materials are seed box cum seed dispenser, bush, collar, ground wheel, furrow opener, furrow coverer and rectangular conduit pipe frame. As the seed drill moves forward the seed box cum seed dispenser rotate on its own axis which dispenses seeds through the orifices of the seed dispenser device.

Seed box cum seed dispenser: It is inferred that the size and shape of seed box cum seed dispenser was designed more than angle of repose of seed to ensure free flow of seed.

Seed box-cum-seed dispenser: It is made of M.S. Sheet in conical section (truncated cone) with larger side diameter of 120 mm and with 140 slope (gradient) and length of 90 mm, two bushes of bore 25 mm are provided on the each side of the seed box through which an axle shaft passes which rotates the seed box powered through the ground wheels. A screw/ bolt is provide on the bush for tightening/ fixing the seed box on the shaft. The seed metering orifices (holes) of 2.36 mm size are provided at a distance of 7.5 mm from the larger end at equal hole to hole spacing along the circumference (periphery) of the conical shape seed box near the larger side for seed dropping. A hole with threaded plug is provided on the conical shape of seed box for filling the seeds. The slope of conical drum facilitates the free flow of seeds towards the metering holes.

Bushes: Two bushes made of M.S. rod, inner diameter 30 mm, outer diameter 35 mm and length 50 mm. it is welded to the 25 mm pipe, which hold the handle frame.

Collars: It is made of M.S. rod of inner diameter 26 mm, outer diameter 35mm, and length 15 mm. two collars, one each side of the conduit pipe with main bush is provided. It restricts the horizontal movement of the furrow opener shaft.

Ground Wheel

Wheel: Made of M.S. flat of 3 mm thickness and 40 mm width having 200 mm inner diameter, 25 mm bush bore with 8 nos. pegs of 35 mm in length of 9 mm diameter is provided at equal distance. Two wheels are provided; one on each side of the main shaft which rotates the seed box-cum-seed dispenser. Pegs are provided for better traction and it also reduces slip during field operation. Pegs also work as marker for the next round/ turn.

Furrow Opener

Furrow opener ploughs: Straight V shaped furrow openers ploughs have been provided on each row with the provision of varying depth and row distances. Ploughs are made of M.S rod which is fitted inside the upper pipe and can be slided up or down. One side of upper

Table 1 Major specifications of the seed drill

Parameters	values
Type	Manually operated seed drill
Length	1490 mm
Width	1040 mm
Row spacing	Normally 250 mm, adjustable between 200 mm to 250 mm
Depth of sowing	Normally 25-50 mm, adjustable up to 75mm
Total weight	13.5 kg
Number of rows	4
Capacity of seed box-cum-seed dispenser, seed	455 g
Seed rate	2.50 to 2.75 kg/ha
Seed of operation	2.0 to 2.5 km/h
Field capacity	0.18 to 0.20 ha/h
Power source	Manual (one man or woman)

Table 2 Physical characteristic of *Corchorus Olitorius* jute seed (JRO-524)

Sl. No.	Parameters	Minimum	Maximum	Average
1	Length (mm)	1.803	2.362	2.09
2	Breadth (mm)	0.813	1.626	1.19
3	Thickness (mm)	0.982	1.105	1.07
4	Frontal area (mm^2)	1.466	3.84	2.975
5	Weight of 1000 seeds (g)	1.922		
6	Shape & size of seed	Irregular shape having 4 to 5 faces with 5 to 6 angles		
7	Bulk density (kg/m^3)	742		
8	Angle of repose (degree)	28.38		
9	Moisture content (%)	8		
10	Germination %	85		

Table 3 Laboratory calibration of the seed drill for jute seed

Test No.	Weight of seed discharge in 100 revolution 1st row (g)	2nd row (g)	3rd row (g)	4th row (g)	Mean discharge (g)	Standard deviation	% of variation from mean discharge 1st row	2nd row	3rd row	4th row	Seed rate* (kg/ha)	Mean seed rate (kg/ha)
1	3.71	3.81	3.92	3.94	3.85	0.11	3.51	0.91	-1.95	-2.47	2.40	
2	3.91	3.70	3.81	3.98	3.85	0.12	-1.56	3.90	1.04	-3.38	2.41	
3	3.70	3.86	3.72	3.74	3.76	0.07	1.46	-2.80	0.93	0.40	2.35	2.39
4	4.01	3.83	3.90	3.72	3.87	0.12	-3.75	0.91	-0.91	3.75	2.42	
5	3.81	3.71	3.70	3.92	3.79	0.10	-0.66	1.98	2.25	-3.57	2.37	

* Seed rate at 25 cm row to row spacing (kg/ha)

pipe is fitted to 25 mm bore bush, which is fixed by appropriate bolt to the furrow opener shaft of 25 mm outer diameter. Depth of sowing is adjusted either by lifting or lowering the handle or sliding down or up the furrow opener plough inside the pipe and fixing by nuts. The furrow openers are adjustable both in horizontal and vertical position.

Seed Covering Device

Seed covering: Link chain of 9.5 mm (3/8'') M.S. rod, length of link 31.75 mm and 600 mm length is provided beside each seed box and it is fitted in the rings. Both ends of chain are fitted with hooks and hook is fitted with ring on the main axle shaft.

Rectangular Frame

Frame: It is made from tube pipe of 25 mm diameter and works as handle and also supports furrow opener plough shaft.

Rings: It is 6 mm M.S. rod of 70 mm outer diameter is provided at both side of the seed box for holding the chain on both sides.

Row to row spacing is 250 mm but it can be easily adjusted by unscrewing of the bolt and sliding the seed boxes and furrow opener ploughs on the respective shafts as required.

The unit consists of seed dispenser devices, main shaft, ground wheels, furrow opener ploughs, plough holding shaft, rings, seed covering devices (mechanism), collars and frame. The major specifications of the drill are as given in **Table 1**.

Table 4 Laboratory test of jute seed dropping Pattern in different rows in 1.05 meters length

Longitudinal distance (cm)	Number of seeds dropped in different rows 1st row	2nd row	3rd row	4th row
0-7	2.2	1.6	2.2	2.0
7-14	2.2	1.8	2.2	2.4
14-21	1.6	2.4	1.6	2.6
21-28	2.4	2.0	2.2	2.2
28-35	1.8	1.6	1.8	2.0
35-42	2.0	2.4	2.2	1.8
42-49	1.8	1.6	2.4	1.6
49-56	1.8	2.4	2.2	2.0
56-63	2.2	1.6	1.8	2.2
63-70	2.4	2.2	1.8	2.0
70-77	2.4	2.2	2.0	2.0
77-84	1.8	2.2	1.6	1.4
84-91	2.0	1.8	2.2	2.6
91-98	2.4	2.2	2.6	2.4
98-105	2.2	2.4	2.2	2.0
Total	31.2	30.4	31.0	31.2
Average	2.08	2.03	2.07	2.08
Standard deviation	0.27	0.33	0.29	0.34

Result and Discussion

Physical Characteristic of Jute Seeds

Physical characteristics of Corchorus Olitorius (JRO-524) Jute seed are given in the **Table 2**. The shape of jute seeds is irregular and having four to five faces. The average length, breadth, thickness and frontal area were found to be 2.09 mm, 1.19 mm, 1.07 mm and 2.98 mm^2 respectively. It was observed that bulk density, angle of repose and weight of thousand jute seeds were 742 kg/m^3, 28.38 degree and 1.92 g respectively.

Laboratory Test

Calibration of Seed Drill

The calibration of the seed drill was done in laboratory for jute crop. The results of the calibration are shown in the **Table 3**. The variation between mean discharge and seed dispensers in different rows ranged 0.40-3.75%. This variation was acceptable within 5%. There was a little variation in seed rate at different seed box-cum-seed dispenser. This variation may be due to unequal size of seeds. Average seed rate was 2.39 kg/ha. This seed rate was significantly lower than the recommended seed rate of 6-7 kg/ha for traditional practice. Thus, this reduced seed rate may help in reducing the total cost of seeding as well as in thinning and weeding operations. Since, jute crop requires optimum plant population for better and quality fibre yield. No mechanical damage of the seed was observed.

Seed dropping pattern in different rows through seed dispenser is presented in **Table 4**. The average number of seeds at each 7 cm bed length distance interval was found as 2.1. This is at par the agronomical recommended plant to plant distance in a row. It was observed that on an average 31 nos. of seeds dropped in a 1.05 meter length in a row.

The percentage inter-row variation in seed dropping and average numbers of seeds dropping in a meter of length of the seed drill was done in laboratory for jute are shown in the **Table 5**. The numerical variation between mean discharge and seed dispensers in different rows ranged 0.8-5.79%. This variation was acceptable as in only one case the variation exceeds 5%. There was a little variation in number of seeds dropped from different seed dispensers. This variation may be due to unequal size of seeds as well as shape of seeds. It was observed that on an average 124 nos. of seeds dropped in an approx. one meter square area.

The seed distribution efficiency of seed drill was calculated using the equation (1) as shown in **Table 6**. It is clear from the **Table 6** that the seed distribution efficiency was varied from 95.24 to 99.20%.

Field Performance of Seed Drill

The seed drill has been tested in different location with jute seed. The locations were CRIJAF experimental field, Singur demonstration firm and farmer's field of four districts of West Bengal shown in **Figs. 2a** and **2b**.

Fig. 2a Four-rows CRIJAF manual seed drill in sowing operation

Fig. 2b Four-rows CRIJAF manual seed drill in sowing operation

The field performance data of the seed drill are presented in **Table 7**. The depth of seed placement varied from 27 mm to 32 mm which could be attributed to the uniformity of soil preparation and it was with in the recommended depth of 25 mm to 40mm. The speed of operation in the field was varied from 1.91 to 2.06 km/h with an average speed of operation was 2.0 km/h. The actual seed rate was varied from 2.50 to 2.75 kg/ha, which was significantly lower than the recommended seed rate of 6 to 7 kg/ha in broadcasting method. Thus, this reduced seed rate may help in reducing the total cost of seeding as well as in thinning and weeding operation. The effective field capacity was varied from 0.163ha/h to 0.176 ha/h with an average of 0.17 ha/h. The average labour requirement was only 5.87 man-h/ha. The average field efficiency and draft requirement was found as 88.74% and 75.16 N respectively. After germination, when the plant developed 2-3 leaves the plant population per square meter area was 60 to 65 plants **Figs. 3a** and **3b**.

Energy utilization by traditional broadcasting and four row seed drill shown in **Fig. 4**.

It is clear from the **Fig. 4** that energy requirement in sowing through seed drill was higher (3.2%) as compared to traditional method of broadcasting, while energy requirement for weeding and thinning was about 27% lower as compared to broadcast method of sowing. In jute crop cultivation the weeding and thinning was the most cost consuming unit operation. Hence, use of four row manual jute seed drill saves cost and energy significantly.

No difficulty was reported in the operation and maintenance of the seed drill and since the average draft requirement of the seed drill was 75.16 N, the operator can easily pull the drill for 1 to 2 h continuously.

Conclusions

The following conclusions may be

Table 6 Seed distribution efficiency (S_e)

Test No.	1st row (%)	2nd row (%)	3rd row (%)	4th row (%)
1	96.00	99.20	97.60	97.60
2	98.41	95.24	95.24	95.24
3	99.17	94.21	95.87	95.87
4	95.24	98.41	95.24	95.24
5	99.19	97.56	95.93	95.93

Table 5 Average number of seeds and inter-opener percentage variation in seed dropping per 1050 mm row length

Test No.	Number seeds discharge per meter length						% of variation from mean discharge			
	1st row	2nd row	3rd row	4th row	Mean discharge	Standard deviation	1st row	2nd row	3rd row	4th row
1	30	31	32	32	31.25	0.96	4.00	0.80	-2.40	-2.40
2	32	30	31	33	31.50	1.29	-1.59	4.76	1.59	-4.76
3	30	32	30	29	30.25	1.26	0.83	-5.79	0.83	4.13
4	33	31	32	30	31.50	1.29	-4.76	1.59	-1.59	4.76
5	31	30	30	32	30.75	0.96	-0.81	2.44	2.44	-4.07

Fig. 3a Seed drill sown farmers' field after germination

Fig. 3b Seed drill sown farmers' field after germination

drawn from the study.

1. The average seed rate in laboratory was 2.39 kg/ha and in the farmers' field the average seed rate was varied from 2.50 to 2.75 kg/ha.
2. The average numbers of seeds dropped in about one meter length row run was 31 seeds.
3. The numerical variation between mean discharge and seed dispensers in different rows was varied from 0.8 to 5.79%.
4. The average effective field capacity, average field efficiency and average draft requirement of the seed drill was found as 0.17 ha/h, 88.74 per cent and 75.16 N respectively
5. The average plant population per square meter was 60 to 65 plants.

Fig. 4 Energy requirement in traditional method verses seed drill jute sown

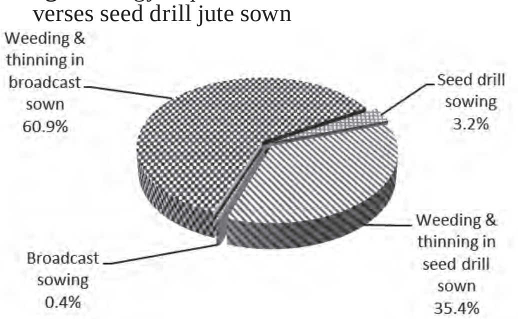


Table 7 Field Performance test result of the seed drill for olitorius jute in farmers fields

Sl. No.	Particulars	Value
1.	Seed germination (%)	85
2.	Area of land under sowing (ha)	0.50
3.	Seed rate (kg/h)	2.50 to 2.75
4.	Row spacing (mm)	250
5.	Depth of sowing (mm)	27-32
6.	Speed of operation (km)	1.91 to 2.06 (2.0)
7.	Effective field / sowing capacity (ha/h)	0.163 to 0.176 (0.17)
8.	Time required (man-hr/ ha)	5.68 to 6.13 (5.87)
9.	Plant stand after emergence (plants/ sq. m)	60 to 65
10.	Draft force (N)	72.87 to 78.26 (75.16)
11.	Field efficiency (%)	84.97 to 90.70 (88.74)

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Performance of Milking Machine at Different Vacuum Levels in Crossbred Dairy Cows Milked in Automated Herringbone Parlour

by

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Abstract

It is well known that need of all animals are not the same and varies according to the category of animal, farm management and prevailing agro-climatic conditions. The mechanized milking systems developed elsewhere may need some modification for different category of animals in different conditions. A study was conducted to investigate suitable vacuum level for milking of crossbred cows in sub-tropics. Fifty six crossbred dairy cows were milked at different vacuum levels (38, 40, 42, 44 and 46 kPa) in automated herringbone milking parlour. Significant ($P < 0.01$) reduction in machine-on time and increase in flow rate was observed with the rise in vacuum level. There was significant ($P < 0.01$) improvement in milking irregularities and completeness of milking with the rise in vacuum. However, it also affected the on-line milk electrical conductivity (EC) values significantly ($P < 0.01$) without affecting somatic cell count (SCC) values. It was concluded that vacuum level of 42 kPa to be the most appropriate for milking of the crossbred cows in tropics under machine milking.

Introduction

The milking machine is designed to remove the available milk from the udder quickly, completely without causing harm to udder and teats (Reid, 2000). Several factors affect the performance of cows in machine milking such as the animals milked, skill of the milker, equipment etc. The use of correct equipment for milking with a correct setting has a considerable role to play (Ali and Farah, 1992; Rasmussen and Madsen, 2000; Spencer et al., 2007). The milking machines have been designed for removal of maximum amount of milk from the cow's udder in minimum time and also improve the quality of production (Bramley, 1992; Marnet and McKusick, 2001).

The role of vacuum applied to the udders have been found to play a major role in all milking operations done with machine affecting the milking both individually as well as in combination with other machine settings such as automatic cluster removal and pulsation (Sinapis et al., 2000; Spencer et al., 2007; Bade et al., 2009). Variations also exist on the use of vacuum in different countries, different parlour types (high-line, middle-line and low-line) and different species of animals (cattle, buffalo, sheep and goat). The Holstein cows performed best at vacuum of 43.9 kPa (Spencer et al., 2007), whereas, in buffaloes it should be higher (Caria et al., 2011). In Italy, the working vacuum levels in buffaloes varied from 40 to 53 kPa with most frequent values (45%) ranged between 44 and 46 kPa

(Data based on field tests of Associazione Italiana Allevatori in 2009). Similarly for sheep and goats, lower vacuum level of 38 kPa have been found to be better than higher range (Sinapis et al., 2006). In camels, the best milking was achieved at higher vacuum and lower pulsation rate (48 kPa/60 cpm) of milking machine (Atigui et al., 2015). The settings, therefore, still remain an enigma in terms of many fundamental interactions between the animal tissue and the milking machine and have been suggested to be determined on an individual farm basis (Magliaro and Kensisnger, 2005).

In many developing countries like India, there are very few studies on these settings, in spite of the fact that the cows are quite different in terms of production and habit. Till date, most of the mechanized milking equipments are developed in advanced dairying countries which are being imported and used throughout in commercial dairies and many government farms (Das et al., 2016). The performance of these cows milked under mechanized milking system differs based on their milk yield and milking conditions (Fahim et al., 2017). The other concern related to milking is improved quality of production with a fewer milking irregularities, especially in parlour based milking operations. In a study, it was found that many parlours in India and neighboring countries do not have standard operating procedures due to which they are facing problems during milking (Rahman, 2004; Das et al., 2016). Under such situations, it becomes imperative to study these settings in native cows for developing our own standards for milking the cows. Due to possible variations in the level of vacuum used for milking the native cows, it was planned to study the milking machine based on different vacuum levels to find out the most appropriate vacuum for milking of crossbred dairy cows.

Fig. 1 Cow with RFID neck transponder for identification

Fig. 2 Milking operation in automated Herringbone milking parlour

Materials and Methods

Description of the Study Site

The study was conducted at Livestock Research Centre, ICAR-National Dairy Research Institute (NDRI), Karnal, Haryana. It is situated at an altitude of 250 m above mean sea level, latitude of 29°42″ N and longitude of 79°54″ E. Ambient temperature of the place ranges from a maximum temperature of 45 °C during summer and minimum temperature of 0 °C during winter with a diurnal variation of 15-20 °C. Average annual rainfall is 700 mm, most of which is received from early July to mid September.

Automated Herringbone Milking Parlour System

The herringbone parlour milking system was DeLaval make- 2 × 8/16 stalling, 30 degrees with automation, milk measurement and automatic cluster removal (ACR) with ALPRO® based herd management system. A manually adjustable breast rail set to ensure smooth loading and gently positioning of cows close to the milker for optimal udder visibility and access during milking of cows. Vacuum controlled entrance and exit gates were operated manually from pit that favoured smooth traffic, flexibility and comfort to both animal and milker. The vacuum pump system consisted of 1 set of vacuum pump type DVP 2300 with capacity of 2300 L/min at 50 kPa running on 5 kW, 3 phase electric supply. The changes in effective milking vacuum level were made by the help of 1 set of vacuum regulator MVR 4000/75 consisting of regulator unit, sensing units, vacuum gauge, adapters, plastic tubes, cable straps, hose clips and drain valves. The machine settings were tested by the help of hand held VPR 100 for performance testing. 16 sets of MC 73 milking cluster units each controlled by milk point controller were installed in the system. The milk meter MM27 BC could detect blood traces in milk, air entry into the liner and level of conductivity for instant quality checks and management decisions during milking.

Animal and Experimental Design

The study was conducted on the crossbred cows maintained at Livestock Research Center. Fifty six cows were monitored through automatic animal identification system consisting of neck transponder (**Fig. 1**), portal identification antenna, system controller and ALPRO windows kit. All the experimental animals were kept in the similar loose housing system under group management practice during the entire period of trial. Milking of animals was done in 2 × 8 DeLaval low-line Herringbone milking parlor thrice a day (**Fig. 2**). A total of five vacuum levels (kPa) (38, 40, 42, 44 and 46 kPa) including the manufacturer's recommendation of 42 kPa vacuum were tested. The changes in vacuum were made keeping the ACR as well as pulsation ratio constant. Each cow had each level of vacuum for three days in a definite sequence allowing one day adjustment time before taking the observation. The same sequence was repeated thrice with all the levels of vacuum. The data on milkablility were collected from the ALPRO programmed windows on the PC. The electrical conductivity (EC) was measured on-line with the help of milk meters MM27BC installed with each milking unit. Somatic cell count (SCC) was measured in DeLaval cell counter (DCC) through disposable cassette.

Ultrasonography Technique for Measurement of Teat Wall Thickness

An Aloka 500 v-ultrasound scanner with a 7 MHz linear probe was used to measure changes in teat tissue on cow's teats. A plastic ring at the opening supported a condom which allowed it to be held in place with one hand, filled with warm water and placed around the cow's teat. A film of lubricating gel was placed on the probe head to improve contact with the condom. The probe was manipulated until a clear image of the teat appeared on the screen as shown in **Fig 3**. When the picture was obtained, the image was frozen on screen. Images of teats were stored were subsequently measured on screen.

Statistitcal Analyses

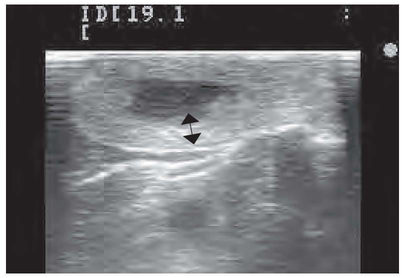
The experimental data on milkability and milk quality parameters were analyzed using General Linear Model in SAS version 9.3 (SAS Inst., Inc., Cary, NC). The effects of different vacuum levels used for milking of cows in milking parlour through milking machine were compared using Duncan's Multiple Range Test.

Results and DiscussionI

Milkability of Crossbred Cows

The effect of vacuum on daily milk yield, milk yield/ session (morning), milk yield first 2 minutes, average milk flow and peak milk flow are presented in **Table 1**. Altering the vacuum level had no significant effect of daily milk yield. However, at lower vacuum level, losses in milk may be seen. The milk yield in the morning session was found to be affected significantly (P < 0.0.1) at lower vacuum (38 kPa). The yield first 2 minutes was found to be maximum (2.76 ±0.08 kg) at 44 kPa and minimum (2.37 ±0.08 kg) at 38 KPa which were statistically significant (P < 0.01). The average and peak flow rate was significantly (P < 0.01) higher at higher vacuum levels due to which machine-on time was significantly (P < 0.01) reduced. However, machine-on time was statistically similar at 42, 44 and 46 kPa. Rasmussen and Madsen (2000) also reported that milking at vacuum of 38 kPa compared with 48 kPa decreased milk yield and milk flow in Holstein cows. Spencer et al. (2007) studied three settings for milking cows i.e. 40.6 kPa, 43.9 KPa and 47.3 KPa and reported that out of the three settings, milk yield was greatest at a vacuum of 43.9 kPa. Spencer and Rogers (2004) reported that both peak milk flow and milking speed increase as milking vacuum is raised. The findings based on our study in crossbred cows were similar to the reports of above researchers. However, contrary to our results Ali and Farah (1992), Hamann et al. (1993) and Bade et al. (2009) reported no effect of vacuum change on milk yield and peak flow rates. Invariably, in all the studies, the reports on machine-on time were similar.

Fig. 3 Ultrasound image of cow teat scanned along the longitudinal section of the teat canal showing teat wall thickness



The effect of vacuum on milk flow rate in two minutes observed over 0-15 sec, 15-30 sec, 30-60 sec and 60-120 sec are presented in **Table 2**. The milk flow rate was similar at all vacuum levels at the start of milking (0-15 sec). However, in 15-30 sec of milking, significant (P < 0.05) differences were observed between lower (38 kPa) and higher vacuum (46 kPa). Milking beyond 30 sec (30-60 and 60-120 sec) showed significant (P < 0.01) differences at different vacuum levels. The highest milk flow rate (1.62 ±0.07) was recorded at 46 kPa and the lowest (1.09 ±0.07) at 38 kPa during the interval of 60-120 sec. It was also noted that during this interval, the flow rates were statistically similar at vacuum level of 42, 44 and 46

Table 1 Effect of levels of vacuum on milkability of crossbred dairy cows in automated herringbone milking system (Mean ± SE) (N = 56)

Vacuum levels (kPa)	Total milk yield/ day (kg)	Milk yield/session (kg)	Yield first 2 min (kg)	Machine-on time (min)	Average milk flow (kg/min)	Peak milk flow (kg/min)
38	13.08 ±0.42	5.86^{A} ±0.21	2.37^{a} ±0.08	5.17^{A} ±0.10	1.18^{A} ±0.05	2.31^{A} ±0.10
40	13.92 ±0.42	6.26^{AB} ±0.21	2.52^{ab} ±0.08	4.95^{A} ±0.10	1.25^{AB} ±0.05	2.50^{AB} ±0.10
42	14.62 ±0.42	6.62^{B} ±0.21	2.73^{b} ±0.08	4.64^{B} ±0.10	1.36^{BC} ±0.05	2.61^{AB} ±0.10
44	14.19 ±0.42	6.54^{B} ±0.21	2.76^{b} ±0.08	4.42^{B} ±0.10	1.40^{BC} ±0.05	2.76^{BC} ±0.10
46	14.20 ±0.42	6.56^{B} ±0.21	2.75^{b} ±0.08	4.25^{B} ±0.10	1.46^{C} ±0.05	2.97^{C} ±0.10

Values with different superscript in upper case letters in column differ significantly at P < 0.01 & in lower case letter at P < 0.05

kPa. The findings of present study are in line with those reported by Spencer et al. (2007) and Bade et al. (2009) in dairy cows.

Milking Irregularities and Milk Quality

The mean cluster slips (%) and cluster reattachments (%) during milking at different levels of vacuum are presented in **Table 3**. The mean cluster slips (%) during milking in the study were found to be maximum (15.40 ±1.30) at 38 kPa and reduced with the rise in vacuum level. The instances of cluster slips were significantly ($P < 0.01$) reduced above 40 kPa with minimum (1.10 ±1.30) slips at 46 kPa. Similarly, the mean cluster reattachment (%) needed after clusters were automatically detached was also higher (13.00 ±2.00) at 38 kPa indicating this level to be least efficient in machine milking operations. However, significant ($P < 0.01$) improvements were seen in milking performance as the vacuum level was raised above 40 kPa. The results obtained for milking irregularities was further supported by the results of milk remaining in the udder after automatic cluster removal. The milk remaining i.e. milk which was left in the udder unmilked by machine but was hand milked was highest (677.73 ±11.27 ml) at 38 kPa and lowest (125.97 ±11.27 ml) at 46 kPa. The milk remaining in the udder at different vacuum levels differed significantly ($P < 0.01$). The cluster slips in the present study was similar to those reported by Rasmussen and Madsen (2000) in low-line milking system where the liner slips were less frequent at a higher vacuum (13.6 % at 32 kPa Vs 2.4% at 42 kPa). In one of the report submitted for milking-time test and guidelines for milking unit, a goal of < 5-10 slips per 100 cow milkings has been suggested as a thumb rule (Mein and Reid, 1996). A wide range of variation (0-25%) in unit reattachment rate was reported in the survey of Wisconsin dairy operators which affected their milking efficiency (Ruegg et al., 2005). The results of our investigation suggested that lower vacuum (< 40 kPa) may not be suitable for milking of these crossbred dairy cows as the cluster slips and cluster reattachments were higher than the prescribed standards mentioned above.

The average values of conductivity and somatic cell count at different levels of vacuum are presented in **Table 3**. The average conductivity was found to be lowest (6.61 ±0.10 ms/cm) at 42 kPa and highest (7.14 ±0.10 ms/cm) at 44 kPa. Statistical differences were observed in conductivity above 42 kPa. The results obtained reveal that any change in vacuum beyond 42 kPa may have significant ($P < 0.01$) adverse effect on the EC values. The somatic cell count was lowest (1.48 ±0.14 × 10^5) at 40 kPa and F highest (1.67 ±0.14 × 10^5) at 46 kPa. However, in all cases the results were found to be statistically non-significant. Scanty reports are available to compare the electrical conductivity on changing the levels of vacuum in the present study. The results reveal that any change in vacuum beyond 42 kPa may have significant ($P < 0.01$) adverse effect on the EC values. The effect of vacuum on milk somatic cell count were similar to those reported by Olney and Mitchell (1983) who found that neither vacuum level nor over-milking affects somatic cell count in the milk. Lam et al. (2011) also reported that the vacuum level of the bucket machines having high vacuum (average 49 kPa) was not found to have any impact on herd SCC, in spite of wide variations in milking pressure. However, contrary to our results, Bramley (1992) and Hamann et al. (1993) reported that continuous high vacuum level over a longer period influences teat tissues negatively which increases the risk for oedema in the teats which is associated with teat orifice damage leading to increase of SCC.

Table 2 Effect of levels of vacuum on milk flow rate in 0-15 sec, 15-30 sec, 30-60 sec, 60-120 sec of milking (Mean ± SE) (N = 56)

Vacuum levels (kPa)	Flow 0-15 sec (kg/min)	Flow 15-30 sec(kg/min)	Flow 30-60 sec(kg/min)	Flow 60-120 sec(kg/min)	Overall mean
38	0.06 ±0.02	0.85^{a} ±0.07	0.92^{A} ±0.06	1.09^{A} ±0.07	0.73^{A} ±0.03
40	0.10 ±0.02	0.91^{ab} ±0.07	1.04^{A} ±0.06	1.35^{B} ±0.07	0.85^{B} ±0.03
42	0.13 ±0.02	1.00^{abc} ±0.07	1.19^{B} ±0.06	1.56^{C} ±0.07	0.97^{C} ±0.03
44	0.13 ±0.02	1.10^{bc} ±0.07	1.28^{B} ±0.06	1.55^{C} ±0.07	1.02^{C} ±0.03
46	0.14 ±0.02	1.17^{c} ±0.07	1.30^{B} ±0.06	1.62^{C} ±0.07	1.06^{C} ±0.03

Values with different superscript in upper case letters in column differ significantly at $P < 0.01$ & in lower case letter at $P < 0.05$

Table 3 Effect of levels of vacuum on milking irregularities and milk quality of crossbred dairy cows (Mean ± SE)

Vacuum levels (kPa)	Milking irregularities			Milk quality	
	Cluster slips (%)	Cluster re-attach (%)	Milk left in udder (ml)	Electrical conductivity (ms/cm)	Somatic cell count (X105)
38	15.40^{B} ±1.30	13.00^{B} ±2.00	677.73^{D} ±11.27	6.74^{A} ±0.10	1.55 ±0.14
40	5.20^{A} ±1.30	7.60^{AB} ±2.00	444.45^{C} ±11.27	6.62^{A} ±0.10	1.48 ±0.14
42	2.90^{A} ±1.30	5.20^{A} ±2.00	166.52^{B} ±11.27	6.61^{A} ±0.10	1.54 ±0.14
44	1.20^{A} ±1.30	3.50^{A} ±2.00	135.15^{AB} ±11.27	7.14^{B} ±0.10	1.61 ±0.14
46	1.10^{A} ±1.30	2.90^{A} ±2.00	125.97^{A} ±11.27	7.10^{B} ±0.10	1.67 ±0.14

Values with different superscript in column differ significantly at $P < 0.01$

Teat Wall Thickness

The mean teat wall thicknesses before and after milking are presented in **Table 4**. The mean difference in teat wall thickness, measured as a difference between pre-milking and post-milking was found to be lowest (0.35 ±0.02 mm) at 40 kPa and highest (1.15 ±0.02 mm) at 46 kPa. The change in teat wall thickness due to effect of vacuum significantly ($P < 0.01$) increased beyond 42 kPa. The results of study were in agreement to the previous reports in which it was stated that increasing the vacuum and changing the b-phase either by changing either pulsation rate or ratio increases teat congestion, as reflected by changes in teat wall thickness after milking, measured by using skin-fold calipers (Hamann et al., 1993) or ultrasonic images (Gleeson et al., 2004; Vinitchaikul and Suriyasathaporn, 2007).

Conclusions

Different vacuum levels used in milking machine affect the performance of crossbred cows under mechanized milking systems. The results for milkability in cows indicated that raising the level of vacuum beyond 42 kPa could increase the milk flow rate without affecting the milk yield and machine-on time. However, at lower vacuum, losses in milk may be seen. The best results for milking irregularities and milk quality were obtained at 42 kPa which could improve the efficiency of milking and quality of production, thus, may help in promoting the production standards of dairy industry. The difference in teat wall thickness pre and post milking was found superior at 42 kPa which could be benefit udder and teat health. Therefore, it can be concluded form the study that the most appropriate vacuum level for milking of the crossbred cows under Indian conditions is 42 kPa which could improve the performance of dairy herds.

Table 4 Effect of levels of vacuum on teat wall thickness (mm) (Mean ± SE) (N=6)

Vacuum levels (kPa)	Teat wall thickness (mm)		
	Pre-milking	Post-milking	Difference
38	7.08^a ±0.27	7.45^b ±0.27	0.37^A ±0.02
40	7.12^a ±0.27	7.47^b ±0.27	0.35^A ±0.02
42	7.03^a ±0.27	7.43^b ±0.27	0.40^A ±0.02
44	7.08^a ±0.27	7.83^b ±0.27	0.75^B ±0.02
46	6.78^a ±0.27	7.93^b ±0.27	1.15^C ±0.02

Values within a column bearing different superscript (A, B) differ significantly at $P < 0.01$ & within row bearing different superscript (a,b) differ significantly at $P < 0.05$

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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.

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

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

Development of Integrated Small Scale Lac Processing Unit

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Abstract

An integrated small scale lac processing unit was developed and evaluated for seedlac manufacturing from sticklac. The developed unit can be operated easily and found that different mechanisms provided in the unit performed as per requirement. Quality parameters of seedlac manufactured through the developed unit were determined within the acceptable limit as per standard values IS: 6921-1973 and colour parameters of the same were found higher compared to seedlac manufactured through Small Scale Lac Processing Unit. About 300 person-days/year can be generated through the developed unit under primary lac processing for seedlac manufacturing from sticklac. Particle size of seedlac manufactured from sticklac through the developed unit are in accordance with the specification IS: 6921-1973. Machine developed for primary processing of lac may switch over comparatively from the existing labour intensive mechanism. Thus, it may reduce the drudgery, time and consequently results into more efficient mechanism for primary level processing of sticklac (resin).

Keywords: primary lac processing, integrated unit, seedlac

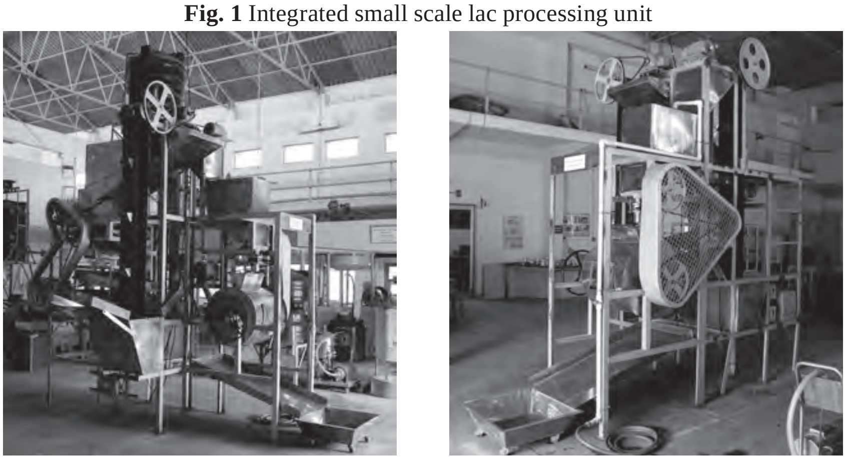
Introduction

Lac is a natural resin secreted by lac insect (*Kerria lacca* Kerr). Lac growers rear lac insects on host trees. *Butea monosperma* (*palas*), *Ziziphus mauritiana* (*ber*) and *Schleichera oleosa* (*kusum*) are the major commercial lac host trees in India. The rearing of lac insects on host trees is known as lac cultivation. Lac growers harvest matured lac from host trees in the form of lac stick and then lac encrustations attached with sticks of host trees are scraped manually using specially devised hand tool known as "*Chhoti Dawali*". Scraped lac encrustation, from lac stick, is known as sticklac which contains impurities in the form of stick, stone, sand, insect body etc. and water soluble lac dye. Lac growers sell their produce in the form of scraped lac or cut bits in local market to merchants. The merchants associated with lac, supply the scraped lac or cut bits to lac processing industries where it is processed into seedlac for its further use in making lac based products. There were about 155 functional lac processing units located in states of West Bengal (102), Chattishgarh (29), Jharkhand (16), Maharashtra (6) and Madhya Pradesh (2) in the year 2013-14 (Yogi et al., 2014). The processing of lac involves five major unit operations like crushing, washing, drying, cleaning and grading. In commercial lac processing unit, out of these unit operations, crushing, washing and grading is done using large capacity crusher, washing machine and grader respectively. Unit operations like drying, cleaning and final grading are done manually.

Lac is mainly produced in India, Thailand, Indonesia, part of China, Myanmar, Philippines, Vietnam, Cambodia etc. and India is the largest producer of lac in the world. In India, lac is mainly produced in Jharkhand, Chattishgarh, Madhya Pradesh, West Bengal, Maharashtra, Odisha and part of Utter Pradesh, Andhra Pradesh, Gujarat and NEH region. Lac production in India was about 21,008 tonnes during year 2013-14 (Yogi et al., 2014). About 70% of lac produced in India is exported to different countries of the world. During year 2014-15 India exported 8,153.1 tonnes of lac in different forms and earned foreign exchange of Rs. 56,853.63 lakhs (US $75.73 million) (Yogi et al., 2014). Due to dependence on export market, there is large fluctuation in price of lac w.r.t. variation in demand and supply. The price fluctuation seriously affects lac growers. It has been observed that, when price of lac goes abruptly down, lac growers discontinue lac cultivation. As lac growers are resource constrained farmers and mainly resides in tribal areas, it becomes difficult to revive lac cultivation, once they discontinue, as price of broodlac (lac seed) remains high beyond their affordable capacity.

The lac growers sell scraped lac or cut bits immediately after harvest at prevailing price which is sometimes very low. Lack of knowledge for proper storage, lack of storage facility and need of immediate cash compels lac grower to sell their produce immediately after harvest. Scraped lac or cut bits converted into seedlac, which can be stored for longer duration like grain, in gunny or metal bin. Having done so, lac grower can sell seedlac whenever they get remunerative price. Therefore, need was felt to develop facility for converting scraped lac or cut bits into seedlac at village level. Considering the need, machines required for establishing such facility at village level in form of small scale lac processing were designed and developed at Indian Institute of Natural Resins and Gums, Ranchi (Prasad et al., 2008). Such processing unit can process 100 kg of sticklac in a day and five persons are required to operate the machine. Though small scale lac processing unit is working well, however need was felt to develop integrated small scale lac processing to reduce the man power requirement considering labour availability problem and reduce cost of primary processing. Accordingly integrated small scale lac processing unit was designed by ICAR - IINRG, Ranchi in collaboration with ICAR - CIAE, Bhopal using Pro-Engineer CAD software. After design, unit was fabricated utilizing fabrication facility at ICAR - CIAE, Bhopal and its performance evaluation was carried out at ICAR -IINRG, Ranchi. The design, development and performance evaluation of the unit is presented in following sections.

Fig. 1 Integrated small scale lac processing unit



Materials and Methods

Primary lac processing operations of making seedlac from sticklac is mainly done by human being which is a tedious job and requires higher input of manpower, capital and time. Considering above points an Integrated Small Scale Lac Processing Unit (Capacity - 100 kg/day) was designed and developed at ICAR - Indian Institute of Natural Resins and Gums, Ranchi and fabricated at ICAR - Central Institute of Agricultural Engineering, Bhopal to reduce manpower requirement, time and drudgery of the person involved in primary lac processing. The detailed description of the developed Integrated Small Scale Lac Processing Unit is as under.

2.1 Development of Integrated Small Scale Lac Processing Unit

An integrated small scale lac processing unit, developed at Processing and Products Development Division, ICAR - Indian Institute of Natural Resins and Gums, Ranchi, consisted of five major units i.e. sticklac handling unit, size reduction unit, grading unit, soaking unit and washing unit with tilting mechanism (**Fig. 1**). The overall dimension i.e. length, width and height of the developed unit was 3,840 × 2,350 × 3,465 mm, respectively. The detailed description of above unit is as under:

2.1.1 Sticklac Handling Unit:

A sticklac handling unit was developed to transfer the sticklac from feeding hopper to size reduction unit continuously. The various components of sticklac handling unit are sticklac feeding hopper, bucket elevator and sticklac receiving trough.

2.1.1.1 Sticklac feeding hopper:

A hopper made of stainless steel sheet having 1.18 mm thickness was provided on the main frame 620 mm above ground level to feed the sticklac manually for transfer of sticklac from sticklac feeding hopper to sticklac receiving trough, through bucket elevator mounted on the main frame of the unit. The sticklac feeding hopper was trapezoidal in cross-section with 520 mm and 300 mm length at upper and lower end (bottom), respectively having 530 mm width with height 540 mm. The side wall of the hopper was inclined, in accordance with the angle of repose of sticklac, for easy flow of the sticklac from sticklac feeding trough to sticklac feeding hopper. In order to easy feeding of sticklac, a trough having channel cross-section made of stainless steel was also attached at upper inclined wall portion of sticklac feeding hopper having 500 mm length, 530 mm width and 1.18 mm thickness. The sticklac feeding trough provided at the top of inclined wall of sticklac feeding hopper was also inclined in accordance with angle of repose of sticklac for transfer of sticklac from sticklac feeding trough to sticklac feeding hopper through gravity. At the bottom portion of the sticklac feeding hopper, arrangement for mounting bucket elevator mechanism has been provided.

2.1.1.2 Bucket elevator:

To transfer sticklac from sticklac feeding hopper to sticklac receiving trough, a material handling mechanism "bucket elevator" was provided. One end of the bucket elevator was mounted at the bottom portion of sticklac receiving hopper and other end was mounted on the main frame of the unit having arrangement for adjustment of tightness of the bucket elevator as per requirement. Bucket elevator provided for transfer of sticklac to sticklac receiving trough was made of flat belt of synthetic rubber plastic materials having total length 5,320 mm and width 200 mm with thickness 6 mm. On the outer flat surface of the conveyor belt, 10 trapezoidal cross-section buckets made of stainless steel sheet were mounted with fasteners at an equal interval of 545 mm. The length of stainless steel bucket was 125 mm; width at top was 85 mm and at bottom 30 mm with 80 mm height for each trapezoidal section. The stainless steel bucket was made of 1.18 mm thickness sheet. Power to the bucket elevator was provided by 1½ hp three phase electric motor mounted at the top of bucket elevator on the main frame of the Integrated Small Scale Lac Processing Unit. Bucket elevator provided in the material handling unit, lifted the sticklac from sticklac feeding hopper and transferred it to sticklac receiving trough made of stainless steel in trapezoidal shape having 1500 mm length and 625 mm width with 1.18 mm thickness mounted on upper portion of main frame of the unit just below the discharge end of bucket elevator mechanism. The sticklac receiving trough was mounted on the main frame of the unit in such a way that one end of the trough receive the sticklac through bucket elevator discharge end and other end guides the flow of sticklac towards size reduction unit. The base of sticklac receiving trough was inclined from discharge end of bucket elevator mechanism to size reduction (crushing) unit confirming the angle of repose of sticklac for easy transfer from upper end to lower end of the base plate of the material receiving trough.

2.1.2 Size Reduction Unit:

To reduce the size of sticklac upto desired size (8-10 mesh) two corrugated rollers (Prasad et al., 2001, Prasad et al., 2005 and Prasad et al., 2006) made of mild steel was provided just below the discharge end of sticklac receiving trough. The total length of corrugated rollers was 630 mm and diameter was 145 mm, respectively with wall thickness 5 mm. Both the corrugated rollers were mounted on the pillow block bearing provided on the main frame of the unit in such a way that both the rollers matched with each other length wise. Both the crushing rollers were rotating in opposite direction in such a way that sticklac received from sticklac receiving hopper was crushed between both the corrugated rollers to reduce the size of sticklac up to desired size i.e. 8-10 mesh (Pandey et al., 2015). A spring actuated mechanism was provided on the driven roller to maintain the desired compression between both corrugated rollers for optimum crushing size of lac particle. Power transmission to the size reduction unit is provided through 1½ hp three phase electric motor mounted on the main frame of the unit above the size reduction unit with belt and pulley arrangement. Corrugated crushing rollers provided in the size reduction unit are rotating in opposite direction with differential speed to achieve compression rubbing/crushing action. The speed of driver roller was 273 and a driven roller was 186 rpm, respectively with 1:45 speed reduction for creating shearing action on the sticklac for size reduction.

2.1.3 Grading Unit:

Grading unit was provided in the unit for differentiating oversize and desired size crushed sticklac. Grading unit mainly consisted of main frame, sieve and at bottom crushed sticklac receiving tray to guide the crushed sticklac of desired size to crushed sticklac receiving hopper provided on the main frame of the unit towards the discharge end of grading unit. Similar hopper as discussed in section 2.1.1.1 was provided below the discharge end of grading unit for collection of crushed sticklac of desired size and transfer it to soaking unit through separate material handling unit "bucket elevator" as described in section 2.1.1.2. The overall length, width and height of the grading unit frame was 750 mm, 680 mm and 550 mm, respectively made of mild steel angle iron of cross-section 35 × 35 × 5 mm. Four mild steel flats having length 480 mm, width 35 mm and thickness 5 mm has been welded at both side of the main frame of the grading unit having 11 number holes of size 10 mm diameter to fix the sieving unit and crushed sticklac receiving tray at desired inclination for easy flow of oversize crushed sticklac and desired size crushed sticklac through gravity and stroke of grading unit. Power to the grading unit was provided through the same three phase electric motor of 1½ hp provided for power transmission to crushing unit with belt and pulley arrangements and cranking system.

2.1.4 Crushed Sticklac Collection Hopper:

Crushed sticklac collection hopper as discussed in section 2.1.1.1 (similar to sticklac feeding hopper in dimensions) was provided on the main frame of the unit in offset position just below the discharge end of crushed sticklac receiving tray of grader unit to collect the crushed sticklac of desired size obtained from grading unit. Similar arrangements were also provided in the crushed sticklac collection hopper as discussed in section 2.1.1.1 for mounting another set of bucket elevator of same design and capacity as detailed in section 2.1.1.2. The bucket elevator provided in the crushed sticklac collection hopper was used for lifting crushed sticklac of desired size from crushed sticklac receiving hopper and transfer it to soaking unit. Power to the bucket elevator was provided through belt and pulley arrangements with separate 1½ hp three phase electric motor mounted above the elevator mechanism on main frame of the unit with arrangement having mechanism for tightening the bucket elevator as per requirement.

2.1.5 Soaking Unit:

Soaking hopper made of stainless steel and having trapezoidal cross-section of size 600 mm long, 400 mm wide and 755 mm height was provided on the main frame of the unit just below the discharge end of bucket elevator provided on the main frame of the unit to receive the crushed sticklac discharged through bucket elevator. The side wall of the soaking hopper was inclined, in accordance with the angle of repose of crushed sticklac, for free flow of the crushed sticklac in to the soaking hopper. In order to discharge the soaked materials (crushed sticklac and water) a manually operated butter fly valve was provided just below the soaking unit at central position of the base of the soaking hopper. One end of butter fly valve was attached with bottom of the soaking hopper with stainless steel pipe having outer diameter 90 mm and internal diameter 80 mm. At the other end of butter fly valve another piece of stainless steel pipe of same diameter (internal diameter 80 mm) was provided to discharge soaked material to washing barrel of washing unit. To discharge the materials easily and churning crushed sticklac with water, a small churning mechanism was also provided at bottom portion of the soaking hopper made of stainless steel pipe of outer diameter 25.5 mm and inner diameter 20.0 mm. On the outer surface of stainless steel pipe, two pieces of stainless steel plate having length, width and thickness 30 mm, 20 mm and 5 mm were welded in opposite direction. Similar pieces of stainless steel plates were again welded at 900 having distance between sets of plates 47.7 mm. A total 10 pieces of above mentioned stainless steel plates were welded to form agitator having 5 sets of churning blades. A stainless steel shaft of diameter 19.6 mm was inserted inside the bottom portion of soaking hopper to mount churning mechanism (agitator) through nut and bolt system for fixing. The shaft was passed through oil seal provided at bottom portion of soaking hopper at both end. The shaft provided for operation of agitator below the soaking hopper was mounted on the pillow block bearing fixed at both side of outer ends of hopper on main frame. The pipe of churning mechanism (agitator) was fixed on the shaft made of stainless steel having diameter 19.6 mm through nut and bolt. Power to the churning mechanism was provided through belt and pulley arrangement with 3 hp three phase electric motor specially provided for washing unit.

2.1.6 Washing Unit:

A cylindrical washing unit (Prasad et al., 2008) made of stainless steel sheet of thickness 1.6 mm and having length 625 mm and diameter 600 mm was provided just below the gate of butter fly valve provided in the soaking unit to receive the soaked material and further churning operation inside the washing barrel. The main components of the washing unit were main shaft, agitator blade, tilting mechanism.

2.1.6.1 Main shaft:

A mild steel shaft of length 980 mm and diameter 30 mm was provided for resting inside the washing barrel having 11 agitators on which washing barrel of size 625 mm length and 600 mm diameter made of 1.6 mm thick stainless steel plate was allowed to rest. The upper portion of cylindrical hopper was having trapezoidal shaped hopper of length 390 mm, width 210 and 110 mm, respectively at top and bottom, made of 1.6 mm thick stainless steel plate. At the upper end of hopper provided on the washing barrel a flap cover made of stainless steel plate of thickness 1.6 mm was provided having perforations to cover the hopper opening during washing operation and to remove washed seedlac through opening the cover. The main shaft provided in the washing barrel was mounted on the main frame of the unit through pillow block bearing provided at both ends. The main shaft comprised of 11 agitators made of stainless steel flat and rods.

2.1.6.2 Agitator blade:

The 11 number agitator blade, made of stainless steel flat and stainless steel rod, were provided on the main shaft of washing barrel at equal distance to form helix so that stricking order for each blade should be different to reduce the load during washing operation. To make agitator blade, stainless steel flat of size 250 mm length, 41 mm width and 5 mm thickness was used. On the face of stainless steel flat, another stainless steel flat of size 80 mm length, 40 mm width and 5 mm thickness were welded. On the face of smaller piece of stainless steel flat, five stainless steel rods having length 65 mm and diameter 10 mm were welded at equal distance of 7.5 mm in parallel direction of the plate having 900.

2.1.6.3 Tilting mechanism:

A manually operated tilting mechanism was provided with washing barrel to discharge the wash water and washed seedlac easily after completion of washing operation. To make tilting mechanism, a gear having 47 teeth with diameter 195 mm and width 23.5 mm was welded on one side wall of washing barrel. The gear welded with washing barrel was matched with another small gear having 18 teeth with diameter 84 mm and width 31.6 mm. In order to provide tilting mechanism, a mild steel shaft of length 250 mm and diameter 25.25 mm was used. One end of the shaft was welded with smaller gear having teeth 18, diameter 84 mm and width 31.6 mm. At another end of the shaft, a commercially available steering wheel having diameter 450 mm was fixed for rotating washing barrel manually. The shaft of tilting mechanism was mounted on the pillow block bearing provided at the main frame of the unit.

2.1.6.4 Material receiving trough:

A rectangle shaped trough made of stainless steel plate of thickness 1.18 mm having length 1300 mm and width 660 mm was provided just below the washing barrel to receive the wash water and washed seedlac. The trough was open at one side and other three sides of the trough were closed with stainless steel plate of same thickness. Open side of the trough was fixed on the main frame of the unit at 260 mm above the ground level and other closed side was fixed at the same frame of the unit at a height 615 mm above the ground level to make the trough in slanting position for easy removal of the material (wash water and washed seedlac).

2.1.6.5 Material collection pan:

A trapezoidal shaped material collection pan made of stainless steel plate was provided below the open side of the material receiving trough to collect the wash water for disposal and washed seedlac for easy transportation from the washing unit to the drying floor made of concrete. The material collection pan was made of 1.6 mm thick stainless steel plate having length 680 mm and width 580 mm at upper portion and 490 mm and 450 mm at bottom portion with height 180 mm which confirms trapezoidal shape for easy discharge of washed seedlac. To transfer washed seedlac from one place to other place using material collection pan, commercially available wheels made of plastic and metal were welded at each corner of bottom portion of the material collection pan for easy movement to any direction.

2.2 Methodology

In order to test the performance of the developed Integrated Small Scale Lac Processing Unit, the following methodology was adopted to determine the various related parameters.

2.2.1 Material Handling Unit

In order to check the functionality of the material handling unit, the raw material (sticklac) was manually fed on the sticklac feeding trough. The fed sticklac on sticklac feeding trough was transferred in to the sticklac feeding hopper continuously through gravity flow and bucket elevator provided in the unit was operated to lift the raw material (sticklac) from sticklac feeding hopper and transfer it to sticklac receiving trough provided just below the discharge end of the elevator. After transfer of sticklac to sticklac receiving trough, the sticklac itself guided towards crushing unit through the slanting base provided in the sticklac receiving trough. The material transfer from sticklac feeding hopper to crushing unit was found to be functioning as per requirement.

2.2.2 Crushing Unit

After receiving sticklac, it was crushed in the crushing unit to make the sticklac up to desired size (8-10 mesh) and dropped on the grading unit through gravity. The crushed sticklac was graded in to two fractions (i.e. over size and desired size) and crushing capacity of the crushing unit was determined.

2.2.3 Grading Unit

Crushed sticklac received from the crushing unit was graded in two fractions (i.e. oversize and desired size). The oversize sticklac obtained from the sieve of grading unit was again transferred automatically to sticklac feeding hopper so that the oversize sticklac is again crushed in next handling and crushing process. This process was continued till whole of the sticklac crushed and graded in desired size. The grading capacity of the grading unit was determined by weighing the crushed sticklac and sticklac separately.

2.2.4 Crushed Sticklac Receiving Hopper

After conversion of sticklac in to desired size fractions, crushed sticklac was collected in crushed sticklac collection hopper from the discharge end of the crushed sticklac receiving trough provided in the grading unit. The crushed sticklac was transferred from the crushed sticklac collection hopper to soaking unit through bucket elevator provided on the unit. The crushed sticklac transfer from crushed sticklac receiving trough was found to be functioning as per requirement.

2.2.5 Soaking Unit

Transferred crushed sticklac from crushed sticklac receiving hopper through bucket elevator was soaked in desired quantity of water and churned through churning mechanism provided in the soaking unit so that proper mixing of crushed sticklac with water was done. After churning for desired duration in the soaking unit, the soaked material was transferred to washing unit through opening the butter fly valve manually provided below the soaking unit. To transfer the whole soaked material from soaking unit to washing unit, the churning mechanism was found to be useful.

2.2.6 Washing Unit

After receiving the soaked material inside the washing barrel of washing unit, the material was churned for desired duration by churning mechanism provided in the washing unit. After completion of washing operation, washed seedlac was discharged on the material receiving trough provided below the washing barrel. To discharge the washed seedlac, washing barrel was tilted in clockwise direction by rotating the circular handle provided in the washing unit manually in anticlockwise direction. The tilting mechanism provided in the washing unit was found to be useful for easy discharge of washed seedlac manually.

2.3 Performance Evaluation of the Developed Integrated Small Scale Lac Processing Unit

Performance of the developed Integrated Small Scale Lac Processing Unit was evaluated for seedlac manufacturing from sticklac. The seedlac yield, colour parameters (lightness - L, redness - a and yellowness - b) and quality parameters (flow, life, colour index, hot alcohol insoluble - impurity, acid value, moisture content and wax content) were determined for the seedlac manufactured through the developed Integrated Small Scale Lac Processing Unit. Colour parameters of seedlac manufactured through the developed unit were also determined using Hunter’s make calorimeter model LabScan XE at Processing and Demonstration Unit of ICAR - Indian Institute of Natural Resins and Gums, Ranchi and quality parameters of the same seedlac were determined as per IS: 6921 - 1973 standard in Quality Evaluation Laboratory, ICAR - Indian Institute of Natural Resins and Gums, Ranchi. During performance evaluation of the unit, time and labour required in seedlac manufacturing through the developed unit was recorded. Later on, economic analysis was also performed for the developed unit for seedlac manufacturing.

Results and Discussion

Primary lac processing operations of making seedlac from sticklac is mainly done manually through human being, is a tedious job and requires higher input of manpower, capital and time. Considering above points an Integrated Small Scale Lac Processing Unit (Capacity - 100 kg/day) was designed and developed at ICAR - Indian Institute of Natural Resins and Gums, Ranchi and fabricated at ICAR - Central Institute of Agricultural Engineering, Bhopal to reduce manpower requirement, time and drudgery of the person involved in primary lac processing. The detailed description of the performance evaluation of the developed Integrated Small Scale Lac Processing Unit for seedlac manufacturing from sticklac is as under.

3.1 Performance Evaluation of Developed Integrated Small Scale Lac Processing Unit

During the process of seedlac manufacturing from sticklac through developed Integrated Small Scale Lac Processing Unit, it was observed that the developed unit was operated easily without any problem. Different mechanisms provided in the unit (sticklac handling mechanism, crushing unit, grading unit, crushed sticklac handling unit, soaking unit and washing unit) were found working as per requirement for different unit operations of seedlac manufacturing under primary lac processing. Operator did not report any discomfort during operation of the developed unit. The performance of the developed Integrated Small Scale Lac Processing Unit was evaluated for seedlac manufacturing from sticklac. The results of seedlac yield from sticklac through the developed unit, colour parameters and quality parameters are detailed as below:

3.1.1 Seedlac Yield, Colour Parameters and Quality Parameters of Seedlac Manufactured Through Developed Integrated Small Scale Lac Processing Unit

Mean yield of seedlac manufactured from sticklac through Integrated Small Scale Lac Processing Unit was determined and found to be 70.84% by weight of sticklac with mean impurity content 2.04%. The mean seedlac yield obtained through integrated small scale lac processing unit was closer to the yield of seedlac manufactured through small scale lac processing unit of seedlac manufacturing. Mean impurity content in the seedlac manufactured through Integrated Small Scale Lac Processing Unit was found within the standard limit as detailed in **Table 1**.

Mean colour parameters (i.e. lightness - L, redness - a and yellowness - b) of seedlac manufactured from sticklac through Integrated Small Scale Lac Processing Unit was determined using Hunter's make calorimeter model LabScan XE. Mean lightness, redness and yellowness values of seedlac was 25.51, 12.06 and 9.39 for seedlac manufactured through Integrated Small Scale Lac Processing Unit and the same were 19.69, 8.44 and 5.94 for seedlac manufactured through Small Scale Lac Processing Unit, respectively.

The lightness (L), redness (a) and yellowness (b) value determined for seedlac manufactured through integrated small scale lac processing unit and small scale lac processing unit indicates that lightness (L), redness (a) and yellowness (b) of seedlac manufactured through integrated small scale lac processing unit were better compared to seedlac manufactured through small scale lac processing unit (**Fig. 2**). Higher value of lightness, redness and yellowness reveals that seedlac manufactured through integrated small scale lac processing unit was comparatively lighter than seedlac manufactured through small scale lac processing unit.

Quality parameters of seedlac manufactured from sticklac through Integrated Small Scale Lac Processing Unit were determined as per standard methods (IS: 6921-1973) in the Quality Evaluation Laboratory, ICAR - Indian Institute of Natural Resins and Gums, Ranchi to confirm the quality parameters of manufactured seedlac with the standard values as detailed in **Table 1**.

Mean flow, life under heat, colour index, hot alcohol insoluble (impurity), acid value, moisture content and wax content of seedlac manufactured through integrated small scale lac processing unit were determined to be 48.75 mm, 44.92 min, 13.83, 2.04%, 74.04, 1.48% and 4.21%, respectively.

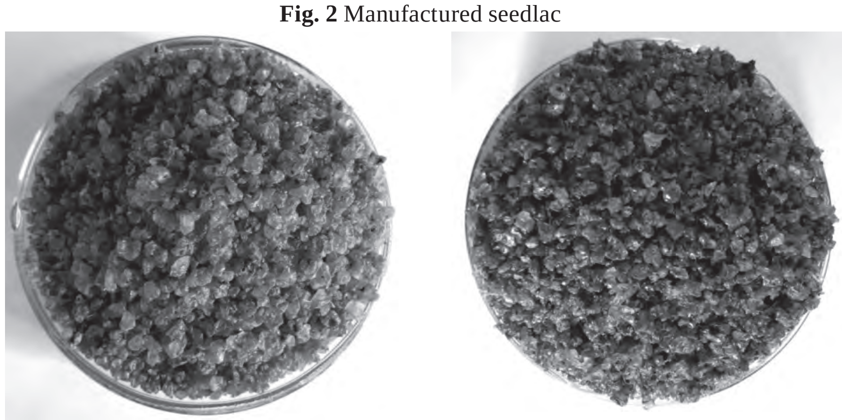
Mean flow and life under heat of seedlac manufactured through integrated small scale lac processing unit were found within the acceptable limit of buyers and sellers (**Table 1**). Average colour index of seedlac manufactured through integrated small scale lac processing unit was found within the range of acceptable limit (**Table 1**) whereas hot alcohol insoluble (impurity), acid value, moisture content and wax content were also found within the standard limits i.e. 2.0-7.0%, 65-75, 2.5% and 2.5-5.5%, respectively (**Table 1**).

3.1.2 Economic Assessment

Approximate expenditure and income analysis of Integrated Small Scale Lac Processing Unit was done at Processing and Demonstration Unit, Processing and Products Development Division, ICAR - Indian Institute of Natural Resins and Gums, Ranchi for seedlac manufacturing from sticklac. Fixed capital requirement, annual expenditure, annual income and annual profit were analyzed as detailed below.

Estimated fixed capital (building with store room, water source, working sheds, drying platform, settling tank, wash water collection pond, tube well, electrical work and machine and equipments etc.) for seedlac manufacturing from 100 kg sticklac through the developed Integrated Small Scale Lac Processing Unit and annual expenditure

Fig. 2 Manufactured seedlac



(a) Integrated small scale lac processing unit

(b) Small scale lac processing unit

Table 1 Quality parameters of seedlac manufactured through integrated small scale lac processing unit

Quality parameters	Standard values					Integrated small scale lac processing unit
	Sample No.					
	Special	A	B	C	D	
Flow, mm	Depend on Buyer's & Seller's					48.75
Life, min	Depend on Buyer's & Seller's					44.92
Colour index	8	10	12	18	30	13.83
Impurity, %	2.0-3.0	3.0-4.0	3.0-4.0	3.0-5.0	5.0-7.0	2.04
Acid value	65 -75	-	-	-	-	74.04
Moisture content, %	2.50 max	2.50 max	2.50 max	2.50 max	2.50 max	1.48
Wax content, %	2.5-5.5	-	-	-	-	4.21

(depreciation on building, machine and equipments and other works, interest on fixed capital, land charges, sticklac requirement, washing agent (caustic soda), markeen cloth, Electrical charges and salary of persons involved in primary lac processing) were analyzed to be Rs. 10 lakhs and Rs. 34,28,900 lakhs, respectively (**Table 3**). (1 US $ - Rs. 75.05)

Under machine parameters, sticklac handling capacity of bucket elevator, sticklac crushing capacity, grading capacity, crushed sticklac handling capacity of bucket elevator, soaking capacity, washing barrel capacity, washing time requirement and particle size of seedlac were found to be 900 kg/h, 675 kg/h, 900 kg/h, 720 kg/h, 60 kg/batch, 35 kg/batch, 2.0-2.5 h/batch and 8-10 mesh, respectively (**Table 2**). The size of seedlac manufactured from sticklac through the developed unit was in accordance with the specification IS: 6921-1973.

Quality parameters i.e. flow, life under heat, color index, hot alcohol insoluble (impurity), acid value moisture content and wax content of seedlac manufactured from sticklac through the developed unit were evaluated as per standard IS: 6921-1973 and found within the standard limit (**Table 1**).

Analysis for employment generation through the developed unit for manufacturing seedlac from sticklac was also determined and found to be about 300 person-days/year through the developed unit with monthly profit of about Rs. 35,000/- (1 US $ - Rs. 75.05) under primary lac processing for seedlac manufacturing from sticklac (**Table 3**).

Table 2 Machine parameters of integrated small scale lac processing unit

Parameters	Values
Sticklac handling capacity of bucket elevator, kg/h	900.00
Sticklac crushing capacity, kg/h	675.00
Grading capacity, kg/h	900.00
Crushed sticklac handling capacity of bucket elevator, kg/h	720.00
Soaking capacity, kg/batch	60.00
Washing barrel capacity, kg/batch	35.00
Washing time requirement, h/batch	2.0-2.5
Particle size of seedlac, mesh	8-10

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* Developed Integrated Small Scale Lac Processing Unit can be operated easily and different mechanisms provided in the unit were working as per requirement for different unit operations of seedlac manufacturing.

Table 3 Approximate expenditure and income analysis of integrated small scale lac processing unit

Sl. No.	Particulars	Rupees
(A) Fixed capital		
1.	Approximate expenditure on building with store room, water source, working sheds, drying platform, settling tank, wash water collection pond, tube well and electrical work etc.	6,50,000/-
2.	Approximate expenditure on machine and equipments.	3,50,000/-
	Total	**10,00,000/-**
(B) Annual expenditure		
1.	Depreciation on building and other works @5%	32,500/-
2.	Depreciation on machine and equipments @10%	35,000/-
3.	Interest on fixed capital @10%	1,00,000/-
4.	Lease charge of 0.2 ha land @Rs. 40,000/- per ha	8,000/-
5.	Sticklac 100 kg/day @₹ 100 per kg (considering 25 working days per month)	30,00,000/-
6.	Washing agent (caustic soda) 30 kg/year @Rs. 50 per kg	1,500/-
7.	Markeen cloth 10 meter @₹ 50 per meter	500/-
8.	Electrical charges for 14 KWH/day @Rs. 7 per KWH	29,400/-
9.	Salary of 1 supervisor and 1 laborer @Rs. 12,500/- and Rs. 6,000/-, respectively on monthly basis.	2,22,000/-
	Total expenditure	**34,28,900/-**
(C) Annual income		
1.	Income from sale of seedlac @Rs. 190 per kg (considering 65% seedlac yield from sticklac)	37,05,000/-
2.	Income from sale of molamma @Rs. 100 per kg (considering 7.5% molamma yield on weight of seedlac)	1,46,250/-
	Total income	**38,51,250/-**
(D) Annual profit (C − B)		**4,22,350/-**
(E) Monthly income (calculated)		**35,195.83/-**
	Monthly income (approx.)	**35,000.00/-**

(1 US $ ≈ Rs. 75.05)

* Mean seedlac yield obtained for seedlac manufactured through the developed unit was within the standard limit. All the quality parameters of seedlac manufactured from sticklac through the developed unit were found within the standard limit as per IS: 6921-1973. Lightness, redness and yellowness of the seedlac manufactured through developed unit were higher compared with seedlac manufactured through Small Scale Lac Processing Unit.
* About 300 person-days/year employment can be generated through the developed unit under primary lac processing for seedlac manufacturing from sticklac.
* The size of seedlac manufactured from sticklac through the developed unit was in accordance with the specification IS: 6921-1973.

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Design and Construction of a Farm Scale Evaporative Cooling System

by

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Abstract

Indoor temperatures especially in hot climate regions, can reach very high values in closed agricultural areas such as in greenhouses and in poultry houses in summer. This causes heat stress for animals and plants. Higher indoor temperatures can also be fatal. Thus, cooling is indispensable in those closed production structures. A smart and practical solution can be fan-pad evaporative cooling system. In this study, a farm scale fan-pad evaporative cooling system has been designed and constructed and evaporative cooling efficiency has been investigated.

Introduction

The demand for production in closed and environmentally controlled areas are increasing rapidly as the population of the world increases. Greenhouses and poultry houses are good examples of this production type. The two main factors that affect the productivity of poultry and plants are genotype and environment. However, the high quality genotypes are not beneficial unless these are raised in suitable environmental conditions. One of the most important environmental factors which directly effect the productivity is the ambient temperature. For example, the heat stress problem begins when the indoor temperatures exceed the thermo-neutral zone 15 to 25 °C for broilers. Heat stress causes some complex physiological changes in the organism of animals that negatively effect the productivity of poultry (Howlider and Rose, 1989; Kutlu et al., 1996; Leenstra and Cahaner, 1992). High air temperatures in animal houses reduces feed consumption, decreases weight gain, milk and egg yields (Al-Amri, 2000). Evaporative cooling (fan-pad and misting) systems are recommended by researches for high indoor temperature problems in poultry houses (Timmons and Gates, 1988; Wilson et al., 1983).

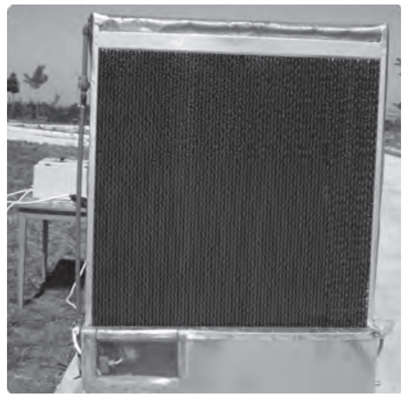
The use of evaporative cooling can be rather efficient in many cases. These methods of adiabatic cooling based on spraying of water into the incoming air through special nozzles (misting systems) or by fan pad system are being used more in practical reality. This system consists of a number of large high capacity exhaust fans located at one end or on one wall of the building and series of wet fibrous pads in a continuous section located at the opposite end or on opposite wall of the building. The experiments with different pad materials showed the possibilities of lower investment costs (Kic and Sleger, 1992; Bottcher et al., 1993; Chiumenti et al., 1996).

The objective of this study was to determine the evaporative cooling efficiency of a farm scale fan-pad cooling systems which is designed and manufactured at Samsun Ondokuz May at University Turkey. The tests were conducted at different air

Fig. 1 Farm scale fan pad cooling unit

Fig. 2 Cooling fan

Fig. 3 Cellulose based cooling pad



velocities passing through the pad material. The aim of the study was to provide practical solutions for the farmers suffering from the high indoor temperatures and engineers trying to find simple technical solution for the reduction of heat stress.

Materials and Methods

A farm scale fan pad evaporative cooling unit was designed and constructed (**Fig. 1**) in the workshop of Agricultural Machines and Technologies Engineering Department of Ondokuz Mayis University in Samsun. The tunnel-type cooling unit is 2 m long and constructed from angle iron. The outer surface is environed by a waterproof canvas. A cooling fan having 950 mm diameter (EM-30 Munters) (**Fig. 2**) was mounted at one end and a cellulose based pad (CEL dek 7060-15) to the other end of the unit. The fan had air -flow capacity of 15,000 m3/h and was driven by a 0.5 kW powered electric motor. The fan speed can be changed continuously by an electronic speed changer connected to the fan motor. The dimensions of the decay resistant pad was 1 × 1.2 × 0.1 m with 45° - 15° chamfer angles (**Fig. 3**).

Water flow rate through the pad was adjusted to 4 L/min as recommended by the manufacturer. Three different air stream velocities 1, 1.5 and 2 m/s were tested for the evaporative cooling efficiencies. An electronic data recorder device (Extech 42270) was used for all the air temperature and relative humidity readings for inside and outside conditions (**Fig. 4**). Airflow velocity through the pad material was measured by a special device (Testo AG 309). Evaporative cooling efficiency of the system is calculated by the equation, below (Timmons and Baughman, 1984; Koca et al., 1991).

$$\eta = [t_e - t_i] / [t_e - t_w] \, 100$$

Where:

η = Evaporative cooling efficiency, %,

t_e = Dry bulb temperature of air at pad entrance, °C,

t_i = Dry bulb temperature of air at pad exit, °C,

t_w = Wet bulb temperature of air at pad entrance, °C.

Cooling unit was tested during the hottest period from May to September in that region. The measurements were taken at the hottest period of the day (12:00 am - 15:00 pm) at each selected air velocity.

Results and Discussion

This study analysed the evaporative cooling efficiency of a farm scale fan-pad cooling system at

Table 1 Measured and calculated values at 1 m/s air flow velocity

Readings	t_e (°C)	Rh_e (°C)	t_w (°C)	t_i (°C)	Δt_{ei} (°C)	η (%)
May I	28.06	56.88	21.63	23.96	4.10	63.76
May II	29.97	35.66	19.20	22.59	7.38	68.52
June I	30.68	40.24	20.68	26.92	3.76	37.60
June II	29.14	51.72	21.63	24.28	4.86	64.71
June III	24.88	52.16	18.16	21.92	2.96	44.05
June IV	30.12	52.92	22.67	28.91	1.21	16.24
June V	32.79	43.60	23.03	25.94	6.85	70.18
June VI	32.05	47.79	23.29	26.67	5.38	61.42
July I	28.74	55.34	21.94	24.86	3.88	57.06
July II	31.61	43.73	22.12	25.51	6.10	64.28
July III	29.74	36.82	19.26	22.62	7.12	67.94
August I	28.29	57.03	21.85	23.97	4.32	67.08
August II	33.93	44.23	24.07	28.38	5.55	56.29
August III	30.50	39.53	20.39	25.68	4.82	47.68
August IV	29.75	45.53	20.99	24.03	5.72	65.3
August V	28.69	43.86	19.82	24.51	4.18	47.13
Sep I	28.86	55.45	22.06	22.63	6.23	91.62
Sep II	28.41	53.23	21.29	25.44	2.97	41.71
Average	29.79	47.54	21.34	24.93	4.86	57.36

Where: t_e = dry bulb temperature of outside air (°C), Rh_e = relative humidity of outside air (%), t_w = wet bulb temperature of outside air (°C), t_i = dry bulb temperature of air at pad exit (°C), Δt_{ei} = de-crease of air temperature (°C); η = evaporative cooling efficiency (%)

Fig. 4 Air temperature and relative humidity sensors

three different airflow rates. Air temperature, relative humidity and velocity of outside air and temperature of inside air were measured and then temperature decreases, wet bulb temperature of outside air and evaporative cooling efficiency were calculated. The calculated values at 1 m/s airflow velocity through the pad are given in **Table 1**. As seen from the table the average evaporative cooling efficiency was 57.36%, the highest evaporative cooling efficiency was achieved as 91.62% in September, where the lowest was in June period as 16.24%. The decrease in air temperature values provided by this system ranged from 1.21 to 7.38 °C at 1 m/s air flow velocity.

The calculated values at 1.5 m/s airflow rate through the pad are given in **Table 2**. The average evaporative cooling efficiency was 50.32%, the highest evaporative cooling efficiency was achieved as 77.80% in June, where the lowest was again in June period as 22.89%. The cooling unit provided a temperature decrease ranging from 1.83 to 8.69 °C.

The calculated values at 2 m/s airflow velocity through the pad are given in **Table 3**. As seen from the table the average evaporative cooling efficiency was 54.29%, the highest evaporative cooling efficiency was achieved as 82.09% in August, where the lowest was in July period as 25.69%. The provided temperature decrease ranged from 1.77 to 7.29 °C at 2 m/s airflow velocity.

Table 2 Measured and calculated values at 1.5 m/s air flow velocity

Readings	t_e (°C)	Rh_e (°C)	t_w (°C)	t_i (°C)	Δt_{ei} (°C)	η (%)
May I	23.59	53.97	17.36	21.76	1.83	29.37
May II	24.31	51.44	17.57	20.2	4.11	60.98
June I	24.99	55.73	18.82	22.69	2.3	37.28
June II	29.01	56.42	22.36	26.78	2.23	33.53
June III	30.22	34.09	19.05	21.53	8.69	77.8
June IV	32.23	37.77	21.35	29.74	2.49	22.89
June V	31.31	45.37	22.21	24.46	6.85	75.27
June VI	28.88	48.6	20.85	26.23	2.65	33.00
July I	31.53	43.72	22.05	25.71	5.82	61.39
July II	27.96	54.05	21.06	25.94	2.02	29.28
July III	30.79	48.57	22.41	26.02	4.77	56.92
August I	32.57	38.57	21.78	27.01	5.56	51.53
August II	28.06	46.52	19.81	23.79	4.27	51.76
August III	28.12	53.65	21.12	24.35	3.77	53.86
August IV	25.51	52.35	18.72	22.25	3.26	48.01
August V	29.16	37.02	18.86	23.95	5.21	50.58
Sep I	30.91	45.13	21.84	24.74	6.17	68.03
Sep II	27.28	49.06	19.63	22.36	4.92	64.31
Average	28.69	47.34	20.38	24.42	4.273	50.32

Where: t_e = dry bulb temperature of outside air (°C), Rh_e = relative humidity of outside air (%), t_w = wet bulb temperature of outside air (°C), t_i = dry bulb temperature of air at pad exit (°C), Δt_{ei} = de-crease of air temperature (°C); η = evaporative cooling efficiency (%)

Evaporative cooling efficiency of the system ranged approximately among 16-91% during the total hot May-September period. The unit provided a temperature decrease in the inside air up to 9 °C against hot outside air that is important enough for the animals and plants. These results were in agreement previous literature studies on evaporative cooling pad systems (Dzivama et al., 1999; Helmy et al., 2013; Dayıoglu and Silleli, 2015; Han et al., 2018). All calculated results of evaporative cooling efficiency η (%) are summarized as a function of outside air temperature te (°C) in the **Fig. 5**. There is obvious tendency of the increased evaporative cooling efficiency with growing temperature of external air.

The system best performed in September period because of the lower relative humidity values at outside air. Evaporative cooling efficiency η (%) as a function relative humidity Rhe (%) of outside air presented in the **Fig. 6** is slowly decreasing with growing relative humidity. Previous studies always stressed that the fan-pad evaporative cooling systems performs very well till the outside air relative humidity values exceed 75%. If the region has more than 75% of relative humidity at outside air, then it's recommended to cool down the ambient without wetting the pads just exchanging the inside air rapidly with cooling fans. Another solution can be applying lesser amounts of water flow up to 2 L/min, through the pad.

Conclusions

The present study analysed the evaporative cooling efficiency of a farm scale fan-pad cooling system

Fig. 5 Evaporative cooling efficiency η (%) as a function of outside air temperature t_e (°C)

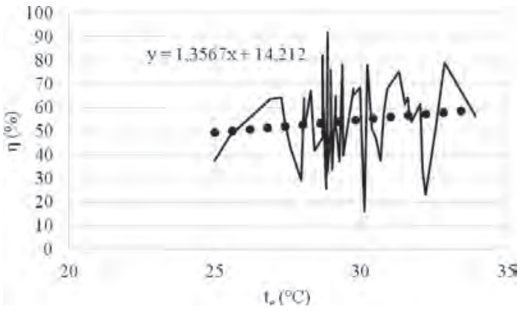
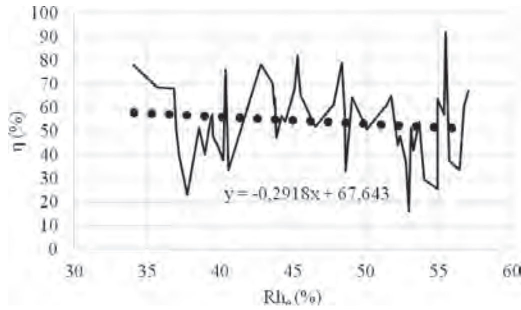


Fig. 6 Evaporative cooling efficiency η (%) as a function relative humidity Rh_e (%) of outside



at varying airflow rates. A mobile and relatively small fan-pad cooling unit was designed and manufactured for farm scale. The system was tested from May to September during the hottest period of the region and all the measurements were taken at the hottest period of the day (12:00 am - 15:00 pm) at each selected air speed. Evaporative cooling efficiency and provided temperature decrease at inside air were calculated from inside and outside air conditions. Best results were taken at 1 m/s of air flow velocity. This is in line with the results of a research done by (Dagtekin et al., 2011). The cooling system gave promising results by achieving 91% of evaporative cooling efficiency. The highest evaporative cooling efficiencies were achieved in the hottest period of the day that is in the 12:30 pm - 14:40 pm time interval. After all, it is recommended to operate this system during periods when the air temperature is high in summer and the air-humidity is low in order to get more efficiency from fan-pad cooling system. Also higher water flow rates than 4 L/min can be applied in dry areas. In conclusion, it is observed that the fan-pad cooling system is effective in removing excessive heat from the interior. Additional researches of this kind are important not only for enhancing the quality and quantity of scientific data, but also as a means of focusing farmers and public attention on this matter.

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Table 3 Measured and calculated values at 2 m/s air flow velocity

Readings	t_e (°C)	Rh_e (°C)	t_w (°C)	t_i (°C)	Δt_{ei} (°C)	η (%)
May I	29.41	37.22	19.09	25.34	4.07	39.44
May II	28.78	38.95	18.95	24.82	3.96	40.28
June I	30.38	50.07	22.36	26.31	4.07	50.75
June II	28.97	40.36	19.38	21.68	7.29	76.02
June III	27.37	39.37	17.95	22.18	5.19	55.10
June IV	32.13	40.57	21.87	28.68	3.45	33.63
June V	29.14	53.09	21.88	25.41	3.73	51.38
June VI	28.82	54.91	21.93	27.05	1.77	25.69
July I	29.27	52.71	21.92	26.54	2.73	37.14
July II	32.87	48.35	24.08	25.93	6.94	78.95
July III	31.74	44.47	22.37	26.7	5.04	53.79
August I	28.96	39.20	19.14	24.03	4.93	50.20
August II	28.72	56.71	22.16	24.74	3.98	60.67
August III	31.68	39.47	21.29	25.76	5.92	56.98
August IV	28.69	45.30	20.09	21.63	7.06	82.09
August V	27.59	39.86	18.21	23.54	4.05	43.18
Sep I	29.38	42.81	20.17	22.17	7.21	78.28
Sep II	26.91	54.92	20.32	22.71	4.20	63.73
Average	29.49	45.46	20.73	24.73	4.755	54.29

Where: t_e = dry bulb temperature of outside air (°C), Rh_e = relative humidity of outside air (%), t_w = wet bulb temperature of outside air (°C), t_i = dry bulb temperature of air at pad exit (°C), Δt_{ei} = de-crease of air temperature (°C); η = evaporative cooling efficiency (%)

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ERRATA

There was a typographical error on the book spine of AMA Vol.51 No.1
Correct as below:

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Development and Performance Evaluation of Tractor Drawn Cultivator Cum Spike-Roller

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Abstract

Seed bed preparation for sowing / planting of different crops is done through primary and secondary tillage operations. Clod breaking operation is required to produce a granular soil structure in the final seed bed. Clod formation subsequent to ploughing or disking is a major problem in Gujarat. Therefore the cultivator cum spike-roller development is essential for tillage as well as clod crushing, it reduces time and saves money.

The spike-tooth roller was developed to break the clods and to develop the seed bed having fine land levelled tilth. The spike-roller consisted of a mild steel roller of 1800 mm length and 325 mm base diameter on which mild steel flat spikes of 50 × 25 × 6 mm length were welded outside its periphery in helical pattern. Total width of spike-roller was 425 mm, flat spikes welded in 14 rows (20 and 21 in each row alternatively). ‘The spike-roller was attached at the back of the cultivator. The weight of the roller is 150 kg but it could be increased up to 350 kg by filling the sand inside the hollow roller.

The completely randomized design (CRD) was used to formulate the design of the experiment. The observations were recorded before and after the operations.. Properties like soil moisture content (db, %), bulk density of soil (g/cc), mean mass diameter of clods (mm), speed of operation (km/h), fuel consumption (L/ha), field capacity (ha/h) and cost of operation ($/ha) were calculated. The moisture content, bulk density, and forward speed were found significant and the results are at par. The fuel consumption was observed significantly less in cultivator cum spike-roller as compared to other operations. The significant MMD of soil reduced in rotavator and cultivator cum spike-roller as compared to control and cultivator with blade harrow.

The total cost of operation per hectare was $20.79, 22.00, 13.60 and 53.88 for cultivator (control), rotavator, cultivator cum spike-roller, cultivator (cross) and blade harrow respectively. The saving in operating cost per hectare was worked out 59.17% and 74.76% for rotavator and cultivator cum spike-roller respectively as compared to cultivator two times (cross) and blade harrow once. The MMD of clod has been found less, while field capacity slightly more and cost of operation was also found low in case of developed spike-roller among others. The all over best result found in case of developed cultivator cum spike-roller as compared to other treatments.

Keywords: Spike-roller, Clod Crusher and Cultivator.

Introduction

India is vast and agriculture-based country. The total geographical area of the country is 329 million hectares, of which 142 million hectares is the reported net sown area. The net sown area works out to be 43% of the total geographical area. The gross cropped area increased to about 189.5 million hectares. The farm holdings in India are classified as: (a) marginal (< 1 ha), (b) small (1-2 ha), (c) semi medium (2-4 ha), (d) medium (4-10 ha), (e) large (> 10 ha).

The tillage operations defined as

mechanical manipulation of soil performed to achieve the desired seedbed to provide optimum environment of seeding germination and plant growth. Seedbed preparation for sowing / planting of different crops is done through primary and secondary tillage operations. Clod breaking operation is required to produce a granular soil structure in the final seedbed. Tine cultivator and disc harrow are used for breaking of clods (Maheshwari et al., 2005). Generally, these are operated after one pass of mouldboard plough or ridger plough. Direct harrowing or cultivator operation is also performed when the fields are clean and free from plant residues of previous crop. The land development, tillage and seedbed preparation together account for a major share of power utilization in the crop cycle (Patil et al., 2009). Clod crushers, patela harrow, etc. are very effective for clod crushing under favourable soil moisture conditions but their effect is confined to soil surface only. Power driven implements like rotavator disintegrate the clods over a wide range of soil moisture and provide uniform and fine size clods or aggregates in seedbed (Kulsuma et al., 1974).

Operation of tools with narrow tines such as comb harrow and spike tooth harrow, in loosened soil, produces a sorting effect, brings larger clods and aggregates on surface. The sorting effect increases with increasing forward inclination of tines and share width and decreasing speed and soil moisture. Large size clods on the surface are recommended because of their stability under rainfall, which helps in reducing soil erosion. Clod breaking strength may be defined as the energy required for breaking the clods into fine tilth. In simple words, it refers to the friability of clods. Some idea about clod friability may be obtained by crumbling soil in hand, but it is a qualitative approach. Quantitative measurements are needed to compute energy requirements to prepare seedbeds (Sharma and Bhagat, 1993).

Clod formation subsequent to ploughing or disking is a major problem in Gujarat. Clods create obstruction to penetration of furrow openers of seed drill and do not allow intimate contact between seeds and soil. Pulverization of clods is necessary to avoid the above problems (Agrawal and Singh, 1988). The farmers usually perform 4 to 5 tillage operations i.e. ploughing, harrowing, clod crushing by land roller or planking for obtaining a desirable tilth for seedbed. All these operations are time consuming and expensive (Anonymous, 2017). The reductions in yield have been reported from 0.3 to 0.5 tones/ha/week in case of wheat when it is sown late after first week of December (Singh and Gupta, 1987). The above problem could be alleviated by developing a suitable combination of tillage tools, which can combine a few of tillage operations in a single pass. A planker is used either in combination with cultivator or independently for breaking of clods and consolidation of seedbed. A planker, however, is not very effective in breaking of clods because it presses hard clods into the soil without proper disintegration (Hann and Heather, 1992).

Looking to the present practice of seed bed preparation among the farmers and implements used to perform different operations, there is need to study the best alternative, either operation wise or equipment wise, by which we can reduce the time, cost of operation, and improves the efficiency of the system. Therefore the cultivator cum spike-roller development is essential for tillage as well as clod crushing, it reduces time and saves money.

Materials and Methods

Design of Spike-roller Attachment to Cultivator

The spiked tooth roller was designed and developed by the Department of Farm Engineering, College of Agriculture, JAU, Junagadh (Gujarat). A clod crusher attachment to the cultivator was developed to ensure timeliness in seedbed preparation. It consists of a frame with cultivator tines, spike tooth clod crusher, framework to mount roller and three-point linkage unit.

The working principle behind the clod crusher attachment to cultivator which is having clod crusher as active unit behind the implement and in front cultivator tines are attached as passive unit. Cultivator tines opened the furrow and spike tooth roller helped in cutting and pulverizing the soil at optimum tillage for seed bed preparation. Spike-roller breaks the clod and converts into small size of the soil particles.

Design Considerations:

The components of clod crusher attachment to cultivator were designed and fabricated based on the parameters like functional requirements, engineering and general considerations.

Assumptions Considered in Design

The assumptions made in the design of pulverizing attachment to cultivator are as follow:

1. Average speed of operation of tractor in the field was in range of 2.5 to 3.5 km/h during field testing.
2. Maximum soil resistance was considered as 0.75 kg/cm^2.
3. A seven or nine-tine cultivator having spacing 22.5 cm and working depth 15 cm was considered.

General Considerations

The machine should be simple in design, safe in operation and should have sufficient power requirement compatible with 35-45 hp tractor. It should cut the uniform furrow slice and be converted into small size of soil particles. It should be cost wise cheaper as far as possible. At the same time, it should be strong enough and durable.

Assessment of Draft and Power Requirement

The draft requirement of the tractor operated clod crusher attachment to cultivator would be estimated using factors related to implement and the type of soil. The specific soil resistance of medium black soil of this area was considered as 0.75 kg/cm^2 (Kepner et al., 2005).

Total working width of cultivator = No. of tine × tine spacing = 9 × 22.5 = 202.5 cm = 2.025 m

Cross section area of 7 furrows = 202.5 × 15 = 3,038 cm^2

Maximum draft = 2370 × 0.75 = 2,278 kg (22.6 kN)

Speed of travel = 3.5 km/h = 3,500 m/h =0.972 m/s. The power required for the designed draft was estimated using formula suggested by (Kepner et al., 2005)

Total power required, hp = [Draft (kg) × Speed (m/s)] / 75 = [2278 × 0.972] / 75 = 29.52 hp (22kW)

Design of Functional Components of Spike-roller Attachment to Cultivator

The detailed design of the components and different mechanisms were carried out. The machine consists of frame, cultivator tines, clod crusher. The design of following components was taken up:

Selection of Cultivator

Seven or nine tynes cultivator is much popular implement used as primary as well as secondary tillage operation and it requires relatively less power per meter of width in these conditions. Frame was made by 50 mm × 50 mm × 5 mm hollow square M.S. square section with sufficient strength to withstand various forces acting on it. It was used to extract the clod from the soil.

Design of Spike-roller

A clod crusher behind the cultivator was provided to break the clods and to develop the seed bed having fine land levelled tilth. The spike-roller consisted of a mild steel roller of 1,800 mm length and 325 mm base diameter on which mild steel flat spikes of 50 × 25 × 6 mm length were welded in helical pattern. Total width of spike-roller was 425 mm, having 14 rows of flat spiked having 20 and 21 in each row alternatively. The spike-roller with attachment has an approximate weight of 150 kg. Weight can be increased up to 350 kg by filling the sand inside the hollow roller for proper working. Design of flat-spike-roller is shown in **Fig. 1a-d** and specifications are given in **Table 1** respectively.

Experimental Procedure:

Experimental details :

(1) Treatments - 4: Cultivator - 2 times (cross) and blade harrow once, Rotavator, Cultivator cum spike-roller, Control (Cultivated),

(2) Experimental design: Large plot technique,

(3) Number of samples: 05 / treatment,

Fig. 1 Developed tractor drawn cultivator cum spike-roller

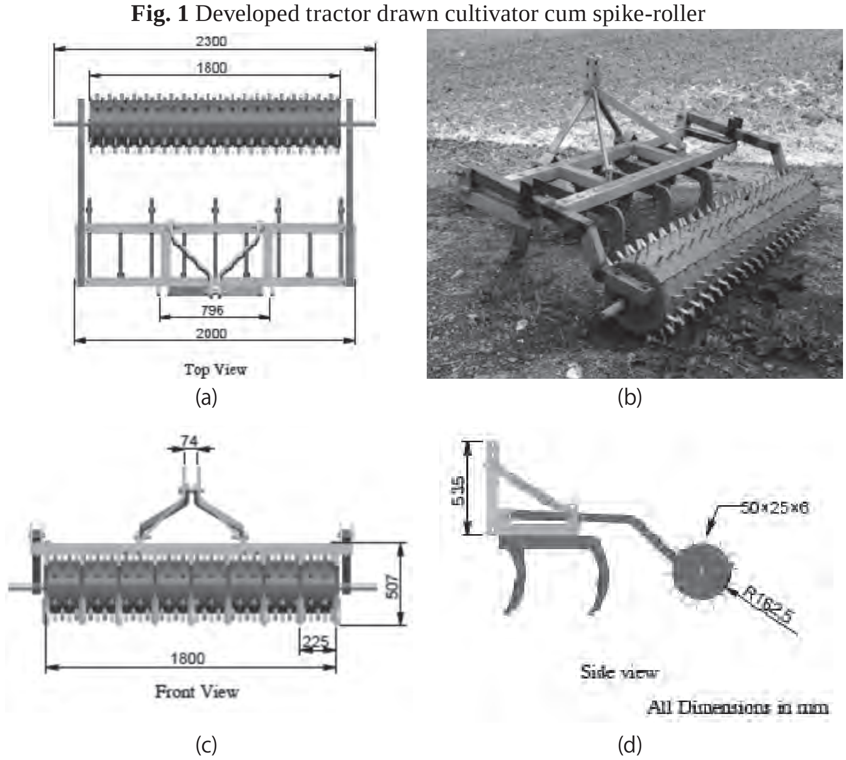

Fig. 2 Detailed layout of field test plot

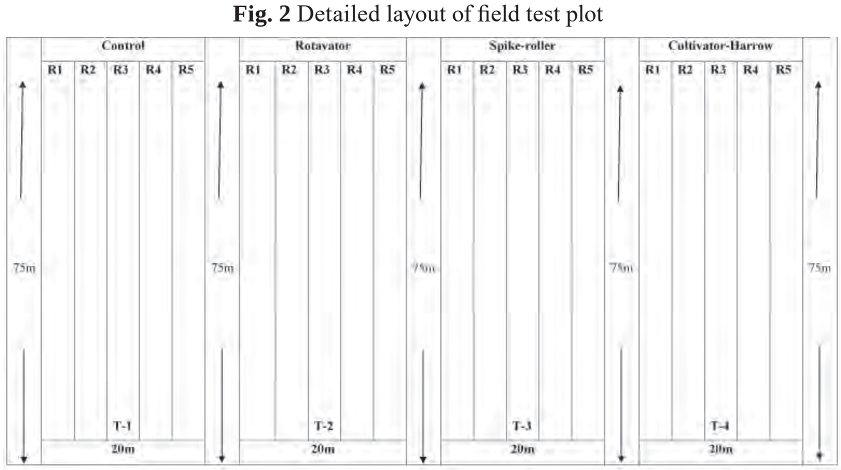

Table 1 Design specifications of spike-roller

Sl. No.	Particulars	Dimensions
1	Diameter of axle rod, mm	50.8
2	Length of axle rod, mm	2,300
3	Length of roller, mm	1,800
4	Base diameter of roller, mm	325
5	Size of flat spike, mm	50 × 25 × 6
6	Total number of spikes rows	14
7	Row to row spike distance, mm	78.5
8	Distance between two spike, mm	90.0
9	Total number of spikes on roller	287
10	Diameter of spike-roller, mm	425

Table 2 Soil moisture content of different treatments, db, (%)

Sl. No.	Treat-ments	R1	R2	R3	R4	R5	Av.
1	T1	15.95	15.70	15.80	15.85	15.75	**15.81**
2	T2	15.25	15.30	15.35	15.20	15.40	**15.30**
3	T3	15.15	15.10	15.00	15.05	15.20	**15.10**
4	T4	14.75	14.75	14.85	14.90	14.95	**14.84**

(4) Plot size: (75 × 20) m. and

(5) Sample size: (75 × 4) m

Observations to be recorded:

Initial soil observations: Soil moisture content (db, %), Bulk density of soil (g/cc), Cone index of soil (kg/cm^2), Mean mass diameter of clods (mm)

After operation:- Soil moisture content (db, %), Bulk density of soil (g/cc), Cone index of soil (kg/cm^2), Mean mass diameter of clods (mm), Speed of operation (km/h), Fuel consumption (l/ha), Field capacity (ha/h) and Cost of operation ($/ha)

Fig. 3 Control (cultivated)

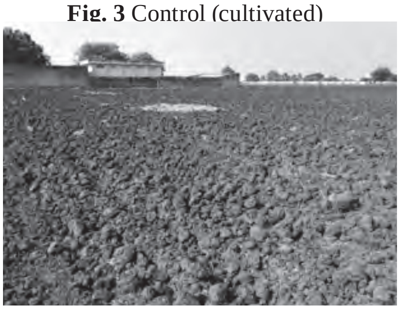

Fig. 4 Operation of rotavator

The developed spike-roller has suitable arrangements for mounting on a nine or seven tynes cultivator. The developed spike-roller comprised of two floating arms of mild steel box section of 60 × 60 × 6 mm size with 1,000 mm length. At the lower end of floating arms, pedestal with bearing was fitted by nuts and bolts. In between floating arms, the spike-roller is mounted on bearings to get uniform rolling action in the field. Both cultivator and spike-roller are attached together as a single unit. Most of the farmers' have nine tines cultivator with effective width 1,800 mm (225 mm × 8). Therefor the width of the spike-roller was selected 1800 mm. For taking benefit of overlap during cultivation and clod crushing, the effective width of cultivator was also reduced by reducing the number of tynes from 9 to 7 and by keeping the spacing of 225 mm between two tynes (Mehta et al., 1995).

Before the field operation, some of the physical observations were taken. The developed roller filled at 1/4th, 1/2nd, 3/4th and full with sand and evaluated the performance. The best result found at roller fully filled with sand, therefore, all data taken at fully filled with sand. All the four treatments were performed in the field, the detailed field layout of testing plot is given in **Fig. 2**. The testing procedure carried out during different field operation according to treatments is shown in **Figs. 3-6**.

The five samples were collected in each treatment for getting moisture content, bulk density, cone index, clod mean mass diameter, forward speed of operation and fuel consumption are given in **Tables 2-6**. The field capacity and cost of operation during different operations were calculated and are given in **Tables 7-8**. The bulk density by core sampler (**Figs. 7-8**) and cone index of soil in each treatment measured with the help of cone penetrometer. Figure showed the mean mass diameter of soil aggregates measured by standard procedure as given in BIS Test Code for Harrow. All the field observations were taken and operational cost was compared within the treatments (**Tables 9-10**).

Fig. 5 Operation of cultivator – 2 times (cross) and blade harrow once

Fig. 6 Operation of cultivator cum spike-roller

Table 3 Soil bulk density of different treatments, g/cc

Sl. No.	Treat-ments	R1	R2	R3	R4	R5	Av.
1	T1	1.400	1.300	1.350	1.370	1.320	**1.348**
2	T2	1.265	1.295	1.345	1.245	1.315	**1.293**
3	T3	1.245	1.225	1.325	1.275	1.295	**1.273**
4	T4	1.290	1.270	1.320	1.370	1.340	**1.318**

Table 4 Clod mean mass diameter of different treatments, mm

Sl. No.	Treat-ments	R1	R2	R3	R4	R5	Av.
1	T1	20.789	25.408	24.521	25.901	24.137	**24.15**
2	T2	17.916	16.394	11.144	13.948	9.825	**13.85**
3	T3	7.747	13.051	10.295	12.572	8.429	**10.42**
4	T4	16.815	17.849	14.263	17.956	14.083	**16.19**

Table 5 Forward speed in different treatments, km/h

Sl. No.	Treat-ments	R1	R2	R3	R4	R5	Av.
1	T1	2.560	2.580	2.570	2.565	2.585	**2.572**
2	T2	2.260	2.265	2.250	2.240	2.245	**2.252**
3	T3	2.995	2.989	2.999	3.015	3.009	**3.001**
4	T4-1	2.560	2.580	2.570	2.565	2.585	**2.572**
5	T4-2	3.180	3.190	3.175	3.155	3.170	**3.174**
Av.		2.870	2.885	2.8725	2.86	2.8775	**2.873**

Table 6 Fuel consumption in of different treatments, l/h

Sl. No.	Treat-ments	R1	R2	R3	R4	R5	Av.
1	T1	4.150	3.850	4.050	4.250	3.900	**4.040**
2	T2	4.185	4.105	4.125	4.185	4.105	**4.141**
3	T3	3.745	4.125	3.945	3.755	4.135	**3.941**
4	T4-1	4.150	3.850	4.050	4.250	3.900	**4.040**
5	T4-2	3.550	3.600	3.750	3.850	3.950	**3.740**
Av.		3.850	3.725	3.900	4.050	3.925	**3.890**

Results and Discussion

The empty weight of spike-roller was 150 kg which was not suitable for working effectively for clod breaking, therefore sand was filled in hollow portion of roller through its side window. About 200 kg of sand was filled in the hollow roller so that total weight of the roller became 350 kg for effective working in the field.

The dry basis moisture content of soil from its initial level of 15.81% was slightly reduced to approximately 15.30 %, 15.10 % and 14.84 % after operation of rotavator, cultivator cum spike-roller and cultivator two times (cross) & blade harrow once respectively. The moisture content of soil at different treatments in the field found at par.

The dry bulk density of soil from its initial level of 1.348 g/cc, reduced to approximately 1.293, 1.273 and 1.318 g/cc after the field operation of rotavator, cultivator cum spike-roller and cultivator two times (cross) & blade harrow once respectively. The bulk density significantly reduced in case of rotavator and cultivator-cum-spiked-roller as compared to cultivator and blade harrow.

The cone index of soil from its initial level of 5.60 kg/cm^2 reduced to approximately 4.70 kg/cm^2, 4.45 kg/cm^2 and 5.43 kg/cm^2 after operation of rotavator, cultivator cum spike-roller and cultivator two times (cross) & blade harrow once respectively. The significant cone index of soil reduced in rotavator and cultivator cum spike-roller as compared to cultivator and blade harrow. The cone index of soil significantly reduced in cultivator-cum-spike-roller as compared to rotavator.

For finding out the index of soil pulverization at different treatments, five soil samples were collected in each treatment and calculated the mean mass diameter (MMD) by sieve shaker having sieve sizes 11.2, 8.0, 5.6, 4.0, 2.8, 2.0 mm. as per standard procedure. The collected samples were analyzed according to Indian Standard Test Code for Disc Harrows. (IS:7640, 1975)

The mean mass diameter (MMD) of soil from its initial level of soil aggregate is 24.15 reduced to approximately 13.85, 10.42 and 16.19 mm after operation of rotavator, cultivator cum spike-roller and cultivator two times (cross) & blade harrow once respectively. The significant MMD of soil reduced in rotavator and cultivator-cum-spiked-roller as compared to control and cultivator with blade harrow. The significant MMD of soil reduced in cultivator cum spiked-roller as compared to rotavator.

The forward speed of operation was measured and average value was found in the tune of 2.572, 2.252, 3.001 and 2.873 km/h for operation with cultivator (Control), rotavator, cultivator cum spike-roller, cultivator (cross) and blade harrow respec-

Fig. 7 Measurement of bulk density

Fig. 8 Sample collection for mean mass diameter (MMD)

Table 7 Field capacity of different treatments, ha/h

Sl. No.	Treat-ments	R1	R2	R3	R4	R5	Av.
1	T1	0.405	0.406	0.405	0.404	0.407	**0.4054**
2	T2	0.362	0.362	0.360	0.358	0.359	**0.3602**
3	T3	0.539	0.538	0.540	0.543	0.542	**0.5404**
4	T4	0.487	0.492	0.488	0.485	0.489	**0.4882**

Table 8 Cost of operation for different treatments, $/h

Sl. No.	Treat-ments	R1	R2	R3	R4	R5	Av.
1	T1	6.83	6.46	6.71	6.95	6.54	**6.70**
2	T2	7.16	7.06	6.93	6.76	6.71	**6.92**
3	T3	6.40	6.81	6.56	6.32	6.69	**6.55**
4	T4	6.46	6.32	6.54	6.71	6.56	**6.50**

tively. The forward speed of the operation was observed significantly more in cultivator cum spike-roller as compared to rotavator and cultivator. The effect of wheel slip during operation of different implements was observed and found within the range. During the testing it was observed that draft requirement was at par for the operation with spike-roller as compared to cultivator.

The fuel consumption per hour was calculated 4.040, 4.140, 3.940 and 3.890 L/h. for operations like cultivator (control), rotavator, cultivator cum spike-roller, cultivator (cross) and blade harrow respectively. The fuel consumption was observed significantly less in cultivator cum spike-roller as compared to other operations considered in the study.

The total cost of operation per hectare is 20.79, 22.00, 13.60 and $ 53.88 for cultivator (Control), rotavator, cultivator cum spike-roller, cultivator (cross) and blade harrow respectively. The saving in the cost of operation per hectare was worked out 59.17 % and 74.76 % for rotavator and cultivator cum spike-roller respectively as compared to cultivator two times (cross) and blade harrow once. All the data were analysed in CRD and presented in **Table 11**. The moisture content, bulk density, forward speed and fuel consumption were found significant in case of cultivator cum spike-roller.

The mean values of clod mean mass diameter of all the four treatments were compared. It shows that clod mean mass diameter of 24.15, 13.85, 10.42 and 16.19 mm was observed corresponding to the Control, rotavator, spike-roller and blade harrow respectively.

The field capacity and cost of operation was calculated in each treatment and given in **Table 12** that shows the data comparison between MMD, field capacity and cost of operation. The MMD of clod found less, field capacity slightly more and cost of operation less in developed spike-roller among others treatments. The overall significant result was found in cultivator cum spike-roller as compared to other treatments.

Conclusions

The developed cultivator cum spike-roller is very useful for seed bed preparation. The moisture content, bulk density, cone index and forward speed were found significant and the results are at par. The fuel consumption was observed

Table 9 Field observation of cultivator cum spike-roller

Plot No.	Treat-ments	Moisture content db (%)	Bulk density (g/cc)	Average clod MMD (mm)	Speed of operation (km/h)	Fuel consumption (l/h)	Width of implement (m)	Theoretical field capacity (ha/h)	Actual field capacity (ha/h)	Field efficiency (%)
1	T1	15.81	1.348	24.151	2.572	4.040	1.575	0.405	0.322	79.75
2	T2	15.30	1.293	13.845	2.252	4.140	1.600	0.360	0.315	85.50
3	T3	15.10	1.273	10.419	3.001	3.940	1.800	0.540	0.482	89.25
4	T4	14.84	1.318	16.193	2.572 3.174	4.040 3.740	1.575 1.800	0.405 0.571	0.322 0.514	79.75 90.00
Average					**2.873**	**3.890**	1.688	0.488	0.418	84.88

Treatments: T1 - Control (Cultivated), T2 - Rotavator, T3 - Spike-roller, T4 - Cultivator and Blade harrow

Table 10 Operational cost comparison of different operation

Plot No.	Treat-ments	Fuel consumption (l/h)	Operating cost of tractor ($/h)	Operating cost of implement ($/h)	Total operating cost ($/h)	Actual field capacity (ha/h)	Total operating cost per hectare ($)	Total operation cost per hectare ($)	Saving ($/ha)	Saving (%)
1	T1	4.040	6.61	0.08	6.70	0.322	20.79	20.79	---	---
2	T2	4.140	6.73	0.18	6.92	0.315	22.00	22.00	31.88	59.17
3	T3	3.940	6.50	0.06	6.55	0.482	13.60	13.60	40.28	74.76
4	T4	4.040 3.740	6.61 6.25	0.08 0.06	6.70 6.32 6.50	0.322 0.514	20.79 12.30	41.58 12.30 total 53.88	---	---

Treatments: T1 - Control (Cultivated), T2 - Rotavator, T3 - Spike-roller, T4 - Cultivator and Blade harrow significantly less in cultivator cum spike-roller as compared to other operations. The significant MMD of soil reduced in cultivator cum spike-roller and rotavator as compared to other operations. It saves 74.76% cost of operation as compared to traditional method.

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LIST OF SYMBOLS USED

Sl. No.	Symbols	Abbreviations
1	%	Per cent
2	$/ha	Dollar per hectare
3	BIS	Bureau of Indian Standard
4	cm	centimeter
5	COA	College of Agriculture
6	CRD	Completely Randomized Design
7	db	dry basis
8	g/cc	gram per cubic centimeter
9	ha/h	hectare per hour
10	hp	horse power
11	JAU	Junagadh Agricultural University
12	kg	kilogram
13	kg/cm^2	kilogram per square centimeter
14	km/h	kilometer per hour
15	L/ha	liter per hectare
16	<	less than
17	>	greater than
18	m	meter
19	mm	millimeter
20	MMD	Mean Mass Diameter
21	m/s	meter per second
22	MS	Milled steel
23	R	Replication
24	s	second
25	T	Treatment

Table 11 Analyzed data for all the treatments as CRD

Plot No.	Treat-ments	Moisture content db (%)	Bulk density (g/cc)	Mean mass diameter (mm)	Forward speed (km/h)	Fuel consumption (l/h)
1	T1	15.81	1.348	24.15	2.572	4.040
2	T2	15.30	1.293	13.85	2.252	4.240
3	T3	15.10	1.273	10.42	3.001	3.840
4	T4	14.84	1.318	16.19	2.873	3.890
S.E.M.		0.0386	0.0177	1.1164	0.0039	0.0591
C.D.		0.1156	0.0531	3.3470	0.0117	0.1773
C.V.		0.5651	3.0293	15.4555	0.3218	3.3140

Treatments: T1 - Control (Cultivated), T2 - Rotavator, T3 - Spike-roller, T4 - Cultivator and Blade harrow

Table 12 Comparison between MMD, Field capacity and Cost for different treatments

Plot No.	Treat-ments	Mean mass diameter (mm)	Field capacity (ha/h)	Cost of operation ($/h)	Remarks
1	T1	24.15	0.4054	6.70	
2	T2	13.85	0.3602	6.92	
3	T3	10.42	0.5404	6.55	Less MMD, More F.C. and Less Cost
4	T4	16.19	0.4852	6.50	
S.E.M.		1.1164	0.0007	5.8400	
C.D.		3.3470	0.0022	17.5082	
C.V.		15.4555	0.3703	2.7858	

Treatments: T1 - Control (Cultivated), T2 - Rotavator, T3 - Spike-roller, T4 - Cultivator and Blade harrow

Development of Mat Nursery Raising and Uprooting Techniques for Paddy (*Oryza Sativa* L.) Crop and Their Field Evaluation with Mechanical Transplanter for South East Asia

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Abstract

The increasing wages, shortage of labour, marginal profits to farmers are increasing in paddy cultivation as well as in other agricultural crops in South East Asia. Mechanization of raising and transplanting operation of paddy seedlings are the solutions to these problems. This study aims at developing a mat type nursery raising and uprooting techniques for paddy crop so as to suit commercially available mechanical transplanter. Three different mat type nursery treatments were raised on 60 gauge perforated polythene sheet and with three different sources of irrigation involving drip (T_1), sprinkler (T_2) and flood irrigation system (T_3). The other treatments of nursery were raised on field soil only (T_5), mushroom waste material as soil filling on polythene sheet (T_6), on wheat straw (T_4), paddy straw (T_7), chopped paddy straw (T_8), and cloth paper (T_9) as a separator instead of polythene sheet, all using soil as nursery raising material using flood irrigation system. Different nursery uprooting techniques were applied. A manual nursery cutter was also developed and used for uprooting treatments T_4 and T_5. Nursery treatments T_1, T_2, T_3 and T_4 were manually uprooted after making a cut in soil with sickle. The uprooted mats were transplanted in puddle field condition using six row four wheel drive paddy transplanter. The mean paddy grain yield was highest in treatment T_4 followed by T_5 which gave values of 3,129.09 kg.acre^{-1} and 2,922.98 kg.acre^{-1}, respectively. Out of flood, sprinkler and drip irrigation systems, the flood irrigation treatment on polythene sheet (T_3) recorded the highest grain yield value of 2,833.08 kg.acre^{-1}. The benefit-cost ratio was highest in treatment T_4 (wheat straw + soil) with a value of 1.92 and for treatment T_5 (field soil only) it was 1.80. The use of field soil as base material for raising mat type nursery with flood irrigation system increased the paddy grain yield when compared with the treatments raised on polythene sheet and uprooting with manual nursery cutter proved to be a more economical and comfortable uprooting technique when compared with other treatments.

Keywords: paddy, mat type nursery, wheat straw, mechanical transplanter, weight, forward speed, yield

Introduction

Mechanization increases land productivity by timely completion of farm operations. It increases labour productivity and reduces human and animal drudgery. It increases production by precision and efficient placement of inputs such as seed, fertilizer, chemicals and irrigation water. Mechanization decreases the cost of production by reducing labour needed for particular operation and economy of power and other inputs. Rice (*Oryza sativa* L.) is the major staple food for more than half of the global population and considered as the "global grain". About 90% of rice grown in the world is produced and consumed only in Asian countries and it supplies 50 to 80% calories of energy to Asians. Rice is grown under wide range of latitudes and altitudes and is the anchors of food security in the world with challenges of climate change (Anonymous, 2008). Total estimated area under rice production in the world is about 161.1 million hectares (Anonymous, 2016a) with a production of milled rice as 480.3 million metric tons (Anonymous, 2016b). India ranks second in the production of rice; which is grown in almost all the states in India. Total estimated area under rice in India is 44.40 million hectares with a production of 104.32 million metric tons. To meet the food demands of the growing population and to achieve food security in the country, the present production levels need to be increased by two million metric tons every year. It is estimated that 120 million metric tons of rice is required to feed the growing population by 2020. To get higher yields, transplanting of healthy and vigorous seedlings is the pre-requisite needed to produce uniform stand with higher yield than direct seeded rice. Transplanting is done manually, which is tough and involves enormous drudgery and human stress in sweltering weather. It requires about 300-350 man hours per hectare, which is approximately 25% of total labour requirement for paddy cultivation. Non availability of labour has compounded the situation and paddy transplanting has emerged as the main problem in the major rice growing areas of these regions. This results in the delay in transplanting leading to decrease in yield. It is reported that a delay in transplanting by one month reduces the yield by 25% and a delay of two months reduces the yield by 70%. In spite of the huge labour requirement, plant to plant and row to row spacing are not achieved as the workers transplant seedlings at wider spacing that is too far than the recommended spacing and hence mechanical weeding is not possible. So also, the scarcity of labour at peak demand period results an increased cost of operation and delays the transplanting operation (Vasudevan et al., 2014). Mechanical transplanting can reduce cost of labour but the cost of raising nursery is more (Azhar and Khan, 1995). Self-propelled Walk Behind Type (Japanese type): 2-row and 4-row paddy transplanters using mat type seedlings have become very popular in Japan .The machine consists of a driving wheel, float, engine, power transmission system, seedling platform, planting crank arms, planting fingers and depth adjusting lever. Two row transplanters have 1.7 hp gasoline engines and weighs 60-70 kg. Row to row spacing is 30 cm and plant-to-plant spacing varies from 13-18 cm. It can cover about 0.6 ha/day when working at a speed of about 2.0 km/h. The planting mechanism used in this case is very complicated as it uses actuating type of fingers. Also the system is very costly as each unit having two fingers is provided with a separate transmission system (Singh and Garg, 1976). Mechanized transplanting recorded more grain yield (6,359 kg ha^{-1}) and net returns (Rs. 31,870/- ha^{-1}) at lesser cost of cultivation (Rs. 29,796/- ha^{-1}) compared to manual transplanting. Mechanized transplanting recorded benefit-cost ratio of 2.3, but it was only 1.76 in the case of manual transplanting. Mechanized transplanting with Yanji rice transplanter can be used successfully as an economic, viable and alternative option for obtaining higher yield and reducing cost of cultivation as the manual transplanting involves more labour and drudgery (Sreenivasulu and Reddy, 2014). It was reported that mechanical transplanting would be more economical provided an area of 28 ha and above is covered every year. Grain yield in both manual and mechanical transplanting methods gave mean grain yield of 5.38 and 5.40 $Mg.ha^{-1}$, respectively (Manjunatha et al., 2009). The highest paddy yield was obtained from single-seedling transplants from potted nursery trays which protect the young seedlings' roots from shock or twisting, compared with the planting of more numerous seedlings grown on flat nursery trays by a mechanical rice transplanter (Chang et al., 2016).

The mean value of working heart beat rate was assessed to be maximum of at 138.32 ±7.67 beats/min in manual hand transplanting and 110.12 ±5.79 beats/min in eight- row paddy transplanter. The measured energy expenditure rate was 18.40 ±0.95 kJ/min in local transplanting method and reduced to 15.17 ±1.68 kJ/min while using paddy transplanter. TCCW (total cardiac cost of work) was found to be 1,965.5 ±63.66 beats for manual transplanting of paddy and 770.58 ±39.93 beats by the use of paddy transplanter whereas the PCW (Physiological cost of work) was calculated to be 227.98 ±22.17 in traditional method and 85.23 ±2.64 in improved method. The economic cost of mechanized transplanting was 47% less than the conventional method (Ojha and Kwatra, 2014). Sowing the rice seeds in the RSS (rice straw as a seedbed) improved the characteristics such as shoot length, root weight, shoot dry weight to shoot length (DW/L), nutrients content of seedling, and biomass and seedling vigour. The length of one seedling mat (SM) measuring 120 × 28 × 3 cm was equivalent to that of two nursery boxes in the conventional soil seed bed (CSS) measuring 58x28x3 cm halving the number of SM required. The SM technique could reduce the working hours for transplanting by one-third of these for the CSS. The mat can be rolled up into a small diameter. The volume of the rolled seedlings was about one-fifth of that of the equivalent amount of seedlings in CSS. A small pickup truck can carry seedlings for a rice field of 2 ha at one trip. Examination of the comparative cost-analysis reveals a strategy for substantially reducing the cost-benefit ratio for rice production with the use of SM technology. This study showed the potential of SM technology in stimulating agriculture in the region and consequently leads to increase in productivity (Haytham et al., 2010). Among the various age of seedlings and concentration of GA3 used for the study, twenty days old seedlings along with spraying of GA3 (gibberellic acid) at 50 ppm on 15 days old seedlings were found most suitable for walk behind mechanical transplanter in order to get better seedling establishment, plant growth, seed yield and to realize more profit by minimizing the cost of seed production (Vasudevan et al., 2014). To ensure uniformity in height of the seedlings, they can be treated with gibberellic acid at 100 ppm for transplanting with a transplanter (Dhananchezhiyan et al., 2013). Seed soaking in GA3 solution increased the emergence rate in rice (Kim et al., 1993; Coale, 1991; Hays, 1992). Maximum nursery height of 17.06 and root length of 10.75 cm were observed in FYM soil and vermisoil, respectively prepared in 1:1 ratio. The mat stiffness was found to be the maximum for a media mixture of field soil and coir-pith at 1:1 and 2:1 ratios with a corrugated sheet base layer. From the results, the soil medium for growth and stiffness was optimized as field soil, FYM and fibrous coir pith in the ratio of 2:1:1 (Dhananchezhiyan et al., 2013). It was reported that rice transplanted from dry bed nurseries at 21 days after sowing (DAS) had high mortality (85%) and consequently low yields whereas seedling broadcasting (21 DAS) significantly reduced rice vulnerability (22% seedling mortality) to snail damage compared to all other methods and resulted in the highest grain yields per plot in our experiments. Seedling broadcasting was suggested as a crop establishment method with potential to sustainably manage apple snails in irrigated rice (Horgan et al., 2014).

Twenty days old seedlings were the most suitable for transplanters namely QUAT, CRRI and Yanji (Aswini et al., 2009). Number of seedlings transplanted per hill varies from country to country. In Burma, one to four seedlings are transplanted per hill, in Sri Lanka only one seedling is used. Usually, 5 to 7 seedlings are transplanted in Philippines. Results in India indicated that the number of fertile tillers were greater with 3-4 seedlings (Hedayetullaha, 1977). It was reported that rice seedling up to 30 days old grown in any of two soils with moisture varying from 10 to 15% could be used to reduce the mat consumption and number of seedlings per hill (Garg et al., 1982). It was reported that the 10 days old seedlings had more vigorous elongation of plant height and higher tillering ability but lower effective tiller rate, when compared with 35-day or 40-day old seedlings (Sangsu et al., 1999).The oldest seedlings (SA_{30}) consistently required the lowest water input and thus resulted in comparable or even better total water productivity. Lowering the seed rate and improving fertilization in the seedbed are important measures to increase yield, to enhance total water productivity and to reduce the delay in crop development (Lampayan et al., 2015). Optimum plant density for higher DMP and grain yield would be 5 seedlings hill^{-1} which produced higher DM with highest partitioning towards panicle followed by stem and leaf (Vijayalaxmi et al., 2016). The mat type nursery raising and uprooting techniques are major constraints for intensification of mechanical transplanting of paddy. Farmers of South East Asian countries like India hesitate from mechanical transplanting technique because they consider mat type nursery raising and uprooting techniques as the complex one. This study was conducted in 2013, 2014 and 2015 on various mat type nursery raising and uprooting techniques with the aim of developing an easy technique for raising and uprooting mat type nursery so as to ease and intensify the mechanical transplanting of paddy through paddy transplanters in South-East Asian countries.

Materials and Methods

Experimental Layout and Detail of Treatments

Mat type nursery grown on polythene sheet gets damaged or severe shock if there is missing of even single irrigation due to power/motor failure or human negligence. Therefore different media instead of polythene sheet were also used for raising it, which included paddy straw, chopped paddy straw, wheat straw and cloth paper as a soil separator and mat type nursery was also raised on mushroom waste material as soil filling on polythene sheet,. The nursery grown on field soil, mushroom waste, paddy straw, chopped paddy straw, wheat straw, cloth paper was irrigated with flood irrigation system and on polythene sheet was irrigated with drip, sprinkler and flood irrigation system in experiments conducted during year 2013, 2014 and 2015. The nursery was raised using the standardized technique of Punjab Agricultural University (PAU), Ludhiana on polythene sheet with different irrigation methods viz. drip irrigation, sprinkler and flood irrigation (**Fig. 1**). The nursery was raised twice in the months of April-May and May-June. Each plot size of the raised nursery was approximately 24 m^2 and the experiment was replicated thrice. Initially, flood irrigation was applied to all the plots for two days so that the soil on polythene sheet gets settled. Thereafter, sprinkler, drip and flood irrigation were applied to the plots. Volume of water applied to the different treatments was also recorded. Mat thickness, root length and shoot length were also recorded. The nursery was uprooted after 25-30 days of sowing and seedlings were transplanted with the help of walk behind type mechanical paddy.

Mortality of seedling was noted after 10 days of transplanting. The number of hills per square meter was also noted after 10 days of transplanting. The number of tillers per square meter was also noted at the time of milking stage. The crop yield was noted as well. The seeds were soaked in water for 48 hours prior to sowing nursery. Then these were pressed under wet jute bags overnight so as to get per-germination and good nursery stand after sowing. A mild steel (MS) frame was used with eight sections each having a size of 28 × 58 cm. The field area dimension required for the two frames was 6.0 × 3.7 m. The 90 cm wide perforated polythene sheet of 60 gauge with 2 mm diameter perforations was used for sowing nursery treatments under drip (T_1), sprinkler (T_2) and flood irrigation system (T_3). In the other two treatments two media were used as wheat straw + soil (T_4) and field soil only (T_5). The wheat straw was used as a base material and soil was placed over it in the frame sections (**Fig. 2**). The weight of wheat straw and soil used per mat of volume 2,923.20cm^3 (28 cm × 58 cm × 1.8 cm) were 156.25 g and 4920 g, respectively.

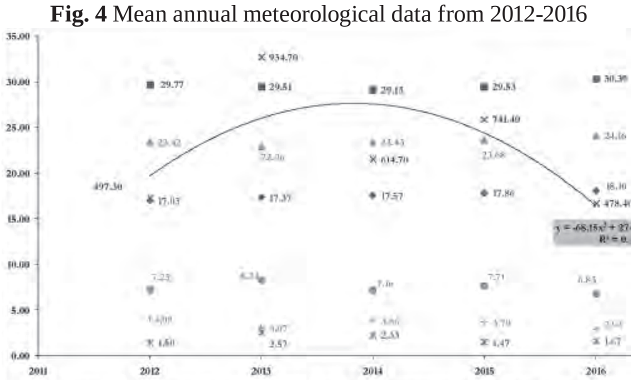
For treatments T_1, T_2, T_3, T_4, T_5, T_7, T_8, T_9 the soil was lifted from both sides of frame with spades to fill the frame sections little lower than frame height and then the soil in frame sections was leveled using a wooden strip and for treatment T_6 the frame sections were filled with mushroom waste instead of soil. The pre-germinated paddy seeds were spread evenly in each compartment using nursery seeder or manual method as shown in **Figs. 1** and **3** in such a manner that the density was 2-3 seeds/cm^2. The seed quantity used per frame section was 100 g. The length of nursery seeder was equal to width of frame and an opening of 1 cm diameter was kept along the full length of the roller. The seeds were covered by a thin layer of soil and water was sprinkled using hand sprayer for proper setting of soil. The seeds were then again covered with a thin layer of soil and frames were lifted and put in next place and the procedure was repeated. For Treatment T_5, the pre-germinated seed was evenly spread on the field soil along the frame sections (**Fig. 3**) and were covered with soil. Water was sprinkled using hand sprayer and the frames were lifted. This procedure used was repeated. In this same manner, the mat type nursery was sown in all the five treatments.

Fig. 1 A view of mat type nursery sowing on perforated polythene sheet as base in field with nursery seeder transplanter

Fig. 3 A view of mat type nursery sowing on field soilsheet as base in field with nursery seeder transplanter

Fig. 2 A view of mat type nursery sowing on wheat straw as base material

Fig. 4 Mean annual meteorological data from 2012-2016



The detail of different techniques used is presented in **Table 1**. In the case of flood irrigation, the flow of water for the first 2-3 irrigations was kept mild and level was uniform so as to prevent newly formed mats. The seedling mats were always kept wet. The mat type nursery treatments were grown under flood, drip and sprinkler irrigation system in such a manner that all mats were always in moist condition because if nursery mats gets dried only once due to lack of irrigation then it can lead to failure of nursery due to water shock. The urea was sprayed on seedlings after an interval of about 10 days at the rate of 300 g urea per 200 mats. As the seedlings reached the appropriate height, they were transplanted into the puddle field using a four wheel drive mechanical transplanter. Laser leveling of experimental plot (transplanting area was done to minimize water requirements and efficient use of other inputs like fertilizers insecticides etc. Mechanical transplanting of nursery was done with four wheel drive paddy transplanter. The parameters were recorded during transplanting and maturity stages. The yield parameters such as panicle length, number of grains per plant, yield in kg/acre etc. were also recorded at maturity stage.

Meteorological Data

Meteorological data which include that of rainfall record of 5 years as shown in **Fig. 4** were used in this study. The average annual rainfall recorded over 5 year was 653.84 mm. The average minimum and maximum temperatures were 17.59 °C and 29.67 °C, respectively, whereas the mean temperature was 23.53 °C. The mean number of rainy days recorded was 1.91, mean sunshine duration was 7.43 h and mean wind speed was 3.53 km/h.

Water Application and Measurements

Record of volume of water applied to the different treatments wase taken during the nursery raising stage. Irrigation water was applied through polyvinyl chloride pipes of 15 cm diameter hole and the amount

Table 1 Specifications of different mat type nursery raising and uprooting techniques

Particulars	T_1	T_2	T_3 (control)	T_4	T_5	T_6	T_7	T_8	T_9
Frame dimensions, L × B × H, mm	280 × 580 × 18		280 × 580 × 18		280 × 580 × 18		280 × 580 × 18		280 × 580 × 18
Base material	60 gauze perforated polythene sheet (T_1-T_3)			Wheat straw	Field soil only	60 gauze perforated polythene sheet	Paddy straw	Chopped paddy straw	Cloth paper
Nursery raising material	Field soil	Field soil	Field soil	Field soil	Field soil	Mushroom waste	Field soil	Field soil	Field soil
Seed spreading technique	Nursery seeder		Nursery seeder		Nursery seeder		Manual broadcasting		Manual broad-casting
Seed spreading technique					Nursery seeder				
Seed rate, kg.ha^{-1} g.mat^{-1}					25-30 110 (Dixit et al., 2007)				
Soaking solution for treating and wetting of paddy seed					10 L water + 20 g Bavistin 50 WP (Carbendazim) + 1 g streptocycline				
Soaking time, h Incubation time, h					24 h 24 h				
Water application equipment (during sowing of nursery)					Manual water sprayer				
Irrigation system	Drip system	Sprinkler system	Flood System (T_3-T_9)						
Dripper discharge, number (for 1 acre nursery), spacing (L × D*), operating pressure					2.4 L.h^{-1}, 96, 0.90 × 0.30 m, 1.0 kg.cm^{-2}				
Sprinkler discharge, number (for 1 acre nursery), spacing (L × S*), operating pressure					16 L.h^{-1}, 24, 1.2 × 1.2 m, 1.5 kg.cm^{-2}				
Submersible motor use	Solar powered 2 hp motor with 2 L.s^{-1} discharge [Initial cost investment- Rs. 1,25,000/- (subsidized rate), running cost-0]								
Soil settlement period after puddling operation, h	48 h for heavy soils, 10 h for light soils								
Nursery uprooting technique/method	Single shallow cut with a sickle on mats and manual uprooting. (T_1-T_3)			Gradual deep (20 mm) cuts with a sickle around mat and manual uprooting	With manual nursery cutter by pushing it.	Single shallow cut with a sickle on mats and manual uprooting. (T_6-T_9)			

of water applied to each experimental plot was measured using a water meter (Dasmesh Co., India). The quantity of water applied was calculated using equation (1).

$Q_w = F \times t$ [1]

where,

F = flow rate ($L.s^{-1}$)

t = time taken during each irrigation (s)

Q_w = quantity of water applied (l)

Field Parameters

Field parameters such as number of tillers per m^2 was measured using a square made of iron rods with dimensions 1.0 × 1.0 m; forward travel of paddy transplanter was measured through the aid of a stop watch; fuel consumption; root length, shoot length, spike length, mat thickness were measured using a centimeter scale whereas missing hills and hill mortality were both measured using a measuring tape.

Operational Speed

The operational speed of machine and equipment was calculated as:

$V = 3.6 \times [S / T]$ [2]

where,

V = operational speed of machine (km/h)

S = distance travelled (m)

T = time taken to cover the distance travelled (s)

Effective Field Capacity

The effective field capacity of combine was calculated using the formula given by Kepner et al. (1978) as:

$C = [SW / 10] \times [E_f / 100]$ [3]

where,

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

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

W = rated width of implement (m)

E_f = Field efficiency (%)

Where field efficiency, E_f, could further be expressed as:

$E_f = [100 \times T_o] / [T_e + T_h + T_a]$ [4]

where,

T_o = theoretical time per hectare (per acre)

T_e = effective operating time = $T_o \times [100 / K]$,

K = percent of implement width actually utilized

T_h = time lost per acre due to interruptions that are not proportional to area. At least part of T_h usually tends to be proportional to T_e

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

Estimation of Fuel Consumption

For paddy transplanter, the engine's fuel tank was completely filled before starting the experiment. The quantity of fuel required to refill the tank after harvesting the test field was measured using a graduated cylinder. Thus, the fuel consumed during the test was determined.

$F = L / A$ [5]

where,

F = fuel consumption ($L.ha^{-1}$)

A = area transplanted (ha)

L = quantity of fuel required to refill the tank after harvesting the test field (L)

For measuring the fuel consumption of tractor operated implements, a fuel consumption meter was attached to the tractor. The fuel consumption reading at the start and end points of the field experiment was observed and fuel consumption value was measured as:

$F = 3.6 \times [L / T]$ [6]

where,

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

L = fuel consumption meter readings difference (i.e. $L_f - L_i$) in ml for a particular length

T = time for particular length (s)

L_f = fuel consumption meter reading at finish of experiment (ml)

L_i = fuel consumption meter reading at start of experiment (ml)

Data Analysis

The results obtained for the different treatments were subjected to statistical analysis using statistical tool such as SPSS and CPCS1.

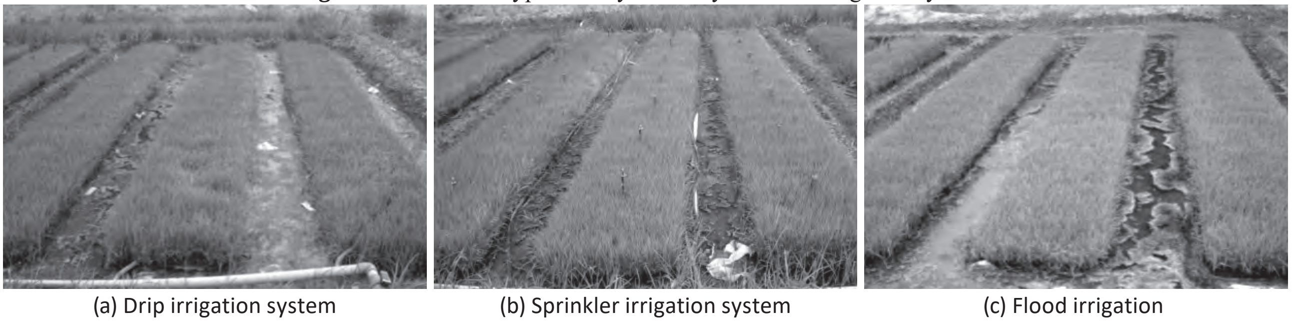
Results and Discussion

Mat Type Nursery Raised on Mushroom Waste as a Soil on Polythene Sheet

Nursery was also raised on mush-

Fig. 5 A view of data observation in nursery trials

Fig. 6 A view of mat type nursery raised by different irrigation systems



(a) Drip irrigation system (b) Sprinkler irrigation system (c) Flood irrigation

Table 2 Water requirement and performance of mat type nursery raised by using drip, sprinkler and flood irrigation and transplanted with walk behind paddy transplanter

Particulars				p value	$F_{cal.}$
	Drip	Sprinkler	Flood		
Water requirement, L/m^2	23.41^a	30.51^b	41.16^c	< 0.001	523.73
Frequency of irrigation, number/day	2-3	2-3	1-2		
Saving over flood method of irrigation, %	43.23	25.74	--		

room waste as a soil on Polythene sheet. The results obtained showed that the nursery can be raised well and mushroom waste can be utilized as soil filling in the frame for mat type nursery grown on polythene sheet.

Mat Type Nursery Raised on Paddy Straw as Separator Instead of Polythene Sheet

Nursery was also raised on paddy straw as a separator instead of polythene sheet. The obtained showed that the nursery was uprooted manually with the help of sickle and more power was required to cut the mat and also the mat was broken as uneven cutting took place.

Mat Type Nursery Raised on Chopped Paddy Straw as Separator Instead of Polythene Sheet

Nursery was also raised on chopped paddy straw used as a separator instead of polythene sheet. The results obtained showed that paddy straw got decomposed and the plant roots penetrated into the soil. Nursery was uprooted manually with the help of sickle and more power was required for cutting the mat and mat thickness was uneven and mat got damaged during uprooting. The word composed was used under your conclusion. Please verify to let me which one among them is correct.

Mat type Nursery Raised on Cloth Paper as Separator Instead of Polythene Sheet

Nursery was also raised on cloth paper used for making bags as a separator instead of polythene sheet. The results showed that some roots got penetrated from the cloth into the soil. Nursery was uprooted manually with the help of sickle and less power was required to cut the mat and also the mat thickness was uneven but mat did not break and more precaution are required while cutting the mat. But the cost of cloth paper is more than the polythene sheet.

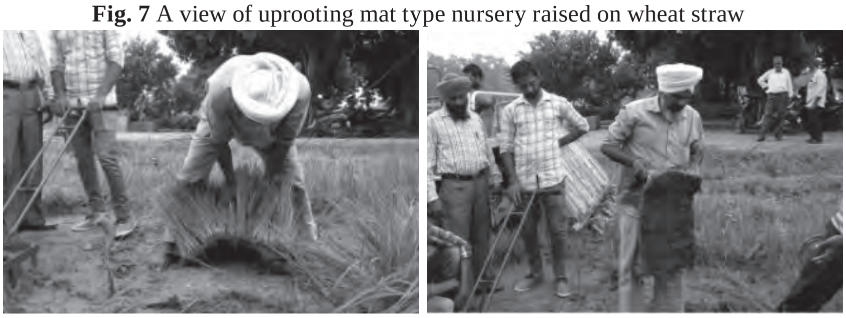


Fig. 7 A view of uprooting mat type nursery raised on wheat straw

Fig. 8 A view of uprooting mat type nursery raised on field

Mat Type Nursery Raised on Polythene Sheet and Wheat Straw

Feasibility test of raising mat type nursery by using micro irrigation techniques was carried out at the departmental farm in year 2013. Nursery grown with different methods has been shown in **Figs. 5** and **6**, respectively.

The results obtained in **Table 2** showed that there was 43.23% and 25.74% saving of water in nursery raised by drip and sprinkler irrigation systems, respectively as there was no record obtained for saving of water in nursery raised by flood irrigation system.

In different experiments the nursery was uprooted after 20 days of sowing so as to get vigorous crop stand and better yield after transplanting. Before transplanting, some data as contained in **Table 3** like complete weight of seedlings per mat, number of seedlings per mat, height of seedlings (above root zone) and mat thickness were recorded.

The nursery data was taken from mats grown under different treatments. The mean soil moisture content at the time of uprooting mats was 18.67 (d.b). The mat nursery raised on wheat straw was uprooted by making cuts with sickle around the mat and pulling it by holding seedlings (**Fig. 7**). The nursery raised on polythene sheet was also cut by making a single cut on frame marks with sickle. The nursery raised on field soil was uprooted

Table 3 Germination data of mat type nursery raised by different techniques

Particulars	T_1	T_2	T_3	T_4	T_5	CD (5 %)
Mean number of seedlings per mat	4,178.19	5,075.90	4,199.84	3,624.23	3,087.40	33.3323
Mean weight of seedlings per mat, g	4,511.29	3,391.63	4,816.96	3,139.19	2,469.74	7.27370
Mean height of seedlings, mm	286.80	284.00	288.80	314.50	317.10	3.62547
Mean mat thickness, mm	20.00	20.00	20.00	20.00	5.0-20.0*	---
Mean time for cutting and uprooting nursery mats for one acre, man-h.acre^{-1}	0.33	0.33	0.33	0.67	0.50	---

*Variation due to manually operated cutter

using a manual nursery cutter by pushing it at a shallow depth (**Fig. 8**). It is clear from **Table 3** that mean number of seedlings per mat was found highest in treatment T_2 as 5,075.90, mean weight of seedlings per mat was found highest in treatment T_3 as 4,816.96 g, mean height of seedlings was found highest in treatment T_5 as 317.10 mm followed by treatment T_4 which had a value of 314.50 mm. The higher height may be attributed to presence of biomass and direct soil under seed for treatment T_4 and T_5, respectively.

The graphical relation between number of seedlings per mat, mean height of seedlings and mean weight of seedlings per mat for the different treatments are shown in **Fig. 9**. The graph trend in **Fig. 9** shows that as the number of seedlings per mat increases, the mean height of seedlings decreases and the weight of seedlings per mat first increased up to 4,400 seedlings per mat and then began to decrease. However, this was an initial plot at the time of uprooting mats; the final conclusions could be made on the basis of yield data.

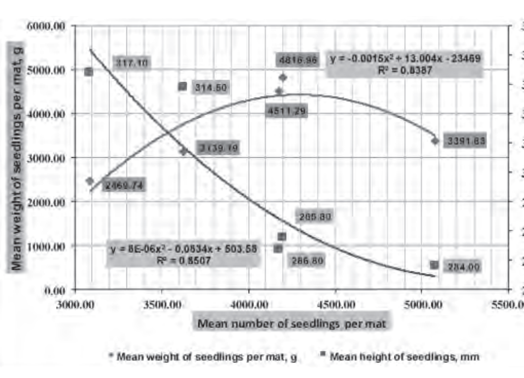
The effect of different nursery raising techniques was found significant for mean number of seedlings per mat. The effect of different nursery raising techniques was found significant for mean weight of seedlings per mat. The effect of different nursery raising techniques was found significant for mean height of seedlings. The prediction equations for height and weight of nursery seedlings as a function of number of seedlings were also obtained (**Table 4**) which can be used for determining nursery seedlings characteristics.

The mat type nursery was uprooted and transplanted in puddled field using four wheel drive mechanical paddy transplanter (**Fig. 10**). The mean forward speed of paddy transplanter during transplanting varied between 1.35 and1.76 km.h^{-1}, mean fuel consumption and field capacity varied between 0.40 and 0.45 ha/h and 2.40 and 2.78 L.h^{-1} respectively. The seedlings were transplanted 2-3 cm deep and number of seedlings planted per hill varied between 2 and 3. The plant to plant (intra-row) spacing was kept at 14 cm and row to row (inter-row) spacing was kept at 30 cm.

After the crop had reached maturity stage as shown in **Figs. 11** and **12**, the paddy crop yield data were taken. **Table 5** presents the results of the crop yield data obtained during maturity stage of the crop.

The mean number of hills were maximum for T_5 and overall effect of treatments was non-significant on hills per m^2 as shown in **Table 5**. The mean weight of straw per plant and stubbles per hill were found maximum as 6.22 g and 2.33 g for treatments T_1 and T_3, respectively and their method effect were significant ($p < 0.05$). For treatments T_1, T_2 and T_3 in which nursery was raised on polythene sheet, the mean weight of grains per plant was maximum (11.44) and yield was also highest

Fig. 9 Graphical representation of Mean weight, number and height of nursery seedlings



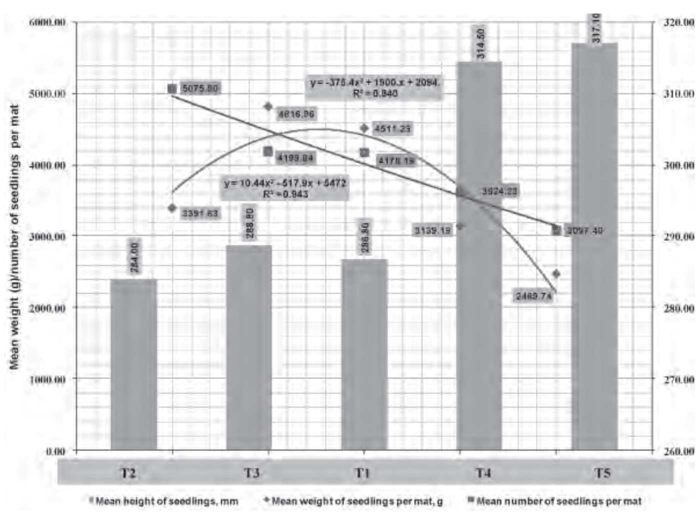


Table 4 Prediction equations for weight and height of mat nursery seedlings as a function of number of seedlings

Measured parameters	f (number of seedlings, n)
Mean height of seedlings per mat	$8E\text{-}06\ n^2 - 0.083\ n + 503.5$
Mean weight of seedlings per mat, g	$-0.001\ n^2 + 13.00\ n - 23469$

(2,881.34 kg.acre^{-1}) for treatment T_2. The higher grain weight and yield for sprinkler system might be attributed to higher number of seedlings per mat (5075.90) and better irrigation to seedlings during nursery growth. Out of the five treatments, the mean number of grains per plant was highest for T_4 (521) followed by T_5 (486) and overall effect of methods was found significant ($p < 0.05$). Mean weight of grains per plant and yield was highest for treatment T_4 as 12.94 g and 3,129.09 kg.acre^{-1}. The higher yield for T_4 might be attributed to presence of biomass beneath mat which led to more number of grains per plant and grain weight per plant after mechanical transplanting. The higher yield of T_5 (field soil) may be attributed to high mean number of grains per plant (486) found among other treatments and highest number of plants per acre among all treatments. The overall yield data was maximum for treatment T_4 followed by T_5 and out of flood sprinkler and drip irrigation system the sprinkler irrigation treatment on polythene sheet (T_4) recorded the maximum grain yield. The effect of five different nursery raising and uprooting techniques was found to be significant on paddy grain yield at 5 % level of significance. The higher yield data for treatment T_4 and T_5 may be attributed to the use of wheat straw (biomass) and field soil at the base in treatments T_4 and T_5 which lead to better growth of seedlings in these two treatments as shown in **Table 2**.

Economics Analysis of Different Nursery Raising and Uprooting Techniques

The economics of five different methods of mat type nursery raising and uprooting technique was calculated and is shown in **Table 6**. The net return and benefit-cost ratio was highest for treatment T_4 followed by T_5 and T_2. The results show that gross return was highest for treatment T_4 at Rs. 45,371.81 per acre.

Conclusions

The mat type nursery can be raised on cloth paper, but the cost is more and more precaution is required during cutting. The mat type nursery cannot be raised on chopped paddy straw as the straw is decomposed and during cutting mat was non-uniform and also mat breaks during cutting. The mat type nursery can be raised on long paddy straw as a base on the soil and during cutting mat thickness was non-uniform and mat does not break. The mat type nursery can be raised on mushroom waste as a soil and can also be mixed with soil. The nursery raised with this was found to be good as the mat did not break during uprooting. The mean number of seedlings per mat was found highest in treatment T_2 which had a value of 5,075.90, mean weight of seedlings per mat was found highest in treatment T_3 which had a value of 4,816.96 g, mean height of seedlings

Fig. 10 Different views of mechanical transplanter in operation

Fig. 12 A view of transplanted mat nursery carried out in 2015

Fig. 11 A view of transplanted mat type nursery raised by different irrigation systems at the time of maturity in 2014

(a) Drip irrigation system (b) Sprinkler irrigation system (c) Flood irrigation system was found highest in treatment T_5 which had a value of 317.10 followed by treatment T_4 which had a value of 314.50 mm. The high height obtained may be attributed to presence of biomass and direct soil under seed for treatment T_4 and T_5, respectively. The mean paddy grain yield was found highest in treatment T_4 followed by treatment T_5 giving values of 3,129.09 kg.acre-1and 2,922.98 kg.acre^{-1}, respectively and out of flood, sprinkler and drip irrigation system the flood irrigation treatment on polythene sheet (T_3) recorded the maximum grain yield as 2,833.08 kg.acre^{-1}. But the labour requirement for uprooting nursery was more for T_4 and T_5 as compared to other treatments as 0.67 and 0.50 man-h.acre^{-1}. However there was water saving of 43.23% and 25.74% in nursery raised by drip and sprinkler irrigation systems, respectively as compared with flood irrigation. The benefit-cost ratio of 1.92 was found to be highest in treatment T4 (wheat straw + soil) and for treatment T5 representing field soil only, the benefit-cost ratio was 1.80. The B:C ratio for treatments T_1, T_2 and T_3 were 1.67, 1.76 and 1.74, respectively. The treatment with use of biomass as base material for raising mat type nursery with flood irrigation system and manually cutting of mats with sickle recorded the maximum paddy grain yield and proved to be the most economical when compared with all other treatments. The use of field soil as base material for raising mat type nursery with flood irrigation system increased paddy grain yield when compared with the treatments raised on polythene sheet and uprooting with manual nursery cutter proved to be more economical and comfortable uprooting technique as compared with other treatments. The climate of India is hot and humid during paddy growing *kharif* season (July to October) in which the nursery raising has to be accomplished in a window period of 20-25 days. The techniques discussed in this paper could be beneficial towards easy mat nursery raising and uprooting for paddy crop and its mechanical transplanting. In regions where wheat paddy rotation is followed, their wheat straw can be used as a soil separator and in other regions not following wheat in cropping pattern mat nursery can directly be raised on field soil and can be uprooted with the help of manual nursery cutter. Along with this, for raising mat type nursery of paddy crop sprinkler system can be used for irrigation for enhanced grain yield and water saving. In case of electric powered motor if there is power failure then it can lead to nursery damage due to irrigation failure. This problem can be overcome by the use of solar powered motor which provides assured irrigation throughout the day.

Acknowledgements

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Table 5 Paddy yield data of different mat type nurseries transplanted by four wheel drive mechanical paddy transplanter

Particulars	T_1	T_2	T_3	T_4	T_5	CD (5 %)
Mean number of hills per m^2	25.00	25.00	24.67	24.00	26.00	NS
Mean plant height, mm	800.00	725.00	880.00	870.00	870.00	110.311
Mean length of stubbles, mm	170.00	200.00	150.00	140.00	140.00	10.1572
Mean panicle length, mm	195.00	230.00	260.00	246.67	260.00	43.4778
Mean weight of straw per plant, g	6.22	4.52	5.58	5.38	6.06	0.220863
Mean weight of stubbles per hill, g	1.76	1.29	2.33	1.05	1.64	0.145932
Mean number of grains per plant	461.40	460.00	450.00	521.00	486.00	12.3264
Mean weight of grains per plant, g	10.84	11.44	11.40	12.94	11.16	0.232483
Mean number of plants per acre	251,865.56	251,865.56	248,515.40	241,815.06	261,916.07	147.209
Mean grain yield kg per acre	2,730.22	2,881.34	2,833.08	3,129.09	2,922.98	9.89330

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Table 6 Economics evaluation of different techniques of raising and uprooting mat type nursery

Particulars	T_1	T_2	T_3	T_4	T_5
Seed cost, Rs.acre^{-1}	450.00	450.00	450.00	450.00	450.00
Seed treatment cost, Rs.acre^{-1}	90.00	90.00	90.00	90.00	90.00
Base material (Polythene sheet /wheat straw) cost, Rs.acre^{-1}	40.00	40.00	40.00	62.50	0.00
Frame, water sprayer, spades, khurpi cost, Rs.acre^{-1}	1,560.00	1,560.00	1,560.00	1,560.00	1,560.00
Nursery seeeder cost, Rs. acre^{-1}	201.62	201.62	201.62	201.62	201.62
Labour cost for nursery sowing (6 man-h.acre^{-1}), Rs.acre^{-1}	187.50	187.50	187.50	187.50	187.50
Irrigation cost (25 irrigations (30 min. for each irrigation))	875.00	875.00	875.00	875.00	875.00
Fertilizer urea 300 g cost, Rs.acre^{-1}	2.00	2.00	2.00	2.00	2.00
Labour cost for fertilizer application (1 man-h.acre^{-1}), Rs.acre^{-1}	31.25	31.25	31.25	31.25	31.25
Man-h required for uprooting 1 acre nursery	1.80 h	1.80 h	1.80 h	3.50 h	2.30 h
Labour cost for nursery uprooting for 100 mats (2 man-h/acre), Rs.acre^{-1}	55.31	55.31	55.31	109.38	78.12
Disc harrow (2) + Cultivator (2) + Planker (1), Rs.acre^{-1}	1,744.47	1,744.47	1,744.47	1,744.47	1,744.47
Laser land leveler cost, Rs.acre^{-1}	1,171.33	1,171.33	1,171.33	1,171.33	1,171.33
Cultivator with pulverizer operation cost, Rs.acre^{-1}	730.75	730.75	730.75	730.75	730.75
Mats loading and unloading (labour 1 man-h + 4 ltr diesel) cost, Rs.acre^{-1}	271.25	271.25	271.25	271.25	271.25
Transplanting cost, Rs.acre^{-1}	989.38	989.38	989.38	989.38	989.38
Irrigation cost (32-35 irrigations (2 h per acre)), Rs.acre^{-1}	7350	7350	7350	7350	7350
Fertlizer and application cost, Rs.acre^{-1}	2,149.00	2,149.00	2,149.00	2,149.00	2,149.00
Weedicide and application cost, Rs.acre^{-1}	510.00	510.00	510.0	510.0	510.0
Insecticide and application cost, Rs.acre^{-1}	3,901.32	3,901.32	3,901.32	3,901.32	3,901.32
Manual weeding cost (2 man-h.acre^{-1}), Rs.acre^{-1}	62.50	62.50	62.50	62.50	62.50
Harvesting cost by combine***, Rs.acre^{-1}	1,200.00	1,200.00	1,200.00	1,200.00	1,200.00
Total cost, Rs.acre^{-1}	23,710.28	23,779.68	23,572.68	23,649.25	23,555.49
Crop yield, kg/acre	2,730.22	2,881.34	2,833.08	3,129.09	2,922.98
Gross return*, Rs.acre^{-1}	39,588.19	41,779.43	41,079.66	45,371.81	42,383.21
Net returns, Rs.acre^{-1}	15,877.91	17,999.75	17,506.98	21,722.56	18,827.72
Net returns, USD**.acre^{-1}	246.20	279.10	271.46	336.83	291.94
B:C Ratio	1.67	1.76	1.74	1.92	1.80

Minimum support price of paddy taken as Rs.14,500.tonne^{-1},(Anonymous, 2016c)** http://www.xe.com/currencyconverter/convert/?From=USD&To=INR, 1 USD = 64.4919 INR, doi : 20-6-2017), Petrol price@Rs, 71.40.l^{-1}, Diesel price@Rs. 57.l^{-1}, Labour cost@Rs.31.25.h^{-1} , Custom hiring rate***@Rs.1,200.acre^{-1}]

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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.

1726

Energy Efficient Passive Wet Tillage Tool for Low Land Transplanted Rice Cultivation: C. Ramana, B. Ravindranatha Reddy, V. Munaswamy, P. Lavanya Kumari

Rice (*Orzya Sativa* L.) is a most important crop and highly relished as staple food in India, covering an area of 44 million hectares with annual production of 90 million tones. 60% of rice production area in India adopts low land transplanted rice method, where in 5-10 cm standing water is maintained in the field between raised bunds. The ponding water leads to the deep percolation losses, in turn increases irrigation water requirement. Puddling (wet tillage) process is proven technology to condition soil tilth and forms impervious layer on loose soil, so as to minimize deep percolation losses. Current practice of using inferior implement for puddling, making farmer to lose time, energy and more importantlyprecious water. To improve the efficacy of puddling, the study was taken up under AP Water Management Project, RARS, Tirupati to develop energy efficient implement without compromising with quality of tilth (field preparation). A passive self activating Vishnu (ANGRAU) puddlerwas developed with optimized machine parameters of soil working unit of paddlesnumber 40; tilt angle of the paddle 11° to 14.5° with staggered alignment on rotating shaft for best performance.

The puddling effect of developed implement (Vishnu puddler)in a farm research was analysed and compared with implements like Rotavator, Disc Harrow and Cultivator (farmer's method),through irrigation requirement and Water Use Efficiency. The experiment on irrigated water savingclearly shown that up to 40% shall be obtained through proper puddling with Vishnu (ANGRAU) Puddler and Rotovator.The highest Water Use Efficiency was recorded as 6.09 and 6.07 kg ha^{-1} mm^{-1} in field prepared by Rotavator and Vishnu Puddler respectively, where as lowest W.U.E observed 4.44 kg ha^{-1} mm^{-1} in farmers practice (using cultivator for puddling). Further more than experiment results for their fuel consumption shown to be 13.32 $L.ac^{-1}$, 7.74 $L.ac^{-1}$, 8.29 $L.ac^{-1}$ and 7.63 $L.ac^{-1}$ with, Vishnu Puddler, Rotavator, Disc Harrow and Cultivatorrespectively. The experiment also concluded that the use of developed Vishnu puddler can createtilth of superior quality (with PI of 32%) on par with the tilth obtained by active tool Rotovator (PI of 32%) with least amount of fuel consumption 7.74 $L.ac^{-1}$ which reduces the operational coast by 72% than the rotovatoruse for attaining same effect of puddling.

1727

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

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

1731

Development and Evaluation of a Continuous Cocoa Pod Breaker: V. Srikanth, G. K. Rajesh, M. M. Santhi, Anjineyulu Kothakota, R. Pandiselvam, M. R. Manikantan

An attempt was made to develop a continuous cocoa pod breaker; because it consists of hopper, metal rollers, chute, rotating cylindrical strainers, frame, prime mover and pulleys. Cocoa fruit was fed manually in to breaker unit through hopper. Gap between the rollers was set so as the cocoa kernels were not damage during the pod breaking process. Tangential force of the roller pushed the cocoa pod towards the gap resulted in breakage. Cocoa pod, kernels and placenta then discharged to strainer through chute. Rotation of strainer separated the cocoa kernels from cocoa pod and placenta, and passed through the pores of the strainer. Performance of the machine was evaluated in terms of capacity, energy requirement, percent bean damage, per cent bean recovery, shelling efficiency and machine efficiency. The average capacity and efficiency of cocoa pod breaker was 550.5 kg/h and 95-98%, respectively. Bean damage percentage was 0.5%. The shelling efficiency and beans separation efficiency of the strainer at inclination, 45°96.42 and 86.5%, respectively.

1744

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

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

1747

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

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

1751

Development and Performance Evaluation of Inclined Plate Planter for Rice Cultivation Under Rainfed Condition: Ajay Kumar Verma

Yield potential of rice crop largely depends on the crop establishment technique to ensure optimal population. More than 21% of total cost of production is accounted for transplanting operation alone. Therefore, adoption of alternative rice culture, which requires less input and possible increase in yield, is highly desirable under rainfed condition. Therefore, the inclined plate seed metering mechanism for direct seeding of rice seeds to maintain plant to plant distance at reduced seed rate was developed. The part modelling was done to optimized inclined plate (inclination angle of inclined plate 450 with horizontal, rotor speed 0.17 m/s, area of single cell 28 mm^2 and forward speed 5 km/h). The prototype of machine was developed and field tested in 20 ha area in research farm and about 100 ha in farmer's field. Its field capacity was 0.77 ha/h with field efficiency 83%. The seed rate required for sowing of rice seeds was 20 kg/ha (20 × 10 cm spacing at 2 seeds per cell), which was low in comparison to seed rate of fluted roller metering seed drill as 82 kg/ha. The average plant population was found 105 plants/ m^2 with inclined plate planter. Study revealed that sowing by inclined plate planter with inverted T type furrow opener was more advantageous in view of crop management under rainfed rice cultivation.

1754

Technology for Extraction of Ribbons/Barks from Jute and Mesta Plants - A Review: V. B. Shambhu, A. K. Thakur, L. K. Nayak

Jute and mesta fibres are natural fibres of commercial importance which play an important role in Indian economy next to cotton. The extraction of Jute and mesta fibre by conventional method is laborious and requires large amount of water with longer duration for appropriate retting. To overcome this problem separation of ribbons/barks from green plants prior to retting can be done with the help of ribbons / barks separating machines. The mechano-microbial retting technology reduced water requirement and duration of retting considerable. In this paper an attempt has been made in view to comprehend the development of decorticator and ribboner for jute and mesta crop.

1758

Multiple Attributed Parametric Review Study on Mechanical Picking of Cotton (*Gossypium hirsutum* L.) Crop in Relevance to Developing Countries: Karun Sharma, Manjeet Singh, Rupinder Chandel, Ankit Sharma

Crop characteristics of cotton helped the researchers to identify the important crop attributes like plant height, canopy width, sympods and monopods distribution, row spacing which affect the performance of mechanical harvesters. Cotton varieties had more affect on the field capacity and picking rate of mechanical harvesters as compared to row spacing owing to difference in crop characteristics. Defoliants commonly are used in conjunction with picker harvesters and advantages of using desiccants include the ability to schedule harvests, increase stripper harvester efficiency, decrease the moisture content of seed and extraneous plant materials, and control weeds. Low temperatures tend to slow the activity and reduce the effectiveness of most harvest aids, including desiccants. Defoliants will not substitute for desiccants in the preparation of cotton for mechanical stripping except under ideal circumstances, because stripper harvesters collect extraneous plant materials including burs, leaves, portions of limbs, stems along with the lint and seed. The trash content including hulls, burs, leaves, sticks etc. in cotton harvested by cotton picker was observed lesser as compared to cotton harvested by cotton stripper. It was found that maximum cotton yield i.e. more than 1000 $kg.acre^{-1}$ was observed for the plant population between 45,000-90,000 $plants.acre^{-1}$ and the minimum crop yield i.e. 700-740 $kg.acre^{-1}$ were observed for the plant population of 33,000 $plants.acre^{-1}$. In higher yielding cotton, pickers had a higher picking rate than strippers. Picking/harvesting efficiency of cotton stripper with both finger and brush type mechanism was higher than the spindle type picker. Picking efficiency of pneumatic picker was higher than the other types of picking mechanisms, but at the less rate of picking capacity. Gin turnout of cotton was higher with cotton picker as compared to cotton stripper owing to lesser trash in picker harvested cotton. The cost of cotton stripper is about 2/3rd of the price of a cotton picker and range from ½ to ¼ the horsepower. The scheduling and monitoring of various activities involved in cotton picking by using a suitable software model can increase the benefits of both growers and harvesting companies. Government policies towards cotton harvesting mechanization must include the alternative jobs, packages for dependent manual cotton pickers and their families.

1762

Design Fabrication and Evaluation of Walnut Grader: Syed Zameer Hussain, Umbreen Showkat, Sheikh Idrees, Monica Reshi

The manual size grading of walnuts is labour intensive, and tedious practice; besides being inconsistent and less efficient. The aim of the present study was thus to design, fabricate and evaluate a power operated walnut grader. The walnuts grown in Jammu and Kashmir state of India were classified into four grades, and all the four grades were evaluated for various dimensional, physical, frictional and mechanical properties to create a database which play an important role in designing of mechanical system for walnut grading. A power operated walnut grader was developed and tested. The machine consists of feed hopper, casing, rotating pipes, delivery chutes, sprockets, driving chain and a control box. The result of the performance tests showed that grading error was significantly affected by feed rate, grader slope and opening size from feeding end to trailing end. The highest mean grading efficiency of 96.3% (least grading error 3.7%) was recorded at a feed rate of 400 kg/hr and 80 of grader slope. The effective throughput capacity of the machine was estimated to be 337 kg/hr. Adoption of this technology will help walnut growers, processors and other stakeholders to make quality graded walnuts available in the competitive markets. This paper describes the design and performance evaluation of the walnut grader as well as the implications of results obtained.

1763

Development and Performance Evaluation of Thresher for Onion Umbels: R. Pandiselvama, R. Kailappanb, Syed Imranc, Anjineyulu Kothakotad, G. K. Rajeshe

At present in India, the post harvest unit operations of onion umbels are being carried out manually. In order to mechanize this process, the present study was carried out to develop an onion umbels thresher. Thresher performance was evaluated at different numbers of rasp bars (2, 3, 4 and 8 numbers), feed rates (25 ±1, 30 ±1 and 35 ±1 kg/h), concave clearance (6.5 and 7.5 mm) and peripheral speeds (2.5 and 3.3 m/s). At 35 ±1 kg/h feed rate, 2 numbers of rasp bars, 7.5 mm concave clearance and 2.5 m/s peripheral speed recorded higher threshing efficiency (97.82%) and lower seed damage (2.08%).

1791

Need and Prospects of Mechanized Water Management in the State of Punjab, India: Anil Bhardwaj

Punjab state having geographical area of about 50,362 sq km is predominantly an agrarian state. The agriculture in the state is dependent on heavy requirement of water. The total availability of water is 3.13 mha-m against the crop water demand of 4.37 mha-m, thus leaving an annual deficit of 1.24 mha-m, which is mostly met with by over-extracting ground water. The water table is declining at a fast rate thereby enhancing the cost of pumping system and requirement of energy. Also, the deficit water resource is threatening the sustenance of even the present level of agricultural production in the state. There is, therefore, an urgent need to use the available water resources judiciously and efficiently by adopting suitable interventions and management strategies to produce on sustainable basis. Mechanization in water management is the potential option to meet the challenge by moving towards precision use of water and can help in enhancing the water input use efficiency and the productivity in the state. But, it should cover the full spectrum of the irrigation water supply system, from diversion and distribution to on-farm application down to the crop root zone. Also, mechanization is now demand driven. With increasing labour wages and agricultural produce market prices as they are, engineered to be low for food and nutritional security and food accessibility to the masses, the farmers, specially medium and large ones, are looking for labour saving devices to remain competitive more so with the globalization of the world markets. This paper discusses the needs of mechanized water management and explores the possibilities of mechanizing the various land and water systems and operations in the state of Punjab.

1796

Technical Evaluation of a Newly-Developed Three-Disc Plow Attachment for Philippine - Designed Handtractor: Elmer G. Bautista, Manuel Jose C. Regalado

In the Philippines, handtractor is useful for plowing, harrowing, side-plowing, leveling and hauling. Its standard accessories are 2-disc plow, harrow and trailer. This study proves that the 3-disc plow is efficient alternative for plowing. The three cutting discs were placed 30 cm apart at 42º and 22º, tilt and disc angles, respectively. The guide wheel was placed 58 cm from the center of travel. The 3-disc plow had an average effective cutting width of 74 cm and travel speed 2.6 km h^{-1}. Field capacity is 1.91 ha d^{-1} with 94.2% field efficiency. The 3-disc plow is highly recommended to make plowing operation cheaper.

17106

Effect of Snowfall on the Span and Width of a Greenhouse: Jeong-Hun Kim, Pandu Sandi Pratama, Soon-Hong Kwon, Sung-Won Chung, Soon-Goo Kwon, Jong-Min Park, Jong-Soon Kim, Won-Sik Choi

Greenhouses can collapse due to unexpected heavy snowfall caused by abnormal weather, even if the greenhouse is installed according to current disaster specifications. In this paper, the correlation of displacement and stress were investigated using structural analysis for different widths of the greenhouse and amounts of snow. It was verified that the structure of the greenhouse can be reinforced by adding a number of roof cross bars. The analysis shows that as the span increases, the displacement and the stress tend to increase, but the increase is negligible, and the same result is obtained even when the span size is increased. As a result, it was concluded that increasing the number of spans or increasing the section modulus of the pipe is meaningless for reinforcing the structure of the greenhouse. Experimental results show that the displacement and the stress change proportionally to the amount of snow. The displacement and stress also grow exponentially as the width of the greenhouse increases according to the amount of snow. It was concluded that larger width increases the risk of collapse of a greenhouse even with smaller snowfall.

17107

Effect of Moisture Contents on Thermal Properties of Fuel Briquettes Made From Ha-zelnut Husk Agricultural Residues: Gürkan Alp Kağan Gürdil, Bahadır Demirel

As we are living in the technology age, we are all dependent on energy. It is known that we will face with fossil fuel shortage in the coming future therefore; any kind of alternative ener-gy source is needed. Biomass obtained from agricultural residues can be a good example of it since a big potential is there everywhere. In this study, fuel briquettes from hazelnut husk res-idue is produced by a hydraulic type briquetting machine and thermal properties of briquettes produced from hazelnut husk agricultural residue are analyzed depending on the moisture contents of the material.

1803

Irrigation and Fertigation Management on Chilli (Capsicum annuum) Under Drip System: Brahmanapuduru Gireesh

Water is the precision source for agriculture growth and quality of agricultural products. In the methods of providing water to crop, the drip system is the first in techniques that provide a high quality yielding and reduce water wastage. Most irrigation water given through control irrigation 961 mm depth of water, throughout the chilli crop period. Followed by 100 pan evaporation (PE), 735.47 mm, 80 PE, 592.81 mm and 60 PE, 441.28 mm through drip irrigation system. Fertilizers are increasingly used to increase investment by assuming that production is high. But with the use of the excess fertilizer, the production is not too high and soil health is also damaged. This results; it may be affected to the future growing crops in the soil. There is no use of excess fertilizer in the experiment done by various fertilizer levels in various water levels, it has been proved that using excess fertilizers, may not effected the production. The randomized block design has three drip irrigation levels (I_1- 60%, I_2- 80% and I_3- 100% of pan evaporation) and one control (furrow) irrigation with three fertilizer levels (F_1- 80%, F_2- 100% and F_3- 120% of RDF through drip) on growth and yield of Chilli. The research experiment results revealed that application of 80% PE with 100% fertilizer level has maximum yield, number of fruits per plant, fruit weight per plant, fruit diameter, primary branches, secondary branches and stem girth were 24.80 t/ha, 78.44 numbers/plant, 261.35 g/plant, 1.18 cm, 11.8, 50.6 and 2.26 cm respectively and minimum was found in control irrigation in all aspects of plant growth and yield attribution. What these results says that, if they use excess water and fertilizers beyond the decline, they will not more effect on the yield.

Chilli crop receiving irrigation supply at 80% PE with a discharge rate of 2 lph and 100% fertilizer application has highest gross income (Rs.496000 ha^{-1}), net income (Rs. 397276 ha^{-1}) and B:C ratio (4.02) than in other treatment combinations.

1805

Development of Mechanical Peeler Cum Corer Machine for Jackfruit: Hareesha T. Shidenur, Santhi Mary Mathew, Sankalpa K. B., Arun Prasath Venugopal

In India most of jackfruit processing unit follows traditional method of peeling, cutting and coring, which are time consuming, causes drudgery and very tedium in manual operation. However, a major chunk of the production is wasted due to lack of post-harvest technological interventions, and hence jackfruit is considered as underutilized fruit. Thus, effective mechanization in processing is a need of the hour. In this context, mechanical jackfruit peeler cum corer was built. The machine consists of a Fruit holder, Peeler assembly, Corer assembly, Power transmission unit and Frame assembly. The machine was designed for peeling and cutting-coring of varying sizes of oblong/round shape matured, unripe jackfruits of Varikka variety.

■■

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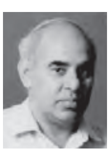
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