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YOSHISUKE KISHIDA

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(Tel.+81-(0)3-3291-3674)
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EDITORIAL

This year, grain markets have fallen worldwide, and this is a tough situation for farmers in the world. The performance of Global large machinery companies like John Deere, New Holland and AGCO is not good with reduction in sales and profit due to lower grain prices. If you see the history, you will find that the grain prices have been repeating to be up and down and agricultural business has been greatly affected by this phenomenon.

Even though the grain prices turn down, a lot of people still impoverished and cannot have enough meal in the world. On the other hand, in advanced countries, obesity caused by overeating is becoming a big problem, and the businesses that solve the obesity such as supplements, exercise equipment and sports gym are booming. These businesses are included in the GDP which represents the economic activity of the country and thus getting to occupy a large weight. It means that there are the people who overeat and the people who starve on the earth.

The problem of hunger in the world is the problem of distribution mechanism and not of the agricultural productivity. Still now, agriculture in the world has been supported by many small farmers. The area per family is less than 2 hectares and they are forced to live on very little money. On the other hand, in advanced countries, agriculture has become industrial farming and many of the huge farms are holding a lot of share of production.

In any hierarchy of agriculture, agricultural machines are needed to assist their production and these are in various from of small machines to large machinery.

AMA was first published in 1971 for the purpose of enriching many farmers in the world by researching, developing, producing and delivering appropriate technology of agricultural machinery in every scale and therefore, improving farming situation by themselves. However, in the real world the gap between the rich and the poor is expanding more than before. In such a situation, the regional wars and conflicts have occurred frequently around the world that has also created a problem that many refugees have flowed into Europe.

Though the situation is becoming more difficult, we have to do what we can do steadily hand in hand with each other for a better future. Under the circumstances that the world population is increasing, we have to increase land productivity of agriculture.

For that, development of agricultural mechanization for working in proper time is extremely essential.

Yoshisuke Kishida
Chief Editor

October, 2015

CONTENTS

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Development and Performance Evaluation of Tractor Operated Onion Harvester

by
T. D. Mehta
Assistant Professor
Deptt. of Farm Machinery and Power,
College of Agril.
Engineering & Technology, JAU,
Junagadh-362 001
INDIA

R. Yadav
Professor and Head
Deptt. of Farm Engineering,
College of Agriculture, JAU,
Junagadh-362 001
INDIA
ryadav61@gmail.com

Abstract

Onion (*Allium Cepa L*) is one of the most important crops of India covering 10.44 % of total area under vegetables in the country. The developed onion harvester was able to dig the onion plants with blub and laid these on the surface of bed unevenly The theoretical field capacity of harvester was found as 0.57 ha/h while effective field capacity was 0.45 ha/h with the field efficiency of 78.95 %. The savings in time required, energy consumed and harvesting cost of onion were 87.64 %, 46.23 % and 78.86 % respectively over manual harvesting method.

Introduction

The present vegetable production in India is 129.077 million tons from an area of 7.98 million ha with an average productivity of 16.20 t/ha (Khura *et al*., 2010). Onion is the fourth most important commercial vegetable crop of India covering an area of 5.34 lakh ha. Out of the 5.34 lakh ha of area under onion, the maximum area of about 12,560 ha (about 23.50 %) is in Maharashtra. Other important states for onion production are Karnataka, Orissa, Uttar Pradesh, Andhra Pradesh, Rajasthan, Madhya Pradesh, Tamil Nadu, Bihar and Gujarat. Maharashtra ranks first in Onion production with a share of 34.78 %, however Gujarat ranks first in productivity as 21.23 t/ha (www.nhrdf.com). The development of onion harvester will help to overcome the difficulty of timely harvesting and reducing the labour cost of harvesting as well as time. Also such a harvester will reduce drudgery to labour and achieve timeliness of this operation. In the developed countries, such types of harvesters are available but they are very huge in size and costly. Looking to the Indian farm holdings, it is highly desirable to develop a small, efficient and economical onion harvester to overcome this problem.

Review of Literature

Sokolowski (1990) explained the phases during two stage onion harvesting. Digging machines (Z412) were used in the first phase, followed by picking up and loading (WZC 3 or MC1). Operating times for the first phase were 22-69 % of the total labour and for the second phase 13-58 %. Labour time could be utilized better if the field was prepared for harvest and labour planned for the field, transport and loading into stores.

Bendix and Krier (2002) developed a mechanical harvester for harvesting, topping and sacking bulb crops, such as onions. The harvester extracts the onions from the ground and transports them rearward to a cutting assembly by conveyor systems that drop out small onions, dirt, rocks and debris. The cutting assembly comprises a set of elongated cutting blades positioned to co-operatively accept and sever the leaves and roots from the bulb. The onions are then transported rearward to a sacking assembly for placing the onions into sacks.

Waszkiewicz *et al.* (2005) reported that the crop damage, losses and contamination were investigated during mechanized onion harvesting in Poland, depending on the one row combine harvester with ground speed (0.43, 0.5, 0.62, 0.75 m/s) at three positions of the mechanical separator scraper. It was found that the plant losses on the mechanical separator, as well as total losses depended on the setting of separator scraper. It was found that onion plantation should be properly prepared to mechanical harvesting in order to achieve the proper quality parameters, since the losses and damage were closely connected to each other.

Laryushin and Laryushin (2009) developed an energy saving harvesting technology for onion which consisted of a set of machines for harvesting onions (bulbs and sets) for removing onion leaves and weed plants, pull type mounted onion digger and onion windrow pickup. With the use of the given set of machines for harvesting onions, the operating cost was decreased as 17.00 %, profit amounted to 8,528 rubles/ha and the annual economic effect was 96,692 rubles. The output of the machine was 0.42-0.60 ha/h, the completeness of digging up the bulbs was 98.00-98.90 % and the damaged bulbs amounted to 1.50-2.00 %.

Materials and Methods

Agronomical Parameters

In general, the onion crops are transplanted with the plant spacing of 10 cm × 10 cm. But looking to local growing practice and the recommendation of agronomist, it was decided to keep the row to row spacing of 15 cm for big onion variety Pilipatti. The field was prepared with the bed width of 180 cm and 45 cm as bund (ridge) width. There is a considerable effect of plant density (intra-row spacing) on yield and yield components. The plant to plant spacing was kept as 10 cm as per the recommendation of the agronomists (Anonymous, 2009). The root depth and its spreading pattern of onion plant were considered in the development of onion harvester. The total depth of roots spreads was considered as 3.5-4.0 cm with spread over 6.0-7.0 cm width. The depth of onion bulb depends on onion variety, soil type and soil condition. It was considered as 4.5-7.0 cm below the surface of soil, but the digging depth of 6.0-8.0 cm was required to prevent the onion bulb damage. When the onion bulbs gets mature, the green tops weaken just above the bulb and fall over (neck fall); at that time the irrigation is required to be stopped. Onions are ready to harvest when about one half of the plants have tops that have fallen over. The moisture content of soil exists in the range of 15.00-21.00 % at the time of onion harvesting. In general, manual harvesting operation required more moisture content, so that labour had to apply less effort to uproot or dig the onion bulbs.

Functional Requirements

The onion harvester should be suitable for varying row spacing as well as plant spacing. It digs up or lifts up the soil layer with onion bulbs from desired depth as well as it should separate the dug up mass that is the onion bulb with leaves and soil. It should be able to minimize the onion bulb damage while harvesting and should leave the harvested onion on soil surface for hand picking. It should have more capacity and efficiency in harvesting onion. It should be simple in design and easily repairable at local level with durable and economical in operation.

Engineering Considerations

The width of harvester should be such that it has maximum width of coverage for a 30-35 hp range tractor which could accomplish the harvesting operation efficiently. The depth of operation should be such that it could dig all the onion bulbs from the soil mass without losing any bulb as buried or damaged. The speed of operations should be in the range of 2.0-4.0 km/h. The field capacity will be high with higher speed of operation; at the same time, it should also consider the damage to the bulbs.

The draft requirement for the tractor operated onion harvester was calculated on the basis of the maximum pull developed by a 35 hp tractor. The working width of the blade was 180 cm and the depth of cut would be maximum 10.0 cm, hence the cross sectional area of row cut out = 180 × 10.0 = 1800 cm^2. The specific soil resistance of heavy black barren land exists as 0.70 kg/cm^2 (Ganeshan, 2004). But at the time of onion harvesting, the moisture content may be as 15.00-21.00 % due to prior irrigation to the crop. So, the specific soil resistance of test field was considered as 0.40 kg/cm^2.

As $D = 9.8 \times R \times C/s\ A$ .... (1)

where D = Draft, N

R= Soil resistance, kg/cm^2 (Take 0.40), C/s A= Cross sectional area of row cut out, cm^2 (Take 180 × 10 = 1800)

So that, $D = 7056$ N,

Now, $P = D \times S$ [14] .... (2)

where P = Power, W, D = Draft, N (Take 7,056) and S = Speed, m/s, (Take max. speed as 4.5 km/h i.e.1.25 m/s)

So that, $P = 8.82$ kW = 11.82 hp. By considering the tractive and transmission efficiency of the tractor as well as factor of safety, a very common and popular 35 hp tractor was found most suitable to operate the developed onion harvester.

Development of Major Components

The onion harvester was developed in successive stages of selection or development of major component viz. main frame, digging blade, soil compacting roller and shaking assembly. Different sized C- channel, spring steel blade, GI pipes, round bright bars, bushing, MS sheet, bearing, pedestal with bearings, etc. were used for the fabrication of tractor operated onion harvester.

Main Frame

The components like digging blade, soil compacting roller and shaking assembly were required to attach with a frame. Considering to lower down the cost of fabrication of onion harvester, it was decide to use the main frame of any existing tractor drawn implement with tynes as main frame of the developed onion harvester.

Digging Blade

The function of the share or blade of root crop harvesting machines is to lift or dig up the layer of soil bearing tubers or bulbs, partially or completely break up the soil layer and deliver the resulting material to the subsequent working components. The construction of blade should ensure minimum soil excavation without slicing or damaging the bulbs. The shares of modern potatoes harvesting machines are in the form of twin-edged wedge. These are divided into two groups based on the nature of their motion; active and passive. These may be flat, trough-shaped, sectioned and disk type. Combination shares are also used consisting of both passive and active elements. The required depth for uprooting of onion bulbs at the time of harvesting operation is about 10 cm. With the greater length of blade, it would result in more draft requirement at the same depth. Considering the draft ability of 35 hp tractor, width of main frame of existing tractor operated blade harrow, width of onion bed and onion crop row to row spacing as 15 cm; to cover more number of rows at a time and thereby getting higher field capacity of the harvester, it was decided to keep blade width as 180 cm considering the width of main frame of the existing tractor drawn implement.

The thickness of blade was calculated by the formula

$M / I = F / y$ ....(3)

where,

M = Bending moment acting on the blade section, kg-cm

I = Second moment of inertia of cross section about the neutral axis, cm^4

F = Bending stress, kg/cm^2 and Y = Distance from neutral axis to the extreme edge, cm

As, $M = Force \times Distance$ ....(4)

= 150 (weight on blade) × (90 / 2) (distance between two successive tynes / 2) = 6750.00 kg-cm

Take F = Allowable bending stress = 900 kg/cm^2,

Y = 10.0 / 2 = 5.00 cm, (Take depth of cut = 10.0 cm)

Now, $I = tb^3/12 = t(10)^3/12 = 83.33t$ ....(5)

where, t = Thickness of blade, cm and b = Max. width of blade, cm

By putting above values in **Eqn. 5**, $t = 6750.00 \times 5.00 / (83.33 \times 900) = 0.45$ cm

Considering, the factor of safety and availability of material, the thickness of blade was kept as 10.0 mm.

Soil Compacting Roller

When the onion bulb is uprooted by the digging blade and before it

Table 1 Specification of developed onion harvester.

Particular	Specifications
Name of the equipment	Tractor operated onion harvester
Type of hitch and its detail	
Linkage	3-Point
Powered by	Tractor PTO
Overall Dimensions	
Length	100 cm
Width	200 cm
Height	102 cm
Weight	150 kg
Main Frame	
Material of construction	Frame (C-channel size: 62 mm × 62 mm × 6 mm) of existing tractor drawn blade harrow with three tynes
Length	58 cm
Width	200 cm
Digging blade	
Material of construction	Spring steel blade
Length	180 cm
Width	10 cm
Thickness	12 mm
Fixed with	Three tynes by bolting
Angle of inclination	Adjusted by the top link of tractor
Soil Compacting Roller	
Material of construction	GI pipe freely rotating on 25 mm Bright bar shaft
Length	180 cm
Dia.	75 mm
Fixed with	Bushing fitted on both side tynes at 30º with horizontal
Shaking Assembly	
Material of constructionGI pipe (say rod) and MS sheet welded on 20 mm bright bar freely rotating shaft	
Length of rod	65 cm
Diameter of rod	16 mm
No. of rod	18
Spacing between two adjacent rod	8.40 cm
Slope	30º (for 19 cm length) – 25º (for 23 cm length) – 18º (for 22 cm length) with horizontal
Sieve	14 Gauge (4 mm) MS Sheet welded with rod assembly and 20 mm dia. hole made on sheet
Fixed with	Hollow bush welded on both side tynes
Driven by	PTO connecting mechanism gives vertical movement as 70-90 mm

fell on the soil surface travelling through the shaking assembly, it was decided to compact the dug soil so as to prepare clean field to achieve ease of collection of onion bulbs.

Shaking Assembly

Separating devices were designed to break up the soil layer lifted by the blade, separated the bulbs from the soil and other impurities and deliver the material to the next set of components for further processing. These components are the rod-elevator, riddles and special devices for separating the haulms, stones, hard lumps of clay and high moisture content soil.

Results and Discussion

The developed onion harvester with specification given in **Table 1** and is shown in **Figs. 1** and **2**. The unit was tested for its working performance at MCF farm of the Junagadh Agricultural University, Junagadh. During the field testing of the same, the observations were recorded as illustrated in **Tables 2** and **3**.

Onion Bulb Damage

After completion of the mechanical harvesting operation by the onion harvester, three plots of 2 m × 2.25 m size were demarked randomly for determining onion bulb damage as harvesting losses. From all the three sample areas, the exposed onion plants with bulbs laying on soil surface were collected and damaged bulbs with plants separated. The buried plants with bulbs were also collected to determine the harvesting losses (**Table 4**). The losses were calculated with the help of following formulae as per the test code for groundnut digger (IS Test code, 1993)

A (kg) = B (kg) + C (kg) + D (kg) ....(6)

where,

A = Total quantity of onion plants with bulbs collected from the sample area, kg

B = Quantity of exposed onion plants with bulb lying on the soil surface of the sample area, kg

C = Quantity of damaged onion bulb with plants collected from the sample area, kg

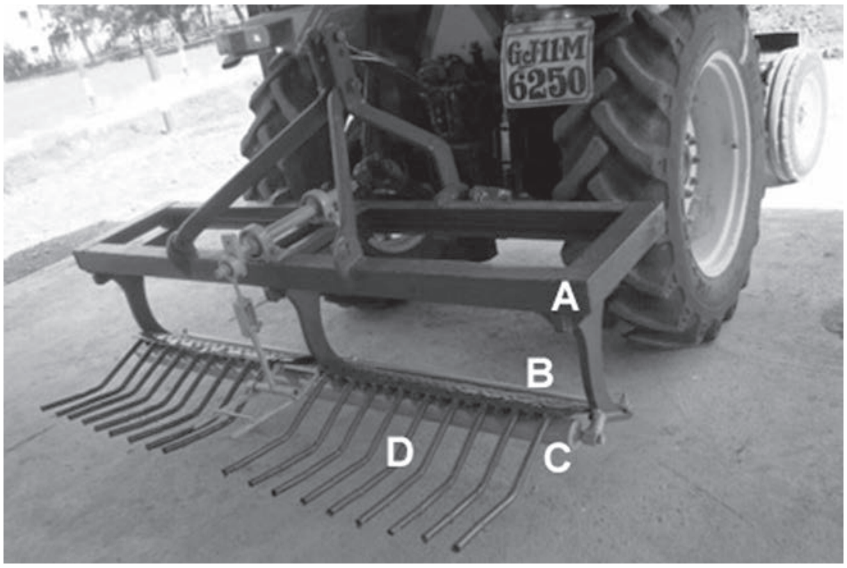
D = Quantity of buried onion plants with bulbs collected from the sample area, kg

Percentage of exposed plants with bulbs = *(B / A) × 100*.............(7)

Percentage of damaged bulbs with plants= *(C / A) × 100*.............(8)

Percentage of buried bulbs plants with bulb= *(D / A) × 100* ......(9)

Harvesting efficiency = *100 − (Percentage of total bulb losses i.e. damaged and buried onion plants with bulbs)*................(10)



A: Main frame, B: Digging blade, C: Soil compacting roller, D: Shaking assembly

Fig. 1 A view of tractor operated onion harvester.

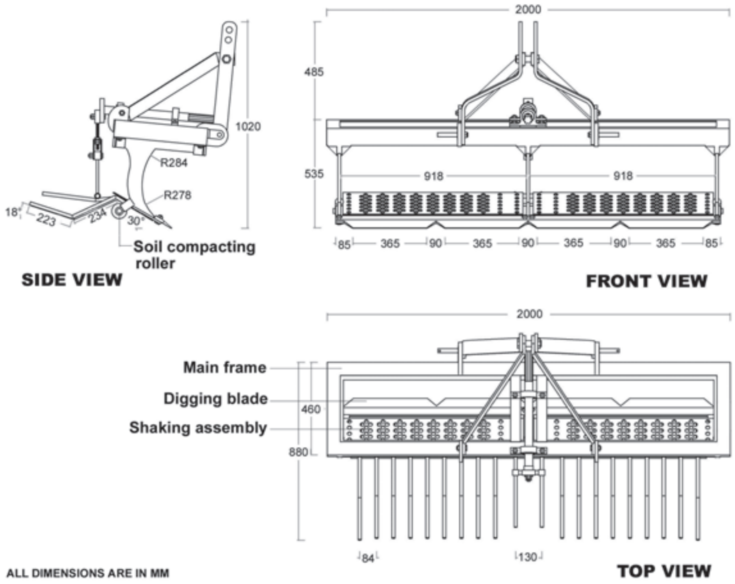


Fig. 2 Schematic view of tractor operated onion harvester.

Economics of Onion Harvesting Methods

The economics of the manual harvesting methods in terms of time, energy and cost of operation was observed and compared with the mechanical cum manual harvesting method of onion crop.

Manual Harvesting Method

The manual harvesting of onion crop is mostly performed in a sitting or bending posture, which rapidly increases fatigue. In this method, the onion bulbs were dug manually and they were also manually gathered in the middle of bed for windrowing the onion crop. During the experiment, time required per unit area for manual harvesting of onion crop as per farmer's practice i.e. onion plants with bulbs uprooting or digging, collecting and arranging them in a row at middle of bed (windrowing) was observed and the time required per hectare was determined. The human energy utilized in manual harvesting method was evaluated by the following formula (Chaudhary *et al*., 2006).

$E_m = 1.96\, N_m\, T_m$ .... (11)

where,

E_m = Manual energy expended, MJ/ha,

N_m = Number of labour spent on a farm activity

T_m = Useful time spent by a labour on a farm activity, h/ha

On the basis of actual labour hours, the operational cost of manual harvesting was calculated. In the present study, it was considered as Rs. 150/- per day of eight hours and thereby the cost of operation per hectare was determined. During the peak season, the labour charge were Rs. 250-300/- per day of eight hours.

Mechanical Cum Manual Harvesting Method

The developed onion harvester was able to dig the onion plants with bulb and laid them in the surface of bed unevenly; but as per the farmers' practice, it was necessary to collect the onion plants with bulb and gathering them in a row at middle of bed (windrowing). For this purpose, the labours were engaged to collect the harvested onion plants with bulb lying on the surface and to windrow the crop. During the field trial, the time required for mechanical harvesting per unit area of the crop was observed and the time required per hectare was determined. In addition to that, the labour time required to windrow the mechanically harvested onion plants with bulb per unit area was also considered. The mechanical energy utilized in mechanical harvesting of onion crop was evaluated by the following formulae (Umar, 2006).

$Ef = 56.31D$ .... (12)

where Ef= Fuel (diesel) energy expended, MJ/ha and D= Amount of fuel (diesel) consumed, l/ha.

The human energy utilized to collect and arrange the harvested onion plants with bulb in middle of bed were also determined by **Eqn. 11** and thereby the total energy i.e. mechanical and human energy utilized per hectare was determined.

The operating cost of the developed onion harvester was worked out by the straight line method. As

Table 2 Preliminary observations during harvesting operation.

Particular	Observation
Name of the crop	Onion
Variety of crop	Pilipatti
Type of soil	Medium black soil
Area of onion grown	0.06 ha
Date of sowing	04/11/2010
Date of transplanting	06/01/2011
Method of transplanting	Manual method
Plant geometry	R-R: 15 cm, P-P: 10 cm
Width of beds	180 cm
Width of bunds	45 cm
Soil moisture content	20.62 %
Date of last irrigation given	12/04/2011
Date of harvesting	20/04/2011
Crop duration	167 days (5 ½ month)
Average no. of plants per m length of bed	119
Root depth	5.5-6.5 cm
Total no. of plants per ha	528,000-533,300
Average weight of onion bulb	46.00 gms

Table 3 Performance of onion harvester.

Parameter	Value
Speed of operation, km/h	2.52
Depth of cut, cm	6.0
Width of cut, cm	180
Width of coverage (incl.bund of 45 cm), cm	225
Net Pull, kg	470
Draft, kg	470
Power requirement, hp	4.39
Fuel consumption, l/h	2.53
Wheel slip, %	19.41
Theoretical field capacity, ha/h	0.57
Effective field capacity, ha/h	0.45
Field efficiency, %	78.95
Field capacity, h/ha	2.22

Table 4 Losses of onion harvester.

Parameter	Value (No. basis)	Value (Wt. basis)
Exposed plants with bulbs	95.75 %	96.45 %
Damaged bulbs with plants	3.40 %	3.21 %
Buried plants with bulbs	0.85 %	0.34 %
Total bulb losses considering damage bulbs and buried bulb with plants as losses	4.25 %	3.55 %
Harvesting efficiency considering total bulb losses	95.75 %	96.45 %

previously discussed, in addition to that, the labour charges expended to collect and to windrow the harvested onion plants with bulb per unit area was also considered.

Economical Comparison of Onion Harvesting Methods

Mechanical harvesting often causes a reduction in harvested crop value per ha in comparison with hand harvesting, especially in non-selective harvesting of crops that do not mature uniformly or in harvesting easily damaged crops. The reduced value may be a result of reduced potential yield, actual field losses or reduction in quality. This factor, as well as hand harvesting costs and machine harvesting costs, must be considered when making an economic comparison. The general cost relation is given as following formula (Kepner *et al.*, 1987).

$N = H - M - LG$ .... (13)

where,

N = Increase in net income due to mechanical harvesting, Rs./ha

H = Total hand harvesting costs, Rs./ha/yr

M = Total mech. harvesting costs incl. machine fixed costs, machine operating costs and labour costs, Rs./ha/yr

G = Gross income or crop value from the hand harvested crop, Rs./ha

L = Loss factor (Reduction in gross income or crop value as a result of mechanical harvesting, expressed as a decimal fraction of G)

R = Break even crop value ratio

At the breakeven point, N = 0 and L = Le so that **Eqn. 13** becomes $H - M - LeG = 0$, where Le = Loss factor.

So, the break even loss factor

$Le = (H - M) / G$ .... (14)

The break even crop-value ratio R would be to equal 1- Le. It is evident from **Eqn. 14** that the percentage loss which can be tolerated is directly related to the amount of reduction in harvest cost and inversely related to the crop value.

Considering the onion bulb damages due to mechanical cum manual harvesting method, bulb loss was found as 3.88 % and also 3.88 % income decreased from mechanically cum manually harvested onion crop, taking into account market price of onion as Rs. 4/- per kg. It is observed that there was 2.16 % increased in overall net realized profit from mechanical cum manual harvested over the manual harvested onion crop.

The mechanical harvesting of onion causes a reduction in harvested crop value. The reduced value might be a result of field losses or reduction in quality. From the results presented in **Table 5**, the following values were found:

Increase in net income, N = Rs. 1,961/- per ha

Total hand harvesting costs, H = Rs. 7,305/- per ha

Total mech. harvesting costs, M = Rs. 1,544/- per ha

Gross income from the hand harvested crop, G = Rs. 98,000/- per ha

By putting above value in **Eqn. 13**, the loss factor L is determined as 0.3877 which was identical with 3.88 % decreased yield due to mechanical harvesting over the manual harvesting method. At break- even point, N = 0 and so L = Loss factor Le. From the **Eqn. 14**, the Le was found as 0.0587 and thereby the break even crop value ratio R is determined as 0.9413 for the mechanical harvesting method.

Hence, the mechanical harvesting method is feasible up to (1.0000 minus 0.9413 i.e. 0.0587) 5.87 % yield loss. As the developed onion harvester had shown the yield loss of 3.88 % (L) only, it is found economically feasible.

Conclusions

1. The average depth of cut by harvester was calculated as 6.0 cm while width of cut was measured 1.80 m and width of coverage determined as 2.25 m including 0.45 m bund.
2. The draft requirement to operate the onion harvester was measured 470 kg at 2.52 km/h speed of operation and power requirement was determined as 4.39 hp (3.27 kW) with the fuel consumption of 2.53 l/h.

Table 5 Economical comparison of mechanical cum manual harvesting with manual harvesting of onion.

Particular	Mechanical cum manual harvesting method	Manual harvesting method	Increase (+) or decrease (−) over manual harvesting method (%)
	X	Y	{(X − Y) / Y} × 100
Total Time required, man-h/ha	48.14	389.62	− 87.64 %
Total energy (human as well as mechanical) consumption, MJ/ha	410.62	763.65	− 46.23 %
Total harvesting cost, Rs./ha	1,544	7,305	− 78.86 %
Yield (considering losses), kg/ha	23,550	24,500	− 3.88 %
Income (considering market price of onion as Rs. 4/- per kg), Rs./ha	94,200	98,000	− 3.88 %
Overall net realization (considering only harvesting cost), Rs./ha	92,656	90,695	+ 2.16 %

3. The theoretical field capacity of onion harvester was found as 0.57 ha/h while effective field capacity was 0.45 ha/h and field efficiency was 78.95 %.
4. On the number basis as well as weight basis, the percentage of exposed bulbs was 95.75 % and 96.45 %, percentage of damaged bulbs was 3.40 % and 3.21 %; and percentage of buried bulbs was 0.85 % and 0.34 % respectively.
5. The harvesting efficiency was found as 95.75 % and 96.45 % for number basis and weight basis respectively.
6. The overall net realization from mechanical cum manual harvested crop was calculated as Rs. 92,656/- per ha, while from the manual harvested crop, it was found as Rs. 90,695/- per ha, thus there was 2.16 % increase in overall net realized profit due to mechanical cum manual harvested method.

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Mechanization Package for Chipping and Planting of Sugarcane Bud Chips Grown in Protrays for Sustainable Sugarcane Initiative in India

by

Ravindra Naik
Senior Scientist,
naikravindra@gmail.com

S. J. K. Annamalai
Principal Scientist

Central Institute of Agricultural Engineering, Regional Centre, Coimbatore, Tamil Nadu, 641 003, INDIA

N. Vijayan Nair
Director

N. Rajendra Prasad
Principal Scientist

Sugarcane Breeding Institute, Coimbatore, Tamil Nadu, 641 041, INDIA

Abstract

Sustainable Sugarcane Initiative (SSI) is a method of sugarcane production which uses less seeds, less water and optimum utilization of fertilizers and land to achieve more yields. Sugarcane bud chip planting is the latest technique of sugarcane planting, wherein the bud along with a portion of the nodal region is chipped off and planted in protray with Farm Yard Manure (FYM), soil and sand. This technology is going to be in great demand for successful SSI method of sugarcane cultivation. Studies on mechanisation of chipping of sugarcane bud chips with mechanical chipper and the planting of settlings from sugarcane buds raised in portrays by tractor drawn two row mechanical planter was developed jointly by Central Institute of Agricultural Engineering-Regional Centre, Coimbatore and Sugarcane Breeding Institute, Coimbatore. The sugarcane buds can be chipped off using pedal operated or pneumatically operated sugarcane bud chipping machine. The capacity of the mechanical model was 550-600 and 900-1,000 chips for pedal and pneumatically operated equipment, respectively. The tractor drawn bud chip settling planter can be attached to a standard three-point hitch arrangement of a 35 hp tractor. The optimum speed of operation was standardized as 1.4 km/h. The field capacity of the equipment was 0.15 ha/h. The biometric parameters viz., diameter of the cane, cane height, single cane weight, juice content and yield of the mechanically planted sugarcane settlings were on par with the manually planted sugarcane settlings. The juice quality of sugarcane from mechanically planted settling in terms of brix, CCS, sucrose and purity was on par with sugarcane from manual planting of settlings at the time of harvest. Cost economic analysis revealed significant saving in cost and labour over manual bud chipping and planting by using mechanical model of bud chipping machine and bud chip settling planting.

Key words: Sugarcane, Sustainable Sugarcane initiative, Bud chipping, Settlings, Planter, Field capacity, Biometric parameters, Cost economics

Introduction

Sugarcane is an important cash crop of India. It is cultivated in an area of 5.025 mha with an average productivity of 68.1 t/ha giving a total production of 342.56 mt of sugarcane and 26.5 mt of sugar in the year 2011-12. The demand for sugar in the country by 2030 will be 36 mt for which the sugarcane production has to be 500 mt (Nair, 2012). This amounts to 40 percent increase over the current production and has to be achieved through vertical improvement in productivity. Significant efforts have been made to increase sugarcane yield through varietal developments, control of pests and diseases, improved cultural practices etc. However, engineering inputs and efficient crop management have to play its role to obtain sustained potential yield.

Sugarcane cultivation requires various operations like seedbed preparation, planting, interculture, earthing up, plant protection, harvesting, transportation and ratoon management. Of these operations, land preparation is done as in the case of other crops by commonly used tillage implements. Planting, interculture, earthing up and transportation are in semi- mechanized stage. At present, the most common method of planting is by using stalk cuttings or setts. This method of cultivation is gradually becoming uneconomical as the cost of "Seed Cane" used for replanting accounts for over 20 % of the total cost of production. In conventional system prevalent in India, about 6-7 t seed cane/ha (nearly 10 % of total produce) is used as planting material, which comprises of about 250-300 mm stalk pieces having 2-3 buds. The requirement of planting material in large quantity poses a great problem in transport, handling and storage of seed cane and undergoes rapid deterioration thus reducing the viability of buds and subsequently their sprouting.

Sustainable Sugarcane Initiative (SSI) is a method of sugarcane production which uses less seeds, less water and optimum utilization of fertilizers and land to achieve more yields. SSI is an alternate to conventional seed, water and space intensive sugarcane cultivation. Planting of bud chip grown in protray is the latest method of cultivation of sugarcane and is gaining popularity among the farmers. In this technique, the bud along with a portion of the nodal region is chipped off and planted in protray/poly bags filled with farm yard manure (FYM) or press mud, soil and sand in 1 : 1 : 1 proportion. Nursery raised from sugarcane bud chips and planting them into the main field was found to be more economical than traditional method of sett planting.

Advantages of sugarcane bud chip technology are as follows:

1. Seed material required is only 1 to 1.5 t/ha and the cane after taking the chips can be sent for milling.
2. Bulk handling of cane material reduced by 80-90 percent, which facilitated easy transport and handling of seed material.
3. Selection of healthy buds eliminated infected seeds.
4. Sett transmitted diseases and pests were kept to minimum.
5. Relatively less expensive and labour saving technique.
6. Reliable method for multiplication of breeder seed as well as promising seed stock.

Although there are several advantages of planting sugarcane by using bud chipping technique for effective SSI, it has disadvantages in terms of additional manpower required for manual planting. For effective mechanization of SSI technology by using sugarcane bud chip technology, there was an urgent need for mechanization of following two operations.

a) Removing of bud chip from sugarcane: This operation was generally carried out manually by using knife. It was usually done in unhygienic manner and there was no control to avoid contamination in manual handling. Although, some hand operated devices for removing sugarcane bud chips are available, which are slow in operation thereby low in output. These are tedious in operation as the persons have to sit down and operate the equipment in bending posture with some difficulty. The number of buds required per hectare is 24,700 (at a spacing of 900 × 450 mm) bud chips and the time required for making these buds, assuming every bud takes 30 s to be chipped out manually, is 205 h/ha.

b) Planting of sugarcane settlings grown in protrays: Manual planting of sugarcane bud chip settling is very tiresome and laborious as the operation is done in a bending posture. This requires labour for pulling the settlings and planting them in the field. The studies on manual transplanting and growth of the plants have indicated some disadvantages of conventional transplanting methods such as high labour requirement in a short period of time, weather hazard often causing farmers to miss the best transplanting period and resulting in low yield. The plant losses expected due to unavoidable human error during the transplanting operation resulting in non-uniformity of stands and the missing plants need to be replanted and hence, extra labour is required (Splinter and Suggs, 1959; Kavitha and Duraisamy, 2007; Annamalai *et al*., 2012; Naik *et al*., 2013). Uniform stands of high livability are rarely achieved by conventional transplanting methods. In the common conventional practice, as the plant is uprooted for transplanting, the major part of the root system supplying the plant with water and nutrients is stripped off. Losses of these roots drastically reduce the absorbing surface of root system. The time required for the plant to recover depends on the individual plant and the environmental conditions. Much of the shock and non-uniformity could be greatly decreased if damage to plant roots is avoided. Usually the irrigation channel for the planted bud chip settlings is formed after a planting is done. This involves additional labour and there are likely chances that the bud chip settlings may be disturbed. Labour shortage during peak season causes delay in transplanting and related operation, leading to drastic reduction in yields.

This paper basically explains the equipment developed by Central Institute of Agricultural Engineering, Regional Centre, Coimbatore, India in collaboration with and Sugarcane

Breeding Institute, Coimbatore, India for removing of bud chips (pedal and pneumatically operated) and tractor drawn mechanical transplanter for planting sugarcane settlings grown in portray.

Materials and Methods

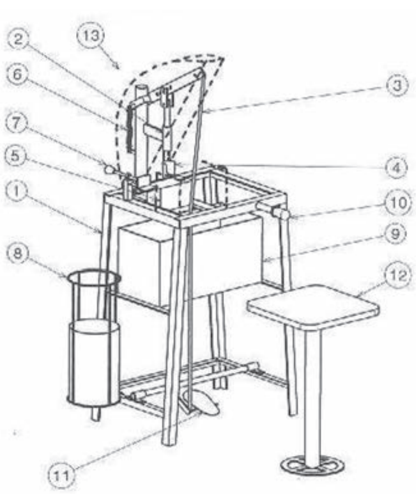
Selection of Sugarcane

Eight months old Co 99004 variety of sugarcane grown in the experimental research plot of Sugarcane Breeding Institute, Coimbatore in India was used for the investigation. Sugarcane buds were taken out from the bottom 1 m portion of 6-8 months old healthy canes, free from insects and diseases attack by using the sugarcane bud chipping equipment.

Equipment for Sugarcane Bud Chipping

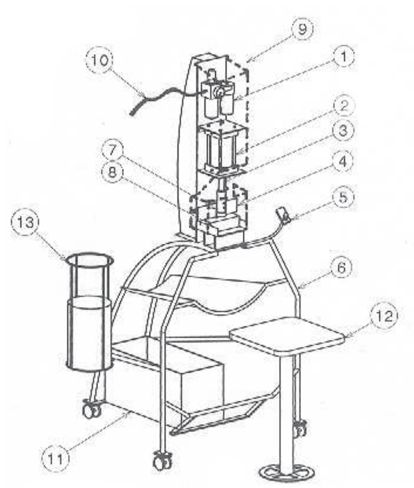
a) Pedal operated sugarcane bud chipping equipment

The equipment (**Fig. 1**) consisted of an outer frame to hold all the functional parts. Chipping blade, semi-circular in shape and made of stainless steel was used to chip out the sugarcane buds from sugarcane. The sugarcane from which the buds were to be removed was placed in the cane holder. Pedal operated linkage mechanism comprised of a pedal, which could be operated by using leg. The applied power was transmitted to the chipping knife through the spring loaded linkage mechanism. A guide mechanism guided the sugarcane to the chipping zone so that the sugarcane bud chips of required size were obtained. Plastic collecting tray was used for collecting sugarcane bud chips. A sugarcane guard screen made of M.S. mesh of 2 × 2 mm was placed in between the operator and bud chipping zone, so that the buds fell into the collecting tray placed below the chipping zone. The hygienic collection of sugarcane bud chips would increase the germination percentage. An adjustable stool was also provided with the machine, so that the operator could sit and operate the equipment, thus avoiding the long standing period during the operation.



1. Outer frame,
2. Bud chipping mechanism
3. Linkage mechanism, 4. Chipping blade
5. Chipping Platform, 6. Spring tension
7. Adjustable guide, 8. Cane holder
9. Collection tray, 10. Handle, 11. Pedal
12. Adjustable sitting stool,
13. Guard

Fig. 1 Isometric view of pedal operated sugarcane bud chipping equipment.



1: Air filter, 2: Pneumatic cylinder,
3: Cylindrical shaft, 4: Cane guide,
5: Joy Stick, 6: Outer frame,
7: Cutting blade,
8: Wooden cane base plate, 9: Guard,
10: Compressor line, 11: Collection Box,
12: Adjustable sitting stool,
13: Cane holder

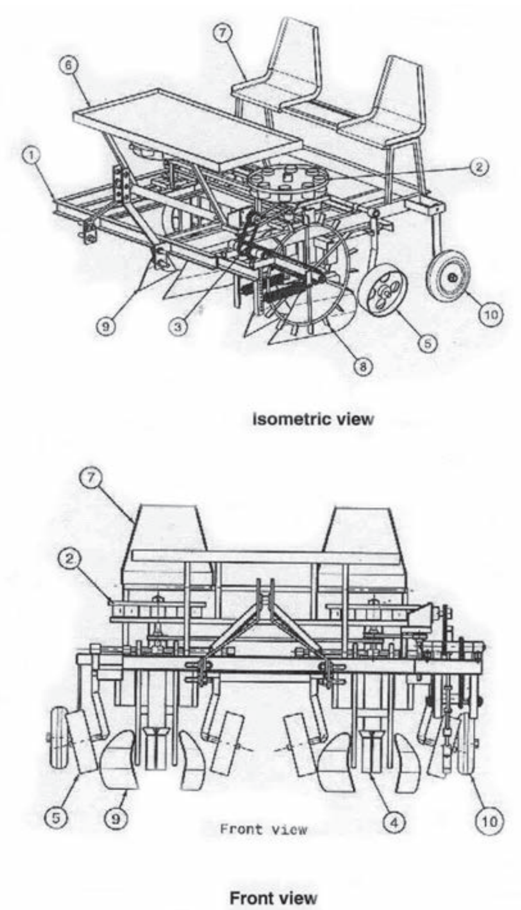
Fig. 2 Isometric view of Pneumatic model of sugarcane bud chipping equipment.

b) Pneumatic model of sugarcane bud chipping equipment

The equipment (**Fig. 2**) consisted of outer frame to hold all the functional parts. Chipping blade made of stainless and semi-circular in shape was used to chip out the sugarcane buds from sugarcane. A guide was used for holding the sugarcane on the chipping platform, from which the buds are to be removed. Pneumatic cylinder was used for operating bud chipping blade attached to stainless steel cylindrical shaft. The chipping blade moved up and down (with a stroke length of 100 mm) by force exerted by the pneumatic cylinder by converting the potential energy of compressed air at 340 to 490 kPa obtained from the air compressor (1.0 hp) into kinetic energy. The sugarcane bud was chipped out during the downward stroke. Since the position of the alternate sugarcane buds were at 1800, the cane had to be turned by 1800, before the next stroke was performed. The pneumatic cylinder was operated by means of a two dimensional joystick which controlled the up or down movement of the cutting blade along the Y axis. A guard screen made of 0.5 mm diameter hole was placed in between the operator and bud chipping zone, to direct the buds into the collecting tray placed below. This guard also provided safety to the operator and avoided direct contact between the operator and the extracted sugarcane buds. This enabled hygienic collection of sugarcane bud chips which could increase the germination percentage.

Growing of Nursery in the Glass House

The extracted bud chips were dried in shade for 2-4 h. The shade dried buds were dipped in malathion 50 EC 0.1 percent (2 ml/1 l of water) and carbendazim 0.1 percent (1 ml/1 L of water) solution for 10 min and again dried in shade. The pretreated sugarcane bud chips were planted in plastic protray filled with FYM, soil and sand in 1 : 1 : 1 proportion and grown in the glass house of Sugarcane Breeding Institute, Coimbatore. The size of each protray was 530 × 270 × 50 mm, round in shape containing 50 cells (10 × 5). The cell measurement was 50 mm ø at top, 30 mm ø at bottom and 50 mm in depth. The weight of each extracted sugarcane bud chip was 10-12 g. The height of settlings for planting was optimized at 150 mm after 35 days of planting (Annamalai *et al.*, 2011).



1: Main frame
2: Metering mechanism
3: Power transmission mechanism
4: Soil opener
5: Soil closer wheels
6: Sugarcane bud chip settling holding tray
7: Feeding men's seat
8: Ground wheel
9: Furrow wheel
10: Depth control wheel

Fig. 3 Isometric and front view of two row tractor drawn mechanical planter for sugarcane bud chip settlings raised in protray.

Tractor Drawn Two Row Mechanical Planter for Sugarcane Settlings

A tractor drawn two row mechanical planter for sugarcane settlings raised from sugarcane bud chips was developed based on Tami Nadu Agricultural University (TNAU) model of vegetable planter (Kavitha and Duraisamy, 2007), with required modifications (Annamalai *et al.*, 2012; Naik *et al.*, 2012; Naik *et al.*, 2013) (**Fig. 3**).

The Different Parts of the Mechanical Planter are as Detailed Below

Main frame: A frame was fabricated with 75 × 40 × 5 mm mild steel channel having a dimension of 1800 × 1600 mm. All components of the mechanical planter were assembled with the main frame in core alignment. A standard three-point hitch arrangement was provided for hitching the frame to the tractor. The top link was made of 2 mild steel strips with a slot. For lower links, two high carbon steel rods of 25 mm diameter and 190 mm length were provided on each side. The metering mechanism, operator's seat, furrow openers, soil opener and soil closure were mounted on the main frame with necessary supports.

Metering Mechanism: The circular metering mechanism consisted of two circular plates of 600 mm diameter mounted on a 25 mm diameter shaft. The discs were kept at a distance of 60 mm with each other. The bottom plate was fixed and had a single hole with a diameter of 70 mm. The top plate, which had 8 holes of 70 mm diameter, was rotated by a belt drive. As and when, the operator placed a settling in each hole on the top plate and as the plate rotates, the settlings would drop due to gravity when holes on the top and bottom plates were coincided.

Drop Chute Pipe: Sugarcane settlings falling at the ground made an angle of 85 to 880 with the horizontal, and fell in the direction of travel of the machine. To make plant upright, the drop chute pipe was inclined at an angle of 150 to vertical. A parabolic cut was made at the bottom of the drop chute pipe.

Power Transmission: The power for the metering unit was taken from ground wheel by means of chain and sprockets to the gear box. The ground wheel was made of mild steel rod of 10 mm thickness and 730 mm diameter. Twelve lugs of 50 mm × 45 mm section were attached at the periphery of each of the ground wheel. By the power transmission from the gearbox, which encompassed a bevel gear, a horizontal shaft transmitted power to a vertical shaft at 1 : 1 speed ratio. The circular metering mechanism was rotated by the vertical shaft. The drive from the ground wheel was transmitted through sprocket and chain mechanism to the main shaft. The speed of planting was a function of both tractor speed and selected power train.

Soil opener shoe: Shoe type furrow opener of 120 mm width was selected for sugarcane bud chip settlings planter (Kavitha and Duraisamy, 2007).

Soil closure wheels: The soil covering wheel assembly consisted of two soil covering wheels of 570 × 75 mm, side mounted on a shaft inclined at 15º to the vertical. The shaft was welded to the main frame through supporting plates. The distance between the two wheels at the top and bottom ends was 175 and 95 mm, respectively. These were tilted at an angle of 750 with the horizontal.

Settling holding tray: A frame was fixed above the settling metering plate to hold the settlings trays. The size of the tray was 620 × 1300 mm.

Operator's seat: A pair of operator's seat was provided on the frame behind planting mechanism. Two persons could sit and feed the settlings in the opening of the circular metering mechanism, enabling planting of the sugarcane settlings.

Furrow opener: To aid in irrigation after planting of settlings, a furrow opener was provided in front of the soil opener for forming irrigation channels on both sides of the settlings planted. It consists of a pair of wings, which was having a spacing of 200 mm at the front and 580 mm towards the wings. A soil cutting tool was provided at the front of the furrow opener to aid in opening of the soil to form the furrows.

The speed of the equipment was finalised based on laboratory experiments as suggested by Suggs, 1979; Way and Wright, 1987; Ladeinde *et al*., 1995; and Juric *et al*., 1997; Kavitha, 2005; Kavitha and Duraisamy, 2007; Naik *et al*., 2013) where in the speed of operation was standardised based on the relationship to efficiency of plantings (percent missing).

Field Performance Evaluation: A field of 75 × 50 m size was prepared for evaluation of the tractor drawn mechanical planter for sugarcane bud chip settlings raised in protray. The seedbed was prepared by two ploughings, followed by rototilling to make fine tilth and broadcasting of recommended dose of urea and super phosphate. Sugarcane settlings were removed from the protays grown in the glass house. The height of the settlings at the time of planting was about 150 mm kept under shade near the planting field (Annamalai *et al*., 2012 and Naik *et al*., 2013). Soil parameters such as moisture content, bulk density and cone index were also recorded. The field performance evaluation, required feed rate, plant missing and plant mortality after 20 days were calculated as suggested by Naik *et al*. (2013).

Machine Parameters

Machine parameters like forward speed, wheel slip, field efficiency, machine capacity and fuel consumption were measured and recorded according to the recommendations of the Regional Network for Agricultural Machinery (RNAM) test codes and procedures for farm machinery (Stevens, 1982 and Anonymous, 1983).

Sugarcane Juice Quality Analysis

Ten sugarcane samples were collected at random. The canes were de-trashed and the tops were removed at a point where it broke when a gentle pressure was applied at the top node. The juice was extracted using a clean three roller power operated crusher with a minimum of 65 percent of juice extraction within 12 hours of harvest. The basic parameters of sugarcane juice viz., 1) Brix by using hand held refractometer 2) Sucrose or pol by Saccharimeter 3) Purity and 4) Commercial cane sugar percent were determined following the procedures of Chen and Chou (1993). Each treatment was replicated five times.

Statistical Analysis

The data were analysed as factorial design. Statistical significance was determined at $P < 0.05$ for ANOVA and the means were separated using Least Square Difference (LSD).

Cost Economics Sugarcane of Mechanical Planter for Sugarcane Bud Chip Settlings

The total cost of bud chipping and mechanical planter for sugarcane bud chips was calculated. The fixed and variable costs for operating the machine per hour were calculated as per the procedure enumerated by Regional Network for Agricultural Machinery (Anonymous, 1983). The performance was compared with manual planting in terms of savings in cost and time. Break-Even Point (BEP) and Pay Back Period (PBP) of the equipment were also worked out.

Results and Discussions

Mechanical Model of Equipment for Removing of Bud Chips from Sugarcane

The performance of the pedal operated (**Fig. 4**) and pneumatically operated bud chipping equipment

Fig. 4 Pedal operated sugarcane bud chipping equipment.

Fig. 5 Pneumatic operated sugarcane bud chipping equipment.

(**Fig. 5**) was measured and compared with conventional method. With the help of pedal operated sugarcane bud chipping equipment, 550-600 buds can be chipped out per hour as compared to 125-150 bud chips per hour under conventional method. The saving in labour and cost of operation was 78-80 percent and 27-28 percent, respectively. By using pneumatically operated bud chipping, 900-1000 bud chips could be chipped out per hour with saving in labour and cost of operation of 85-88 percent and 60-62 percent, respectively. The cost of pedal operated bud chipping equipment and pneumatically operated bud chipping machine (with compressor) was Rs. 5,000 ($100) and Rs. 35,000 ($700), respectively.

Planting of Sugarcane Bud Chip Nursery Using Tractor Drawn Mechanical Planter for Sugarcane Bud Chip Settlings Raised in Protray

The sugarcane bud chip settlings were carefully removed from the protrays and placed on the sugarcane bud chip settling tray. Tractor of 35 hp power was operated at about 1.4 km/h choosing the best tractor gear. Two persons seated on the rear of the equipment constantly dropped the sugarcane settlings through the holes of the rotating metering device (**Figs. 6** and **7**). While falling through the chute, due to the combination effect of soil at the root base and parachuting effect of leaves, the root portion was always at the bottom and tip of the settlings was on the top. During the movement of the tractor in the forward direction, shoe type soil opener opens up the soil. Sugarcane settlings which were dropped by the person fell into this opened soil. After a small time lag, the soil closure wheel which was placed at an angle of 15o provided the side support to the settlings, thereby avoiding it to fall down.

The intra row spacing could be adjusted from 0.45 to 1.2 m based on the requirement and the plant to plant distance by the gear ratio between the power transmission mechanism and the ground wheel. Since there is likely to be some slip in the motion of the tractor in its forward motion and also in the ground wheel in contact with the soil, the plant to plant distance could not be maintained accurately. While the tractor was moving in the forward direction, the furrow opener opened up the irrigation channel on both sides of the sugarcane settlings planter. The plant missing, plant mortality after 20 days, depth of planting, planting angle, plants in lying down position were recorded.

The performance evaluation of tractor drawn two row mechanical planter for sugarcane bud chips settlings is given in **Table 1**. The field capacity of the mechanical planter was 0.15 ha/h at 75 percent field ef-

Fig. 6 Field operation of two row tractor drawn mechanical planter for sugarcane bud chip settlings raised in protray (side view).

Fig. 7 Field operation of two row tractor drawn mechanical planter for sugarcane bud chip settlings raised in protray (rear view).

ficiency.

Biometric Data of the Settlings Planted with Two Row Tractor Drawn Mechanical Planter for Sugarcane

The biometric observations and juice analysis is given in **Table 2**. The biometric observations were recorded in terms diameter of the cane a middle, height of the cane, single cane weight, juice percent and yield was recorded on the 240th, 300th day and at the time of harvest. It is seen from the table all the biometric characterises such as diameter at middle of the cane, height of the sugarcane plant and single sugarcane weight at the time of harvest of the mechanically planted sugarcane buds chips was on par with that of manually planted sugarcane bud chip settlings.

The juice quality was analyzed in terms of degree brix, Commercial Cane Sugar (CCS), sucrose percent and purity percent. It is observed that the juice of the cane obtained from settlings planted using tractor drawn settling planter was on par with manually planted sugarcane settlings.

Table 1 Performance of two row tractor drawn mechanical planter for sugarcane bud chip settlings raised in protray.

Particulars	Details
General	
a) Type	Tractor drawn
b) No. of rows	Two
c) Power source	35 hp Tractor
Overall Dimension (L × B × H), mm	1800 × 1600 × 1400
Total weight of the implement, kg	400
Soil conditions	
Moisture condition, percent (d.b)	12-13
Bulk density, kg/m^3	1,350
Machine performance	
Width of operation, m	1.35
Row to row spacing, m (Adjustable)	0.45 -1.00
Plant to plant spacing, m (Adjustable)	0.45
Optimum speed of operation, km/h	1.4
Required feed rate, Plants/min/row	28-30
Planting density, Plants per hectare	15,000 -25,000
Slip at 12% moisture content, percent (d.b)	3-4

Table 2 Biometric observation and juice analysis of sugarcane bud chip settlings planted by mechanical planter.

Particulars	240 days	300 days	Harvest
Biometric observation of sugarcane plants			
Diameter at middle, cm	2.67 ±0.21^{a}	3.00 ± 0.23^{b}	3.2 ± 0.19^{c}
	(2.65 ±0.29)^{*a}	(2.98 ± 0.13)^{*b}	(3.11 ± 0.16)^{*c}
Height, cm	200 ± 8.12^{d}	228 ± 7.52^{e}	239 ± 6.92^{f}
	(198 ± 6.16)^{*d}	(226 ± 5.87)^{*e}	(236 ± 4.98)^{*f}
Single cane weight, kg	1.13 ± 0.26^{g}	1.36 ± 0.21^{h}	1. 4 ± 0.19^{i}
	(1.09 ± 0.25)^{*g}	(1.29 ± 0.19)^{*h}	(1. 35 ± 0.19)^{*i}
Juice, percent	55.32 ± 0.81^{j}	57.65 ± 0.76^{k}	60.65 ± 0.98^{l}
	(54.82 ± 0.76)^{*j}	(56.52 ± 0.61)^{*k}	(59.39 ± 0.66)^{*l}
Yield, t /ha	N. A	N. A	131.24 ± 8.26^{m}
			(130.39 ± 5.68)^{*m}
Sugarcane juice quality			
Brix (degree)	18.56 ± 1.03^{a}	20.56 ± 0.67^{b}	23.18 ± 0.98^{c}
	(18.58 ± 1.16)^{*a}	(20.50 ± 0.63)^{*b}	(23.22 ± 1.08)^{*c}
CCS, %	11.56 ± 0.67^{d}	12.96 ± 0.87^{e}	14.43 ± 0.54^{f}
	(11.59 ± 0.71)^{*d}	(12.97 ± 0.91)^{*e}	(14.45 ± 0.65)^{*f}
Sucrose, %	16.56 ± 0.65^{g}	18.21 ± 0.88^{h}	20.50 ± 0.98^{i}
	(16.59 ± 0.55)^{*g}	(18.18 ± 0.81)^{*h}	(20.47 ± 0.61)^{*i}
Purity, %	90.28 ± 0.44^{j}	90.67 ± 0.62^{k}	91.92 ± 0.27^{l}
	(90.09 ± 0.33)^{*j}	(90.21 ± 0.55)^{*k}	(91.37 ± 0.36*)

Note: The values of all parameters are statistically on par 5 % df
Superscripts a, b, c, d, e, f, g, h, i, j, k depicts if the values are statistically on par or not
N.A = Not applicable
Each observation is a mean ± CD (n = 5)
*Values in parenthesis is for manual planting of bud chips

Cost Economics of Mechanical Model of Sugarcane Bud Chipping Equipment and Two Row Tractor Drawn Mechanical Planter for Sugarcane Bud Chip Settlings

The cost of two row tractor operated sugarcane bud chip planter worked out to Rs. 60,000 ($1200). The cost economics analysis revealed that the cost of planting / hectare was Rs. 5,410 ($108) with the tractor drawn two row sugarcane bud chip planter while it was Rs. 8,950 ($179) with manual bud chip planting. The saving in cost and labour was 40 percent and 85 percent, respectively by planting with tractor drawn two row sugarcane bud chip settling planter over manual bud chip planting. The breakeven point was 336 ha and the payback period was 2.50 year for two row tractor operated sugarcane bud chip planter

Conclusions

Sustainable Sugarcane Initiative (SSI) is a technology which is being adopted by large farming community in India which uses less seeds, less water and optimum use of input resources with higher economic returns. Use of sugarcane bud chip technology is a big step towards successful adoption of SSI. This is catching in a fast way in Indian Scenario. Removing of bud chips from sugarcane and planting of the bud chip settlings are the two major labour intensive operations while adoption of bud chips technology for SSI. To mechanize these operations, mechanized sugarcane bud chipping equipment and tractor drawn planter for bud chips settlings have been developed. The cost economic studies revealed that these equipment were faster than the manual method and also are more economic in operation, leading to significant saving in cost and time. These equipment are a boon to entrepreneurs who are involved in large scale production of the sugarcane bud chip nursery with an aim to undertake the Sustainable Sugarcane initiative programme in Indian Scenario.

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Development of a Box Pallet for Post-harvest Bulk Handling System for Onions

by
J. Park
Professor

D. Choi
Post-harvest Engineering Division
National Academy of Agricultural Science
KOREA

S. H. Kwon
Professor

S. Chung
Professor

S. G. Kwon
Professor

W. Choi
Professo

J. Kim
Assistant Professor
Jongsoon-kim@pusan.ac.kr

Department of Bio-industrial Machinery Engineering, Pusan National University, KOREA

Abstract

In this study, a box pallet for bulk handling system of onions was developed to reduce the cost of net-packaging. The dimensions of the box pallet were 1,300 × 1,100 × 1,600 mm (length × width× height) with three ventilating pipes installed in it. Performance test of the prototype box pallet was conducted to analyze temperature distribution of stacked onions and dispersion of loading for quality preservation. In addition, volumetric efficiency and truck stacking efficiency were analyzed for logistics.

Introduction

Post-harvest handling process for onions in Korea involves harvesting, curing, net-packaging, carrying, storage, sorting, grading, packaging, and shipping. Among those processes, net-packaging needs repeated work by two or three times in the field and it requires substantial amount of manual workload. According to a report from National Agricultural Cooperative Federation (2007), quality preservation of onion was not guaranteed because the onions net packaged received excessive contact pressure and ventilated air was blocked during drying and storage. The report also indicated that 30 % loss in the storage process was caused by improper loading methods and outdated pre-storage processing techniques.

Therefore, post-harvest bulk-handling system for onions should be developed to preserve onions' quality and to reduce the processing cost. This study was aimed to design a box pallet which is the essential part in the development of bulk-handling system for onions.

Design Factors and Details

Design Criteria

Five aspects were considered to design a box pallet for bulk-handling system of onions.

- Pickup and carrying: efficiency of logistics in the field, ease of use
- Forced-air drying: air circulation, preventing bruises caused by pressure
- Storage: cooling efficiency, air circulation, uniformity of the temperature distribution, preventing bruises caused by pressure
- Connection between the processes: pallet loading and unloading, sorting & packing-line and forced-air drying
- Versatility and easy of structural changes: applicability to other crops, minimizing storage volume

Detail Designs

Dimensions and Format Design of the Box Pallet

The length and width of the box pallet were 1,300 × 1,100 mm, which was determined by considering the effective ceiling height of existing cold warehouse (7-8 m) and the width of 5-ton truck freight container (2,280 mm). The effective height of the pallet was determined to be 1,582 mm to satisfy the following conditions.

- Loading capacity: 1 ton
- Bulk density of onions: 541.80 kg/ m^3 (Park *et al*., 2013)
- Ventilating pipe: 3 pipes with outside diameter φ100 × 1,220 mm
- Empty ratio occupied by ventilat-

ing pipe and four corners of the pallet: 5 %

- Height of entry of pallet: 75 mm (KST 2002; 2029)

Therefore, the outside dimensions of the pallet were 1,300 × 1,100 × 1,600 mm (length × width × height), and its format was a 4-way pallet which was connected with each other easily.

Strength of the Pallet and Design of the Main Structure

The main elements of the box pallet were vertical frame, ventilating pipe, and loading plate. The pins were used to assemble the pallet to enable folding and unfolding.

1) Vertical frame

The vertical frame was a key element of the pallet stiffness. It was considered as a beam-column which received the axial force (σ_c) from multiple columns of palletized load as well as the bending moment (σ_b) from the stacked onions (**Eq. 1**) (Young, 1989).

$$\sigma = \sigma_c + \sigma_b = F/A + \{(M_z \times c) / I_z\} \quad \text{......(1)}$$

Based on the combined stress in **Eq. 1**, the dimension and material of the vertical frame were determined using allowable-stress design method (**Eq. 2**) (Young, 1989).

$$F/A + \{(M_z \times c) / I_z\} \le \sigma_{all} \quad \text{.......(2)}$$

where, F = axial force (N)

A = cross-sectional area of vertical frame (m^2)

M_z = maximum bending moment (N-m)

c = distance from the centroid to the applied point of maximum stress (m)

I_z = moment of inertia for neutral axis (m^4)

σ_{all} = allowable (working) stress (= yield strength/safety factor) of shaft material (Pa)

In the **Eq. 2**, F meant an axial force on the vertical frame of pallet and was calculated at four-column of palletized load (**Eq. 3**).

$$F = \{(\text{weight of stacked onions} + \text{weight of pallet}) \times (4 - 1)\} / 4 \quad \text{.(3)}$$

The total horizontal force on the lateral wall of the pallet and its location should be estimated in order to know the bending moment of the vertical frame in the pallet. Total horizontal force was calculated by integrating along the stacking depth or stacking width using Janssen equation (**Eq. 4**) which represents distribution of parabolic lateral pressure with stacking depth (Mohsenin, 1986; Sitkei, 1986).

$$p_y = \gamma R/\mu\ [1 - \exp\{-(\mu k/R)\ y\}],$$
$$(p_y)_{max} = (\gamma R/\mu) \text{ for } y = h \quad \text{......(4)}$$

If the horizontal force in the **Eq. 4** is distributed evenly for the entire width, the total horizontal force can be calculated using the **Eq. 5**.

$$P = \int_0^{l,w} \int_0^h P_y dy dz\ (dx) = (\gamma \times R) / \mu\ [h + \{R \exp(-\mu k/R)\ h)\} / \mu k - (R / \mu k)] \times l, w \quad \text{......(5)}$$

where,

p_y = horizontal pressure on the lateral wall at stacking depth of y (Pa)

μ = static-friction coefficient between onion and the pallet wall

γ = specific weight of the onions (N/m^3)

R = hydraulic radius (ratio of cross-sectional area to perimeter) (m)

k = lateral pressure coefficient {= (1 − $\sin Ø_i$) / (1 + $\sin Ø_i$)}

$Ø_i$ = angle of internal friction of the onions (deg)

P = total lateral force on the wall (N)

l, w, h = inside length, width, and height of the pallet (m)

The position of P, the total horizontal force on the lateral wall of the pallet, became $(\bar{z}, \bar{y}) = (l/2, 5h/8)$ or $(\bar{w}, \bar{y}) = (w/2, 5h/8)$ which was calculated from the principle of the second moment of area.

Since the **Eqs. 4** and **5** used the hydraulic radius, it can be applied to any shape of containers. Data values used in the **Eqs. 3-5** are follows:

$Ø_r$ = 22° (Mohsenin, 1986; Park *et al.*, 2013)

$\mu = \tan Ø_r = 0.4040$

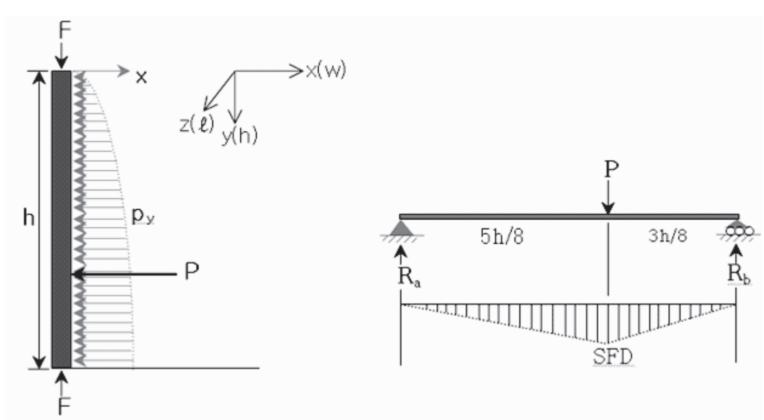
$k = (1 - \sin Ø_i) / (1 + \sin Ø_i) = 0.4550$

$\gamma = \rho g = 5315.06\ N/m^3$

$R = [lw / \{2(l + w)\}] = 0.2778$

The section modulus by allowable-stress design was estimated using the above values. After the repeated process of comparing this value with the yield strength of the material used, the cross-sectional area of the final material was determined. When calculating the combined stress, a safety factor of 4-5 was applied to the compressive stress on the vertical frame with the consideration of the dynamic conditions. The carbon steel square pipes, SPSR 400 (KS D 3568) with *40 × 40* (t = 2.3 mm, weight per unit length = 25.70 N/m, A = 3.332 cm^2, Z = 3.86 cm^3), were adopted for the vertical frame because it had enough strength even considering the safety factor.

$$\sigma_y = \sigma_c + \sigma_b = 99.8 + 132.4 = 232.2\ MPa \le \sigma_{YS}\ (245\ MPa)$$



(a) lateral pressure distribution (b) simplification to simple supported beam

Fig. 1 Simplification of vertical frame of pallet.

2) Fastening element

An assembly-pin was used in connecting four parts of the lateral walls as well as the lateral wall and the loading plate. Bending force acting on the face, l × h, is a dominant factor for designing the assembly-pin. As shown in **Fig. 1**, the lateral wall can be considered as a simply supported beam which had the hinged end in the lower part and the roller end in the upper part.

When taking the moment of upper part in the vertical frame, the shear force (S) which the assembly-pin should hold, was determined as follows:

$$\sum M_o = 0 \rightarrow P \times 5/8h - S \times h = 0 \rightarrow S = 5/8P \qquad (6)$$

The pin was made of the material S 45C (KS D 3752), and its diameter was calculated by applying safety factor of 5 (**Eq. 7**).

$$S_{all} = \tau_{all} \times nA \rightarrow d = 11.4\ mm \qquad (7)$$

where,

S_{all} = allowable shear force acting on the whole pin (N)

τ_{all} = allowable shear strength {= (compressive yield strength/2) / safety factor = (343/2)/5} (MPa)

A = cross-sectional area of the pin (m^2)

N = number of the pin (= 2)

One side of the loading plate should be open for connecting to the sorting/packaging process. For doing so, two hinges and two pins were attached on the both sides of the loading plate. **Fig. 2** shows the loading surface of the pallet which had the hinged end and the roller end at each side.

A total vertical force on the loading plate, 6.53 kN, was calculated by subtracting the total vertical force on the lateral wall by friction between lateral wall and onions from the total weight of onion using **Eq. 8** (Sitkei, 1986).

$$V = \gamma hA - \mu \{(\int_0^h p_y\, d_y) \times p_L\} = \gamma hA - \gamma R\, [\{h + \{R \exp(-\mu k/R)\, h)\} / \mu k - R/\mu k] \times p_L \qquad (8)$$

where,

V = total vertical force acting on the loading surface, N

A = cross-sectional area of the pallet, m^2

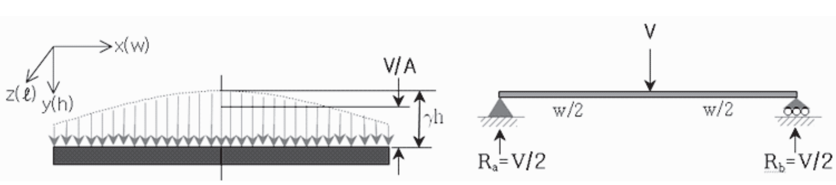
p_L = perimeter of the pallet, m

As shown in **Fig. 2b**, the one end of the loading plate was fixed with the pin; thus, the load needed to bear became V/2. In addition, considering the safety factor as 5, the pin diameter of 21.8 mm was obtained (**Eq. 9**).

$$S_{all} = \tau_{all} \times nA \rightarrow d = 21.8\ mm \qquad (9)$$

3) Ventilating pipe

Three ventilating pipes were installed in the pallet to improve the cooling speed and to distribute temperature evenly (**Fig. 3**). In addition, these pipes were installed to disperse the vertical load acting on the loading surface. The outer diameter of a ventilating pipe was 10 cm, and there were small-sized holes on the surface. Its aperture rate, the ratio of the holes area to the total surface area, was higher than 40 % to minimize onion's physical damage while contacting with them. The aperture rate at the loading surface was also higher than 40 % in order for the cooling air to flow upward freely from the bottom of the pallet without damaging to onions.



(a)vertical pressure distribution on loading plate
(b) simplification to of simple supported beam

Fig. 2 Simplification of loading surface of pallet.

Performance Evaluation and Considerations

Temperature Distribution at Different Positions of Stacked Onion Bulbs

One ton of the onion which was preconditioned for 5 days at the atmospheric conditions of 18 ºC (relative humidity, 50 ± 5 %) was loaded in the developed box pallet. It was, then, stored at a low temperature warehouse which was set to 2 ºC, and the temperature change was measured continuously during the experiment.

A temperature sensor was made using K-type thermocouple and plastic sphere (30 mm diameter) with many holes to measure the air

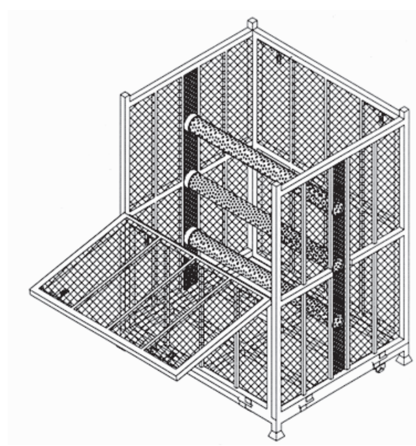


Fig. 3 3D drawing of prototype pallet.

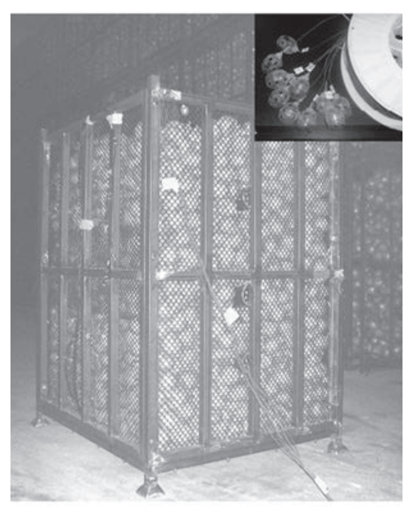
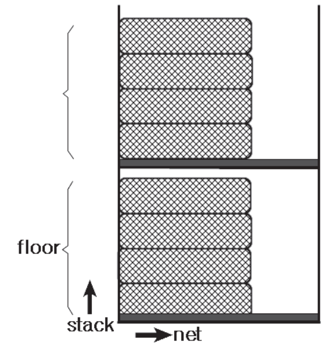


Fig. 4 Sensors for measuring temperature changes at different layers.

Table 1 Contact pressure in 20kg-net package stacking.

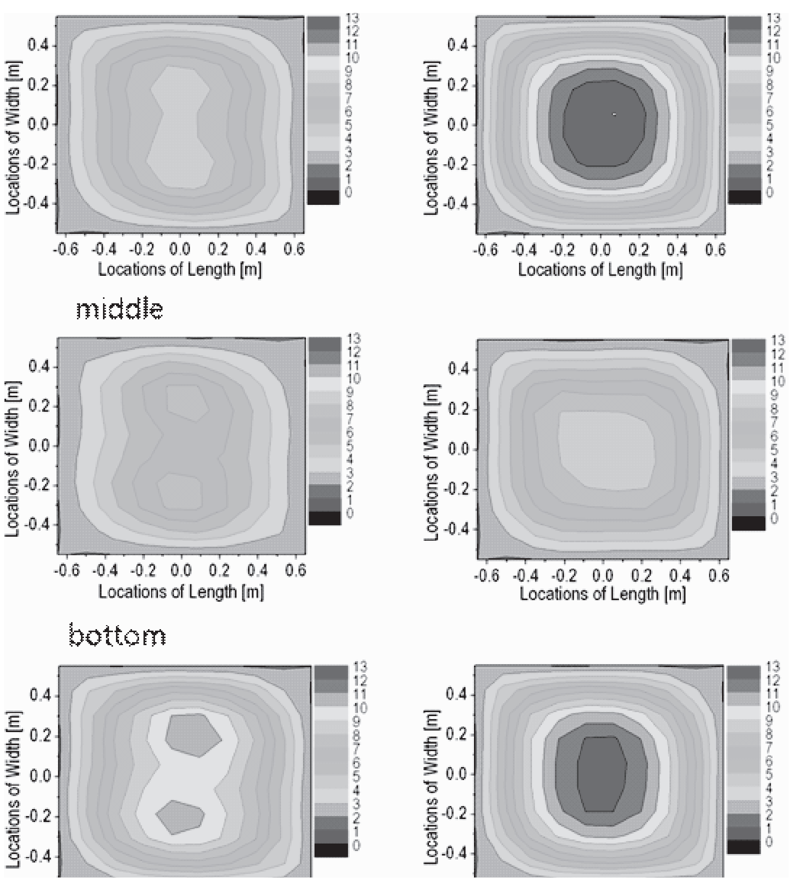
Symbol	Outer dimensions of the pallet L × W × H (mm)	Stacking method[1] (net × column × floor)	Total number of net-package	Sealing rate of loading surface (%)	Load acting on the contacting bulb (N)[2]	Contact pressure (kPa)[3]
K-1	1265 × 1260 × 1900	8 × 4 × 2	64 net	28.1	116-100	20.5-17.6
P-1	1260 × 1245 × 1810	8 × 4 × 2	64 net	30.0	116-100	20.5-17.6
P-2	1260 × 1245 × 1500	8 × 3 × 2	48 net	30.0	82-70	14.4-12.3
H-1	1350 × 1260 × 1800	8 × 8 × 1	64 net	39.1	167-143	29.5-25.2
H-2	1300 × 1250 × 1600	8 × 7 × 1	56 net	39.1	146-125	27.8-22.1
C-1	1370 × 1260 × 1500	8 × 7[4] × 1	50 net	30.2	169-145	29.8-25.6
S-1	1405 × 1000 × 2400	7 × 5 × 2	70 net	39.9	102-88	18.1-15.5
S-2	1460 × 1100 × 1800	7 × 4 × 2	56 net	39.1	83-72	14.7-12.6

Note: 1) alternative tires row pattern, 2) the value considering floor sealing rate, dimension of 20 kg-net package: perimeter 720 ± 10 mm, height 810 ± 10 mm, the number of onion bulbs on the loading surface: 24-28, 3) value calculated with the onion (diameter 85 mm), 4) two 20 kg-net package in the seventh column



temperature in the layers of onion (**Fig. 4**). The total of 18 sensors were placed in the box pallet.

Fig. 5 shows the temperature changes at different positions in the pallet with/without ventilating pipes. For the pallet with the ventilating pipes, the temperature was low in the lower layer, whereas it was high at the central area around the pipe. The pallet without the ventilating pipe showed the high temperature widely in the middle section of the stack. Overall, the pallet with ventilating pipes showed a uniform temperature distribution and less temperature variation between each layer of loads.



(a) pallet with ventilating pipes (b) pallet without ventilating pipes

Fig. 5 Distribution of air temperature at different layers after 20 hours.

Pressure Distribution of Loading Surface

A pressure measuring device, which had one set of five load cells (MS Corp. SM601, 100 kg) with load button (10 cm diameter), was made to analyze the pressure acting on the loading surface of the pallet (**Fig. 6**). The pressure was measured

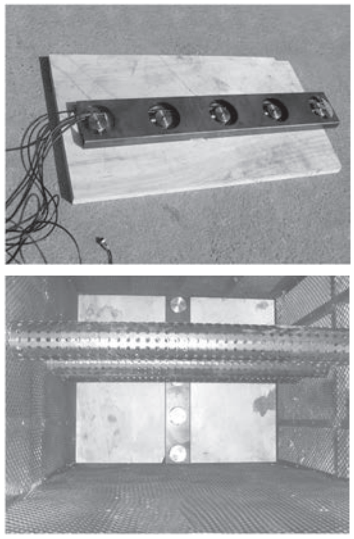


Fig. 6 Pressure measuring device on the load surface.

Table 2 Volumetric efficiency and truck stacking efficiency of the pallets.

Symbol	Load per pallet (kg)	Load per unit volume (kg/m^3)	Truck stacking efficiency[1] (%)		
			11.5-ton (9250 × 2340)	8-ton (8000 × 2340)	5-ton (6250 × 2280)
K-1	1,280	422.7	1 row × 7 (51.5 %)	1 row × 6 (51.1 %)	1 row × 4 (44.7 %)
P-1	1,280	450.8	1 row × 7 (50.7 %)	1 row × 6 (50.3 %)	1 row × 4 (44.0 %)
P-2	960	408.0	1 row × 7 (50.7 %)	1 row × 6 (50.3 %)	1 row × 4 (44.0 %)
H-1	1,280	418.1	1 row × 7 (55.0 %)	1 row × 6 (54.5 %)	1 row × 4 (44.7 %)
H-2	1,120	430.8	1 row × 7 (52.6 %)	1 row × 6 (52.1 %)	1 row × 4 (45.6 %)
C-1	1,000	386.2	1 row × 7 (55.8 %)	1 row × 6 (55.3 %)	1 row × 4 (48.5 %)
S-1	1,400	415.2	2 row × 6 (77.9 %)	2 row × 5 (75.1 %)	2 row × 4 (78.9 %)
S-2	1,120	387.4	2 row × 6 (89.0 %)	2 row × 5 (85.8 %)	2 row × 4 (90.2 %)
Prototype	1,000	426.4	2 row × 7 (92.5 %)	2 row × 6 (91.7 %)	2 row × 4 (80.3 %)

Note : 1) applied the allowed size 40 mm (KS T0003) for length and width of plan view size of unit-load

along with the length of the pallet. On the loading surface of the pallet, small onion bulbs (60 mm diameter, Korean Grading Standard) (NAQS, 2008) were spread tightly so that the stacked onion should contact with the load button uniformly. One ton of large onions, then, were stacked above the small ones.

Fig. 7 shows pressure distribution in the pallet with/without the ventilating pipes. The pattern and size of the pressure showed big difference between them. The pallet with ventilating pipes showed the maximum pressure value in the right and left center of a ventilating pipe, whereas the pallet without ventilating pipes showed the maximum value at the center of the load surface. The maximum pressure of the pallet with ventilating pipes was 6.9 kPa which was 24.7 % lower than the one without the pipes (9.1 kPa).

The maximum pressure in the pallet with ventilating pipes was smaller than that of hydrostatic pressure (γh = 8.5 kPa). That might be that the ventilating pipes support some of the vertical load of onions and dispersed the load with the friction between onions and walls. In contrast, the maximum pressure without the ventilating pipes showed the similar value of hydrostatic pressure, and the pressure value away from the center became smaller because of the shear force caused by the friction between onions and walls.

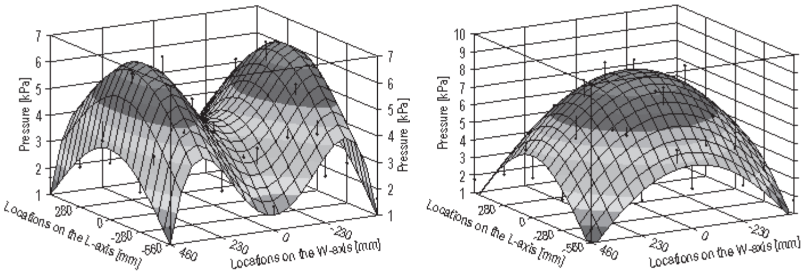
Table 1 shows the list of contact pressure for the 8 types of pallet which is widely used in major onion-producing regions in Korea. A 20 kg-net packages were stacked by different ways in the pallet, and the contact pressure between onion bulb and loading plate was analyzed.

The load acting on an onion bulbs ranged between 70-170 N, and its pressure was 12.3-30.0 kPa in large onions (85 mm diameter, Korean Grading Standard of onions) (NAQS, 2008). This pressure was much larger than the values at the bulk stacking, in which the maximum pressure was 6.9 kPa with ventilating pipes and 9.1 kPa without ventilating pipes. This pressure difference was due to the low sealing rate of pallet at the net-package. In particular, the difference with the ventilating pipe was larger due to load distribution caused by the ventilating pipe.

Analysis of Logistics Requirements

Table 2 shows the volumetric efficiency and truck stacking efficiency of the pallet developed for this study and various pallets presented at the **Table 1**.

Loads per unit volume at the pallets currently used ranged between 386-451 kg/m^3, and for the pallet developed in this study, it showed 426.4 kg/m^3. Both Loads per unit volume were similar in terms of volumetric efficiency, even though the developed one was used for bulk stacking. That is because the three layers of the pipes caused the air flow with ease inside the stacked onions and dispersed the loads in the pallet. The truck stacking efficiency was also high at the pallet developed in this study; the stacking efficiency at the currently used trucks (5-ton, 8-ton, and 11.5-ton) was around 50 % while the trucks with the pallet developed in this study was over 80 %.



(a) pallet with ventilating pipes (b) pallet without ventilating pipes

Fig. 7 Pressure distribution with/without ventilating pipes.

Summary and Conclusions

In this study, a box pallet was developed for bulk handling of onion to reduce the cost of net-packaging. Performance test of the prototype box pallet was conducted to evaluate temperature distribution of stacked onions and dispersion of the loading for quality preservation. Volumetric efficiency and truck stacking efficiency were analyzed as well. The results of the study are as follows:

1. The prototype box pallet installed the ventilating pipe showed small temperature variation between the stacked layers.
2. The box pallet with the ventilating pipes showed the maximum pressure value in the left and right center from a pipe, and the pallet without ventilating pipes showed the maximum pressure value in the center of the loading surface. The maximum pressure value in the box pallet (6.9 kPa) was less by 24.7 % than in the pallet without ventilating pipe (9.1 kPa). In addition, the pressure in the box pallet with bulk stacking was far less than the pallet with net-package (12.3-30.0 kPa), which means that the box pallet in bulk stacking has better filling efficiency. Therefore, the prototype box pallet will disperse the loading effectively and will reduce the damage in the storage.
3. Volumetric efficiency of the prototype box pallet was similar to the pallet with net-package. However, truck stacking efficiency with the prototype box pallet (over 80 %) was significantly higher than the value with the conventional pallet (around 50 %).

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Post-Harvest Practices of Ginger in Odisha, India —Present Status and Scope for Development

by
Sanjaya K. Dash
Professor and Head
sk_dash1006@hotmail.com

Suchismita Dwivedy
Research Associate

Uma Sankar Pal
Associate Professor

Sandeep Dawange
Ex-Senior Research Fellow

H. N. Atibudhi
Professor, Agric. Economics

Department of Agricultural Processing and Food Engineering, College of Agricultural Engineering and Technology, Orissa University of Agriculture and Technology, Bhubaneswar- 751 003, Odisha, INDIA

Abstract

Ginger is a major cash crop of the Odisha (earlier called Orissa) state of India, which is mainly grown in the tribal dominated districts. The lack of proper pre- and post -harvest management and absence of value chain have been causing huge losses to the farmers in these areas. The loss of ginger after harvest has been reported as high as 20-30 %. Thus, an initiative was taken up under the National Agricultural Innovation Project of the Indian Council of Agricultural Research to improve the post-harvest management and strengthen the value chain of ginger. The different weak links were identified and some need based interventions were incorporated into the system with forward and backward linkage support so as to reduce wastage and to assure good remuneration to the farmers. This paper presents the status of the post-harvest management of ginger in Odisha state of India to provide a guideline for future researchers and policy makers for the development of the system.

Introduction

Ginger (Zingiber officinale Roscoe) is an important spice crop of India as well as the world. This tuberous perennial plant is native to southern Asia. Although often referred to as a root, ginger is actually a rhizome or stem that grows underground and bears both roots and shoots. India is the largest producer and exporter of ginger in the world. China, Indonesia, Jamaica, Nigeria and Japan are the other major ginger producers. Apart from use in preparation of tasty curried dishes, ginger is also widely used in processed foods, medicines and cosmetics. Its nutraceutical properties have been of interest to the food and pharmaceutical industries since long (Malhotra and Singh, 2003 and Mohanta *et al*., 2011). With the growing health consciousness among all classes of people and use in pharmaceuticals, demands for organic as well as value added ginger has increased over years.

India is one of the major ginger producing and exporting countries of the world. The production of ginger in the country during 2010-11 was 0.94 million MT in an area of 0.17 million ha. The production figures for different major ginger growing states of India during 2009-10 and 2010-11 are given in **Table 1** (Spices Board, 2013). India is also a major exporter of ginger and the export is steadily increasing (**Fig. 1**). USA, UAE, Saudi Arabia, Morocco, Bangladesh, Spain, UK, Yemen Arab Republic and Netherlands are the main importers of ginger from India (Spices Board, 2013). Odisha was the second largest producer of ginger in the country during the last production year, which contributed 13.4 % of the national ginger production. During 2010-11, the state had 17,120 ha of area under ginger with a production of 0.13 million MT (DAFP, 2012 and Spices Board, 2013). The ginger cultivation area of the state has significantly increased in last three years due to the initiatives taken by the National Horticulture Mission, National Agricultural Innovation Project and several other agencies. The peculiar feature of the ginger farming in Odisha is that it is mostly cultivated in tribal domi-

Table 1 Production of ginger in India during 2009-10 and 2010-11.

State	2009-10		2010-11	
	Area, ha	Production, MT	Area, ha	Production, MT
Karnataka	44,837	135,031	46,511	168,310
Orissa	16,840	117,720	17,120	126,530
Assam	15,690	107,893	16,386	112,548
Meghalaya	9,321	54,009	9,438	52,922
Arunachal Pradesh	6,401	49,663	6,601	52,304
Gujurat	3,170	47,694	4,378	69,581
Uttaranchal	4,007	40,418	4,153	41,944
Sikkim	6,700	35,970	6,700	35,970
Kerala	5,408	28,603	6,088	33,197
West Bengal	11,221	24128	11,406	24,606
Andhra Pradesh	2,317	16,674	2,472	23054
Other states	16,177	50,453	39,704	201,894
Total	142,089	708,256	170,957	942,860

Source: Spices Board, 2013

nated districts of Koraput, Kandhamal and Keonjhar. The diverse agro-climatic conditions coupled with abundance of natural resources provide these districts a comparative advantage for the production of ginger. Besides, due to the uneven topography, the land in these areas is not suitable for most other crops and hence, ginger (or turmeric) farming is usually the only option left for the farmers. Nevertheless, ginger has been a key spice of the state contributing substantially to the income and employment of the tribal people of the state. In fact, looking at the potentiality, the state government has declared these districts as organic ginger zones and has taken up different programmes to encourage organic ginger cultivation in these areas.

Proper postharvest practices and value chain management are essential for the sustainability of the farming operations. However, most of the farmers resorted to unscientific postharvest and storage methods and value chain was almost absent. The farmers tried to sell their produce immediately after harvest, thus getting a low return. About 20-30 % of the ginger production was reported to be lost, which was due to either lack of or inefficient postharvest management. Therefore, an intervention was made under the National Agricultural Innovation Project (NAIP) of the Indian Council of Agricultural Research (ICAR) to study the status of postharvest operations of ginger in the state of Odisha and to intervene at points where there was scope of improvement. The key findings of the study are presented in this paper.

Methodology

The study on the harvest and postharvest practices followed by the farmers was conducted at Koraput and Kandhamal, two major ginger growing districts of the state of Odisha. These two districts alone contributed to 56.78 % of the total ginger production of the state during 2010-11. Most of the people engaged in ginger farming are either small or marginal farmers or landless labors. Information regarding the methods used for different unit operations and associated features were collected by direct field observations and through questionnaire sheets. Large and small scale processors were also included in the domain of study to gather information on existing practices in processing. The collected information was analyzed to find out the points of interventions for the improvement of the system. Some interventions at critical points were taken up and their potential benefits and adaptability within the farming community were also assessed.

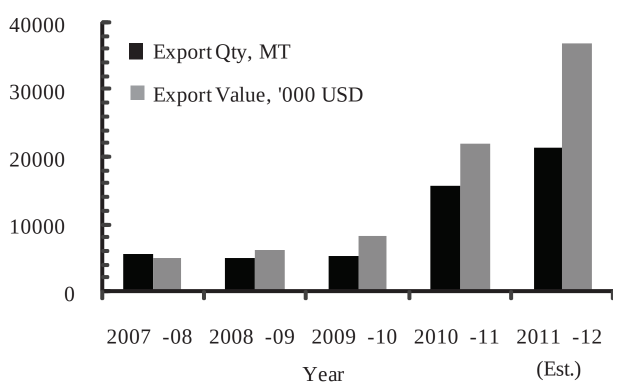

Fig. 1 Export of ginger from India during the last 5 years (1 USD has been taken as 55 Indian Rupees).

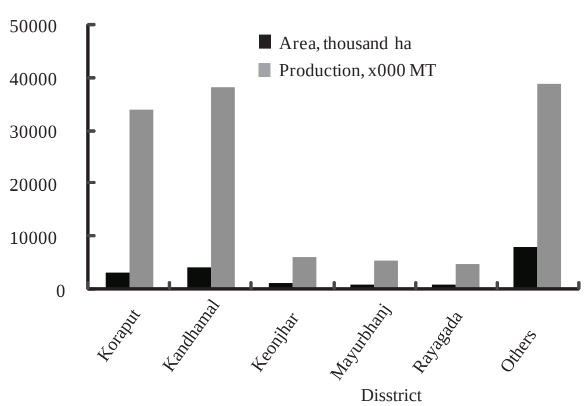

Fig. 2 Ginger production in different districts of Odisha during 2010-11.

Ginger Production and Varieties in Odisha

The ginger area and the production in the state of Odisha have been constantly increasing in the past years. Kandhamal, Koraput, Keonjhar, Mayurbhanj and Rayagada are the major ginger producing districts of the state. **Fig. 2** gives the importance of these districts in terms of ginger area and production (DAFP, 2012). Tribal people form the major part of population of these districts. Ginger farming in Odisha is thus done mostly by tribal farmers, who lack the basic infrastructure facilities for farming. They resorted to indigenous means of production for which the productivity was low as compared to many other states in the country. The major factors inhibiting the production, productivity and value addition of the ginger crop in these areas include biotic and abiotic stresses, genetic erosion, and poor quality planting material, post-harvest loss, lack of value chain and market support.

Most of the farmers of the area used to grow about 6-8 non-descript varieties of ginger, which offered low yield and were susceptible to diseases. Though some recognized varieties had been earlier introduced in some squares, they had gradually disappeared from most of these patches. However, the NAIP has been intervening to replace these varieties with the improved varieties like Suprava and Suruchi for the last three years and the farmers are increasingly shifting to these varieties for higher yield and better quality. These varieties, developed by the state agricultural university, have less fibre content, large rhizomes, light yellow flesh, are less pungent and have high commercial values. Jayashree *et al*. (2012) have also reported that the ginger grown in different parts of the country varies considerably in its intrinsic properties and suitability for processing. The important quality parameters of ginger are its fibre content, volatile oil content and non-volatile ether extract. The general characteristics of Suprava and Suruchi along with some other promising varieties for the area are given in **Table 2** (Parthsarathy *et al*., 2008).

Harvest and Post-Harvest Operations at Farm Level

Harvesting

The ginger is usually planted in the months of May-June after the onset of rain. Depending upon the variety, majority of the crop is harvested after the leaves have died (seven to nine months after planting) and the ginger root has fully matured. Internal flesh colour should be pale yellow. Shriveling, yellowing and withering of leaves, accompanied by drying and lodging of the stems indicate to farmers about maturity and harvest time. However, the harvesting period of ginger in the state extends from October to January. This spread in time of harvesting is dependent on two major factors, viz. the financial condition of the farmers and the market price.

In the state, ginger is mostly cultivated under rainfed conditions and as mono crop, though a number of small farmers also grow ginger under irrigated conditions as a mixed crop with different types of vegetables. This system ensures better utilization of land, water, fertilizer and labor. The farmers also report that this system reduces the incidence of disease/pests. However, the most important reason for the mixed cropping is the interim cash flow for sustenance of livelihood. Further, ginger, being a long duration crop, takes about 7-9 months to fully mature and to give the desired return. Hence the small farmers, who entirely depend on ginger cultivation during the period, intend to earn some money at intervals within this period by harvesting some portion of the crop before full maturity. Thus the harvesting period stretches to months.

First, the mother plant is harvested in September/October. Subsequently, the farmers, harvest a part of the crop during the months of October-December as per their requirement and the amount harvested is dependent on their cash requirement. At that time, the crop is not fully mature and is known as green ginger. The harvest gives some return to the needy farmers and also makes the land ready for next crops. But the well-to-do farmers wait for the market price to rise and harvest the produce depending upon the market situation. The fully matured crop is harvested in last fortnight of December and first fortnight of January. For seed purpose, a portion of the crop is left in the field till end of February. The cost of ginger varies between $ 0.25 /kg fresh ginger during early harvesting to about $ 0.3-0.8 /kg fresh ginger during the peak harvesting period. The price in fact fluctuates a lot during the harvest season depending upon the production and the market demand.

The farmers use spades to dig the

Table 2 Characteristics of some promising ginger varieties.

Variety	Fresh Mean yield (t/ha)	Maturity (days)	Dry recovery (%)	Crude Fibre (%)	Oleoresin (%)	Essential Oil (%)
Suprabha	16.6	229	20.5	4.4	8.9	1.9
Suruchi	11.6	218	23.5	3.8	10.0	2.0
Suravi	17.5	225	23.5	4.0	10.2	2.1
Himagiri	13.5	230	20.6	6.4	4.3	1.6
IISR Varada	22.6	200	20.7	4.5	6.7	1.8
IISR Mahima	23.2	200	23.0	3.2	4.4	1.7
IISR Rejatha	22.4	200	19.0	4.0	6.3	2.3
Nadia	28.55	200	22.6	3.9	5.4	1.4

rhizomes out of the soil. They are aware that the crop should be damaged as little as possible for better storability. The fibrous roots are trimmed, and the soil is removed by shaking. The farmers typically do not wash the crop at this stage, the basic reason being the shortage of water required for the purpose. Usually the digging work is done by men and trimming of fibrous roots and removal of soil and dirt are done by women (**Fig. 3**). Harvesting during very wet or very dry conditions is to be avoided as this would reduce the ease of harvesting and increase the extent of damage. Only the green ginger rhizomes are washed in water 2-3 times and then sun dried for a day before sending to market.

Curing

After harvesting and removing the adhering soil as mentioned above, the rhizomes are cured for 3-4 days in shade. The drying and curing helps to heal the injured, scratched and cut surfaces. Curing also helps in prolonging the storage life and check the attack/spread of disease, etc. The periderm formation is favored by high temperature and optimum relative humidity.

Washing

In general, the on-farm primary processing of ginger has been almost absent in the state. After curing, the farmers again removed the dry soil adhering to the surface of ginger rhizomes, separated the mother rhizomes, and marketed them as such. However, with the initiatives under the NAIP, the farmers have adopted the preliminary washing step to remove the soil and sticky dirt, immediate subsequent drying under sun to remove the surface moisture and grading and sorting operations (**Fig. 4**). It has resulted in fetching a better price to the farmers.

Under the improved system, the rhizomes are soaked overnight in water for cleaning in the next morning and drying. Flexible pipes are used to spray water to facilitate washing. Mechanical washers of different capacities are commercially available, but are beyond the reach of the primary processors due to their high cost. It was observed that the farmers' reluctance for washing of ginger was mainly because it required a huge amount of water and availability of water in the vicinity of ginger fields was a problem during harvesting months. Hence, to reduce the amount of water, a small soaking/washing tank for ginger was developed and promoted (**Fig. 5**). It consists of two drums which are kept one inside the other. The outer drum made of GI sheet (2 mm thick) has the inner dimensions of 61.5 cm × 34 cm (D × H). The inner drum is made up of a 16 gauge square wire mesh (mesh size 1.5 cm × 1.5 cm) and has dimensions of 56 cm × 29 cm (D × H). The clearance at the base between the inner and outer drums is kept at 2 cm with the help of a stopper. The ginger rhizomes are kept in the wire drum during soaking and spraying operations (by a flexible pipe), which helps in easily separating the dirt into the main outer drum. The ginger is thoroughly washed two to three times to remove adhering dirt and soil. The wire mesh drum can be easily taken out for unloading and subsequent spreading for drying. When not being used for ginger, the drum can be used for other purposes like lime treatment of ginger, storage and cooking, etc., which is a highly motivating factor for the small farmers to own such a drum. The washed produce is dried under sun to remove the surface moisture.

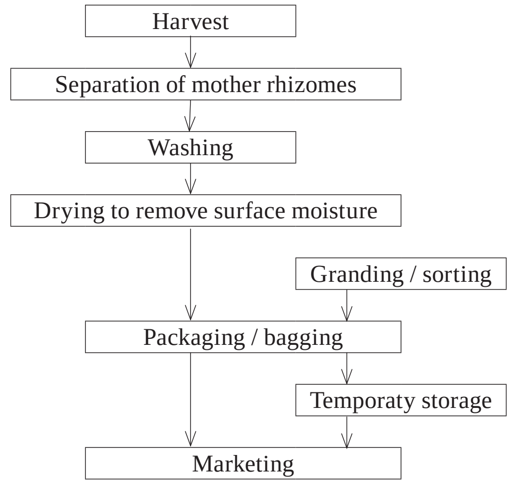

Fig. 4. Handling of raw mature ginger at farm level

Sorting and Grading

Sorting is usually done by hand (**Fig. 6**). After removing all dam-

Fig. 3 Ginger collection after harvesting by tribal women.

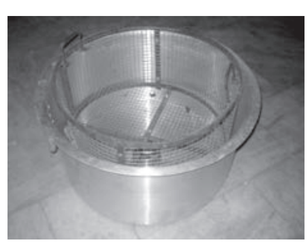

Fig. 5 Small washing tank for ginger.

Fig. 6 Manual sorting of ginger.

aged and injured rhizomes, the remaining marketable rhizomes are sorted according to size and overall appearance. Grading of ginger is done on the basis of utility, colour, shape, size, pungency, fibre content, and oleoresin content, etc.

Sorted ginger surface should be clean, bright yellow brown, and appear fresh. It should not be wilted or have any evidence of sprouting. The rhizomes should be free from bacteria or fungal infection and not have any objectionable skin blemishes. High quality ginger is characterized by large thick rhizomes with limited branching, light skin colour, and a glossy appearance. The skin colour will slowly darken and lose its shine during storage.

The minimum rhizome size for export is 250 g. The main stem should not be less than 30 mm thick and 120 mm long. Market requirements demand that rhizomes be large and well-formed with limited branching. Export quality ginger should be smooth and firm, with uniform shape and size, be free from insect damage and decay, and have a uniform peel colour typical of the variety.

Packaging and Transportation

Standard jute/gunny/poly-fibre bags are used for the packaging of ginger (**Fig. 7**). Usually one such bag holds about 30 kg ginger. Besides, bamboo baskets having a capacity of 15-20 kg fresh ginger are also used for conveying and transportation to different domestic markets (**Fig. 7**). Recently the farmers have started using card board packs as well as brace boxes (wire banded crates) to ensure ventilation for ginger and to minimize mechanical damage.

Often a part of the produce is retained by the farmers, which they treat with lime and store. They soak the rhizomes in water for a day and later in thick milk of lime (1 kg slaked lime/120 L water). The material is then dried under sun and rubbed with hessian cloth to remove last remnants of the skin. This gives a smooth finish to the finished product. The lime treated and dried ginger has demand as traditional medicines.

Some traders operate marketing centers in villages and buy ginger from farmers at low price during harvest season and store in their warehouses. Most of the farmers are not aware of the grades of the ginger and are thus exploited by the middle men and traders. The farmers usually gather ginger at a common collection centre where the rhizomes are separated as green immature, green mature, ripened and dry ginger. The actual grading and sorting are done after the traders/middle men own the materials. These middlemen sell the ginger to processors or send to urban markets. Ginger with less fiber usually have a better market demand than fibrous ones. The processors, who require the ginger for oil or oleoresin purpose, prefer mature ginger.

Storage of Ginger

The large farmers harvest and sell the materials depending upon the market demand. The small farmers usually keep the planting materials for next season (seed rhizomes) with themselves and sell out the remaining stock immediately.

The seed rhizomes are usually stored for a period for 4-5 months, from the time of harvest in Dec-Jan till the time of sowing, which is usually in the month of May. During this period, there is chance of loss due to desiccation in improper storage conditions. Besides, the rhizomes are susceptible to attack by insects, fungi and white ants, and hence, seed treatment is mandatory. Well developed and disease free rhizomes are selected for seed. Seed treatment is usually done near the storage place. A small pit is dug in the soil with length of about 2 m, width 0.6 m, and a depth of about 0.3 m (**Fig. 8**). A tarpaulin or thick polythene sheet is spread in the pit so that it can hold the treatment solution. The solution is usually prepared by adding Bavistin (2 g/litre) and Dithane M-45 (3.5 g/litre) in water. About 100 litres of water is used for treating 1 quintal of ginger. In some places an insecticide (Chloropyriphos 50 EC @ 2 mL/L) is also added to the treatment solution. These may be also be treated with 0.25 % solution of wettable Ceresan (155 g wettable Ceresan in 45 L of water) for 30 minutes as prophylactic measure against soft-rot. Treating with 0.3 % solution of Vitigram also gives good results. The ginger seed is kept in bamboo baskets and dipped inside the treatment solution

Fig. 7 Plastic fibre bags, gunny bags and bamboo baskets used for carrying ginger.

for about half an hour, drained and then spread under shade for removal of surface moisture. The produce is dried under sun on a tarpaulin sheet if the intensity of sunlight is low.

The treated rhizomes are stored in pits. An elevated well drained site is selected and pits of about 4-6 m in length, 1 m width and about 0.15 m depth are dug in the soil. Then some straws and leaves are burnt in the pit to kill the surface organisms (**Fig. 9**). After the leaves have completely burnt, it is cleaned and layers of straw are placed in the pit with sufficient overhang. Then the treated and dried ginger rhizomes are heaped in the pit (**Fig. 10**). Usually the height of the pit is less than 0.6 m. Two to three layers of straw are placed on the rhizomes so that these are fully covered. The top of the straw layer is mud plastered. In some places cow dung is mixed with mud. After that some holes are made through the mud plaster for ventilation and respiration of the stored rhizomes. In some cases the pit is covered with a wooden plank, leaving some space between seed rhizomes and plank, and the cover is plastered with mud; a small hole is made in the plank through which a hollow tube is inserted for aeration of rhizomes.

In another method, the pit is made 1 m deep and 0.5 m wide. The bottom of pit is filled with 20 cm layer of sand. Then after every 30 cm layer of rhizome, another 20 cm layer of sand is spread. The top is covered as above.

A number of such pits are prepared side by side and the whole area is covered with thatched roof so as to protect the pits from sun and rain. The pit storage can store ginger for 4-5 months and the losses are assessed to be within 10-15 %. The rhizome-rot, sprouting, rooting and shriveling are some problems associated with ginger rhizomes during traditional storage.

The small farmers, who have a small quantity of seed rhizomes, store these in bamboo baskets in a room or heap them indoors (**Fig. 11**). In case of bamboo baskets, a thin layer of straw is spread at the bottom and at all sides of the basket. After filling the rhizomes, the top surface is covered with straw and mud plastered. For heaping indoors, a corner of the room is selected, ginger is heaped and then the top surface of the bulk ginger is plastered with mud without any straw lining.

Fig. 8 Seed treatment.

Fig. 9 Burning of pit.

Fig. 10 Storage in pit.

Fig. 11 Bamboo structures for seed storage.

Yet another practice to store ginger seeds, though not common, is to leave them in the field unharvested and thus the ginger rhizomes will remain in good condition till they sprout with the advent of rain. This is known as in situ storage. This method is prone to rhizome rot, rhizomes start sprouting in course of time and harbour insect pests (Rahman *et al*., 2009).

Storage life of fresh ginger could be increased if rhizomes are harvested at the proper stage of maturity, are cured properly and are free from diseases, nematodes, and bruises. Precooling of freshly harvested ginger with forced air or room cooling followed by storage at 12-13 ºC and 85-90 % RH is also recommended (Valenzuela, 2011). Storage at 65 % RH led to dehydration and wilting of ginger. Our studies also established that cleaned ginger could be stored in the cold storage at 10-12 ºC up to 6 months without any significant loss in freshness and with acceptable physiological loss in weight (PLW). But at present there is no commercial cold storage facility of ginger in the area. Some cold storages are being developed in public private partnership (PPP) mode in the ginger growing areas which are expected to be fully functional within 2-3 years.

Thus, in the absence of cold storage facilities, the farmers are compelled to dispose the commodity as early as possible. Hence, the zero energy cool chambers or evaporatively cooled (EC) chambers were promoted for ginger as a compromise to the cold storages (Dash *et al*., 2004; Dadhich *et al*., 2008; Singh and Yadav, 2012). The chambers were made in the farmers' premises and had the inner dimensions of 1 m × 0.5 m × 0.5 m (**Fig. 12**). The side walls were made of two layers of brick with a gap of 10 cm in between. The total thickness of the wall was thus 35 cm. The annular gap was filled with river bed sand. The floor of the structure was made of a single layer of brick spread over 5 cm soil layer on the ground. Thus, the floor of the structure was 12.5 cm above the ground level. This was done to prevent moisture seepage through walls and accumulation of water on the floor of the structure. The top cover of the structure was made of a bamboo mat. A thick hessian cloth was kept on the bamboo mat covering only the top cover. During the storage, the samples were kept inside the structure and then a thick PE sheet was covered on the top before placing the bamboo mat. A temporary shed was constructed over the structure so that there was no solar insolation on the top surface. The site was selected so as to allow sufficient natural draft of ambient air around the structure. The structure was completely saturated before keeping the samples inside the structure and then the side walls and top covers were kept wet throughout the day by drips spread in the sand layers and sprinkling of water at the top.

It was observed that these structures were capable of maintaining higher humidity and lower temperature in the structure as compared to ambient and thus reduced the shriveling and dehydration of ginger. When the ambient maximum temperature was between 32.6-40.6 ºC, the inside maximum temperature varied between 21-28 ºC (the maximum temperature during the storage period ranged between 18-28 ºC). The inside RH was 90-98 % when the maximum ambient RH varied between 28 % and 43 % during the period of storage (February to June). The ambient RH varied between 28-93 % in different parts of the day. An on-farm study was conducted to compare the above EC structure with normal room storage and the traditional sand storage method (in which the farmers store ginger covered with a layer of sand; the sand is periodically sprinkled with water) and the results are shown in **Fig. 13**. Suitably treated ginger seeds were stored in all the conditions. The EC chamber considerably reduced the physiological loss in weight (PLW) of ginger; after 105 days, the PLW was 9.86 % in the EC chamber, 41-42 % in room temperature storage and 18-20 % in sand storage. It was observed that at the end of 4 months storage there was complete sprouting of ginger, which was considered good for subsequent planting and the farmers appreciated that.

Unit Operations at Primary Processing Facility

There was practically no processing facility for ginger in the state before 2008. It caused huge exploitation of the farmers and loss to the producers. However, under the NAIP, the value chain was formed for the overall benefit of the farming community. The existing value chain in the area before our intervention and the presently adopted value chain in the target areas are shown in **Figs. 14** and **15**. As indicated in **Fig. 15**, two model agro-processing centres were established in the two major ginger growing districts of the state, viz. Kandhamal and Koraput. In these centres, facilities have been created for preparation of dehydrated ginger in form of cubes, flakes and powders, ginger pickles, ginger candy, ginger paste and ready to serve (RTS) beverage, etc. However, the preparation of the ginger powder and flakes, RTS and candies are more popular due to the market demand. Some local non-Government organizations (NGOs) have also taken up ginger processing after being trained and supported by the NAIP.

The unit operations for the preparation of dehydrated ginger products is given in Fig. 16. The details of the unit operations and the interventions are given below.

Washing and Cleaning

As mentioned earlier, during on farm processing, minimization of water use during washing could be achieved by using small washing drums. In the primary processing facility, two or three-stage washing in tanks made of cement concrete were promoted. For that two or three cement concrete tanks with dimensions of 1 m × 0.5 m × 0.8 m (Length × Breadth × Depth) were constructed side by side (**Fig. 17**).

Fig. 12 Evaporatively cooled storage structures used for storage of seed ginger.

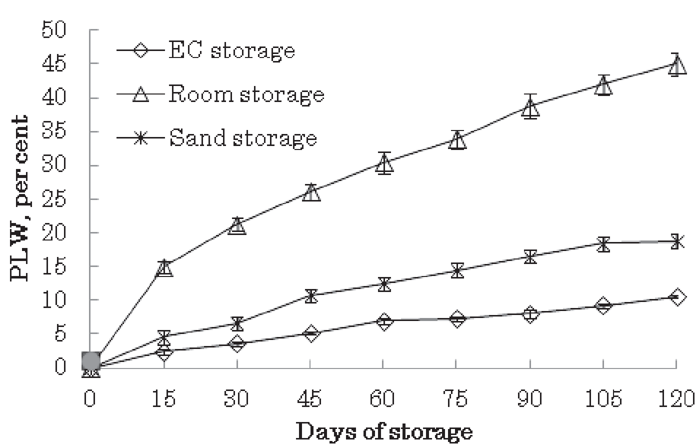

Fig. 13 PLW of ginger in different storage methods.

The cement tanks have a perforated (mesh) floor at about 0.15 m from the bottom. The perforated floor holds the ginger rhizomes and allows the soil to settle below. Shuffling the water manually helped increase the washing efficiency. The system reduced the amount of clean water required for the washing purpose as most of the water could be reused.

Sorting and Grading

During this process, the mother rhizomes are separated from the stock and small pieces of ginger and extraneous materials are removed.

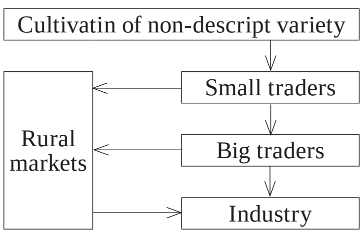

Fig. 14 Existing supply chain of ginger.

The operations are carried out manually, so as not to make the unit capital intensive and dependent of electrical power sources.

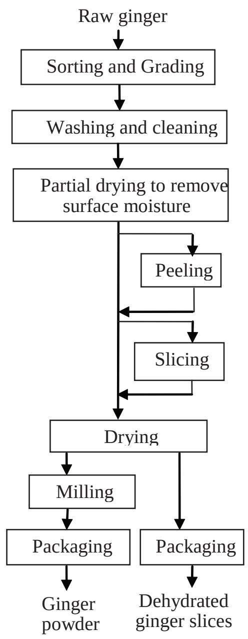

Fig. 16 Flow chart for preparation of dehydrated ginger products.

Peeling

Peeling or scraping reduces drying time, thus minimizing mold growth and fermentation during drying. The removal of outside corky skin also reduces the fibre content. However, the epidermal cells in ginger contain most of the essential oils, which are responsible for the characteristic aroma and are important in deciding its market value. Thus, only the outer skin is to be removed and improper peeling affects the grade of the finished product. The loss of ginger flesh from underneath the skin would result not only in loss of weight, but also in its economic value.

Peeling is done either manually or mechanically. Manual peeling is traditionally done by using bamboo splinters. So, to overcome the problem, an electrical operated abrasive peeler having 2-2.5 kg/batch (40-50 kg/hour) capacity was developed (**Fig. 18**).

Fig. 17 Cement concrete tanks constructed along the wall of an existing building for three stage washing of ginger.

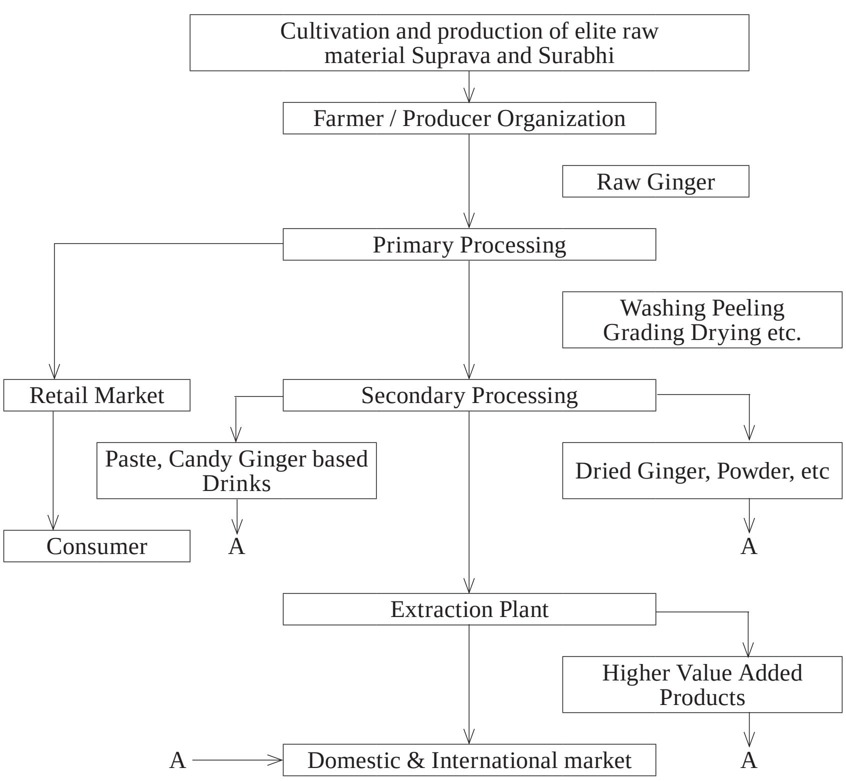

Fig. 15 Improved value chain of ginger.

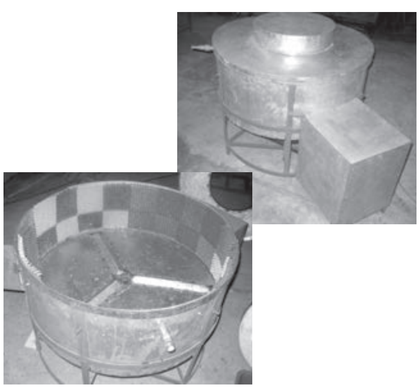

Fig. 18 Ginger peeler (outside and inside views).

The machine consists of a rotating surface on to which the ginger is fed. Due to the rotation, ginger is pushed to the periphery of the drum, where it is made to rub against an abrasive plastic surface. Simultaneously water is sprinkled on the ginger rhizomes to take out the separated peel. **Fig. 19** shows the peeling efficiency of the peeler with different loads of ginger. Though the peeler could reduce the time required for peeling, which was very important, but the peeling efficiency was maximum up to the level of 75 %, after which manual peeling for the remaining parts of the skin was required. An attempt to increase the peeling efficiency of the equipment by peeling for more time scratched the surfaces and caused loss of flesh. A person can peel a maximum of 3-4 kg of ginger in one hour if the work is carried out without rest, though the loss in ginger flesh is almost negligible. As the maximum peeling efficiency is limited to 75 %, finishing peeling after peeling in the equipment is recommended.

Slicing

Slicing of ginger is carried out either manually or by mechanical slicers. Manual slicing is done by stainless steel knives. It is a highly time consuming process. Mechanical slicers specific to ginger is not available, and hence, mechanical slicers, otherwise used as potato slicers, were used for the purpose. However, due to the fibre content of ginger, the blades wear out very rapidly. Thus high quality steel blades are required for the purpose. There is requirement for a ginger shredder for preparing ginger shreds and small cubes. However, no such machine presently satisfies the requirement and manual labour is used for preparing shreds of uniform sizes.

Drying

The small quantity of ginger, which was dried at the farmers' level, was mostly dried under sun. It caused inferior quality product. Hence, tray type mechanical dryer and low tunnel type solar dryers were introduced to the ginger processors. However, considering the power availability (there is frequent power cut in those areas) and its cost, solar dryers/ low tunnel type dryers were considered better options in the project area. One such low cost portable solar dryer (made of steel and bamboo frame with UV stabilized PE sheet as the cladding material became popular in the region (**Fig. 20**).

On-farm trials were conducted to appraise the farmers about the potential advantages of mechanical/ solar drying as compared to sun drying in terms of quality and time. **Fig. 21** shows the drying times obtained for ginger slices (4 mm and 8 mm thick) and whole peeled samples in mechanical dryers at 3 drying temperatures (40º, 50º and 60 ºC), drying under shade, open sun drying and the low tunnel type solar dryer. The initial moisture content of the ginger samples varied between 3.77 and 3.35 g per g dry matter and in the mechanical as well as solar drying, the final moisture content was kept at 0.07 g per g dry matter. To reduce losses in quality, cleaning and drying should be done as fast as possible after harvesting.

Milling

Ginger powder has a good domestic as well as international market. Earlier for the small quantity of the ginger powder, which a few self help groups were preparing, ginger powder was prepared by hand pounding. But considering the increase in production in the project area and the good production practices, the demand for production of ginger powder in the area increased and thus two hammer mills have been installed in two primary processing centres, one in each district. These mills are used for milling of the ginger flakes to powder form. Other size reduction machines did

Fig. 20 Low cost solar dryer.

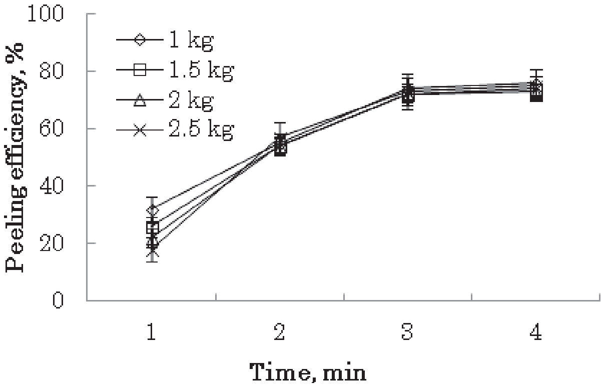

Fig. 19 Peeling efficiency of the ginger peeler.

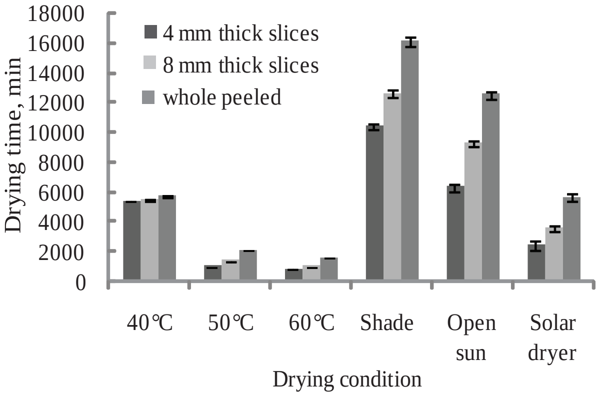

Fig. 21 Comparison of drying times of ginger.

not prove successful due to the fiber content of the ginger. It was observed that for the Suprava variety, 100 kg of fresh unpeeled washed ginger yielded about 20 kg ginger powder. The producers have been linked with some industries preparing secondary products from ginger flakes and powders and export houses. A consortium partner of the NAIP also has developed extraction facility for ginger. Some advanced countries' regulations require that the ginger should be milled only in machines having stainless steel working elements. However, such equipment is not available in the area.

Packaging and Storage

Suitable packaging reduces the post-harvest losses of ginger. As mentioned earlier, the raw fresh ginger is brought into the processing centre in woven gunny bags/ polyester sacks or bamboo baskets. The dehydrated ginger slices and powders are packed in polythene packages to prevent moisture ingress. Metalized PE / laminated films have also been found to extend the shelf life of dried ginger. Subsequently the retail packs are kept in big cartoons or bags for transportation. However, there is a lot of scope to improve the packaging for better acceptability in the international market.

The packaged ginger is normally stored at room temperature till it is sent to the destination. A few wholesalers and commission agents attempted to store dried flakes in gunny bags, but incurred loss to the tune of 30 % as the storage extended beyond the month of June (due to the onset of monsoon). Therefore, suitable storage facilities for dry ginger on cooperative / custom basis are required at production points. Application of ethylene oxide @ 50 ppm is also suggested for fumigation of dried rhizomes.

The dried ginger stores are even better in cold rooms at 10-15ºC as the valuable ingredients within ginger are better preserved (Zhang *et al.*, 1994). If cold storage facility is not available, extraction or distillation of dried ginger should be done as quickly as possible because the oil content decreases considerably in room temperature storage.

The ginger powder prepared by the processing facilities is now available in the market throughout the year. The ginger paste and candies are also slowly gaining market acceptance. The other value added products as ginger RTS are also prepared by some self help groups and NGOs and are sold in different trade fairs and exhibitions only, owing to their comparatively shorter shelf life and because of lack of suitable promotion facilities.

Secondary Processing and Value Addition of Ginger

Ginger oleoresin, ginger oil and several value added products can be prepared from the primary processed products. However, no such facility presently exists in Odisha. But under the NAIP, collaboration has been made with some secondary processors in other states and secondary processing (extraction) facility has been developed in those areas. The dehydrated ginger in flake form is sent to those facilities for further processing and extraction of nutraceuticals. A facility for extraction of ginger oil and oleoresin is being developed in Odisha in PPP mode, which could be functional in the next 2-3 years.

Future Research and Development Needs

1. Development of suitable on-farm washing machine for ginger
2. Development of slicer and shredders for ginger
3. Development and popularization of suitable storage facility for ginger and ginger products
4. Development of low capital and energy input dryers
5. Establishment of primary processing facilities of ginger in production catchments and centralized secondary processing facilities in PPP mode
6. Incorporation of quality management system in the complete value chain of ginger
7. Integration of suitable forward and backward linkages for ginger production system

Conclusions

The ginger farming and post-harvest situation in the tribal dominated districts of the state have improved under the initiatives of the National Agricultural Innovation Project and support of National Horticultural Mission, local NGOs and private partners. A value chain on the ginger and ginger products has been established and the farmers have started processing and adding value to ginger, which was earlier mostly under distress sale. There is a need to sustain the growth and to involve more players in the post-production stage of ginger to make the ginger farming and processing more competitive and also to generate additional income and employment. Co-operative societies should be formed to look into the processing and marketing aspects of ginger. There is a need to develop cooperative cold storage facility as well as to promote low cost storage structures in farm yards for short duration storage. Further, development of commercial facility for secondary value addition of ginger can assure better return to the ginger farmers and help in further increasing ginger production and quality. Quality management and assurance systems need to be strictly incorporated in the supply chain, so as to attract more international buyers.. With the global demand for the organic ginger, Odisha can lead the export market as the ginger grown in the area is by default organic and little bit training to the farmers and facilitation for certification can improve the overall status of ginger farmers of the state.

Acknowledgement

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Development and Performance Evaluation of Multi Crop Planter in *Bt Cotton* and *DSR*

by
S. Mukesh
Assistant Agricultural Engineer
mukeshjainhisar@rediffmail.com

Anil Kumar
Assistant Professor

Vijaya Rani
Assistant Professor

N. K. Bansal
Head

Pooja Chaudhary
M. Technology

Department of Farm Machinery and Power Engineering, CCS HAU, Hisar-125004

Abstract

A tractor drawn multi-crop planter was developed and evaluated with provision of sowing all major cereal crops, pulses and oilseeds at desired row to row as well as seed to seed spacing especially for paddy by direct seeding technique and Bt Cotton. The machine had provision of chain sprocket arrangement for power transmission through a gear box with varying speed ratio of 1.6 to 4.5 times reduction from ground wheel to seed metering plate. The seed metering plate had varying number of cells and cell size to match recommended spacing of major crops. The speed reduction of ground wheel to fertilizer metering shaft was 2.3 : 1. The fertilizer hopper has inclinations for accomplishing easy emptying and better utilization of fertilizer from hopper to fertilizer box having vertical roller discs with eight cells in each disc. For small seeded crops, separate seed hopper and seed metering mechanism/attachment with six vertical roller discs each having 8 cells on its periphery was also provided.

The performance evaluation of developed prototype was carried out under field condition for Bt Cotton and direct seeding of rice (*DSR*) during 2011 and 2012. The effective field capacity of machine for the crops was 0.50 ha h^{-1} and 0.45ha h^{-1} respectively at an average forward speed of 3 km h^{-1}. The field efficiencies were 61 percent and 83 percent, respectively. The distribution of plants in rows and crop response at field indicated that mean plant spacing was 48 cm and 10 cm with a quality of feeding index as 77 percent and 78 percent for Bt Cotton and DSR crop, respectively. The missing index and multiplying index recorded in Bt Cotton were 15 and 8 percent respectively, whereas it was 16 and 6 percent in DSR crop. The precision in spacing observed was 6.3 percent and 7.1 percent in Bt Cotton and DSR respectively. The cost of operation for Bt Cotton and DSR crop was Rs.700 ha^{-1} and Rs. 777 ha^{-1} respectively.

Key words: Planter, Metering mechanism, DSR

Introduction

Sowing technique is most important operation among all major operation performed in agriculture because production mainly depends upon field emergence and initial crop establishment. Presently, different sowing machines are used for various crops like Bt Cotton planter, zero till machine for wheat and seed drill for direct seeding of rice. It is not possible for a farmer to have different machines for sowing different crops. So, option left with farmer is either to adopt machine on custom hiring or to have a machine with which all the crops can be sown. To achieve this, there is a need of uniform distribution of seed at the desired row to row as well as seed to seed spacing. A need was felt to develop a machine which can sow all major cereal crops. Therefore, a tractor drawn multi-crop planter was developed and evaluated having provision of sowing different crops especially for direct seeding of rice (DSR) and Bt Cotton. The seed metering mechanism used was cell type inclined plate and vertical cell disc roller. The transmission system was designed in such a way that it had provision of adjustment of the furrow opener according to type of crop and recommended spacing for them. Requisite type of metering mechanism and number of seed box were provided to obtain desired seed to seed spacing.

Design considerations are to drop the seeds in rows maintaining accurate seed rate and seed spacing with minimum damage to seeds during metering. This mainly depends on forward speed of the planting equipment, rotary speed of the metering plate, shape and size of cells and alignment of seed tubes (Gupta, 1999 & Bhatt, 2009). So, a need was felt to develop an inclined cell plate type multi-crop planter with which all cereals, oilseeds and pulses could be drilled/planted especially for DSR and Bt Cotton (Sharma, 2010). Keeping in view the above, "Development and evaluation of multi crop planter in Bt Cotton and DSR" was undertaken to enable farmers to reduce input cost, timely operation such as sowing and reduce the drudgery.

Materials and Methods

Design and Development Of Metering Mechanism

To meter different seed rates and vary the seed to seed spacing, various speed ratios and speed reduction unit were required (Anonymous, 2007). Considering the availability, various gear combination were selected to design speed reduction from 1.6 to 4.5 times. A gear box with four gears was provided to change the speed of movement of inclined plates (to vary seed spacing). The four speed reduction ratios were (4.5 : 1, 3.1 : 1, 2.15 : 1 and 1.6 : 1) by which seed spacing can be varied. The speed reduction unit is shown in **Fig. 1**

Seed Metering Cell Plate

The seed-rate may also be changed by changing inclination of inclined plates. Varying the number of cells on vertical inclined plate can vary seed spacing. Three types of plates were provided with different cell size and number of cells on the periphery to suit various crops. First type was for wheat and DSR, second type was for Bengal gram and DSR (and may also be used for cotton & green gram), and third type was for cotton (for wide seed spacing). Also for small seeds with very less seed rate separate metering mechanism with a small seed box was provided. The detailed specifications of cell plate are given in **Table 2** and **Fig. 2**

Constructional Details Of Developed Prototype

The constructional details of the tractor drawn inclined cell plate type multi-crop planter are described below:

Table 2 Detailed specifications of seed metering cell plate.

Particular	Specification
Cell plate diameter, mm	140
Number of cell per plate	20, 8, 4
Shape of cell	U type
Approx. peripheral distance between cell, mm	22, 55, 110
Size of cell (width × depth), mm	10 × 8, 12 × 10, 10 × 8

The main frame (2300 × 660 mm) of the unit was fabricated using a mild steel channel section of size (70 × 70 mm). The seed hopper, fertilizer box and speed reduction unit have been mounted on the main frame. Three point hitch assembly is provided on the frame so as to hitch the unit to prime mover. The ground wheel diameter 380 mm is fabricated using (50 × 12 mm) wide mild steel flat and it is mounted in the right side of the frame. Twelve lugs (35 × 90 mm) were provided on its periphery for reducing the

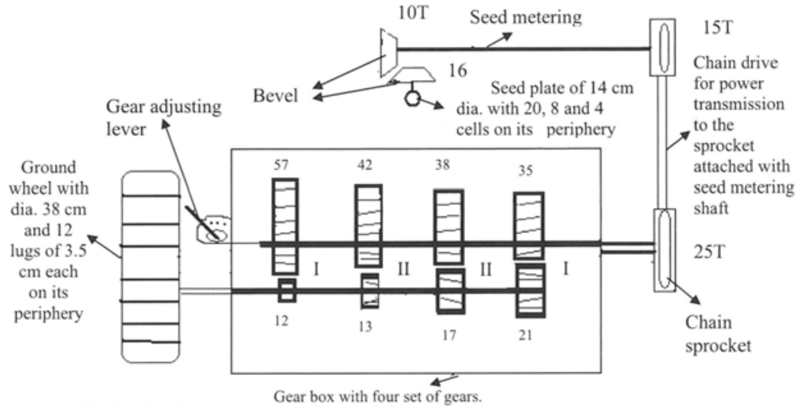

Fig. 1 Line diagram of power transmission and speed reduction unit of metering mechanism.

For Cotton | For Cotton, Pulses, Castor, Bengal gram | For DSR & Wheat

Fig. 2 Different types of seed plates.

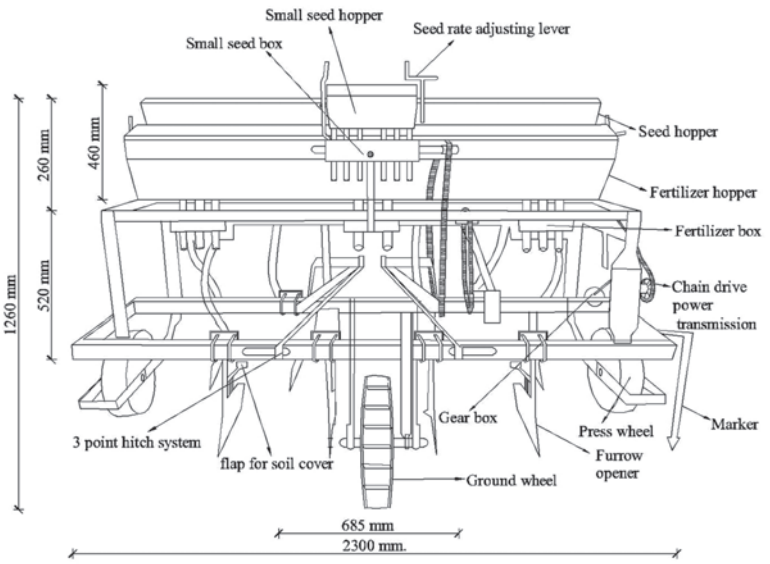

Fig. 3 Front view of multi-crop planter.

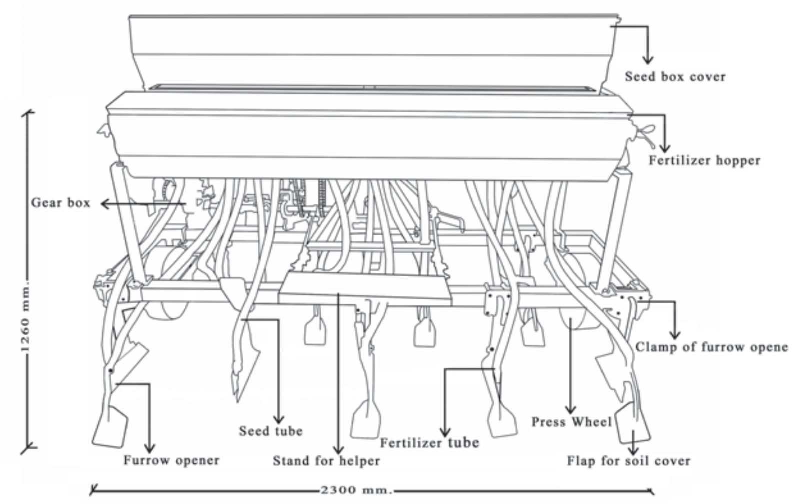

Fig. 4 Rear view of multi-crop planter.

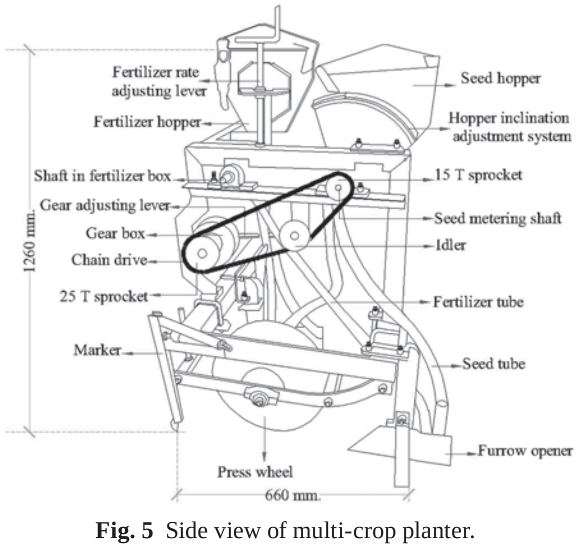

Fig. 5 Side view of multi-crop planter.

slippage during the operation. Two depth wheels without lugs were provided to left and right side of the frame. A power transmission assembly made of chain and sprockets is used to transmit the drive from ground wheel to seed and fertilizer metering units/shafts. The power (for seed metering) is transmitted in two stages, first from ground wheel to speed reduction unit, then from speed reduction unit to seed metering drive shafts. For fertilizer metering the power is transmitted in single stage, from ground wheel to fertilizer metering drive shafts. The speed ratio of ground wheel to fertilizer metering shaft is 2.3 : 1, while ground wheel to the seed metering unit can be taken as 1.6 : 1, 2.15 : 1, 3.1 : 1 and 4.5 : 1 as per requirements. The chain and sprockets are mounted between the ground wheel and counter shaft at the right side of the main frame with suitable frameworks (Jena, 2009 and Priti, 2011).

The trapezoidal shaped seed box frame is fabricated using M.S. sheet and its rear side was fitted with inclined cell plates at proper spacing. Around three cell plates, circular box made from M. S. sheet were provided for cotton seed metering purpose. Three types of inclined cell plate with twenty, eight & four (as per requirement) U shape cell cut around its periphery at uniform distance are provided. The drive of the inclined cell plate is given by the main drive shaft through the bevel gear set. The trapezoidal shaped fertilizer box with cross section (upper side 1830 × 240 mm, lower 1830 × 120 and 240 mm deep) was made from 20 gauge MS sheet. The fertilizer metering mechanism (vertical cell type roller) was fitted at the bottom of fertilizer box. The depth of planting can be adjusted by varying the height of ground wheels from the ground level with the help of suitable mechanism provided. The different views of developed multi-crop planter are shown in **Figs. 3- 5**.

performance Evaluation of Multi Crop Planter

After laboratory calibration (Anonymous, 1971) and adjustments at recommended seed rate for the Bt .cotton and DSR respectively, field evaluation of multi- crop planter for direct seeding of rice and Bt Cotton for initial crop establishment were carried out in Kaul and Hisar respectively during 2011 and 2012. Rice crop (CSR-30) and Bt Cotton (Rasi-134) were sown in the respective fields at desired depth and recommended seed rate with the machine during both the years (Yadav, 2009). The whole field was sown by developed inclined cell plate planter. Trials were conducted in order to assess the field capacity, field efficiency, plant stand till 21 days, and soil cover over seed sown. Field emergence in plot was recorded after 7 days, 14 days and 21 days after sowing of the crop. Cost analysis based on labour requirement and cost of operation was also conducted.

Results and Discussion

Field Performance

The adoption of any implement/ machine mainly depends upon satisfactory performance of the machine under actual field conditions. The performance of developed multi-crop planter in Bt Cotton crop (Rasi-134) and direct seeded rice crop (CSR-30) was carried out with a recommended seed rate of 3 kg ha^{-1} and 25 kg ha^{-1} respectively at farmers field in Hisar and Kaul, Kaithal respectively. The tractor was operated at 3 km/h. Row to row spacing of 900 mm and 200 mm was kept for Bt Cotton and DSR respectively. The field performance results of developed prototype for Bt Cotton and direct seeded rice planters are given in **Table 3**. It is clear from these data that an average seed to seed distance of 48 cm was achieved against the designed spacing of 54 cm in Bt Cotton whereas seed to seed spacing of 10 cm was achieved against designed spacing of 11 cm in Direct seeded rice of paddy crop. Its effective field capacity was observed as 0.50 ha h^{-1} and 0.45 ha h^{-1} for Bt Cotton and direct seeded rice crop respectively and field efficiency was found to be 61 percent and 83 percent for Bt Cotton and DSR respectively. The observed efficiency were obtained at 270 cm working width of machine for Bt Cotton and 180 cm working width of machine for DSR at 900 mm and 200 mm row to row spacing for Bt Cotton and DSR crop, respectively. Low efficiency of the planter was due to the fact that it took more time in turning. This is in agreement with the findings of Kathirvel *et al.* (2005) where low field efficiency was obtained while testing ridger seeder, pneumatic planter and cultivator seeders in the field conditions.

Uniformity of Plant Spacing

The uniformity of plant spacing achieved by developed planter was evaluated in terms of missing index, multiply index, and precision in spacing values. The plant spacing was measured 15 days after planting of crop. Performance results are reported in **Table 4**. It is clear from these data that percentage of missing index was 15 % and 16 %, multiply index recorded was 8 % and 6 %, precision in spacing recorded was 6.3 % and 7.08 % for Bt Cotton and DSR, respectively. The plant population counted 21 days after planting of crop is also given in **Table 4**. The plant population observed in the field planted by prototype in Bt Cotton was 20-28 plants/10 m row length and DSR crop was 140-150 plants/10 m row length. This is higher than the plant population of 8-10 plants/ 10 m row length observed by Kamaraj and Kathirvel (2008).

The cost economics of developed prototype for Bt Cotton and paddy crop was carried out and it was found that the cost of operation was Rs.350 h^{-1} for both the crops while it was Rs 700 ha^{-1} for cotton and Rs. 777 ha^{-1} for DSR crop. The labour requirements with planter for cotton and paddy crop were 1.66 man^{-h}/ha and 2.5 man^{-h}/ha respectively.

Summary and Conclusions

1. The actual field capacity of developed prototype in Bt Cotton and DSR crop observed were 0.50 and 0.45 ha h^{-1} respectively at an average forward speed of 3 km h^{-1}.

Table 3 Field performance data of developed prototype in Bt Cotton and DSR (Pooled data of 2011 and 2012).

Parameters	T_1 (Bt Cotton)	T_2 (DSR)
Area covered (m^2)	4,000	1,500
Average Hill to hill/(seed to seed) distance (cm)	48	10
Row to row spacing (cm)	90	20
Depth of sowing or depth of soil cover over seed (cm)	3-4	2-3
No. of seeds/seedling hill^{-1}	1-2	2-3
No. of hill m^{-2}	2-3	50
No. of plants m^{-2}	4-6	150
No. of missing hills m^{-2}	0	0
Missing index (%)	15.0	16.66
Fuel consumption (l h^{-1})	2.54	2.6
Theoretical field capacity, ha h^{-1}	0.81	0.54-0.65
Time lost in per turn, sec	35	35
Actual field capacity (ha h^{-1})	0.50	0.45-0.53
Field efficiency (%)	61	83

The field efficiencies were 61 percent and 83 percent respectively.

2. The field emergence (No. of plants /10m furrow length) observed by the use of developed prototype were 12-20 plants (7 days after planting), 18-30 plants (15 days after planting) and 20-28 plants (21 days after planting) in Bt Cotton crop. In comparison to this the seed germinations of 125-140, 135-155 and 140-150 plants 7 days, 15 days and 21 days after seeding were recorded in DSR crop. Increase or variation in germination at 7 and 15 days after seeding is due to moisture availability or some other favorable source and decrease at 21 days after seeding is due to some mortality.
3. The distribution of plants in row and crop response at farmer's field indicated that mean plant spacing observed was 48 cm in Bt Cotton and 10 cm mean spacing was recorded in DSR. The values of missing index were 15 and 16 percent in Bt Cotton and DSR respectively. The precision in spacing observed was 6.30 and 7.08 percent in Bt Cotton and DSR respectively and clearly indicate satisfactory performance of developed prototype.
4. The cost of planting by developed prototype in Bt Cotton was Rs. 700 per hectare against Rs. 777 in DSR crop. The labour requirement with developed prototype in Bt Cotton was 1.66 man-h ha^{-1} whereas in case of DSR it was 2.5 man^{-h} ha^{-1}.

Recommendation and Suggestions

1. The developed prototype should be commercialized as a precision sowing machine especially for different varieties of Bt Cotton and DSR.
2. The sowing should be done on well prepared seedbed to reduce deviations in seed to seed spacing.
3. Studies should be further conducted on the field performance evaluation of planter with regard to germination, plant population, crop yield and its economics under different agro-climatic zones.

Table 4 Plant distribution in rows and crop response (Pooled data of 2011 and 2012).

Particulars	Bt Cotton	DSR
Average plant spacing after germination, cm	48	10
Missing index, %	15	16
Multiply index, %	8	6
Quality of feeding index, %	77	78
Standard deviation from mean	3.04	0.708
Precision in spacing, %	6.3	7.08
Average number of plant in 10 m length		
7 DAS	12-20	125-140
15 DAS	18-30	135-155
21 DAS	20-28	140-150

* Calculated by (standard deviation from mean/ average plant spacing after germination) × 100, i.e. (3.04/ 48) × 100 and (0.708/10) × 100

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New Co-operating Editor

Dr. Ahmad Addo

Date of Birth: 14 March 1963
Nationality: Ghana
Present Position: Associate Profesor, Department of Agricultural Engineering Kwame Nkrumah University of Sci. and Tech. (KNUST), Kumasi, Ghana.
Education:
2002: PhD Agricultural Engineering, Institute of Agricultural & Forest Engineering, University of Tsukuba, Japan/ 1997: MSc. Biosystem Science, Graduate School of Biosystem Studies, University of Tsukuba, Japan/ 1994: Certificate in Farm Mechanisation, Tsukuba International Agricultural Training Centre, Japan International Cooperation Agency, Japan/ 1990: BSc. (Hons) Agricultural Engineering, KNUST, Kumasi, Ghana/ 1984: GCE "A" level at Ghana Secondary Technical School, Takoradi, Ghana/ 1982: GCE "O" level at T. I. Ahmadiyya Secondary School, Kumasi, Ghana.

Work Experience
2010-to date: Associate Professor of Agricultural Engineering, College of Engineering, KNUST, Kumasi, Ghana/ 2005-2010: Senior Lecturer in Agricultural Engineering, College of Engineering, KNUST, Kumasi, Ghana/ 2003-2005: Lecturer in Agricultural Engineering, College of Engineering, KNUST, Kumasi, Ghana/ 1991-1994: Agricultural Engineer, Kpong Farms Limited, a subsidiary of Volta River Authority, Akuse, Ghana.

Dr. Enkhbayar Gonchigdorj

Date of Birth: 26 July.1967
Nationality: Mongolia
Present Position: Director of the School of Engineering and Technology, Mongolian University of Life Sciences
Education:
1996: Ms, Mongolian State University of Agriculture; Mechanical Engineering/ 2008: PhD, Mongolian University of Science and Technology, (MUST)/ 2014: Associate Professor, Mongolian University of Life Sciences, (MULS)

Employment Record:
Lecturer, Eneering School, Mongolian State University of Agriculture, (MSUA) from 2000 to 2004/ Head of the Department, of Engineering School, MSUA, from 2005 to 2009/ Director of the School of Engineering, MSUA, from 2009 to 2013/ Director of the School of Engineering and technology, from 2014

Current Research Interests:
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Effect of Three Honeycomb Interplant Distances on Yield and it Components of Two Cultivars of Bean

by
Iman J. Abdul Rasool	Ali H. Annon

Department of Horticulture, Agricultural college, University of Baghdad, IRAQ

Abstract

A factorial experiment (2 × 3) in randomized complete block design (RCBD) with three replications was conducted to examine the effect of honeycomb selection method using three interplant distances on yield and its components of two cultivars of bean, Bronco and Strike. Interplant distances used were 75 × 65 cm, 90 × 78 cm, and 105 × 91 cm (row x plant) represent short (high plant density), intermediate (intermediate plant density), and wide (low plant density) distance, respectively. Parameters used for selection were number of days from planting to the initiation of first flower, number of nodes formed prior to first flower, and number of main branches. Results showed significant superiority of the Bronco cultivar represented in the number of pods per plant, number of seeds per pod, and the total length of pods which were 23.1 pods/plant, 5.71 seeds/pod, and 13.09 cm, respectively. Moreover, total carbohydrates %, fibers %, and total soluble solids % were significantly higher in the pods of Bronco cultivar compared to Strike. Low and intermediate plant density gave the highest yield per plant. However, the high plant density gave the highest early and total yields which were 0.517 and 1.719 ton/ha, respectively.

Key words: Competition, Interplant distances, Genotype, Phaseolus vulgaris, production.

Introduction

Most of the breeding programs have focused on the improvement and maintenance of the economically important traits that linked to the yield. Beans (*Phaseolus vulgaris L.*), refers to food legumes, are one of the most important horticultural crop that considered a crucial source of proteins contributed to the human diet. Unfortunately, beans have been facing quality depression such as delay in maturation along with seeds and pods disfiguration due to recurrent growing for many generations. Therefore, it is recommended to practice selection for every 2-3 growing cycles (Sibernagel *et al.*, 1993). Selection is considered one of the most important means of plant breeding which can increase gene frequency of the trait selected for when applied to large populations that show significant level of variation (Elsahooeke, 2004). Selection can also lead to high ratio of heritability (Ntanos and Roupakias, 2001). Single plant selection is one way of selection where the effect of interplant competition can be significantly reduced and at the same time elevates the additive gene effect. According to Fasoulas (1981), the two main factors affecting the efficiency of single plant selection are soil heterogeneity and interplant competition which can be dealt with as follows. Interplant competition can be alleviated by growing plants in the field at low density while the negative effect of soil heterogeneity can be avoided by comparing plants grew next to each other (Fasoulas, 1981). To ensure fair selection, Fasoulas (1973) adopted a triangular pattern of planting positions and called it the honeycomb selection technique. In honeycomb selection, single plant are spaced in hexagonal way with a pattern that every plant is positioned in the center of the hexagon and compared with six equidistant neighbors (Fasoulas, 1973). Many studies have reported the effective use of honeycomb selection design in durum wheat (Mitchell *et al.*, 1982), winter rye (Kyriakou and Fasoulas, 1985), oat (Robertson and Frey, 1987), and cabage (Koutsos and Sotiriou, 2001). This study was conducted to examine the best interplant distance on the efficiency of honeycomb selection design for two cultivars of beans after one cycle of selection.

Materials and Methods

Two cultivars of locally known beans (*Phaseolus vulgaris L.*), named Bronco and Strike, were selected based on their highly yielding potential and environmental adaptation to participate in this study. The experiment was performed in the field of the Department of Horticulture and Landscape Gardening / College of Agriculture / University of Baghdad in the autumn of 2009. Seeds were sown according to the honeycomb design using three distances between rows which were 75 cm, 90 cm, and 105 cm representing short, intermediate, and wide distances, respectively. The distances between plants were calculated according to the equation given by Fasoulas (1988) as fallow: Interplant distances= d √ 3/2 where d was the distance between rows. The equation yielded the following planting combinations (row x plant):

(75 × 65 cm) represents the short distance and symbolized D_1

(90 × 78 cm) represents the intermediate distance and symbolized D_2

(105 × 91 cm) represents the wide distance and symbolized D_3

The factorial experimental designed included two factors, two bean cultivars and three interplant distances, was performed in RCBD with three replications.

The experiment consisted of 18 experimental units each contained approximately 50 plants grown in a 6 m length rows counted as 6, 8, and 10 rows in D_1, D_2, and D_3, respectively. Moving circle selection with 20 % selection pressure (10 plants from each experimental unit) was applied. The criteria used for selection were number of days from planting to the initiation of first flower, number of nodes formed prior to first flower, and number of main branches. From each sample, parameters of total yield (tons/hectare), early yield (first harvest only), and number of pods per plant were recorded. When pods reached physiological ripening, readings of length (cm), weight (g), number of seeds per pod, total soluble solids (TSS), proteins, carbohydrates, and fibers were also collected according to the Association of Official Analytical Chemists (AOAC) protocols (1980). An additional experimental unit for each bean cultivar was used as control where beans are planted in its conventional way spaced 15 cm between plants and 75 cm between rows. A sample of 20 plants from each control unit was selected and all the physiological and biochemical analyses were also applied. Data were analyzed using the Duncan multiple range test at 95 % level of significance (Elsahookie and Wahib, 1990).

Results and Discussion

Results in **Table 1** are showing significant differences in mean values between the two cultivars, Bronco and Strike, in terms of yield, number of pods per plant, number of seeds per pods, and pod's length which probably due to genotype heterogeneity. Interestingly, coefficient of variation (% CV) showed high values in the Bronco cultivars compared to Strike which indicates decreased uniformity within population and therefore, selection is necessary. According to Tollenaar and Wu (1999), Low % CV values

Table 1 Mean ($\bar{X}$) and coefficient of variation (% CV) for yield and its components of two cultivars of beans (Bronco and strike) in autumn, 2009. (Tcal. Stand for the value of T calculated.)

Traits / Cultivars		Yield (gm/Plant)	No. of pod/ plant	No. of seed/ pod	Pod Length (cm)
	$\bar{X}$	103.1	18.2	5.80	12.64
	% CV	26.95	23.99	10.90	7.44
Strike	$\bar{X}$	54.2	13.4	4.2	10.1
	% CV	12.89	12.28	10.04	11.14
Tcal. Value		3.18	9.23	19.05	5.20

**significant at P=0.01

Table 2 Effect of cultivar (V_1, V_2), interplant distances (D_1, D_2, D_3), and their interaction on the traits of yield component of beansin autumn, 2009. Means within the same column that share the same letter are not significantly different.

Trait / Cultivar	No. of pods/ plant	Weight of pod (gm)	No. of seeds/ pod	pod length (cm)
Bronco (V_1)	23.10_a	1.65_a	5.71_a	13.09_a
Strike (V_2)	21.66_b	1.72_a	5.31_b	12.19_b
Interplant distances				
D_1	17.43_c	1.80_a	5.83_a	12.72_a
D_2	26.80_a	1.76_a	5.53_{ab}	13.07_a
D_3	22.90_b	1.49_a	5.17_b	12.13_a
Interaction				
V_1D_1	15.10_c	1.86_a	6.27_a	12.67_a
V_1D_2	27.50_a	1.64_{abc}	5.60_b	13.60_a
V_1D_3	26.70_a	1.43_c	5.27_b	13.00_a
V_2D_1	19.77_b	1.74_{ab}	5.40_b	12.77_a
V_2D_2	26.10_a	1.87_a	5.47_b	12.53_{ab}
V_2D_3	19.10_b	$1.55b_c$	5.07_b	11.27_b

are an indication of reduced variability within populations and can be considered as important characteristic to improve elite cultivars.

Yield Components and Characteristics:

The main and most important yield components in beans are pods number and pods weight as yield is directly associated with these variables. However, these two components are in contrivers with each other (Dursun, 2007). Data in **Table 2** are showing significant differences between the selected cultivars in term of number of pods per plant. As observed, Bronco showed to produce more pods per plant while no such differences were found in terms of pod weight. Pods length and seeds number showed to be affected by the genotype which exhibited a significant increase in Bronco (13.09 cm and 5.71, respectively) than Strike (12.10 cm and 5.31, respectively). Wide and intermediate (D_3 and D_2) interplant distances showed to increase the number of pods in both cultivars compared to the short distance (D_1). However, the number of seeds per pods was significantly increased when using D_1 compared to D_3 (**Table 2**). The weight and length of pods did not show any response to interplant variation although interaction between interplant distances and cultivars showed to have a significant effect on all the traits under investigation. When using both cultivars with D_2, a significant increase in the number of pods per plant was exhibited when reached 27.5 and 26.1 (pod/plant) in Bronco and Strike, respectively (**Table 2**). In term of pod's weight, cultivar Bronco scored the highest weight when using D_1 which reached 1.86 g. However, D_2 showed to be the best interplant distance for cultivar Strike when the pod's weight reached 1.87 g (**Table 2**). As for the pod's length, all interplant distances used with cultivar Bronco significantly increase their pods length while only D_1 showed to have a significant effect on the pod's length for the cultivar Strike (**Table 2**). Interestingly, all interplant distances used have significantly reduced the seed number/ pod except when using D_1 in cultivar Bronco which significantly increased the seed count.

Yield is the final outcome of its components which associated with numerous plant physiological and biochemical processes and are affected by the interaction between genotypes and environment (Elsahookie, 2006). Results in **Table 3** show significant increase in yield/plant, early yield, and total yield in Bronco compared with Strike and clearly indicate the important role of genotype (two cultivars)/environment (three interplant distances) interaction. As for the different interplant treatments, both D_2 and D_3 significantly increased yield/plant which were 111.8 and 108 g/plant, respectively in comparison with D_1 that gave only 83.3 g/plant. However, early and total yield were significantly increased when using D_1 (high plant density). Early yield was significantly increased when using the cultivar Bronco with D_1 and D_2 and yielded 0.576 and 0.533 ton/ha, respectively. The highest yield/plant was obtained in widely spaced (D_3) Bronco cultivar which reached 130.5 g/plant while the highest total yield was obtained when using Strike cultivar with D_1 and reached 1.909 ton/Ha.

Yield from the genetic perspective is the result of different gene acts of different traits which resemble a complex syndrome. In another hand, yield from the phenotypic perspective is the result of its component that affected by the interaction between the genotype and the environment (Tollenaar *et al*., 2004). In general, low plant density (D_3) gave the highest yield/plant which was mostly due to reduced competition between plants and an increase in some growth parameter that indirectly increased pod's weight and count. On the other hand, high plant density (D_1) gave the highest yield/Ha due to the increased number of plant per unit area which was about 20,000 plant/Ha, 14000 plant/Ha, and 10,000 plant/Ha in D_1, D_2, and D_3, respectively.

Quality Characteristics of pods:

Percentage of carbohydrates, protein, TSS, and fibers are considered good indicators to determine the nutritional and marketing value of

Table 3 Effect of cultivar (V_1, V_2), interplant distances (D_1, D_2, D_3), and their interaction on the early yield and productivity of beans for autumn, 2009. Means within the same column that share the same letter are not significantly different.

Trait / Cultivar	Early yield (ton/h)	Yield/plant (g/plant)	Total yield (ton/h)
Bronco (V_1)	0.493_a	109.4_a	1.545_a
Strike (V_2)	0.361_b	92.9_b	1.410_b
Interplant distances			
D_1	0.517_a	83.8_b	1.719_a
D_2	0.454_{ab}	111.8_a	1.592_a
D_3	0.311_b	108.0_a	1.122_b
Interaction			
V_1D_1	0.576_a	74.6_d	1.529_{ab}
V_1D_2	0.533_a	123.2_{ab}	1.757_{ab}
V_1D_3	0.371_{ab}	130.5_a	1.350_{bc}
V_2D_1	0.458_{ab}	93.0_{bcd}	1.909_a
V_2D_2	0.375_{ab}	100.3_{abc}	1.429_{ab}
V_2D_3	0.250_b	85.4_{cd}	0.893_c

pods in beans (Boras *et al*., 2011). Results in **Table 4** show the effect of genotype contribution to the trait reflected in a significant increase in carbohydrates, fibers, and TSS in Bronco cultivar compared to Strike. However, no significant difference was observed in term of protein levels between the two cultivars. As for the Interplant distances effect, D_2 significantly increased both carbohydrates and proteins which were 11.97 % and 18.42 %, respectively. Nevertheless, D_3 significantly reduced the content of carbohydrates that reached 9.77 % whereas D_1 significantly reduced the content of proteins in pods and reached 16.49 %. None of the interplant distances used had any significant effect on TSS while D_1 treatment significantly increased fibers content in pods more than 15 % compared with D_2 and D_3 which were 13.2 % and 12.57 %, respectively. A significant effect was observed resulted from the interaction between interplant distances and cultivars which showed highest levels of carbohydrates and fibers (13.9 and 17.43 %, respectively) in the pods of shortly spaced (D_1) Bronco cultivar and the highest level of proteins (19.07 %) in the pods of Strike cultivar when using D_2 treatment. In addition, the highest TSS level was observed in the pods of Bronco cultivar when using D_1 or D_3 which reached 5.17 % in both treatments, while using D_2 with Strike also yielded a high TSS level (4.67 %) compared with other combinations. The response of both cultivars to D_2 and D_3 led to the improvement of nutritional value of pods such as high protein and TSS levels and reduced in fibers. This enhancement can be due to the lack of competition between plants especially in D_2 and D_3 treatments used in the experiment. Moreover, using the wide interplant distance treatment helps to overcome the negative effect of environment such as soil heterogeneity and gave a better representative and independent samples of original population (Fasoula and Fasoula, 2000). Finally, these results were in agreement with some previous reports (Mitchell *et al*., 1982; Kyriakou and Fasoulas, 1985; Robertson and Frey, 1987; Bussemakers and Bos, 1999; and Koutsos and Sotiriou, 2001) that suggested using low plant density while selecting with honeycomb method.

Table 4 Effect of cultivar (V_1, V_2), interplant distances (D_1, D_2, D_3), and their interaction on the qualitative yield traits of beans for autumn, 2009. Means within the same column that share the same letter are not significantly different.

Trait / Cultivar	Carbohydrate %	Protein %	T.S.S. %	Fibers %
Bronco (V_1)	12.42_a	17.03_a	4.67_a	14.38_a
Strike (V_2)	9.36_b	18.19_a	3.78_b	13.05_b
Interplant distances				
D_1	10.93_{ab}	16.49_b	4.33_a	15.39_a
D_2	11.97_a	18.42_a	4.17_a	13.20_b
D_3	9.77_b	17.93_{ab}	4.17_a	12.57_b
Interaction				
V_1D_1	13.90_a	16.24_c	5.17_a	17.43_a
V_1D_2	12.20_{ab}	17.76_{abc}	3.67_b	13.17_b
V_1D_3	11.17_b	17.09_{abc}	5.17_a	12.55_b
V_2D_1	7.97_c	16.74_{bc}	3.50_b	13.34_b
V_2D_2	11.73_{ab}	19.07_a	4.67_a	13.22_b
V_2D_3	8.73_c	18.77_{ab}	3.17_b	12.59_b

Conclusions

Wide interplant distance (low plant density) proved to be the most efficient treatment when using the honeycomb method of selection in beans which improved trait components of yield, yield per plant, and the quality of pods in both cultivars. Therefore, a mass selection program of beans using the honeycomb selection method is recommended with wide interplant distance especially to improve local bean varieties that encountered a prolonged genetic depression.

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Anthropometric Measurements of Indian Women Farmers of Central Himalayan Region

by
Vijayshree Dhyani
Ex-Ph. D. Scholar
College of Home Science
vsdhyani@gmail.com

Promila Sharma
Professor
College of Home Science
promila23@gmail.com

T. C. Thakur
ICAR National Professor
College of Technology
drtcthakur@yahoo.com

G.B. Pant University of Agriculture and Technology, Pantnagar-263 145, Uttarakhand, INDIA

Abstract

Cultivation in hilly region of the Himalayas is being practiced mostly by the women farmers in their own traditional way using locally developed hand tools and implements. For ergonomically designed tools with improved safety and comfort, it is imperative to carry out anthropometrical measurements of hill women farmers which are very much lacking at present. In this context, a total of 100 women farmers from Garhwal and Kumaun hill regions of Uttarakhand were selected through simple random sampling without replacement and their 42 body dimensions were measured and analyzed. The mean height and weight of hill women in the working age group of 20-45 years were found to be 151.49 (± 5.93) cm and 40.27 (± 5.08) kg, respectively. Significant differences were not observed in most of the standing and sitting heights but a few body depths and most of the body breadth showed broader body size of women from Kumaun region. A comparison of selected standing anthropometric dimensions of different states in the plain region of India showed higher value than those of hill women of Uttarakhand. Also, all the selected sitting anthropometric dimensions of Andhra Pradesh (Hyderabad), Rajasthan (Udaipur) and Haryana (Hisar) states were found to be higher than those of hill women. The geographical area and gender specific anthropometric dimensions need to be considered for developing efficient tools and gadgets for the hilly region.

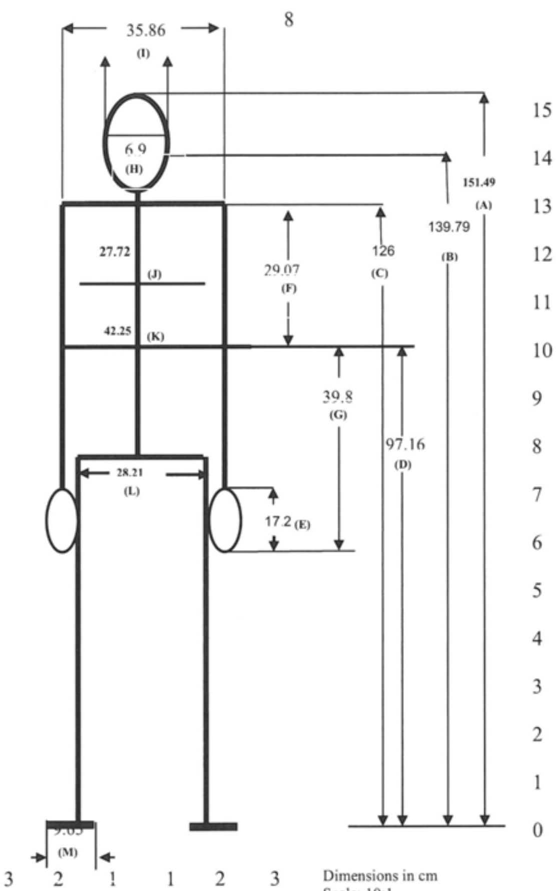
Introduction

The central Himalayan region of India includes the state of Uttarakhand which extends from 280 43´N-310 27´N longitude to 770 34´E-810 02´E latitude and surrounded by International boundaries of China in the North and Nepal in the East. This state is broadly divided into two zones i.e. Kumaun (Eastern region) and Garhwal (Western region) with altitude varying from 600 m in Tarai plain to > 2400 m above m.s.l. upto snow clad peaks of the great Himalayas. In India, the women workforce in agriculture and allied sector is estimated to be about 45 % of the agricultural workers which is projected to increase up to 60 % in the next four decades. This is primarily because of migration of male workforce to more remunerative jobs in non-agricultural sectors (Anonymous, 2013). In hilly region of the country, even higher percentage of women workforce is engaged in agricultural activities.

In Uttarakhand state, over 80 % of women are engaged in agriculture. Except heavy work like tillage operations, which are generally performed by men, most of the work in production agriculture, fetching of fodder, water and firewood, livestock rearing and daily household chores are performed by women. For some of the agricultural operations, hand tools and implements are available. These equipment, however, have been primarily developed for male workers and the same are being used by women which not only result in lower system efficiency but also occupational health hazards to working women. It should be realized that women have different ergonomical characteristics than men. Therefore, there is a need to develop and introduce tools and gadgets especially for hill women farmers by taking into consideration their anthropometrical dimensions and physiological capabilities.

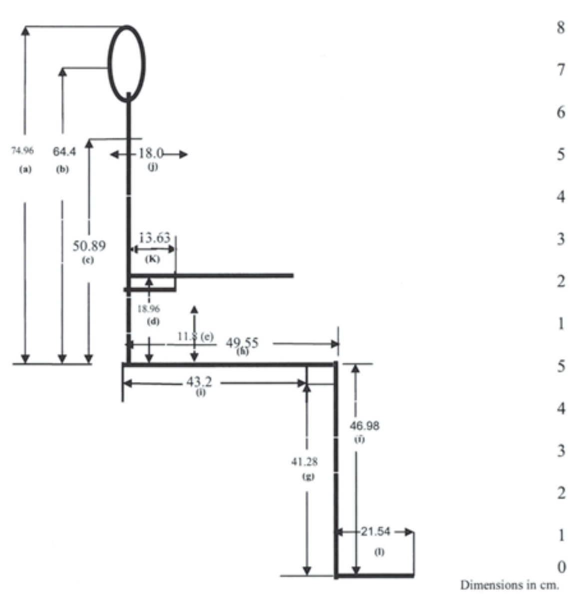
Anthropometry is the measurement of human body, which includes the body dimensions and the mechanical aspects of motion using anthropometric kit. In the past, most of the work on anthropometric measurements was carried out on male workers (Gupta *et al*., 1983; Gite and Singh, 1997; Dewangan, 2005; Adak, 2006). There is a little information available on the anthropometric dimensions of women farmers in India (Nag *et al*., 2003; Chandra and Sharma, 2012; Gite *et al*., 2009), however, have complied 79 body dimensions of 12,525 workers including women from 12 states of India collected through AICRP on 'Ergonomics and Safety in Agriculture'. But the information in respect of women farmers of hilly region in particular is almost negligible (Dhyani *et al*., 2013). The anthropometric dimensions are used to evaluate the interaction of workers with tasks, tools, machines, vehicles and personal protective equipment. Designs that are incompatible with anthropometric dimensions of working women and are based on the dimensions of men, show high prevalence of musculoskeletal disorders. It has been reported that the musculoskeletal disorders are more common among women than men, especially in neck and shoulder disorders (Pheasant, 1996, Kilbom *et al*., 1998; Punnet *et al*., 2000; De Zwart, 2001).

It is evident from general observations that there are differences in anthropometric dimensions between various regions as well as within the geographical locations of same region in the hills. This is in conformity with Hsiao (2002) and Lin *et al*. (2004) who reported that the gender, age, race and geographical region are associated with differences in body dimensions. With this in view, the present study was undertaken to find out whether there are significant differences in anthropometric dimensions of Garhwal and Kumaun regions which belong to the same hill state of Uttarakhand, and also to compare the anthropometric dimensions of hill women with the dimensions of women from Indian states of plain region.



[Notations] A: Height, B: Eye height, C: Shoulder height, D: Elbow height, E: Hand length, F: Shoulder-elbow length, G: Forearm-hand length, H: Interpupillary distance, I: Shoulder breadth, J: Chest breadth, K: Maximum body breadth, L: Standing hip breadth, M: Foot breadth

Fig. 1 Mean anthropometric dimensions of hill women of Uttarakhand in standing posture.



Dimensions in cm, Scale: 10 : 1

[Notations] a: Sitting height, b: Eye height, c: Shoulder height, d: Elbow height, e: Thigh height, f: Knee height, g: Poplietal height, h : Buttock-knee length, i: Buttock-knee length, j: Chest breadth, k: Waist depth, l: Foot length

Fig. 2 Mean anthropometric dimensions of hill women of Uttarakhand in sitting posture.

Materials and Methods

A total of 100 women from hill region of Uttarakhand i.e. Garhwal (N = 50) and Kumaun (N = 50) were purposively selected for anthropometric measurements through simple random sampling without replacement. Forty two body dimensions essential for the design of tools and gadgets were categorized in five groups, viz. seven standing posture (**Fig. 1**), ten sitting posture (**Fig. 2**), seven hands, ten body breadths and eight body circumferences and depths. All the subjects were clothed as lightly as possible and were barefoot. Standing measurements were taken in an erect, but not so rigid posture. The sitting posture was arranged such that the feet rested flat on the floor, and an angle of 90º is formed at the knee and hip joints. The nomenclature for all the anthropometric dimensions was adopted as per Morgan and Cook (1963) except that the chest and waist circumferences were taken according to Chakravarti (1997). In the present study, the mean, standard deviation and percentiles (5th, 50th, and 95th) were determined to analyze the anthropometric data and one way ANOVA was used for testing the hypothesis that the mean dimensions of women farmers of Garhwal and Kumaun regions of Uttarakhand state are equal.

For comparison of anthropometric dimensions of hill women of Uttarakhand with that of women from other plain regions of India, a total of 16 anthropometric measurements were selected. These dimensions included five standing posture, eight sitting posture and three hand posture. All the anthropometric dimensions of other plain regions of India were the data base from different centres of AICRP in 'Home Science' operating at SAUs and other organizations (Anonymous, 1994-96). All the sitting heights measurements of other states were taken from the floor. However, in this particular study the sitting height measurements were taken from the seat surface. Therefore, for comparison a constant value of 41 cm (seat height of chair from floor / poplietal height seating) was added to the seating height measurements of hill women of Uttarakhand.

Results and Discussion

The anthropometric dimensions including mean, standard deviation, percentiles and F-values of these dimensions are presented in **Table 1**. The mean weight of hill women was found to be 40.27 (± 5.08) kg which was 40.80 (± 4.58) kg and 39.74 (± 5.48) kg for Garhwal and Kumaun regions, respectively. No significant difference was found in the weight between women of two regions. The dimensions measured alongwith their mean values in standing and sitting postures of Uttarakhand hill women are illustrated by line diagrams in **Figs. 1** and **2**, respectively.

Standing Posture

The mean height, eye height, shoulder height, elbow height (standing), knuckle height (standing) and overhead reach of hill women were 151.49 (± 5.93), 139.79 (± 7.09), 126 (± 5.12), 97.16 (± 5.23), 67.41 (± 7.01) and 167.5 (± 6.33) cm, respectively. Significant difference ($p < 0.05$) was found only in case of eye height between the women of Garhwal and Kumaun regions.

Sitting Posture

The mean sitting height, eye height, shoulder height, elbow height, thigh height, knee height and poplietal height of hill women were 74.96 (± 3.68), 64.40 (± 3.89), 50.89 (± 3.70), 18.96 (± 2.75), 11.80 (± 1.71), 46.98 (± 4.64), 41.28 (± 3.87) cm, respectively. The buttock-leg length, buttock-knee length and buttock- poplietal length were 95.57 (± 5.88), 49.55 (± 4.11) and 43.28 (± 3.95) cm, respectively. Significant differences were found between Garhwal and Kumaun regions in sitting height ($p < 0.05$) and sitting elbow height ($p < 0.01$).

Measurements of Hands

The mean hand breadth at metacarpal, hand breadth at thumb, hand length and hand thickness of hill women were 7.49 (± 0.53), 9.24 (± 0.64), 17.20 (± 1.00) and 1.64 (± 0.21) cm, respectively. Similarly the shoulder-elbow length, forearm-hand length and arm reach were 29.07 (± 2.31), 39.88 (± 2.55) and 74.38 (± 3.53) cm, respectively. Significant differences were found between Garhwal and Kumaun regions in hand thickness ($p < 0.01$) and shoulder-elbow length ($p < 0.05$).

Body Breadths

The interpupillary distance, head length and head breadth were 6.90 (± 1.03), 19.88 (± 1.73) and 11.28 (± 2.10) cm, respectively. Similarly, the shoulder breadth, chest breadth, maximum body breadth, elbow-elbow breadth, sitting hip breadth, standing hip breadth and knee-knee breadth were 35.86 (± 2.81), 27.72 (± 2.30), 42.25 (± 4.10), 38.10 (± 4.67), 32.31 (± 2.47), 28.21 (± 3.06) and 13.29 (± 1.96) cm, respectively. Significant differences ($p < 0.01$) were found between Garhwal and Kumaun regions in head breadth, shoulder breadth, elbow-elbow breadth, knee-knee breadth and sitting hip breadth showing that women from Kumaun region have broader body size than Garhwal region.

Body Circumferences and Depths

The chest and waist circumferences were 82.10 (± 6.50) and 70.59 (± 7.44) cm, whereas various body depths such as chest depth, waist depth, maximum body depth and buttock depth were 18.00 (± 3.06), 13.63 (± 2.47), 22.28 (± 3.36) and 13.75 (± 2.22) cm, respectively. Foot length and breadth were found to be 21.54 (± 1.53) and 9.65 (± 0.98) cm,

Table 1 Anthropometric dimensions of hill woman farmers of Uttarakhand state (India).

Dimensions	F-value	Mean values			Percentiles								
		Garhwal N=50	Kumaun N=50	Uttarakhand N=100	Garhwal region			Kumaun region			Uttarakhand state		
					5th	50th	95th	5th	50th	95th	5th	50th	95th
Standing anthropometric measurements, cm													
Weight, kg	1.086 ns	40.8 (4.58)	39.74 (5.48)	40.27 (5.08)	33.45	40	46.55	32	38.5	48	32.95	40	48
Height (A)	0.007 ns	151.48 (4.43)	151.6 (6.98)	151.49 (5.93)	145	151.5	159.1	139.4	152	164.2	141.9	152	161
Eye height (B)	5.101*	138.22 (6.25)	141.36 (7.51)	139.79 (7.09)	127.4	138	148.5	127.9	142	155.7	127	140	149.1
Shoulder height (C)	0.608 ns	126.4 (4.89)	125.6 (5.30)	126.00 (5.12)	119	126	135	117.9	125	133.5	119	125	135
Elbow height (D)	2.061 ns	96.32 (5.60)	98 (4.69)	97.16 (5.23)	90	97	104	89.35	98	104	89.95	98	104
Knuckle height	0.034 ns	67.54 (8.40)	67.28 (5.31)	67.41 (7.01)	58.9	66	83.15	58	67.5	75	58	67	76
Overhead reach	1.052 ns	166.72 (4.40)	168.28 (7.69)	167.50 (6.33)	159.4	168	172	157.4	169	179.5	158	168	179
Sitting anthropometric measurements, cm													
Sitting height (a)	4.880*	75.76 (3.49)	74.16 (3.70)	74.96 (3.68)	70.4	76	80	67	75	79.5	68.9	75	80
Eye height (b)	2.931 ns	65.06 (3.93)	63.74 (3.73)	64.4 (3.89)	58.4	65	71.1	57	64	69.1	57	65	70.05
Shoulder height (c)	2.947 ns	51.52 (3.77)	50.26 (3.53)	50.89 (3.70)	44.4	52	57	44.4	51	54	44	51	57
Elbow height (d)	31.862**	17.6 (1.77)	20.32 (2.88)	18.96 (2.75)	15	18	20	16	20	25	15.9	18	25
Thigh height (e)	3.016 ns	11.51 (1.35)	12.1 (1.96)	11.80 (1.71)	9.45	11	14	8	12	15	8.95	12	15
Knee height (f)	2.164 ns	46.3 (4.27)	47.66 (4.894)	46.98 (4.64)	40.9	45	53.6	41	48	55.1	40.9	46	55
Poplietal height (g)	0.129 ns	41.42 (4.21)	41.14 (3.51)	41.28 (3.87)	36.4	40.5	49.6	36	41	46.5	36	41	47
Buttock-leg length	2.011 ns	94.74 (5.74)	96.4 (5.89)	95.57 (5.88)	88	93	105	87.9	97	105	87.9	95	106
Buttock-knee length (h)	0.642 ns	49.22 (3.79)	49.88 (4.37)	49.55 (4.11)	44.4	49	57.1	43	50.5	56	43	50	56.1
Buttock-Poplietal length (L)	0.827 ns	43.64 (3.66)	42.92 (4.18)	43.28 (3.95)	38.9	43	50.6	35.8	42	50	37.9	42.5	50.1
Anthropometric measurements of hands, cm													
Hand breadth at Metacarpal	0.036 ns	7.5 (0.36)	7.48 (0.65)	7.49 (0.53)	7	7.5	8	6.5	7.5	8.5	6.5	7.5	8.5
Hand breadth at Thumb	1.194 ns	9.31 (0.51)	9.17 (0.73)	9.24 (0.64)	8.5	9	10	8	9	10	8	9	10
Shoulder-elbow length (F)	6.881*	29.66 (2.30)	28.48 (2.17)	29.07 (2.31)	25	30	33.1	25	29	32	25	29	32
Forearm-hand length (G)	1.242 ns	40.17 (2.32)	39.6 (2.74)	39.88 (2.55)	36.9	40	44	35	40	43	35	40	44
Arm length	1.423 ns	73.96 (3.87)	74.8 3.10	74.38 (3.53)	68.9	74	80	70.45	75	79.55	69.95	74.5	80
Body breadths, cm													
Interpupillary distance (H)	0.414 ns	6.974 (1.41)	6.84 (0.41)	6.90 (1.03)	6.5	7	7.275	6	7	7.5	6	7	7.5
Head length	1.082 ns	20.06 (1.76)	19.7 (1.67)	19.88 (1.73)	18.45	20	22	17	20	22	17	20	22
Head breadth	23.463**	10.36 (2.01)	12.2 (1.75)	11.28 (2.10)	8.725	10	12	10	12	15	9	11	15
Shoulder breadth (i)	30.156**	34.5 (2.26)	37.22 (2.64)	35.86 (2.81)	32	34	39	33	38	41.55	32	35	41
Chest breadth (J)	3.086 ns	28.12 (1.76)	27.32 (2.66)	27.72 (2.30)	25	28	31	24	27.5	31.55	24	28	31
Maximum body breadth (K)	1.710 ns	41.72 (3.89)	42.79 (4.23)	42.25 (4.10)	34.45	43	47.55	36.9	43	48	35	43	48
Elbow-elbow breadth	29.461**	35.87 (3.89)	40.34 (4.28)	38.10 (4.67)	29	36	42	32	40	48.55	30.95	39	45.05
Sitting hip breadth	14.697**	31.42 (1.73)	33.2 (2.75)	32.31 (2.47)	28.45	32	33	29	33	37.55	28.95	32	37
Standing hip breadth (L)	2.169 ns	27.92 (1.33)	28.5 (2.41)	28.21 (3.06)	25.45	28	30	24.45	28.5	32	25	28	35.1
Knee-knee breadth	41.85**	12.22 (1.09)	14.36 (2.04)	13.29 (1.96)	11	12	14	12	14	18	11	13	17

Dimensions	F-value	Mean values			Percentiles								
		Garhwal N=50	Kumaun N=50	Uttarakhand N=100	Garhwal region			Kumaun region			Uttarakhand state		
					5th	50th	95th	5th	50th	95th	5th	50th	95th
Body circumferences and depths, cm													
Chest circumference	2.418^{ns}	81.1 (5.43)	83.11 (7.27)	82.10 (6.50)	73.45	80.5	90	70.9	84	94.55	71.9	82	94.05
Waist circumference	19.095**	67.6 (6.65)	73.58 (6.95)	70.59 (7.44)	58	67.5	77.55	62.9	73	86.2	60	70	84
Chest depth (J)	11.292**	17.02 (3.13)	18.98 (2.64)	18.00 (3.06)	12.45	17	21.55	15	19	23	13	18	23
Waist depth (k)	6.396*	13.02 (2.23)	14.24 (2.54)	13.63 (2.47)	10	12	17.1	11	14	19	10	13	18
Maximum body depth	26.203**	23.82 (2.66)	20.74 (3.28)	22.28 (3.36)	19.45	24	28	16	21	25.55	16	23	28
Buttock depth	0.181^{ns}	13.64 (1.94)	13.8 (1.8)	13.75 (2.22)	11	13	16	12	14	17	11	13	17
Foot breadth (M)	13.537**	9.99 (0.87)	9.31 (0.95)	9.65 (0.98)	8.5	10	11	7.45	9.5	10.5	8	10	11
Foot length (l)	0.016^{ns}	21.56 (1.73)	21.52 (1.29)	21.54 (1.53)	19	22	24.55	19.45	22	23.55	19	22	24

Note:- Values in parentheses indicate the standard deviation, *: Significant at 5 % level of significance, **: Significant at 1 % level of significance, Dimensions in capital letters A, B…M are shown in **Fig. 1**, Dimensions in small letters a, b…l are shown in **Fig. 2**.

respectively. Significant differences were found between Garhwal and Kumaun regions in waist circumference, chest depth, waist depth, maximum body depth and foot breadth ($p < 0.01$) besides waist depth ($p < 0.05$).

It could, therefore, be inferred that though the significant differences were not observed in most of the standing and sitting heights, yet a few body depths and most of the body breadth showed broader body size of women from Kumaun region probably due to the differences in geographical conditions and farm activities they used to perform. The women of Kumaun region have been found to perform comparatively less physical activities than the Garhwal region which is having high altitudes and poor infrastructure facilities.

Comparison of Anthropometric Measurements of Hill Women Vis-à-Vis Women of Other Plain Regions of India

A comparison of standing and sitting anthropometric measurements of hill women with that of women from other states in the plain regions of India is shown in **Table 2**. This table reveals that all the anthropometric measurements of Haryana (Hisar) state women were greater than those of hill women except the arm length. Also, besides the sitting eye height, sitting thigh height, buttock-poplietal length and three hand measurements (hand, forearm and total arm length) of Punjab (Ludhiana) state women, all other anthropometric dimensions were greater than hill women. Similarly, all the anthropometric dimensions of Andhra Pradesh (Hyderabad) women were greater than hill women of Uttarakhand except the arm length.

All the anthropometric dimensions except the arm length and forearm length of Rajasthan (Udaipur) women were greater than the hill women. In case of Tarai plain region (Pantnagar) of Uttarakhand, except standing elbow height, sitting shoulder height, sitting eye height, sitting thigh height, buttock-poplietal length, arm length and forearm length, all other anthropometric measurements were greater than the hill women. Similarly, except standing height, standing eye height, sitting height, sitting eye height, sitting elbow height, sitting knee height, buttock-knee length, buttock-poplietal length and arm length, all other anthropometric measurements of Karnataka (Dharwad) state women were greater than the hill women.

Conclusions

The study revealed that there are differences in anthropometric dimensions amongst women farmers of hill and plain regions as well as within the same region having different geographical conditions. The selected standing anthropometric measurements of all other states were higher than those of hill women farmers except the standing height and eye height of Karnataka (Dharwad) women. Also, all the selected sitting anthropometric measurements of Andhra Pradesh (Hyderabad), Rajasthan (Udaipur) and Haryana (Hisar) States were higher than the hill women. This study has demonstrated the importance of designing hand tools and farming implements by considering the anthropometric dimensions of hill women for their safety and comfort rather than simply providing them with tools and implements designed for other regions of the country, either for men or women, to avoid serious musculoskeletal disorders.

Table 2 Comparison of standing anthropometric measurements of hill woman farmers of Uttarakhand state with other plain regions of India.

Anthropometric dimensions	Mean values						
	Hill women[a] (Uttarak-hand)	Haryana (Hisar)	Punjab (Ludhiana)	Andhra Pradesh (Hyderabad)	Rajasthan (Udaipur)	Uttarakhandb (Pantnagar)	Karnataka (Dharwad)
	N = 100	N = 1000	N = 1000	N = 1000	N = 1000	N = 1000	N = 1000
	Standing posture, cm						
Weight, kg	40.27	46.72 + 6.45	53.30 + 13.03	43.66 + 3.39	43.72 + 3.45	46.32 + 6.05	43.90 + 3.63
Height	151.49	157.44 + 5.95	156.79 + 5.3	152.54 + 1.05	151.99 + 0.5	151.97 + 0.48	149.40 - 2.09
Eye height	139.79	145.91 + 6.12	144.08 + 4.29	142.46 + 2.67	141.78 + 1.99	140.21 + 0.42	139.29 - 0.5
Shoulder height	126.00	132.50 + 6.5	130.81 + 4.81	127.61 + 1.61	126.99 + 0.99	126.26 + 0.26	126.74 + 0.74
Standing elbow height	97.16	112.89 + 15.73	99.69 + 2.59	99.44 + 2.28	98.90 + 1.74	95.75 - 1.41	97.21 + 0.05
Hand length	17.35	18.07 + 0.72	15.06 - 2.29	17.60 + 0.25	18.55 + 1.2	18.56 + 1.21	18.11 + 0.76
Fore arm length	40.17	44.94 + 4.77	39.52 - 0.65	40.98 + 0.81	39.92 - 0.25	39.17 - 1.0	41.13 + 0.96
Arm length	73.96	71.56 - 2.4	67.25 - 6.71	68.19 - 5.77	67.44 - 6.52	66.80 - 7.16	68.69 - 5.27
	Sitting posture, cm						
Sitting height	116.76	118.89 + 2.13	118.77 + 2.01	117.25 + 0.49	116.89 + 0.13	117.53 + 0.77	114.93 - 1.83
Shoulder height	92.52	115.27 + 22.75	93.56 + 1.04	92.67 + 0.15	94.13 + 1.61	92.31 - 0.21	93.12 + 0.6
Eye height	106.06	116.13 + 10.07	105.45 - 0.61	106.91 + 0.85	107.80 + 1.74	105.84 - 0.22	104.19 - 1.87
Elbow height	57.6	60.70 + 3.1	62.55 + 4.95	63.49 + 5.89	65.42 + 7.82	62.10 + 4.5	64.03 - 6.43
Knee height	46.3	50.41 + 4.11	48.35 + 2.05	49.24 + 2.94	48.26 + 1.96	46.71 + 0.41	45.54 - 0.76
Thigh height	11.51	12.43 + 0.92	8.61 - 2.9	13.23 + 1.72	14.62 + 3.11	11.50 - 0.01	11.84 + 0.33
Buttock-knee length	49.22	56.24 + 7.02	50.70 + 1.48	53.50 + 4.28	50.31 + 1.09	50.45 + 1.23	49.05 - 0.17
Buttock-poplietal length	43.64	48.54 + 4.9	41.48 - 2.16	47.34 + 3.7	45.13 + 1.49	42.54 - 1.1	43.30 - 0.34

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Date of Birth: 1940
Nationality: Cuban
Present Position: Associate Professor, Agrarian University of Havana (UNAH), Faculty of Technical Science
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Teaching activities:
Professor of Conservation Agriculture disciplines, Physics (mechanics), Hydraulics; Hydraulic drives, Design of Machine Elements; Conveyors, Theory of Tractors and Automobiles, Operation and Administration of Agricultural Machinery, Agricultural Machinery Theory, Agricultural Mechanization and other Agricultural careers./ Tutor (director), consultant and advisor to undergraduate and graduate students; specialists in the above field. As well as writing books and teaching materials; Master's and Doctoral programs./ Investigator on Conservation Agriculture, Hydraulics; Operation and Administration of Agricultural Machinery; Agricultural machinery; Extension and Advisory in the field of conservation agriculture.

Dr. Yanoy Morejón Mesa

Date of birth: 28 November 1983
Nationality: Cuban
Present Position: Agricultural Engineer, Agrarian University of Havana, Technical Sciences Faculty
Scientific Category: Master Sciences, 2012
Professional Experience:
Professor (Technical Sciences Faculty. Agrarian University) 2007-at present/ Lectures and practices of Thermodynamics (68 hours) 2007-at present. Careers: Agricultural Mechanization Engineering and Agricultural Engineering/ Lectures and practices of Technological Process II (56 hours) and III (44 hours), Career: Agroindustrial Process Engineering. UNAH./ Court of diplomas defense. Technical Sciences Faculty. Agrarian University. Careers: Agricultural Mechanization Engineering, Agricultural Engineering, Agroindustrial Process Engineering Courses: (2007-...2015)/ Court of Master Degree in Agricultural Mechanization. Technical Sciences Faculty. Agrarian University of Havana. Courses: (2011-...2013)/ Court of Scientific-student Journey of the Technical Sciences Faculty. Agrarian University. (2009...2012)/ Court of Master Degree in Electric Engineering. UPT-MBI. Venezuela. 2014.

Technical and Socio-Economic Relevance in Technical Adoption: Case Study on Rotary Tillage Equipment in South West of Nigeria

by

A. F. Adisa
Agricultural Engineering Department,
Federal University of Agriculture, Abeokuta,
NIGERIA
alexadisa@yahoo.co.uk

I. O. Vaughan
Institute of Food Security,
Environmental Resources and Agricultural Research,
Federal University of Agriculture, Abeokuta,
NIGERIA

A. A. Aderinlewo

P. O. O. Dada

Agricultural Engineering Department, Federal University of Agriculture, Abeokuta, NIGERIA

Abstract

The present and future shortage of farm labour for agriculture requires consideration in developing countries including Nigeria. As much as 80 % of farm power is provided for by human labour, which now call for need to develop and possibly engage simple and avoidable equipment to replace some manual tools for farming operations. Adoption of power tillers for tilling has brought some significant changes on overall production and sustainability of small farm systems. Addressing this requires acquisition of appropriate mechanized farm tillage tools. This began with the technical and social- economic assessment and recommendation for adoption which took place at Federal University of Agriculture, Abeokuta, South West of Nigeria based on performance efficiency, affordability, durability, acceptability and ease of operation for the smallholders. A 6 hp (4.48 kw) Husqvarna T560 RS rotary cultivator of 0.78 m width was acquired for field performance test for appraisal and adoption for small scale farming as part of the front-end concern in the procurement- adoption chain. The effective field capacity of the machine on a land that was already under cultivation was found to be 0.033 ha/hr (i.e. 5 working days/hectare) and about 12 hours to till one acre in well cleared stone-free soil type where it was tested. The soil tillage of this equipment was found suitable for crops that can tolerate zero to shallow tillage depth of 0.21 m which this equipment was able to provide in the sandy loam under friable soil moisture condition. The awareness of the machine was 39 % among the farmers, 67 % rated the machine useful for tillage but the machine price range was above what their individual income can sustain in the study area. The machine was hereby recommended only for introduction to research institutions, private horticulturalists and vegetable cooperative farmers in the rural and urban farming communities with one to two hectare farm holding capacity.

Keywords: Technical, social- economic, cultivator adoption, smallholder and soil tilth.

Introduction

Adequate knowledge of the past and present is always a good key component for the improvement of the planning process that will impact agricultural sector of a place in years to come. It is eminent that if population is not controlled or agricultural production is not drastically stepped up, by the year 2025 there will be no enough food to feed the estimated eight billion people in the World Zangeneh *et al.* (2010). In intensive cropping, timeliness of operations is the most important factor which can only be achieved with appropriate agricultural machines, Salokhe and Oida (2003). The present and future shortage of farm labour for agriculture requires consideration in developing countries including Nigeria where there is drifting of working class citizens from rural to urban cities where they are making more money, for an example motorcycle transport business than farming labour operation services.

As much as 80 % of farm power is provided for by human beings, which now call for need to develop and possibly engage simple and avoidable equipment to replace some manual tools for farming operations, Salokhe and Oida (2003). Such type of equipment for small holder farming must be easily repairable and maintainable, inexpensive and environmentally friendly. Also it must be suitable for small farms, simple in design and technology and versatile for use in different farm operations. The report of Okurut and Odogola (1999) was that apart from land, farm power is the second most important input to agricultural production. Also Barton (1999) stated in his report that farm power determines the scale and intensity of farm operation. The report of Sarker (1999) was that adoption of power tillers for tilling has brought some significant changes on overall production and sustainability of small farm systems.

Tillage

Tillage can be defined as soil cultivation to provide good conditions for seeds germination and plants growth for maximum yields. It requires soil structure opening for easy root development, cutting and burying of weeds, manure and fertilizer incorporation. Among all agricultural operations, soil cultivation is most demanding of time and energy which therefore, should not exceed the necessary level for the crop to thrive in a given soil, climate or farming system, Matthews (1985). With hand tools, a farmer may not exceed cultivating more than 2 ha, animal- powered equipment will cover more depending on the type of equipment and type of animal used as prime mover.

Agricultural mechanization as system engineering, requires not only machinery development and applications but also certain environmental, agricultural, social and economic conditions that must be ascertained to favour its investment in technologies and their sustainable use, Ou *et al*. (2002). Some other factors apart from timeliness of tillage and other crop cultivation operations that influence successful mechanization are socio- economic factors, supporting infrastructure, land and agro-ecological conditions, and technical skills and service (Olaoye, 2007). In Nigeria as of today, there is sound national awareness of the immense potential of agriculture in boosting our economy if sustainable mechanization is embarked upon, Olaoye and Rotimi (2010).

Social Economic Relevance of Tillage Equipment

Solving the labour-intensive unpleasantness of smallholder farming remains a front-burner issue. The wearing-down effect of the drudgery on the physique of the human source of farm power is incontrovertible. Moreover it is recognized that the appreciation and eventual adoption of tillage machine is a function of the socio-economic characteristics and features of the farmers.

Motorized cultivator are found suitable for small holder farmers in areas grown with high value crops and where fuel and maintenance / repair services are readily available, Matthews (1985). As one engages range of cultivation equipment from hand tools to animal- drawn equipment to low- powered cultivators, farmers can benefit avoidable labour bottlenecks during critical stages of crop production, improved crop establishment conditions, improved operations timeliness and possible multiple cropping in irrigation cultivation.

The high level of labour use in smallholder farming remains a big challenge and an albatross to the operators. Any effort, therefore, to alleviate the drudgery should enhance farmers' yields and eventual output (Schwenke, 1998). A priority candidate tool which is the small roto tiller is typically propelled forward by one to five horse power engine rotating tines that do not have traction wheels, though may have small transport/ level control wheel(s) (LSU AgCentre, 2010). To keep the machine from moving too fast forward, an adjustable tine is usually fixed just behind the blades so that through friction with deeper untilled soil, it acts as a brake, slowing the machine and allowing it to pulverize the soils. The slower a roto tiller moves forward, the better is the soil tilth or pulverization achieved (Buckingham *et al*., 1984). The operator can control the amount of friction/ braking action by raising and lowering the handle bars of the tiller. Roto tiller do have reverse gears while in some, reversing is done by pulling machine backward manually. Roto tilling is generally faster than manual tilling, but can be difficult to handle and exhausting to work with, especially in the heavy and higher horse power models. If the roto tiller is clogged by a substance or an object, such as tree roots and buried garbage, it can cause the roto tiller to abruptly and violently move in any direction.

The Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR) of Federal University of Agriculture, Abeokuta (FUNAAB), Nigeria, has as an item of its mandate, the concern of ''identifying agricultural problems and needs of Nigeria's farmers and address them within the context of overall national development''. This requires among others, the acquisition or development of mechanized farm tillage tools appropriate for smallholder farming for field performance testing and the recommendation for adoption based on performance efficiency, affordability, durability and ease of operation (Humble and Shankland, 2012). A Husqvarna T560RS rotary cultivator was acquired by IFSERAR by the end of 2011 for field technical performance test and socio- economic relevance appraisal for small scale farming which was the main reason for this study as part of the front-end concern in the procurement-adoption chain drive in the Institution.

Methodology

A field performance test of a newly purchased Husqvarna T560RS rotary cultivator (**Fig. 1**) weighing 55kg was carried out on a newly cleared field Teaching and Research Farm Directorate (TREFAD) and at the horticultural garden for the Environmental Management Unit (EMU), Federal University of Agriculture, Abeokuta (FUNAAB), Nigeria, on June 12, 2012 and July 25, 2012 respectively on a loamy sand soil of friable moisture condition as indicated in result sections (Buckingham *et al*., 1984). The rotary cultivator was powered by a 4.48 kw petrol engine. Four members of the EMU/IFSERAR staff were trained in the operation and handling of the machine by the equipment sale agent's operator which was carried out both on the TREFAD newly cleared field and EMU horticultural field on different days. The machine's performance on TREFAD newly cleared field was found to be very poor, hence more attention on the machine testing was on EMU horticultural garden field plots.

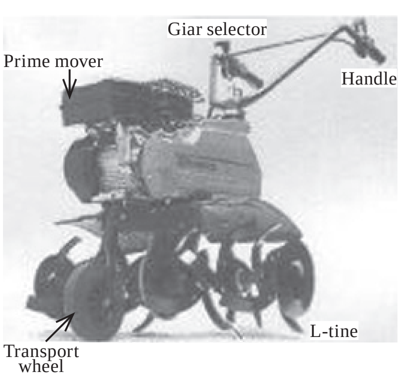

Fig. 1 Husqvarna T560RS rotary cultivator.

The experiment was carried out on three plots, each measuring 10 m × 5 m. The pedestrian controlled self propelled cultivator is powered by a 5-hp petrol engine. On each of the plots, the following parameters were measured: length of the field plot covered by the cultivator, the average width covered by the equipment, depth of cut, time taken to cover the tilling of the plot plus turning time, equipment unclogging and other idle time inclusive and fuel consumption. A trial run was earlier conducted on the TREFAD farm of FUNAAB on a newly cleared land with stony sand loamy soil type which came up with poor result, hence the test did not continue on this field. It was after this trial that equipment sale agent's operator came to train our operators and assisted us in the experiment conduction that took place on EMU'S horticultural garden. Lengths along the row and furrow width were measured by 30 m field measuring tape, ruler was used to measure depth of cut of the loosed soil. Time at start and finishing of operation was taken by digital stop watch and the fuel consumption was measured by the use of calibrated cylinder to always top the fuel tank to a marked level after each operation and taking note of volume used for topping each time. Soil samples were collected from the three plots before and after tillage operation and taken to the laboratory to determine the soil moisture content and bulk density. Soil moisture content and bulk density before and after the tillage operation were investigated using the method of core sample to depth: 0-10 and 10-20 cm.

A CP20 penetrometer self-recording type, manufactured by Agri RIMIK, Toowoombola (1994), Australia was used to take soil tilth measurements before and after plowing operation on the three plots at depth ranging from 0 to 22.5 cm under a friable soil moisture condition. It is an ultrasonic depth recording mode penetrometer type which was operated by driving stainless steel cone (apex angle of 30^o and a basal area 78.5 cm mounted at the end of a steel shaft of length 1 m of 10mm diameter vertically into the soil. Insertion of the probe was eased by a rubber mounted on two handles at the upper end of the instrument. A footplate with a hole for passage of the 1 m shaft ensured stability of the unit during the measurements. The maximum depth that the equipment was configured to measure was 50 cm at depth interval of 2.50 cm. The equipment was sensitive enough to terminate measurements if the rate of penetration was too fast or too slow, according to its user-dependent calibration. The implication of this is that the cone index sensor is depth calibrated because it was able to remove subjective push of penetrometer into the soil. Furthermore, it could take penetrometer resistance up to 5,000 kPa (N/m^2). In addition, a convenient feature was a digital readout that showed the readings during operation. An excel micros software was used for the downloading of the data to computer from where cone index value were obtained for the three plots' soil resistance before and after tillage operation.

Parameters Measured
Length of the plot, m
Machine theoretical width (equipment plow width), m
Working width of cut (plow width), m
Working depth of cut (plow depth), m
Time of operation, hr/ha
Fuel consumption, L/ha
Soil tilth (soil resistance before and after plowing operations), N/m^2
Soil moisture content determination, %

Parameters Computed

Theoretical field capacity, effective field capacity and machine field efficiency Parameters were computed with the following equations (Kepner *et al*., 2005):

$TFC = (S \times W) / 10$ .... (1)

$EFC = (SW \times WW) / 10$ .... (2)

$MFE = EFC / TFC \times 100$......... (3)

Where:

TFC = Theoretical field capacity, ha/hr

EFC = Effective field capacity, ha/hr

MFE = Machine field efficiency, %

S = Machine rated speed, km/h

W = Rated width, m

SW = Machine working speed, km/h

WW = Working width, m

Results

Eqs. 1, 2 and **3** were used to calculate the theoretical field capacity, effective field capacity and machine field efficiency. **Tables 1-5** were obtained from data measured and computed from the field tests carried out. **Sections 6** and **7** are the results of the social economic assessment.

Social Economic Assessment of the Rotary Tillage Equipment

This section therefore considers the farmers' assessment of the machine. To accomplish this, a sample of 200 farmers was selected using a 2-level (administrative and ward) multi-stage sampling procedure concluded with snowballing. This was done because of the non-existence of a complete list of farmers in Abeokuta North Local Government Area (ABNLGA) of Ogun State, Nigeria. In fairness to ABNLGA, this weakness with regard to support to sampling in socio-economic studies is not limited to this LGA. It is a common challenge in virtually all 774 LGAs of Nigeria. These 200 farmers were interviewed using a one-page questionnaire designed for the purpose. Conscious of the possibility that some farmers might have not seen the machine before the interview, its photocopy was produced and shown to such respondents as well as those that could not identify with its generic name.

The awareness of the machine among farmers is still very low as only 58 farmers representing 39 % of the respondents had ever heard of it. Moreover, only 36 farmers of this lot had seen it operated on the farm. The remaining 142 (71 %) had never heard of it while 164 (82 %) of them had never seen it operated on the farm. These coefficients concerning awareness are not commensurate to the efforts being put into promoting the uptake of the machine. Therefore, the marketing companies involved are charged to be more strategic in the effort. Meanwhile, about 67 % of those that have heard of it rated the machine useful for the tilling of farms. Concerning how much the farmers can pay for an outright purchase of the machine, the farmers' offer was an outcry from its current market price of ₦ 200,000 − 180,000 ($ 1.0 = ₦ 155.0). The low price being attached to the machine could either mean that the farmers do not appreciate its worth or that a signal is being sent to its manufacturers and potential marketers to revisit the price. Unexpectedly, the farmers are willing to pay prices in the range of ₦ (65,000 − 45,000). Contrarily and surprisingly, they are willing to pay as much as ₦ (7,500 − 6,250) as charges for 1.0 hectare tilled farm by the machine. At present, service providers are charging about ₦ 12,500 per hectare of (tractor) ploughed farmland.

Section A: Other relevant information provided by the farmers on the machine are:

- Machine is not operationally gender-friendly –female farmers cannot operate the machine because of its ruggedness; in fact not all men can operate it either;
- Machine is not as simple as advertised; and
- Targeted quality training is required for farmers to promote an effective use

Section B: Other statistics of the farmers are:

Table 1 Field performance test for T560RS rotary cultivator.

Parameter	Plots I	Plots II	Plots III	Average
Length of plot (m)	10	10	10	10
Machine rated width (m)	0.78	0.78	0.78	0.78
Machine rated speed (km/h)	0.55	0.55	0.55	0.55
Working width of cut (m)	0.62	0.63	0.65	0.63
Depth of cut (plow depth) (m)	0.19	0.21	0.22	0.21
Average time taken per plot (min/plot)	1.18	1.20	1.13	1.18
Fuel consumption (L/ha)	49.25	47.50	46.50	47.75
Working speed (km/hr)	0.51	0.50	0.53	0.51
Theoretical field capacity (ha/h)	0.043	0.043	0.043	0.043
Effective field capacity (ha/h)	0.032	0.032	0.034	0.033
Machine field efficiency (%)	74.42	74.42	79.07	75.97
Soil moisture content before plow (%) (w.b.)	14.11	15.02	12.87	14.00
Soil moisture content after plow (%) (w.b.)	13.64	12.81	15.13	13.86

Table 2 Soil properties before tillage operation.

Depth (cm)	Bulk density (g/cm^3)			Average (g/cm^3)
	Plots I	Plots II	Plots III	
0-10	1.44	1.38	1.34	1.39
10-20	1.45	1.38	1.36	1.40

Table 3 Soil properties after operation Depth (cm).

Depth (cm)	Bulk density (g/cm^3)			Average (g/cm^3)
	Plots I	Plots II	Plots III	
1.35	1.31	1.24	1.30	1.39
1.29	1.27	1.25	1.27	1.40

- Farmers' age: 30-65 yr. (all males);
- Size of farms cultivated: 0.16- 1.75 Ha.;
- Major enterprise: cassava/Maize (with leafy vegetables, tomatoes, cocoyam, yam as decided by each farmer);
- Farming experience: 12-28 yr.

Discussion

The average values of the parameters obtained from the field performance tests are shown in **Table 1**. The average time of operation was 1.18 minutes per plot. The average field efficiency was 76.74 % which shows that the machine was efficient for the tillage operation in terms of the work rate for the small farm holding. The moisture content before (14.00 % average, wet basis) and after (13.86 % average, wet basis) plowing operation showed slight reduction because of water draining to some extent after plowing on the loamy sand soil. The average rated speed of the machine was 0.55 km/h at average rated width of 0.78 m compared with the average working speed of 0.51 km/h at average working width was 0.63 m.

Soil physical properties (texture and structure) before the experiment are shown in **Tables 2- 5**. The average bulk densities increased marginally by depth plowing operation as shown in **Table 2**. **Table 3** shows the bulk densities after the experiment which decreased when placed side by side with **Table 2** at every level all through and it also decreased with depth. This shows that the machine improved the structure of the soil for instance at depth 10-20 cm on plot 111, the bulk density was 1.40 g/cm^3 before plowing and became 1.27 g/cm^3 after plowing. The cone index readings (soil resistance) of the plots before and after the experiment are as shown in **Tables 4** and **5**. It can be seen that soil resistance of the plots after the tillage operation reduced. This shows that the machine was effective in breaking soil clods or compacted soil within the seed and root bed zones providing good soil condition for crop establishment.

Table 4 Cone index before tillage.

Depth (cm)	Cone index kN/m^2			Average
	Plots I	Plots II	Plots III	
2.5	861	876	664	800
5.0	1,028	1,142	1,157	1,109
7.5	1,021	1,733	2,423	1,726
10.0	1,134	2,248	2,779	2,054
12.5	1,680	1,589	2,582	1,950
15.0	2,271	960	2,862	2,031
17.5	2,074	1,202	3,719	2,332
20.0	1,900	1,672	5,000	2,857
22.5	2,855	2,506	5,000	3,454

Table 5 Cone index after tillage.

Depth (cm)	Cone index kN/m^2			Average
	Plots I	Plots II	Plots III	
2.5	316	566	566	483
5.0	937	786	528	750
7.5	1,748	1,051	331	1,043
10.0	930	861	854	882
12.5	1,536	823	1,794	1,384
15.0	1,513	1,551	2,605	1,890
17.5	1,847	2,286	2,552	2,228
20.0	2,082	1,986	3,560	2,544
22.5	2,112	1,945	2,855	2,304

By interpretation of the effective field capacity (0.033 ha/h) result obtained from this experiment, it will take about 30.30 hours to plow one hectare (i.e. 5 working days at 6 hours/day) and about 12 hours to plow one acre in well cleared stone free soil type where tested. The experience form these tests on the TREFAD farm where there the land was newly cleared with great stumps and gravel type of soil, it would take more time to accomplish the same operation.

It was observed that more time was spent on **plot 2** due to time taken to turn the machine and overcome obstructions in form of stumps as well as other field conditions as the blades were noticeably clogged. **Plot 3** was lightly raked to reduce obstructions thus lesser time was spent compared to **plot 2**, as the operator got more familiar with the working conditions, less time was spent in **plot 3**.

More fuel was consumed on **plot 1** due to fuel losses as a result of leakage and extent of tilting of the machine on unlevelled ground. It was noticed that when the loose parts of the fuel tank was adjusted, the fuel consumption reduced greatly on **plot 3** because of further adjustment of fuel leakage and the raking of **plot 3**.

The machine was found to be rugged, did not breakdown, easy to operate and has minimum moving parts with replaceable cutting edge. The handling of the machine was not too difficult for the first timers who within short time of training mastered the operation.

Conclusions

Going by the result obtained from this experiment, 30.30 hours was required to plow one hectare amount-ing to 5 working days at 6 hours/day and about 12 hours to plow one acre on an old land where the trash has been cleared and the soil is stone free, the type of which the operation was carried out. The experience on the TREFAD farm where the land was newly cleared, had stumps and gravel type of soil was not encouraging.

Recommendations

The equipment can be used for both secondary tillage operation but can work effectively and efficiently better on land that had been cleared of trash already; void of stones and not weedy as in gardens, vegetable farms and horticultural fields. Though the machine capacity is small, if well handled, it will perform well in soil loosening and pulverization for good seed bed under friable soil moisture condition. The soil tillage performance of this equipment will be suitable for crop seeds that can tolerate zero to shallow tillage plowing depth of 0.21 m which this equipment was able to provide. Husqvarna T560RS rotary cultivator is hereby recommended based on its performance efficiency, affordability, durability and ease of operation for smallholder farms. The machine was is not operationally gender- friendly, just 39 % farmers awareness, not simple to operate as advertised and target training is required in the study area.

To this extent, this equipment is hereby recommended to be introduced to all relevant Colleges, Departments, Institutes and Centres of the University for patronage. Also it is hereby recommended to be introduced to private horticulturalists and vegetable cooperative farmers in the rural and urban farming communities. The current price (N 200,000.00) is within what some farming groups can afford to improve and increase their size of holdings, output and incomes.

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Production of Biodiesel from *Jatropha Curcas L.* Oil Having High Free Fatty Acids Content

by

V. B. Shambhu
Senior Scientist,
National Institute of Research on Jute & Allied Fibre Technology,
12, Regent Park, Kolkata -700 040,
West Bengal, INDIA
vbs9605@yahoo.co.in

T. K. Bhattacharya
Professor & Head,
Department of Farm Machinery & Power Engineering,
G. B. Pant University of Agriculture & Technology,
Pantnagar -263 145, INDIA

Abstract

The present experiment examines the production of biodiesel from Jatropha curcas Seed oil having high free fatty acids (16.4 % FFA). The high FFA level of Jatropha curcas Seed oil was reduced to 0.23 % FFA for Jatropha Methyl Ester (JME) and 0.27 % FFA for Jatropha Ethyl Ester (JEE) by a two step acid-base transesterification. The first step was carried out with 10 : 1 molar ratio of methanol/ethanol-to-oil in the presence of sulphuric acid as an acid catalyzed at a temperature of 60 ± 1 ºC and 70 ± 1 ºC for methyl esterification and ethyl esterification respectively. The second step was transesterified using 6 : 1 molar ratio of methanol/ethanol-to-oil and 3 % w/w KOH as an alkaline catalyst to produce biodiesel at 60 ± 1 ºC and 70 ± 1 ºC for jatropha methyl ester and jatropha ethyl ester respectively. The yield of jatropha methyl and ethyl ester under the optimized condition was found to be 97 and 95 percent respectively.

Keywords: Jatropha curcas, Biodiesel, Methyl ester, Ethyl ester, Pretreatment, Transesterification

Introduction

The growing concerns of environmental pollution caused by lavish consumption of conventional fossil fuels and the realization that they are non-renewable and rapidly depleting have led to search for more environment friendly and renewable source of fuels. Among various options investigated for diesel fuel, biodiesel obtained from vegetable oils has been recognized world over as one of the strong contenders for reductions in exhaust emissions. There are a number of non-edible tree born oil seeds available in India with an estimated annual production of more than 20 Mt. these oil seeds have great potential of being transesterification for making biodiesel. Biodiesel extracted from vegetable oil is one such renewable alternative under consideration, the production of biodiesel would be cheap as it could be extracted from non-edible oil sources. Jatropha curcas, a non-edible oil-bearing and drought-hardy shrub with ecological advantages, belonging to the Euphorbiaceae family, was found to be the most appropriate renewable alternative source of biodiesel. Jatropha (Jatropha curcas) is one of such non-edible tree born oils, which has an estimated annual production potential of 200 thousand metric tonnes in India and it can be grown in waste land. The oil should not contain more than 1 % FFA for alkaline catalyzed transesterification reactions. As FFA levels increase this becomes undesirable because of the loss of feedstock as well as the deleterious effect of soap on glycerin separation. The soap promotes the formation of stable emulsions that prevent separation of the biodiesel from the glycerin during processing. An alternative process is to utilize acid catalysts that do not form soaps. The acid catalysts are too slow to be practical for converting triglycerides to biodiesel. Therefore, a procedure for converting high FFA feedstocks to biodiesel is very much required. Few researchers have worked with feed stocks having high FFA levels using alternative process i.e. pretreatment step to reduce the free fatty acids of these feed stocks to less than 1 % before transesterification reaction is completed with an alkaline catalyst to produce biodiesel.

The present study was, therefore, conducted to establish optimized parametric conditions of the pretreatment process for reducing the FFAs (16.4 %) content of jatropha oil to below 1 % for maximum biodiesel production.

Materials and Methods

The jatropha curcas seed oil used in this experiment was procured from market. The physical and chemical properties of raw jatropha oil were measured in the renewable energy laboratory of the department of Farm Machinery & Power engineering, college of Technology, G.B.U.A. & T., Pantnagar, India. Jatropha curcas oil was used for the biodiesel production on both laboratory-scale and batch type biodiesel plant by two steps process, first, pretreatment (Acid- catalyzed esterification) then alkaline-catalyzed transesterification reaction was extracted. All chemicals used in the experiments such as methanol (99.5 %), ethanol (99.9 %), sulfuric acid (99 % pure) analytical reagent (AR) Grade, KOH, and Phenolphthalein indicator was purchased from local market. The KOH in pellet form was used as an alkaline catalyst for transesterification reaction. Experiments were first conducted in a laboratory-scale setup to investigate the effects of reaction time and catalyst amount on the acid-catalyzed conversion of free fatty acids to fatty acid methyl and ethyl esters. The reactor consisted of a 1000 cc glass flasks with airtight caps that retained any vaporized methanol/ethanol to the reacting mixture. The flasks were kept in a shaking water bath and stirred at 500 rpm for laboratory scale and reaction temperature was maintained at 60 ± 1 ºC and 70 ± 1 ºC for methanol and ethanol respectively, just below the boiling point of methanol and ethanol respectively. So, that the reaction vessel did not need to be pressurized. The mixture was stirred at 600 rpm in batch type biodiesel plant for all runs. The same setup was also used for the alkaline-catalyzed transesterification.

Pretreatment Process (Acid Catalyzed Esterification)

Unrefined raw jatropha oil was highly viscous and yellowish in colour. The total acid value of oil/fuel samples was measured as per standard titrimetry method. The initial acid value of raw jatropha oil was found to be 32.8 mg KOH/g corresponding to a FFA of 16.4 % which is far above the 1 % limit for satisfactory transesterification reaction using alkaline catalyst and it belong to brown grease (FFA > 15 %). Therefore, a two-step process, acid-catalyzed esterification (pretreatment process) and followed by alkaline-catalyzed transesterification process, were selected for converting jatropha curcas oil to methyl/ethyl esters of fatty acids. The first step was acid esterification and pretreatment for reducing FFA in the oil, which is mainly a pretreatment process. High FFA jatropha oil was converted to esters in a pretreatment process with methanol/ethanol using an anhydrous H_2SO_4 (acid catalyst). The variables affecting acid esterification such as acid catalyst concentration and reaction duration were studied to get the maximum conversion efficiency of high FFA content oil to low FFA content oil. In this step jatropha oil was preheated to a reaction temperature of 60 ± 1 ºC and 70 ± 1 ºC for methanol and ethanol respectively. The required amount of solution of methanol/ethanol and anhydrous H_2SO_4 were added to the preheated oil and maintained reaction temperature for 15 min, 30 min, 45 min and 60 min. After the different reaction durations the mixture was transferred to a separating funnel and mixture was allowed to settle for 24h. The effectiveness of the first step was determined by measuring the acid value of the products separated at the bottom. Acid value is defined as the amount of KOH required to neutralize 1g of fat. Second step was alkaline- catalyzed transesterification.

Transesterification

The transesterification reaction was carried out at 6 : 1 methanol/ethanol-to-oil molar ratio using 3 % w/w KOH as an alkaline catalyst. The acid esterified product was preheated to the temperature of 60 ± 1 ºC and 70 ± 1 ºC for methanol and ethanol respectively before starting the reaction. The potassium hydroxide-methanol/ethanol solution was prepared. The alkaline methoxide / ethoxide solution was added to preheated product of the acid esterification. The reaction was carried out at 60 ± 1 ºC and 70 ± 1 ºC for methanol and ethanol respectively and stirring at 600 rpm for one hour in batch type biodiesel plant. The reacted mixture was pumped to the separation tank and allowed to settle for a period of 24h under gravity for formation of two layers. The glycerol layer was removed from the bottom of separating tank to get the jatropha methyl/ ethyl ester, separated upper layer as biodiesel.

Fuel Properties and Characteristics

The fuel properties such as density at 15 ºC, kinematic viscosity at 40 ºC, flash point, pour point, ash content, carbon residue, acid value and calorific value of petro-diesel, jatropha oil and their methyl and ethyl ester (biodiesel) were determined as per the prescribed methods and compared with the existing American and European standards for biodiesel.

Results and Discussion

Fuel Properties and Characteristics

The acid value of jatropha oil was found to be 32.4 mg KOH/g and therefore its FFA content is 16.4 %. Jatropha oil biodiesel is rich in oleic acid and Linoleic acid. Free Fatty acid analysis of jatropha curcas oil biodiesel is given in **Table 1**. The fuel properties of petro-diesel, jatropha oil and jatropha biodiesel (JME and JEE) are summarized in **Table**

2. The fuel properties of Jatropha methyl ester (JME) and jatropha ethyl ester (JEE) were in agreement with that of petro-diesel and meet to the existing standards for vegetable oil derived fuel also conforming to the American and European standards for biodiesel.

Pretreatment Process (Acid Catalyzed Esterification)

During the experiment it was observed that a thick jelly like substance was formed when 16.4 % FFA Jatropha oil was treated with 5 % concentrated H_2SO_4 at 10 : 1 molar ratio using both anhydrous methanol and ethanol (**Table 3**).

The acid value of jatropha oil reduced to 3.748, 2.690, 2.316 and 2.306 mg KOH/g when the oil was treated with 10 % concentrated H_2SO_4 and methanol for the reaction time 15, 30, 45 and 60 minutes respectively as shown in **Table 3**. However, with anhydrous ethanol the reaction did not occur and a jelly like substance was formed. The Table 3 also indicate that the acid value of jatropha oil when treated with anhydrous methanol keeping H_2SO_4 concentration as 15 %, reduced from 32.8 mg KOH/g to 2.597, 2.190, 1.875 and 1.839 mg KOH/g at the reaction time of 15, 30, 45 and 60 minutes respectively. The jatropha oil when treated with 15 % concentrated H_2SO_4 and anhydrous ethanol was found to have acid value of 7.785, 6692, 5.524 and 4.952 mg KOH/g at 15, 30, 45 and 60 minutes respectively.

At 20 % H_2SO_4 concentration, the acid value of jatropha oil when treated with methanol at 15, 30, 45 and 60 minutes reaction time was observed as 5.099, 3.328, 2.685 and 2.545 mg KOH/g respectively. The acid value of 6.911, 5.645, 4.973 and 4.295 mg KOH/g was observed when jatropha oil was treated with anhydrous ethanol using 20 % H_2SO_4 concentration for reaction time of 15, 30, 45 and 60 minutes respectively. It is thus evident from the above results that the reduction in FFA of jatropha oil was more when the oil was reacted with 15 % H_2SO_4 using methanol and reduction of acid value was higher when oil was treated with 20 % concentrated H_2SO_4 using ethanol. It also appears from the results that with an increase in duration of reaction time the reduction of FFA also increases at all levels of acid concentration. However, it is evident from the results that < 1 % FFA in oil could be achieved if the oil is treated with 15 % concentrated H_2SO_4 and anhydrous methanol for 45 minutes.

Table 3 also shows that acid

Table 1 Free Fatty Acids analysis of jatropha curcas oil biodiesel.

Fatty acids	Formula	Amount (%)
Palmitic acid	$C_{16}H_{32}O_2$	13.38
Palmitoleic acid	$C_{16}H_{30}O_2$	0.88
Stearic acid	$C_{18}H_{36}O_2$	5.44
Oleic acid	$C_{18}H_{34}O_2$	45.79
Linoleic acid	$C_{16}H_{32}O_2$	32.27
Others		2.24
Total		100

Table 2 Fuel properties of petro-diesel, jatropha oil and their biodiesels.

Property	Unit	Petro-diesel	Jatropha oil	Jatropha methyl ester (JME)	Jatropha ethyl ester (JEE)	Biodiesel Standards	
						ASTM D 6751-02	DIN EN 14214
Density at 15 ºC	kg/m^3	838	881	872	878	870-900	860-900
Kinematics Viscosity at 40 ºC	mm^2/s	3.08	32.67	4.91	5.28	1.9-6.0	3.5-5.0
Flash point	ºC	63	229	198	195	> 130	> 120
Pour point	ºC	− 9	3	1	− 1	− 15 to 10	-
Ash content	%	0.01	0.1	0.01	0.01	< 0.02	< 0.02
Carbon residue	%	0.14	6.35	0.68	0.57	-	< 0.30
Acid value	mg KOH/g	0.38	32.8	0.46	0.55	< 0.80	< 0.50
Calorific value	MJ/kg	45.58	40.80	39.88	41.50	-	-

Table 3 Effect of Types of Alcohol, Catalyst Amount and Reaction Time on Reduction of FFA of Jatropha Oil.

H_2SO_4 Concentration (%)	Types of Alcohol							
	Anhydrous Methanol				Anhydrous Ethanol			
	Acid Value of Jatropha oil (mg KOH/g)							
	Reaction Time (min)				Reaction Time (min)			
	15	30	45	60	15	30	45	60
5	*	*	*	*	*	*	*	*
10	3.748	2.690	2.316	2.306	*	*	*	*
15	2.597	2.190	1.875	1.839	7.785	6.692	5.524	4.952
20	5.099	3.328	2.685	2.545	6.911	5.645	4.973	4.295

* A jelly like emulsions was formed.

value decreases with the increase in concentration of H_2SO_4 up to 15 % thereafter increases with methanol. Hence for methanol the lowest acid value of 1.839 mg KOH/g (0.92 % FFA) which is less than 1 % FFA was obtained at 15 % H_2SO_4 concentration and 60 minutes reaction duration at molar ratio of methanol to oil 10 : 1 and reaction temperature 60 ± 1 ºC. Therefore, 15 % acid concentration, 60 minutes reaction duration, molar ratio of methanol to oil 10 : 1 and 60 ± 1 ºC reaction temperature has been found an optimized condition for FFA reduction of jatropha oil.

The experiment also revealed that the acid value of jatropha oil was 6.025 mg KOH/g when it was treated with 25 % H_2SO_4 concentration and ethanol for 60 minutes reaction duration. This shows that in the case of ethanol, the acid value decreases with the increase in H_2SO_4 concentration up to 20 % then there is an increase. Therefore, for ethanol, the lowest acid value of 4.295 mg KOH/g (2.15 % FFA) at 20 % H_2SO_4 concentration, 60 minutes reaction duration molar ratio of ethanol to oil 10 : 1 and reaction temperature 70 ± 1 ºC was found optimum.

It can therefore be said that the reduction in acid value of raw jatropha oil having 16.4 % FFA was higher with methanol as compared to ethanol at the same condition except the reaction temperature.

Transesterification

The biodiesel production from pretreated Jatropha oil through transesterification was conducted in batch type biodiesel plant of 100 L/d capacity. The transesterification of pretreated 10 kg oil samples that had acid value of 1.839 mg KOH/g (0.94 % FFA) in case of methanol and 4.295 mg KOH/g (2.15 % FFA) in case of ethanol was carried out with 3 % w/w KOH at a 6 : 1 molar ratio of methanol/ethanol to oil at 60 ± 1 ºC for methanol and 70 ± 1 ºC with ethanol for 1 h reaction time. After the reaction the mixture was pumped to the separation tank and allowed to settle for 24h. The glycerol from the bottom in a separating tank was then separated and biodiesel was obtained. The biodiesel was then incubated with wash water having 48-50 ºC temperature for 45 minutes. The wash water was then removed. This treatment was performed to remove glycerin, excess alcohol and catalyst. Three consecutive washing of biodiesel was done. For each washing the amount of water was taken 5 times the volume of biodiesel. The yield of methyl and ethyl ester was found to be 97 and 95 percent respectively.

Conclusions

The biodiesel production (methyl ester) from high FFA Jatropha oil (16.4 %) requires its pretreatment with methanol and 15 % concentrated H_2SO_4 for FFA reduction to a level of 0.92 %. The biodiesel production (ethyl ester) from high FFA Jatropha oil (16.4 %) requires its pretreatment with ethanol and 20 % concentrated H_2SO_4 for FFA reduction to a level of 2.15 %. After pretreatment, the product was used for an alkaline-catalyzed final transesterification reaction with molar ratio of methanol/ethanol to oil 6 : 1, 3 % w/w KOH, reaction time 60 min and reaction temperature at 60 ± 1 ºC and 70 ± 1 ºC for methanol and ethanol respectively. This process gave a yield of jatropha methyl and ethyl ester of about 97 and 95 percent respectively. The fuel properties of obtained biodiesel are in agreement with those of petro-diesel and satisfying the American and European standards for biodiesel.

Acknowledgements

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Ergonomics of *Bt Cotton* Picking Bags

by
Sunita Chauhan
Subject Matter Specialist,
Home Science, Krishi Vigyan Kendra,
Nagpur, INDIA
soyentp@rediffmail.com

A. Ravinder Raju
Senior Scientist
Agronomy
bumaraju@gmail.com

G. Majumdar
Senior Scientist
Farm Power and Machinery
gama62@rediffmail.com

M. K. Meshram
Principal Scientist
Plant Pathology

Central Institute for Cotton Research (CICR), Nagpur-440 010, Maharashtra, IINDIA

Abstract

Participatory adoptive research work was conducted on ergonomically designed cotton picking bags during 2008-11 for picking efficiency, energy expenditure, carrying capacity, ease, comfort, safety, loading and unloading etc. with Bt hybrid cotton in Nagpur (21º 09´ N, 79º 09´ E.). HAU, Hissar designed back loaded cotton picking bag was having 50 % higher carrying capacity, ease in tying, longer picking time, exerted 37 % less load on heart beats, 18 % lower energy expenditure kJ kg cotton with a break even of 17 days and requires 25 % extra cost of cloth over MAU bag.

Introduction

Introduction and popularization of Bt hybrid cotton during 2004-2008 brought changes in hand picking due to synchronization and early maturity at least by 20 days Hebbar *et al*. (2007) which brought severe labour shortages experienced in intensively cultivated states of Andhra Pradesh and Tamil Nadu in India. Manual cotton picking by women (**Fig. 1**) sometimes up to 11 hrs/ day involves a lot of drudgery due to posture, load of picked cotton and abrasion of fingers due to sharp points of dried bracts with musculoskeletal discomforts (Anonymous, 2011; Sangwan *et al*. 2011). Hand picking operation requires 450-500 women-h/ha which costs $.113 tonn^{-1} and $ 79-248 ha^{-1} (Chaudhary, 2011). An aid to reduce drudgery, efficient collection and field transportation in manual picking cotton would require less labour to pick cotton per unit area thus reducing the cost of cultivation. Cotton picking bags were designed, tested and popularized to improve cotton picking efficiency and reduce trash content (AICRPH, 2002, 2004). The present on farm adoptive research was concentrated on evaluation of ergonomically designed picking bags in participatory mode by cotton farm women for reducing the drudgery and adoptability.

Materials and Methods

A participatory On-farm research project was conducted during 2008-11 for the evaluation of cotton picking bag designed and tested under Home science department of Marathwada Agriculture University, Parbhani, (MAU) (**Fig. 2**), whereas cotton picking bag of Chaudhary Charan Singh Haryana Agriculture University, Hissar (CCS, HAU) (**Fig. 2**), designed and tested under All India Coordinated Research

Fig. 1 Manual cotton picking by farm women.

Fig. 2 Operational view of MAU.

Project on Home Science, Ergonomics of Farm Women's Drudgery and Family Resource Management division which was suitable to different age groups as main and sub plots in split plot design with 9 replications. The data were analysed using ANOVA technique with IASRI software.
Parbhani and HAU, Hissar Picking Bag

Selection and Training of Subjects

Eighty one farm women in the age range of 18 to 52 years with normal health/ blood pressure and body temperature were selected from Nagpur (21º 09′ N, 79º 09′ E.) district, India. Care was taken to avoid any subjects with any major illness or cardiovascular problems. Knowledge, skills for using these picking bags were imparted and allowed them to acclimatize.

Classification of Subjects

Height and body weight of cotton picking women were measured for calculating Body Mass Index (BMI), scores were interpreted as per Garrow (1987). Heart beats/ min were measured before and after cotton picking operation in cotton fields, energy expenditure (kJ/min) per kg cotton was calculated from this during Bt hybrid cotton picking.

Stiching of Bags

Cotton bags along with technical literature were procured from original source (MAU, Parbhani, CCS, HAU, Hissar) and stitched to assess their suitability for cotton picking women folk of Nagpur district.

Testing Cotton Picking Bags

Output of Bt hybrid cotton picked was measured per unit area and time using two picking bags and local picking aid called Fadka or a piece of old cotton /synthetic cloth usually tied around the waist of farm women to temporarily store and transport cotton picked in field.

Masculo Skeletal Problems

Incidences of musculo-skeletal problems during the activity were identified with the help of body map (Corlett and Bishop, 1976), which indicates different body parts viz; upper body parts (eye, neck, shoulder joint, upper arm, elbows, wrist/hands) and lower body parts (lower arm, low back, upper leg/ thigh, knees, calf muscles, ankles, feet). The perceived discomfort i.e. rating of perceived exertion (RPE) was recorded in terms of pain felt on a 5 point scale developed by Varghese *et al.* (1994) to record the intensity of the pain in the various parts of the body viz., 5, 4, 3, 2, 1 for the Intensity of the pain as very severe, severe, moderate, mild and very mild respectively.

Results and Discussion

Ergonomic Evaluation of Ergonomically Designed Cotton Picking Bags

Family resource and management division, CCS, HAU, Hissar ergonomically designed back loaded cotton picking bag was having 50 % higher carrying capacity and ease in tying proved significantly superior over Home Science department, MAU, Parbhani designed front loaded pouch type of cotton picking bags as it facilitated longer picking time with less interruptions (**Table 1**).

HAU bag exerted

Table 1 On-farm evaluation of cotton picking bags in Nagpur district.

Picking bags	Average rest HR b min^{-1}	Average working HR b min^{-1}	Δ AWHR over rest b min^{-1}	Output Kg h^{-1}	Output area hr^{-1}	BMI	Energy expenditure kJ min^{-1}	Δ AWHR over rest b $min^{-1}kg^{-1}$	Δ AWHR over rest b $min^{-1}m^{2}$	Earning day^{-1}	Pickers /ha	Energy expenditure kg^{-1} cotton picking	Physiological work load: Energy expenditure kJ min^{-1}	Physiological work load: HR $bmin^{-1}$
HAU	83.9	105.0	21.1	5.3	75.1	16.4	8.0	5.3	6.4	127.3	33.2	642.2	M*	L*
MAU	82.9	100.5	17.6	4.9	85.1	17.7	7.3	4.7	10.1	120.6	26.2	780.4	L	L
TT	81.6	105.6	24.0	4.8	61.8	17.9	8.1	6.8	3.0	134.4	34.0	481.7	L	M
SE	2.5	3.9	3.4	0.5	15.5	0.6	0.6	1.0	4.3	17.0	6.9	161.5		
Age group of women pickers involved in on farm evaluation														
18-25	84.6	101.6	16.9	5.0	72.6	17.0	7.4	4.3	9.6	122.7	30.4	679.0	M	L
26-35	80.7	103.9	23.2	4.7	69.7	17.5	7.8	6.6	4.3	126.6	35.0	579.7	M	L
36-52	83.1	105.7	22.6	5.4	79.8	17.5	8.1	6.0	5.6	132.9	28.0	645.7	M	M
SE	2.1	3.0	0.4	10.7	1.0	0.5	0.0	2.7	11.8	3.7	100.5			
CD + 5 %			4.5					1.5						
Interaction														
SE	11.5	16.8	12.4	2.3	56.0	5.4	2.7	4.4	14.7	65.0	20.5	554.0		

37 % less load on heart beats, 18 % lower energy expenditure KJ kg cotton (**Table 1**) with a breakeven of 17 days (**Table 2**) due to ease in field movement compared to MAU bag which created hindrance for forward movement due to front load of cotton. These results were in agreement with those observed the suitability of cotton picking bags under Haryana conditions (Sangwan *et al.* 2011). HAU, designed cotton bag requires 25 % and 15 % extra cloth and costs over MAU bag although, without any protection of hands.

MAU, designed cotton picking bag only offers protection for arms from sun and physical abrasion of cotton bracts and special extra linen (shirts) are used in rest. The conventional cloth system exerted more load on left knee due to forward motion with front load of cotton. However, the cotton cloth selection made in the improved picking bags also created less suffocation compared to synthetic cloth used in the local method needs attention of researchers for further comfort (**Table 3**).

On-farm Evaluation of Ergonomically Designed Cotton Picking Bags

Average heart rate at rest beats min^{-1} and after work (**Table 1**) was non- significantly influenced by both picking bags and age groups due to lighter nature of physiological work load both in improved picking bags and younger and middle age group (18-35years) of farm women compared to traditional picking tool Fadka (women used cloth1.25 M^2) in higher age group (36-52 years) as moderate nature of work as described by Garrow (1987). These observations were confirmed from energy expenditure kJ /hr/ kg picked cotton (**Table 1**). However, the delta average working heart rate b/min during picking was significantly lower in relatively younger age group of 18-25 years compared to their senior counter parts 26-35 and 36-52 years due to their anxiety or reserved energy which can be spent at ease. Bt hybrid cotton picked area, delta heart beats /m^2 and quantity /hour were non- significantly influenced by both picking bags and age groups due to the nature of work load as discussed earlier.

The synchronous nature of Bt hybrid cotton and the need for timely picking of cotton against abnormal weather can be addressed to some extent by the use of picking bags. Young and middle age groups are at an advantage due to their physiological efficiency, the major concern being in a poor nutrition and energy status of Indian farm women. The earning /day was not significantly influenced by picking bags or age groups which may be due to short term job lasting for one hour and a break to empty the bag due to lighter nature of workload in a cohesive team manner despite being on competitive contract for payment on the basis of quantity of seed cotton picked. The breakeven economics for cotton picking bag was 17 days only compared to picking period of 60 days in every season (**Table 2**). It is wiser to make cotton picking bags as apron for farm women themselves which protects and saves energy from the improved efficiency the cost can be realized.

Table 2 Economics of cotton picking bag.

Picking bags	Cloth required m^2	Cost Rs./ bag	Earnings / day	Break even days
HAU, Hissar	1.55	115	127	17.2
MAU, Parbhani	1.24	101	121	
Conventional	1.25	14	134	

Table 3 Ergonomic evaluation of cotton picking bags in Nagpur district.

Parameters of evaluation	HAU bag	MAU bag	Traditional tool	CD + 5 %
Carrying capacity Kg	6	3.8	4	0.92
Ventilation	2	2.6	3	2.47
Safety /comfort ability				
Protection of Arms	4.0	1.7	4.0	26
Suitability & liking				
Frequent emptying	2.0	4.0	4.0	10.4
Tying ease	2.0	5.0	4.1	
Cost of bag	118	138	39	40
Body discomfort				
Mid back	0.0	3.6	3.5	3.11
Lower back	0.0	3.6	3.5	3.11
Left knee	0.0	3.4	3.0	4.47
Right Knee	0.0	2.6	2.5	2.23
Left foot	0.0	2.6	2.5	2.23
Right foot	0.0	2.6	2.5	2.24
Shoulder left	1.0			0
Shoulder right	1.0			0

Conclusion

Cotton picking bags could reduce drudgery of cotton farm women if adopted; the bag cost could be realized in single season besides improving personal safety and picking efficiency.

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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.

1513

Role of Channel Size on Water Distribution Uniformity in Beds under Drip Laterals: **Nauman A. Qamar**, Department of Irrigation and Drainage, University of Agriculture, Faisalabad, PAKISTAN; **Muhammad Arshad**, same; **Aamir Shakoor**, same; **Alamgir A. Khan**, Agricultural Mechanization Research Institute, Multan, PAKISTAN, alamgirakhtar@hotmail.com; **Ijaz Ahmad**, Water and Sanitation Agency (WASA), Faisalabad, PAKISTAN

Conventional irrigation methods, such as basin and border systems have very low irrigation efficiencies compared to furrow-bed, drip and sprinkler irrigation systems. At present, most of the vegetables are grown on furrow-bed system with gravity flow of irrigation water; however, efficiency of irrigation system can be improved by placing drip lateral on the beds. Drip lateral placement in V-ditch or channel would prevent run off, hereafter the size of channel containing the drip lateral becomes important. Accordingly, an experiment was conducted on thirty raised beds of 60 cm wide and 30 m long. Thirty beds were subdivided into three treatments, each treatment contains ten beds. Size of channel containing drip lateral was 10cm for 1st treatment, 7.5 cm for 2nd treatment and 5 cm for the 3rd treatment. The onion nursery was transplanted on all beds with the same intensity of plants. Distribution uniformity of water in soil was determined by taking soil samples at the depths of 0-15, 15-30 and 30-45cm from three locations such as: right, center and left sides of the beds. The results showed that the average water distribution uniformity was 5.44, 4.73 and 4.09 % for 10, 7.5 and 5 cm channel sizes, respectively. It was concluded that maximum water distribution uniformity was in the bed with 10 cm channel size. Similarly, maximum yield was obtained from the 10cm channel size, which indicated that channel size for the drip lateral had impact on the water distribution uniformity and resultantly on the crop yield.

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Farm Hand Tools and Machinery Accidents —A Case Study in Ahmedabad District of Gujarat, India

by
Hitesh B. Shakya
Assistant Professor (FMPE), Krishi Vigyan Kendra,
Anand Agril. University,
Arnej, (Dist: Ahmedabad), Gujarat
INDIA
shakya1970@gmail.com

Jaydip Rathod
Senior Research Assistant,

R. Swarnkar
Professor and Head,
Dept. of Farm Machinery & Power Eng.,

College of Agril Eng. & Technology,
Anand Agril. University, Godhra
INDIA

Abstract

India consist 260 million work force of the world's work force involved in agricultural and related activities. They are using 800 million hand tools and 160 million agricultural machineries. Even though, there is a very little information available about agricultural accidents in our country. To generate data of agricultural accident of Ahmedabad district, a study was conducted by Krishi Vigyan Kendra, Anand Agricultural University, Arnej.(Dist:Ahmedabad) during May-July, 2013. Farm hand tools and agriculture machinery related accident data were collected from thirty villages (three villages per block) for five year period from March, 2008 to March, 2013 in Ahmedabad district of Gujarat state, India that were generalized to the whole district according to the survey. The estimated number of the victims was 772 in 2013. Out of the total, 56 accidents were fatal and remaining 716 were non-fatal. The agricultural accident-incidence rate per 1,000 workers per year in the Ahmedabad district was worked out as 0.95.

Introduction

In India, 260 million workers are involved in agricultural and related occupations (Census, 2001) consisting one fifth of the world's agricultural work force. Traditionally, human and animals were main power sources in Indian agriculture. But, since early 70's, the share of draught animals has come down to 13.67 % in 2009-10 whereas that of tractors, power tillers, diesel engine and electric motors has gone up to 86.33 % during same period (Singh et.al.). There are 800 million hand tools and 160 million agricultural machineries being used in the country. The annual production of tractor and power tillers has crossed over 419,270 and 39,900 in 2011-12. (C-DAP report Ahmedabad district, 2013).

It is very much evident from the fact that farm mechanization has increased the production and productivity of Indian farms. But, it has also increased the problem of worker's safety in large extent. An injury to the workers or loss of human life in agricultural accidents not only creates difficulty or sorrow to the victim's family but also causes considerable financial loss to the country.

There is a paucity of reliable data on farm workers disease, injury or death during farm work in India. It becomes difficult to quantify the economic burden of these farm accidents and to suggest means of minimizing them. Thus, availability of nationwide realistic data on agricultural accidents is most desirable.

Keeping in view, the case study was conducted on Farm hand tools and machinery accidents in Ahmedabad district of Gujarat state for the period of five year from March, 2008 to March, 2013.

Material and Methods

Farm hand tools and machinery accident data were collected for the period of five year (From March, 2008 to March, 2013) of Ahmedabad district of Gujarat, India. The study was conducted by Krishi Vigyan Kendra, Anand Agricultural University, Arnej (Dist: Ahmedabad) during month of May to July, 2013. Three villages per block were selected from all the ten block of Ahmedabad district for the survey. The villages were selected by considering the availability of labor force for agriculture, irrigation facility, cropping intensity and distance from block or district place. After that, contacts were established with Gram sevak (Village level extension functionary of state government), head of village panchayat (Sarpanch), Farmers' groups and village level medical practioners of selected villages. All of the thirty villages were visited and with the help of Gram sevak, Sarpanch and farmers' groups; and information on agriculture and its related accidents was collected. After this, each victimized farmer was contacted for collecting detailed information.

Result and Discussion

The total farm hand tools and machinery accidents in surveyed villages of different blocks during five year period (From March, 2008 to March 2013) was 179. Out of 179 accidents, 87 accidents were due to farm hand tools, followed by farm machinery (75) and others related to agriculture (17). **Table 1** represents the accident-incidence rate. The accident-incidence rate of farm hand tools was 0.163 per 1000 workers per year followed by farm machinery 1.44 per 1,000 machines per year and others were 0.064 per 1000 workers per year. However, the total agricultural accident-incidence rate was 0.95 per 1,000 workers per year in Ahmedabad district of Gujarat state, India. These data shows that farm hand tools related accident were insignificant as compared to farm machinery accidents.

Table 2 shows source of classification of agricultural accidents in surveyed 30 villages. Serrated sickle accidents were highest, which constituted 15.08 % of the total accidents followed by tractor (13.40

Table 1 Total farm hand tools and machinery accidents and incidence rate in surveyed thirty villages of Ahmedabad district.

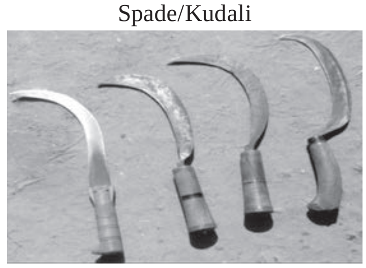
Type of accident source	Nos. of accidents	Incidence rate
Farm hand tools	87	0.163
Farm machinery	75	1.44
Others	17	0.064
Total	179	0.95

Table 2 Source classification of farm hand tools and machinery accidents in surveyed thirty villages of Ahmedabad district.

Source of agriculture accidents	Total number of victims (% of total accidents)	Total numbers of hand tool/ machinery	Incidence rate/1000/year
A. Hand Tools			
Plain edge sickle	19 (10.61)	21135	0.18
Serrated sickle	27 (15.08)	7625	0.71
Chopper knife	11 (6.14)	3537	0.62
Fork	09 (5.02)	15317	0.12
Khurpi	14 (7.82)	12213	0.23
Spade/Kudali	06 (3.35)	12380	0.10
Cotton stalk puller	01 (0.56)	360	0.55
B. Farm Machinery(Accident prone)			
Tractor	24 (13.40)	570	8.42
Power tiller	02 (1.11)	30	0.01
Thresher	12 (6.70)	1257	1.91
Diesel engine	05 (2.79)	1795	0.56
Electric motors & pump sets	03 (1.67)	1780	0.34
Chaff cutter	14 (7.82)	430	6.51
Puddler	05 (2.79)	670	1.50
Rotavator	02 (1.11)	120	3.33
Cultivator	02 (1.11)	1835	0.22
Disc harrow	03 (1.67)	865	0.70
Iron plough	03 (1.67)	1045	0.57
C. Others			
Snake bite	05 (2.79)	-	-
Fall from tree	02 (1.11)	-	-
Toxic effect of Insecticides / pesticides during spraying	07 (3.91)	-	-
Slipping in the field	03 (1.67)	-	-
Total	179		


Spade/Kudali


Cotton stalk puller


Plain edge sickle

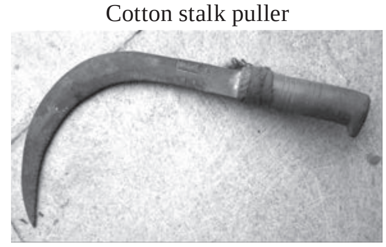

Plain edge sickle

Fig. 1 Farm hand tools.

%), plain edge sickle (10.61 %), chaff cutter and khurpi (7.82 %), thresher (6.70 %), chopper knife (6.14 %), fork (5.02 %), spade/kudali (3.35 %), toxic effect of insecticides/pesticides during spraying (3.91 %), diesel engine, puddler and snake bite (2.79 % each), slipping in the field, electric motors & pump sets, disc harrow and iron plough (1.67 % each), power tiller, rotavator, cultivator and fall from tree (1.11 % each), and cotton stalk puller (0.56 %). Machine related accident-incidence rates were calculated on the basis of total number of each type of machine in all the villages. Highest and lowest accident-incidence rate per 1,000 machines per year was for tractor (8.42) and spade/kudali (0.10) respectively. Due to adoption of tractor in various farm activities, accidents by tractor were increasing in large extent day by day.

Accident Estimation for Each of the above Categories:

A. Farm hand tools:

Farm hand tools such as serrated sickle, khurpi, Plain edge sickle, chopper knife, fork, spade/kudali and cotton stalk puller are included in this category. To estimate the number of hand tool related accidents, the incidence rate was calculated from the total number of reported accidents due to accident prone hand tools and total number of these tools in thirty villages of the Ahmedabad district. Total hand tool accident was calculated by multiplying the incidence rate with the total number of farm hand tools in the surveyed thirty villages of the district. The population of farm hand tools in the Ahmedabad district was estimated by multiplying the number of farm hand tools per worker in the surveyed villages by total number of the agricultural workers in the Ahmedabad district as below.

- Number of farm hand tools related accident in thirty villages per year = 87/5 = 17.4
- Total number of hand tools in thirty villages = 72,567
- Total number of agricultural worker in thirty villages = 36,370
- Number of farm hand tools per worker in surveyed villages = 72,567/36,370 = 2
- Estimated population of agricultural workers in Ahmedabad district for the year 2013 (**Table 2**) = 951,380
- Estimated number of hand tools in Ahmedabad district for the year 2013 = 2 × 951,380 = 1,902,760
- Accident-incidence rate per 1000 hand tools per year= (17.4/72,567) × 1000 = 0.24
- Estimated number of hand tools related accidents per year in Ahmedabad district = (0.24 × 1,902,760)/1000 = 456

B. Farm machinery:

In this category accidents related to farm machineries, excluding farm hand tools were included. To estimate the number of farm machinery related accidents, the accident-incidence rate was calculated from the total number of reported farm machinery related accidents and total number

Fig. 2 Farm machineries.

of accident prone farm machineries in thirty surveyed villages. The accident-incidence rate was multiplied by the total number of accident prone farm machineries in Ahmedabad district during year 2013 for calculating the total number of farm machineries related accidents. The estimation of the total farm machineries in Ahmedabad district during the year 2013 was 176,921.

- Number of Farm machinery related accident in thirty villages per year = 75/5 = 15
- Number of machinery related fatal accident per year in surveyed villages = 9/5 = 1.8
- Number of machinery related non-fatal accident in surveyed villages per year = 66/5 = 13.2
- Total number of accident prone agricultural machines in thirty villages = 10,397
- Accident- incidence rate per 1000 machines per year = (15/10,397) × 1,000 = 1.44
- Incidence rate of fatal accidents per 1,000 machines per year = (1.8/10,397) × 1,000 = 0.173
- Incidence rate of non- fatal accidents per 1000 machines per year =(13.2/10,397) × 1,000 = 1.27
- Estimated number of accident prone agricultural machinery in Ahmedabad district for the year 2013 = 176,921
- Estimated number of machinery related accidents per year in Ahmedabad district = (1.44 × 176,921)/1,000 = 255
- Estimated number of machinery related fatal accidents per year in Ahmedabad district =(0.173 × 176,921)/1,000 = 31
- Estimated number of machinery related non-fatal accidents per year in Ahmedabad district = (1.27 × 17,6921)/1,000 = 224

C. Others

Accidents due to Snakebite fall from tree, slipping in the field and toxic effect of insecticides/pesticide during spraying were included in this category. To estimate the number of accidents of this category, the accident-incidence rate per 1,000 workers per year was calculated from the total number of reported accidents under this category and total number of agricultural workers in thirty surveyed villages. This accident-incidence rate was multiplied by the total number of the agricultural workers in Ahmedabad district during the year 2013 to get the total estimated number of Accidents under this category.

- Number of other related accident in thirty villages per year = 17/5 = 3.4
- Number of fatal accidents in surveyed thirty villages per year = 7/5 = 1.4
- Number of non-fatal accidents in surveyed thirty villages per year = 10/5 = 2
- Total number of agricultural workers in thirty villages = 53,277
- Accident-incidence rate per 1000 worker per year = (3.4/53,277) × 1,000 = 0.064
- Incidence rate of fatal accidents per 1000workers per year = (1.4/53,277) × 1000 = 0.026
- Incidence rate of non-fatal accidents per 1000workers per year = (2/53,277) × 1000 = 0.037
- Estimated population of agricultural workers in Ahmedabad district for the year 2013 (**Table 2**) = 951,380
- Estimated number of other agricultural accidents per year in Ahmedabad district = (0.064 × 951,380)/1,000 = 61
- Estimated number of fatal accidents under this category per year in Ahmedabad district = (0.026 × 951,380)/1,000 = 25
- Estimated number of non-fatal accidents under this category per year in Ahmedabad district = (0.037 × 951,380)/1000 = 36

Thus, the total number of agricultural accidents in Ahmedabad district worked out to be as 772 given in **Table 3** and **Fig. 1**.

Table 3 Estimated number of farm hand tools and machinery related accidents for the year 2013.

Types of sources	Fatal accident	No-fatal accidents	Total
Farm hand tools	-	456	456
Farm machinery	31	224	255
Others	25	36	61
Total	56	716	772

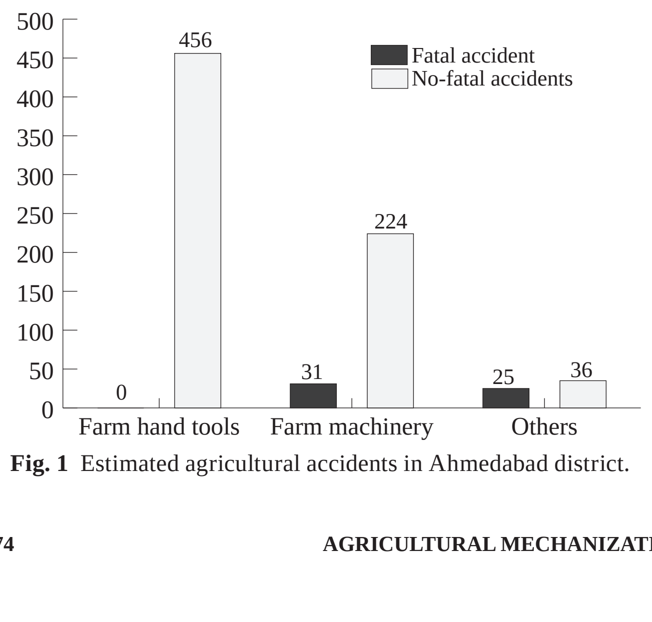


Fig. 1 Estimated agricultural accidents in Ahmedabad district.

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News

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Development and Evaluation of Zero Till Drill for Maize Crop

by

A. Srinivasa Rao
Ex.M.Tech student
Dept. of FMP, CAE,ANGRAU,
Bapatla,522101, Guntur dt, AP
INDIA
arudra.pandu4u@gmail.com

Aum Sarma
Professor & Head
Dept. of FMP
FIM Scheme
ANGRAU,Hyderabad
INDIA

K. V. S. Rami Reddy
Asst.professor
Dept.of FMP
CAE,Bapatla-522101
Guntur dt,AP
INDIA

Abstract

During the last 5 years, there has been a growing effort by the government to increase the area under maize cultivation, because this crop has ability to thrive under minimal water requirement of 400-600 mm. However, the desired success has not been achieved due to its lower productivity level owing to poor level of mechanization. Preparation of seed bed is the most drudgery operation which requires more energy and cost. To reduce the cost involved in preparation of seed bed and to complete the sowing operation in time; a zero till drill has been developed for maize crop which can sow the maize seed in paddy harvested field without any seed bed preparation. After fabrication and assembly of zero till drill, the field tests were carried out. For calculation of cost economics, the zero till drill sowing was compared with conventional method of manual dibbling. Effective field capacity of zero till drill was 0.357 ha/h, efficiency of the zero till drill was 74.3 %. Grain yield in zero tillage method was 8.5 t/ha and manual dibbling method was 7.8 t/ha. Zero till drill results in saving of production cost by 17 %, saving in time by 75 % and increase of yield by 9 % over conventional method of manual dibbling.

Key Words: Zero tillage system, Manual Dibbling, Field efficiency, production cost

Introduction

The greatest challenge for India during the 20th century was to enhance agricultural production and productivity to ensure food security for a fast growing population to avert large scale starvation of people. This challenge was duly met by ushering in the green revaluation in mid-60's. This was achieved through adoption of biological, chemical and mechanical innovations coupled with right government policies by providing the required instructions, inputs, incentives such as minimum support price to the farmers. Degradation of natural resources is threatening the agricultural productivity. Hence during the 21st century balancing food, national and environmental security is going to be the toughest challenge for India. The population is increasing at about 2 % per year whereas cultivable land is either constant or the matter of fact reducing. To reach the demand of high population, the production has to be increased and more than one crop has to be cultivated in a year in the same field.

Andhra Pradesh farmers are cultivating maize as second crop after paddy. Delay in sowing leads to poor yield. Researches have shown that timeliness is important in sowing of maize crop. Hobbs (1995) indicated a reduction of 80-100kg/ha/day in grain yield of maize crop under delayed sowing. There may be several reasons for delayed sowing, of which the main reason is non availability of labour during the peak season. Traditionally farmers are sowing maize seeds in the paddy harvested field by manual dibbling. Traditional method of sowing involves more cost, time delay and more energy consumption. To reduce time, energy and cost of seed bed preparation, zero till drill has been specially designed which can sow maize directly after the harvesting of rice without any tillage operation in available field moisture after harvesting paddy.

Marerials and Methods

The field experiment was conducted at Agricultural Research Institute (ARI), Rajendranagar, Hyderabad, India. The experiment was carried out in manual harvested paddy field. The zero till drill was calibrated in the laboratory at Farm Implements and Machinery scheme, ARI, Rajendranagar, Hyderabad. The metering mechanism seed rates were adjusted as 20 kg/ha as per recommendation and recommended dose of fertilizer @N-120 kg, P_2O_5-40 kg, and K_2O-40 kg per hectare. In the second field sowing of maize seed was done with manual dibbling method. Regular observations on plant emergence, plant height, crop yield attributes were noted. All the measurements were taken using standard measuring equipment and by adopting standard measurement techniques.

Details of Fabricated Tractor Drawn Zero Till Drill

The whole assembly was mounted on the mild steel frame of 150 cm length and 75 cm in width having square cross section. The metering mechanism used for seed and fertilizer are pick up wheel and fixed hole opening type. Seed metering system is provided with wide range of pick up wheels according to the shape of seeds. In fertilizer box, an agitator is provided at each outlet to avoid bridging. The seed and fertilizer boxes are kept at a height of 85 and 90 cm respectively from the ground. The power for seed and fertilizer metering device is provided from a floating ground drive wheel with the help of chain and sprocket. The ground drive wheel is situated at front of the machine and it is provided with lugs on its periphery for better traction and undisturbed power transmission to the metering system. Height of lugs is 35 mm and welded parallel to the axis of rotation. Diameter of ground drive wheel is about 350 mm and width is 100 mm. Total weight of the no-till ferti- seed drill is approximately 255 kg. Two supporting wheels each at either side are provided for better support as well as depth adjustment. Technical specification of fabricated Zero till drill was given in **Table 1**. Working condition of zero till drill are shown in **Fig. 1**.

Manual Dibbling

In manual dibbling method maize seeds were sown with the help of dibbler (a wooden stick having sharp edge). For making straight rows a string was used. The string was tied to two wooden sticks in each edge of the field. Two persons are required for manual dibbling of each row. One person requires for making holes and another for placing seeds (1 or 2) in the holes and covering. Efficiency of the work depends on the skill of the labour.

Operational Parameters

Fuel Consumption

This is one of the main parameters which was considered while comparing performance of the machines. The fuel consumption has direct effect on cost economics of the machine or tillage technique. The fuel consumption was measured using 'Topping Method'. The fuel tank of the tractor was filled at its full capacity. The tractor along with zero-till drill was run in the test plot at constant speed. After completing the passes, fuel was refilled in the tank up to the original level. The quantity of refilled fuel was measured by measuring cylinder and time required for the completion of passes was noted down.

Effective field capacity

It is the actual area covered per unit of time by a machine. Effective field capacity was determined by using the following relationship:

Effective field capacity, ha/h = area covered / time taken

The total time taken in above relationship includes time losses in turning, machine adjustment required during operation.

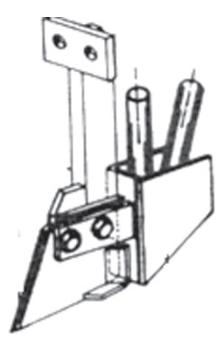

Fig. 1. Inverted T type Furrow Opener.

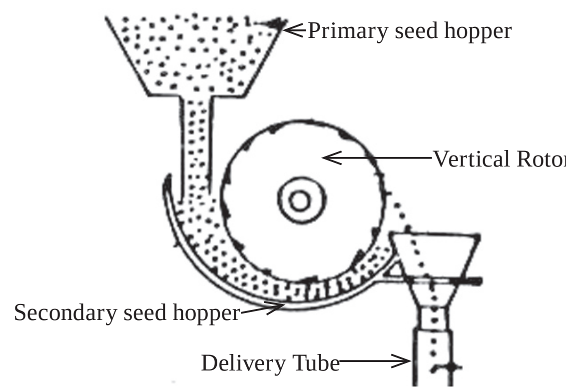

Fig. 2 Vertical rotor with cells on its periphery seed metering mechanism.

Table 1 Technical specifications with material of construction of different components of tractor drawn zero till drill.

Component	Dimensions (mm)	Material of construction
Furrow opener	60 × 35 × 4	Mild steel sheet
Hopper		
Rectangular portion	1100 × 250	18 gauge, Galvanized Iron sheet
Trapezoidal portion		
Top	1100 × 250	
Bottom	1100 × 120	
Frame	1500 × 750	8 mm thick, Mild steel sheet
Seed metering mechanism	220 Dia,12 cups- 10 × 6	Mild steel sheet
Ground wheel	350 Dia,30 lug height	Mild steel sheet

Field Efficiency

Field efficiency is the ratio of effective field capacity and theoretical field capacity. It was determined by the following relationship.

Field efficiency = Effective field capacity, ha/h / (Theoretical field capacity, ha/h) × 100

The theoretical field capacity was determined using the following relationship:

TFC = WS/10

Where,

TFC = Theoretical field capacity, ha/h

W = Width of operation, m

S = Speed of operation, km/h

Determination of Sowing Parameters

Sowing parameters such as plant to plant spacing, depth of sowing, number of seeds per hill, percentage of missing hills were observed in manual dibbling system and zero tillage system. For each parameter twenty observations were taken. Observations were taken by using standard procedures.

Determination of Crop Parameters

Crop parameters such as plant emergence, plant height, cob length, and cob girth, and cob weight, number of seeds per cob, test weight, grain yield and stover yield were observed. For each parameter five randomly selected samples were selected and average was taken.

Determination of Cost Economics

Production cost includes the total cost involved in seedbed preparation, sowing, seed, fertilizer and cost involved in irrigation, harvesting and threshing operations in different treatments. Out pot costs such as grain and stover was taken to calculate the total output cost in both zero tillage and manual dibbling method.Net income was calculated on the basis of cost involved in the production of maize crop and cost of maize grain and Stover obtained as output. The difference between the output cost and the total production cost gave the net income.

Results and Discussions

Operational Parameters

Fuel Consumption and Time Requirement

Fuel consumption of the tractor operating with zero till drill was observed by using the 'topping method'. It was observed that the fuel consumption of the tractor was 5.02 L/ha. Total time required to complete sowing of one hectare was calculated by measuring the difference between the initial and final timings of the operations .It was observed that the time required to complete one hectare sowing was 2.80 hours.

Effective Field Capacity

Effective field capacity of the tractor drawn zero till drill was calculated as 0.357 ha/h.

Field Efficiency

Theoretical field capacity of the machine was 0.48 ha/h and field ef-

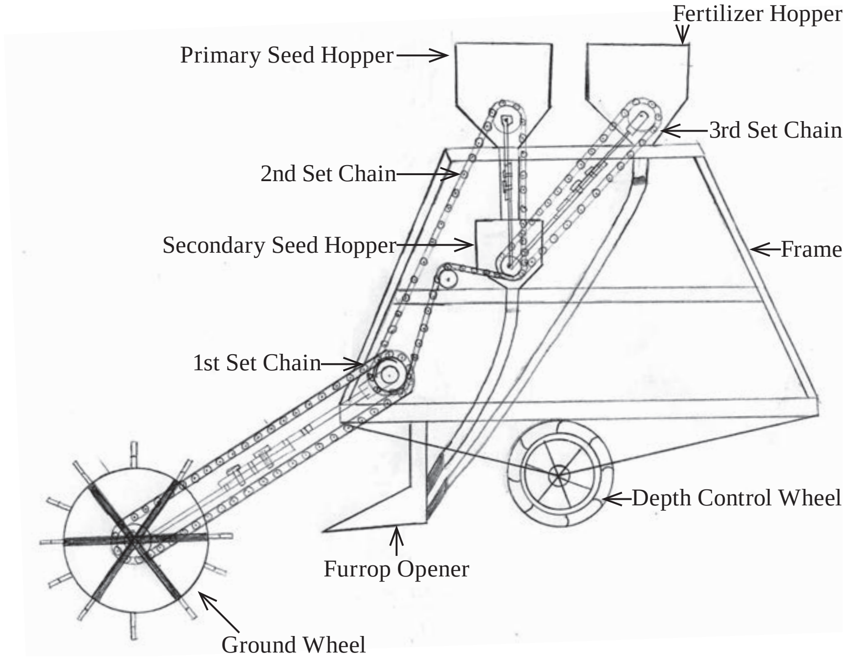

Fig. 3 Complete driving system of Zero Till Drill for transmission of power from ground wheel.

Fig. 4 Field evaluation of Zero Till Drill.

Table 2 Comparison of various sowing parameters between Zero tillage and Manual Dibbling.

Parameter	ZT*	MD*
Plant to plant Spacing	20.1	18.5
Number of seeds per hill	1	2
Plant emergence	8	10
% of missing seeds in m^2	2.5	0
% of excessive seeds in m^2	7.5	20.0
Depth of sowing	35.2	31.0

Table 3 Comparison of various Crop parameters between Zero tillage and Manual Dibbling.

Parameter	ZT*	MD*
Cob length, cm	19.66	17.32
Cob girth, cm	17.1	16.7
Number of seeds per cob	343	293
Weight of grain per cob, g	111.1	77.4
1000 grain weight, g	275.9	246.2
Grain yield, t/ha	8.5	7.8
Stover yield, t/ha	9.3	8.5

*ZT for Zero Tillage and *MD for Manual Dibbling

Table 4 Cost of cultivation per hectare for maize crop with zero tillage and manual dibbling methods.

Operation	Zero tillage		Manual dibbling	
	Material/labor	Cost (Rs/-)	Material/labor	Cost (Rs/-)
Seed bed preparation				
Seed cost	20 kg	4,000	30 kg	6,000
Sowing	5.75 LD, 3.0 hrs	600	2M* + 8F*	1,200
Thinning	----	0.00	5F	500
Fertilizer cost	230 kg	3,335	230 kg	3,335
Fertilizer application-1	----	----	6F	600
Irrigation-1	22LD	858	22LD	858
Weeding	8F	800	20F	2,000
Fertilizer cost	230 kg	3,335	230 kg	3,335
Fertilizer application-2	6F	600	6F	600
Irrigation-2	22LD	858	22LD	858
Pesticide cost	Endosulphon	1,275		
Endosulphon	1,275			
Spraying of pesticide	4M	800	4M	800
Fertilizer cost	230 kg	3,335	230 kg	3,335
Fertilizer application-3	6F	600	6F	600
Irrigation-3	22LD	858	22LD	858
Harvesting of cob	20F	2,000	20F	2,000
Harvesting of Stover	10F	1,000	10F	1,000
Threshing of cobs	300/t	2,550	300/t	2,340
Total input cost		Rs. 26,804		Rs. 31,494

*M for Male worker and *F for Female worker

1 litre Diesel (LD)	= Rs.39.17	1 liter Endosulphon	= Rs.230.00
1 Kg seed	= Rs.200.00	1 Kg carbofuran 3G	= Rs.70.00
1 Female	= Rs.100.00	1 hour tractor rent	= Rs.100.00
1 Male	= Rs.200.00	1 Kg Atrazine	= Rs.345.00
1 Kg Fertilizer	= Rs.14.50	1 tone threshing	= Rs.300.00

Table 5 Gross and net income for zero tillage over manual dibbling methods.

Parameter	Zero till seed cum Fertilizer drill (Rs./ha)	Manual dibbling (Rs./ha)
Gross return		
From grain @ Rs. 10000/t	85,000	78,000
Form stover@ Rs. 500/t	4,650	4,250
Total gross income	89,650	82250
Cost of cultivation	26,804	31,494
Net income	62,846	50,756
Additional income over manual dibbling	12,090	

ficiency of the machine was 74.37 %.

Sowing Parameters

Sowing parameters such as plant to plant spacing, number of seeds per hill, plant emergence, missing and excessive hills and depth of sowing were observed while evaluating the zero till drill and the results were compared with manual dibbling method. For every parameter observation five replications were taken and the average values are presented in **Table 2**.

Crop Parameters

Crop parameters such as cob length, girth, Number of seeds per cob, weight of grains per cob, 1000 grain weight, grain yield, Stover yield and Harvest index were observed while evaluating the zero till drill and the results were compared with manual dibbling method. For every parameter five replications were taken and the average values are presented in **Table 3**.

Cost Economics

The production cost per hectare of zero tillage method was observed as Rs.26804, whereas Rs.31,494 was observed in manual dibbling method (**Table 4**). Output cost observed in zero tillage method was Rs.89,650, whereas output cost in manual dibbling was Rs.82,250. Net income of Rs.62,846 per hectare was observed in zero tillage method, Rs.50,756 in manual dibbling method (**Table 5**).

Conclusions

The time required to complete one hectare of sowing operation was observed as 3.0 hours with zero till drill, whereas in case of manual dibbling 150 man-hours were taken. There was considerable saving in time of 75 % with zero till drill over conventional method of manual dibbling. The production cost with zero tillage method was observed as Rs.26,804, whereas Rs.31,494 was observed in manual dibbling. There was saving of 17 % of production cost in zero tillage method over conventional method of manual dibbling. There was increase in yield of 9 % with zero tillage system over conventional method of manual dibbling method.

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Effect of Operating Parameters on Performance of Target Actuated Sprayer

by

Jayashree. G. C.
Assistant Professor,
Department of Agricultural Engineering
University of Agricultural Sciences
Bangalore- 560065. INDIA
jayashreegc@gmail.com

D. Anantha Krishnan
Professor,
Department of Farm Machinery
Agricultural Engineering College
and Research Institute,
Tamil Nadu Agricultural University
Coimbatore- 641 003. INDIA
tnauananth@yahoo.com

Abstract

Chemical pesticides have played and will continue to play a major role in the rapid advancement of agricultural production. In crop spraying, off target application resulting in air and soil pollution has to be reduced. Hence an attempt has been made to develop a target actuated sprayer to reduce the off target application of chemical and thereby soil and environmental pollution. The different parameters taken for this study are concentration of the spray, width of plant canopy, height of the sensor from the canopy and forward speed of operations. Optimization test were also conducted by using different connectors namely 'T' joint, 'Y' joint, non-return valves and with four models of eductors. From the observations, it is concluded that eductor model IV was found to be the best connector with mixing chamber for the chemical and carrier liquid. The range of pressures adopted for chemical and carrier liquid produced droplets with VMD and NMD ranging between 101 to 200 µ and VMD/NMD ratio of 1.09 to 1.29 which is classified as fine spray. The amount of chemical delivered decreased with the increase in forward speed and height of sensor and with decrease in chemical concentration while it increased with increase in simulation plate width. The Analysis of Variance for optimum amount of chemical delivered as influenced by concentration of chemical, width of simulation plate, height of sensor above the plant canopy and forward speed of operation indicated that the selected variables and their interactions significantly affected the amount of chemical delivered. The mean comparison tests indicated that the minimum amount of chemical delivered (499 µl) was achieved at a chemical concentration of 25 percent, 100 mm width of simulation plate, 3.5 km h^{-1} forward speed and sensor height of 300 mm above the plant canopy. A prediction model on the amount of chemical delivered was developed based on multiple linear regression analysis ($q = -707.1769461 + 70.08855205C + 16.13430133W - 809.1538611S$). The analysis of variance of lag time indicated that the selected variables and their interactions significantly affected the amount of chemical delivered at one percent level. The minimum lag time of 1 ms was observed for the combination of 100 mm width of simulation plate forward speed of 3.5 km h^{-1} and sensor height of 300 mm above the plant canopy.

Keywords: off target spraying, target actuated sprayer, spray droplet size, and spray deposition.

Introduction

In crop spraying, off target application resulting in air and soil pollution has to be reduced. Off-target chemical application is a costly and time consuming problem for agricultural producers and turf grass managers. Application problems include: skipped areas, double application, unintentional application, or application to environmentally sensitive areas. Reducing or eliminating off-target application is increasingly important in a society that places high value on environmental quality and in global markets that are extremely competitive. Targeted application of chemicals provides an economic benefit in that less material is applied and a corresponding environmental benefit with less chemical introduced to the environment. It is known that sprayer settings are important for spray distribution in crop canopy. Matching spray volume and direction to crop size and shape can reduce chemical application, thus reducing operational costs and environmental pollution. Manual or sensor actuated sprayers have shown potential reductions in agrochemical use of 30 % and more. Hence, there is a need to develop technologies that automatically detect the presence of target plants and actuate the device to apply the pre-determined dose of pesticide.

Review of Literature

Azimi *et al.* (1985) investigated the nozzle spray distribution for pesticide broadcast application, with spray table (patternator) having troughs to measure the distribution across the sprayed swath from single nozzle. It was reported that the distribution pattern was dependent on the nozzle type, nozzle pressure, height of the nozzle above the target surface and the angle at which the nozzle was oriented with respect to the motion of the sprayer. Solie and Gerling (1985) reported that the nozzle height must be considered in order to achieve uniform coverage or distribution across the swath of the boom nozzle.

Wang *et al.* (1995) investigated the effect of nozzle height on uniformity of spray distribution. A laboratory set up including a simulated boom sprayer system and a spray deposition measuring system were used for the study. It was observed that the nozzle height had a strong effect on spray distribution uniformity. The width of plant canopy is the parameter that decides the width of spray to be applied on it such that the width of spray should go inside the average width of plant canopy to get maximum coverage. (Speelman and Jansen, 1974 and Giles and Comino, 1989). Whitney *et al.* (1989) examined the effect of ground speed (1.6, 2.8 and 4.0 km h^{-1}) on upper and lower leaf surface deposition using different air blast sprayers and spray volume and stated that the speed of operation significantly increased deposition

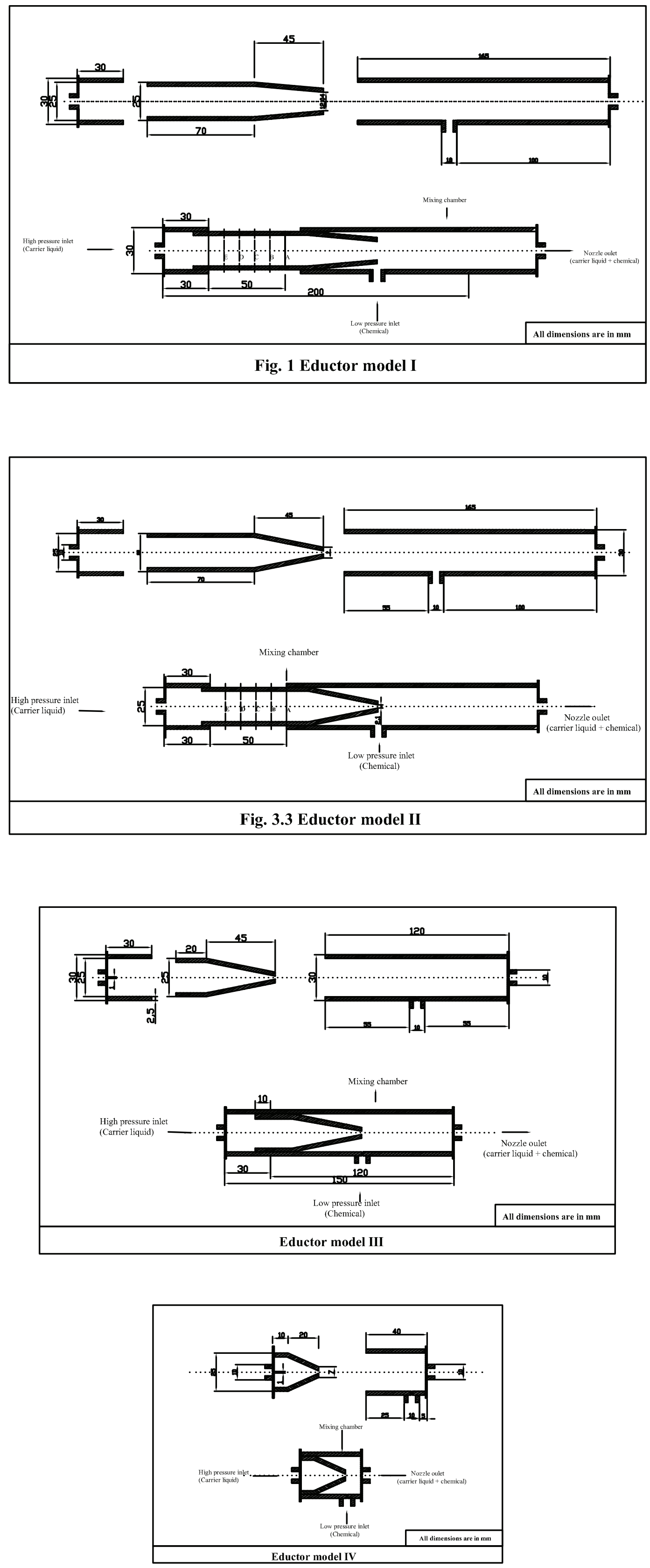

Fig. 1 Different models of eductors (I, II, III, IV).

on the upper leaf surface, but not on the lower leaf surface.

Materials and Methods

The concentration of spray chemical is decided by the pressures at which the chemical and the carrier liquid are delivered to the mixing chamber and mixed. These pressures also decide the discharge rate of the spray and the distribution of droplet size. Hence the pressure in the chemical tank and pressure in the carrier liquid tank are to be optimized with respect to the discharge rate and the droplet size distribution at desired concentration level. The different parameters taken for this study are concentration of the spray, width of plant canopy, height of the sensor from the canopy and forward speed of operations.

Measurement of Discharge Rate

An experimental test rig was developed to measure the discharge rate at different pressure combinations of chemical and carrier liquid. The different levels of pressure adopted were 0.05, 0.1, 0.15, 0.2, 0.25, 0.3 and 0.35 MPa in both tanks. Different combinations of chemical and carrier liquid pressure were adopted to get pressure differences of 0.00, 0.05 and 0.1 MPa between chemical and carrier liquid. The discharge (v) for each pressure difference was collected for a known time (t) and the rate of discharge (q) was calculated as

$q = v/t$, L s^{-1} .... (1)

From the discharge rate the application rate (Q) was calculated as,

$Q = 36000q / (S \times w) \times 10^4$, L ha^{-1} .... (2)

Where ,

Q: application rate, L ha^{-1}

q: discharge rate, L s^{-1}

S: speed of operation, km h^{-1}

w: row to row spacing, m

Optimization of Pressure of Carrier and Chemical Liquid

Optimization of pressure is very important for achieving desired combination to get particle size and mixing of carrier and chemical in recommended proportion. Optimization tests were conducted by using different connectors namely ‘T’ joint, ‘Y’ joint, non-return valves and educators of various models (I, II, III, IV) shown in **Fig. 1**.

Optimization of Spray Concentration

Mixing ratio of chemical and water at different pressures will indicate the concentration of chemical achieved. Spraying concentrated chemical without dilution is dangerous and it results in scorching of leaves. Pre-dilution of chemical is based on stage of the crop and the recommended dosage. Pre-diluted chemical is again mixed with carrier at the time of spraying. To achieve proper mixing of carrier and chemical with difference in pressure, connector was designed.

Droplet Size Determination

The size of spray droplet is the most important parameter that influences penetration and carrying ability of hydraulic sprayer. It also influences the efficiency of catch of sprays by plant surfaces and insects. Droplet size also affects the uniformity and completeness of coverage on plant surfaces and drift of the material from the treated area (Kepner *et al*., 2000; Farooq *et al*., 2001, Senthil Kumar, 1995).The uniformity of spray deposition was expressed as VMD (Volume Median Diameter), NMD (Numeric Median Diameter) and VMD/NMD ratio.

Volume Median Diameter (VMD)

VMD is the diameter of spray droplet which divides the volume of the droplets deposited on the photograph paper into two equal halves. In other words, it is the diameter of the spray droplet, which divides the droplet spectrum into two halves where the total volume of spray droplet which is smaller in size, will equal the total volume of spray droplets which are larger in size.

Numeric Median Diameter (NMD)

NMD is the average diameter of the droplet, which divides the number of droplets into two equal halves. In other words it is the diameter of the spray droplet, which divides the droplet spectrum into two halves where, the total number of spray droplets which are smaller in size will equal the number of spray droplets which are larger in size.

VMD/NMD ratio

VMD/NMD ratio is a factor used for indicating the breadth of the spectra. For uniform distribution of spray particles the VMD/NMD ratio should equal to unity. The VMD/NMD ratio was calculated from NMD and VMD obtained in the droplet size measurements.

The droplet size was determined by measuring the diameter of circles formed by droplet deposition on multilayer microporous ink –receptive white photographic paper. Methylene blue solution was used as the dye solution, at the rate of 10 g L^{-1}. The photographic paper was cut into (70 × 70) mm size. The photographic paper was kept on a horizontal surface directly below the nozzle. The target was enclosed in a ring and covered by a top sheet.

Plant Sensors

Sensing of plants mainly depends on the spectral properties of plants. An optical sensor is an electronic component that detects the presence of visible light, infrared (IR) transmission, and/or ultraviolet (UV) energy. Optical sensors consist of semiconductor having a property called photoconductivity, in which the electrical conductance varies depending on the intensity of radiation striking the material. Sensing of crops can be done by using different types of sensors and in this study optical sensor was used. The Equinox optical sensor is PNP type, working on 10 to 30 V DC battery. The optical sensor will sense the object when the obstruction comes in front of the sensor. The sensing distance can be adjusted from 10 mm to 400 mm.

Width of Plant Canopy (W)

The width of plant canopy decides the actuation period of the sensor which in turn controls the duration of spray on that particular plant. The minimum width of plant canopy was 90 mm and the plant to plant spacing in a row was 300 mm. Hence the levels of variables is fixed between 100 mm and 250 mm with an increment of 50 mm. Artificial targets in the form of simulated green colored plates of width 100 mm, 150 mm, 200 mm and 250 mm corresponding to the width of plants were used in the lab set up for optimization.

Height of Sensor from the Canopy (H)

The machine vision sensing system was used to sense the plant canopy and produce a signal which activated an electrically operated solenoid valve through a relay switch to switch between ON/OFF. A non-contact type 10 to 30 V DC Equinox optical sensor of PNP type was used to sense the plant material which interferes with in its sensible range which is shown in **Fig. 2**. A 12 volt battery was used to energize the optical sensor. Infrared proximity switches work by sending out beams of invisible infrared light. A photo detector on the proximity switch detected any reflections of this light. These reflections allowed infrared proximity switches to determine whether there was an object nearby. Since the maximum range of the IR sensor used in this study was 350 mm, the levels of variable selected namely height of the sensor from the plant canopy were 100, 150, 200, 250 and 300 mm only. A height adjustable frame was developed to hold the sensor and also to adjust the heights between the plant and sensor and widths based on the row spacing which is shown in **Fig. 3**.

Forward Speed of Operation (S)

The variation in forward speed of operation influences the duration of sensor activation, the amount of spray and in turn the amount of chemical deposited on the plant. The minimum speed of tractor in the field can be 1.5 km h^{-1} while the maximum field speed of tractor can be 4 km h^{-1}. Hence the levels of forward speeds of operation were selected from 1.5 to 3.5 km h^{-1} with an increment of 1.0 km h^{-1}.

Development of Prototype Target Actuated Sprayer

The parameters such as travel speed, height of sensor and the pres-

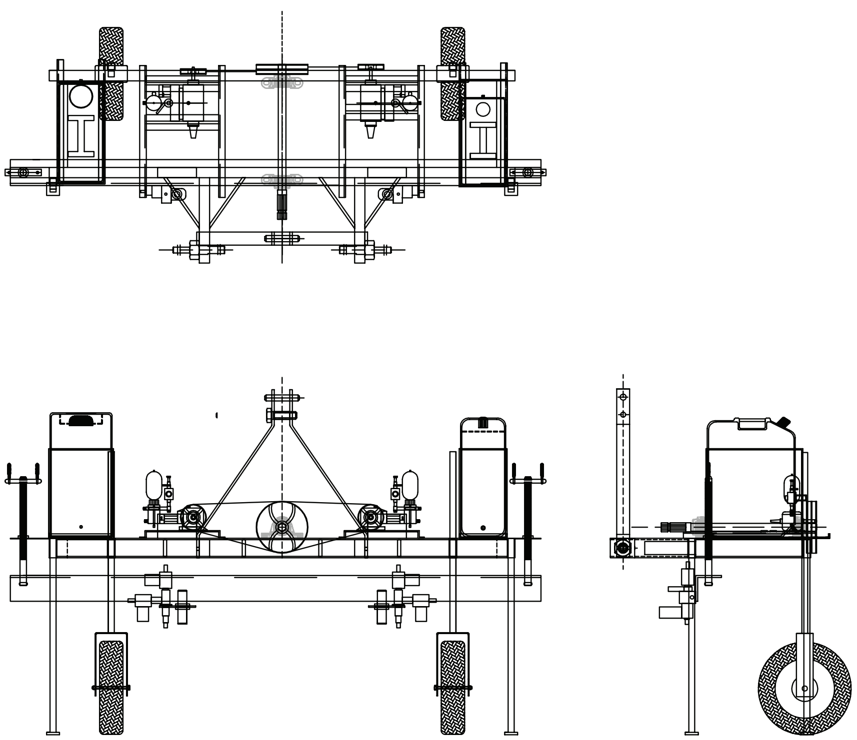

Fig. 4 Schematic diagram of the target actuated sprayer.

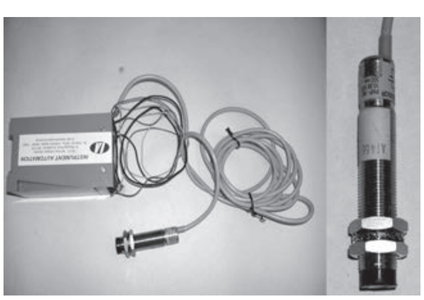

Fig. 2 Non-contact type 10 to 30 V DC Equinox optical sensor.

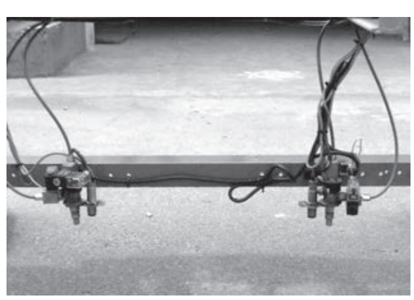

Fig. 3 Sensor is fixed to the Adjustable frame.

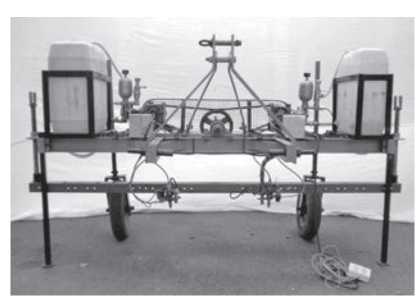

Fig. 5 Developed Target actuated sprayer.

sure of carrier liquid and chemical were optimized based on the observations of the experimental set up to give desired chemical deposition on the plant canopy. These optimized values were used for the development of prototype target actuated sprayer.

The schematic diagram and prototype target actuated sprayer is shown in **Figs. 4** and **5**. The rotary power to drive the hydraulic pumps of the prototype was taken from the PTO of the tractor while the electrical power required for operating the solenoid valve and the sensors was taken from the battery of the tractor. The prototype target actuated sprayer consisted of the following major components like main frame, single acting pump, double acting pump, carrier liquid tank, chemical tank, sensor, solenoid valve, educator, nozzle, spray boom with height adjustment and power transmission system

Results and Discussion

The pressure of chemical and that of carrier liquid determines the concentration of spray. These pressures also decide the discharge rate and the droplet size distribution. The pressure in the chemical tank and the pressure in carrier liquid tank were optimized with respect to discharge rate and droplet size distribution. The outlets from the chemical and carrier liquid were connected using T joint, Non return valves, Y joint and the eductor and the discharge from both the tanks were measured and the results were tabulated.

The pressure of carrier and chemical liquid for getting maximum discharge using different connectors namely T joint, Non return valves, Y joint and the eductor were varied for getting pressure difference of 0.0, 0.05 and 0.1MPa and the corresponding total discharge and chemical contribution were measured and tabulated. From the tabulated values it was observed that a higher chemical concentration of 49 percent at 0.0 MPa pressure difference, 39 to 40 percent at 0.05 MPa pressure difference and 23 to 25 percent at 0.10 MPa pressure difference was achieved with eductor model IV. Since the inner volume of the eductor was drastically reduced, there was no accumulation of the liquid in the eductor. Hence the discharge of chemical stopped instantaneously at the moment of cut off by the chemical solenoid. Hence eductor model IV has been selected as the connector and mixing chamber for the chemical and carrier liquid.

Droplet Size Distribution

The droplet size was determined by measuring the diameter of circles formed by droplet deposition on photographic paper. Methelyne blue was added as dye solution to the chemical at the rate of 10 g lit^{-1}. The photographic paper of size 70 × 70 mm was used to collect the droplet samples produced at different pressure combinations. The droplet images were digitalized and analyzed using the software developed with MATLAB. The properties of individual entity in an image such as NMD, VMD and VMD/NMD ratio, were recorded and presented in **Table 1**.

Table 1 Droplet size distribution.

Carrier tank pressure (MPa)	Chemical tank pressure (MPa)	VMD	NMD	VMD/ NMD
0.0 MPa pressure difference				
0.1	0.1	185.56	144.31	1.29
0.15	0.15	169.25	138.72	1.22
0.2	0.2	165.38	142.56	1.16
0.25	0.25	156.69	124.35	1.26
0.3	0.3	148.62	123.86	1.2
0.35	0.35	138.92	120.8	1.15
0.05 Mpa pressure difference				
0.1	0.05	183.03	141.67	1.29
0.15	0.1	167.94	159.38	1.2
0.2	0.15	161.85	134.87	1.2
0.25	0.2	146.59	117.86	1.24
0.3	0.25	140.73	110.28	1.28
0.35	0.3	138.48	131.88	1.05
0.10 Mpa pressure difference				
0.15	0.05	153.32	118.75	1.29
0.2	0.1	153.63	120.31	1.28
0.25	0.15	146.35	120.48	1.22
0.3	0.2	133.63	122.92	1.1
0.35	0.25	112.54	106.28	1.06

From **Table 1**, it is observed that the Volume Median Diameter (VMD) and Number Median Diameter (NMD) were ranging between 106.28 to 185.56 μ and VMD / NMD ratio was between 1.09 to 1.29. If VMD and / or NMD is within the range of 101 to 200 it is classified as fine spray as per the classification given by Thronhill and Mathews (1995). Hence the particle size distribution with eductor model IV under the various pressure combinations tested was categorized as fine spray which is recommended for effective spray.

For uniform particle size distribution the VMD / NMD ratio should be close to unity. The results of the above study show that the VMD / NMD ratio was in the vicinity of unity. Hence the pressure ranges adapted for the particle size distribution was used in the tests conducted for the optimization of the variables affecting the chemical deposition.

Effect of Forward Speed on Quantity of Chemical Delivered

The effect of forward speed on the quantity of chemical delivered with respect to width of the simulation plate and height of sensor at 50, 40, and 25 percent concentration achieved by 0.0, 0.05 and 0.1 MPa pressure difference between the chemical and carrier liquid tanks is represented in **Fig. 6**.

It was observed that the amount of chemical delivered was reduced to one third for all heights of sensor for 100 mm simulation plate width when the speed was increased from 1.5 to 3.5 km h^{-1}. For simulation plate width of 150 mm, it was reduced to about 50 percent for all concentrations and heights of sensor. For simulation plate width of 200 mm, it was reduced to about 58 percent for all concentrations and height of sensor. For simulation plate width of 250 mm, it was reduced to about 34 percent for all concentrations and heights of sensor. The reduction in the amount of chemical delivered with increase in speed was due to the fact that the duration of exposure of the simulation plate to the sensor was reduced as the speed was increased.

Effect of Simulation Plate width on Quantity of Chemical Delivered

The effect of width of the simulation plate on the quantity of chemical delivered at different heights of sensor and forward speed with 50, 40 and 25 percent chemical concentration achieved by a pressure difference of 0.0, 0.05 and 0.1 MPa between chemical and carrier liquid tanks is shown in **Fig. 7**. It is observed that when the simulation plate width was increased from 100 to 250 mm the chemical delivered for all heights of sensors and at all concentrations for a travel speed of 1.5 km h^{-1} was almost doubled. Similarly it was increased by about 2.5 times for all heights of sensor and all concentrations when the forward speed was 2.5 kmh^{-1}. It was increased by 3.7 times for all the concentrations and heights of sensors when the forward speed was 3.5 km h^{-1}.The increase in the amount of chemical delivered with the increase in the width of the simulation plate was due to the increased activation time of the sensor. At the same time the reduction in the increase of the amount of chemical delivered with the increase in forward speed was due to reduction in exposure time to the sensor.

Effect of Chemical Concentration on Quantity of Chemical Delivered

The effect of concentration on the chemical delivered at a forward speed of 1.5, 2.5 and 3.5 km h^{-1} for different simulation plate widths and different heights of sensors is presented in **Fig. 8**. It was observed that when the chemical concentration was decreased from 50 to 25 percent the amount of chemical delivered was almost doubled for all combinations with different forward speed, different widths of simulation plates and different heights of sensors. The increase in the quan-

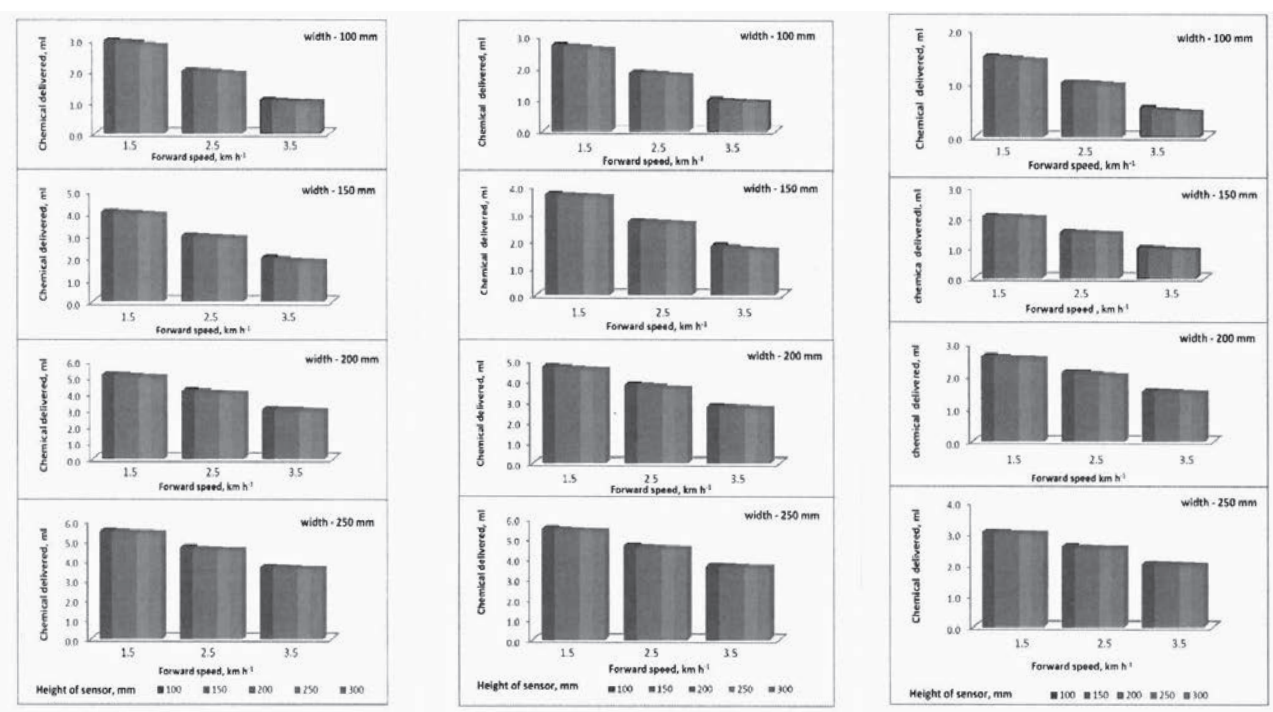

Fig. 6 Effect of forward speed and height of sensor on quantity of chemical delivered for different simulation plate widths at 50, 40 and 25 % chemical concentration.

tity of chemical delivered was due to the injection of higher volume of chemical when the pressure difference was increased from 0.0, 0.05 and 0.10MPa

Effect of Height of Sensor on Quantity of Chemical Delivered

The effect of height of sensor on

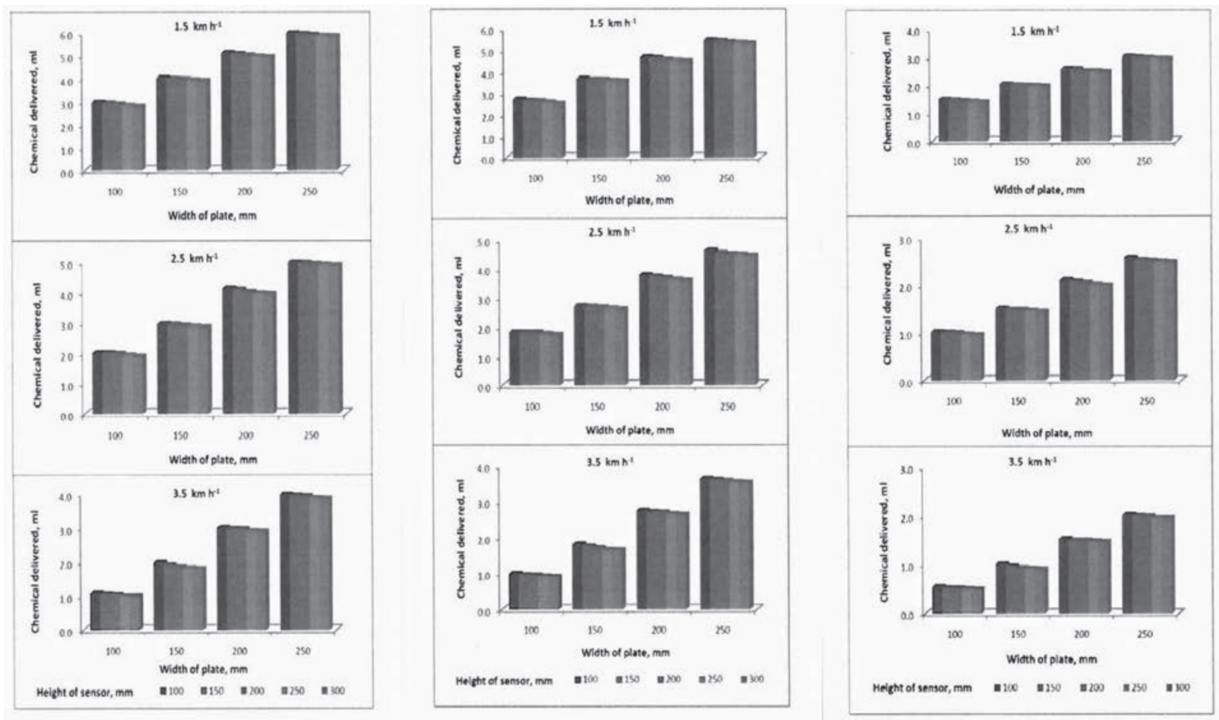

Fig. 7 Effect of simulation plate width and height of sensor on quantity of chemical delivered for different forward speeds at 50, 40 and 25 % chemical concentration.

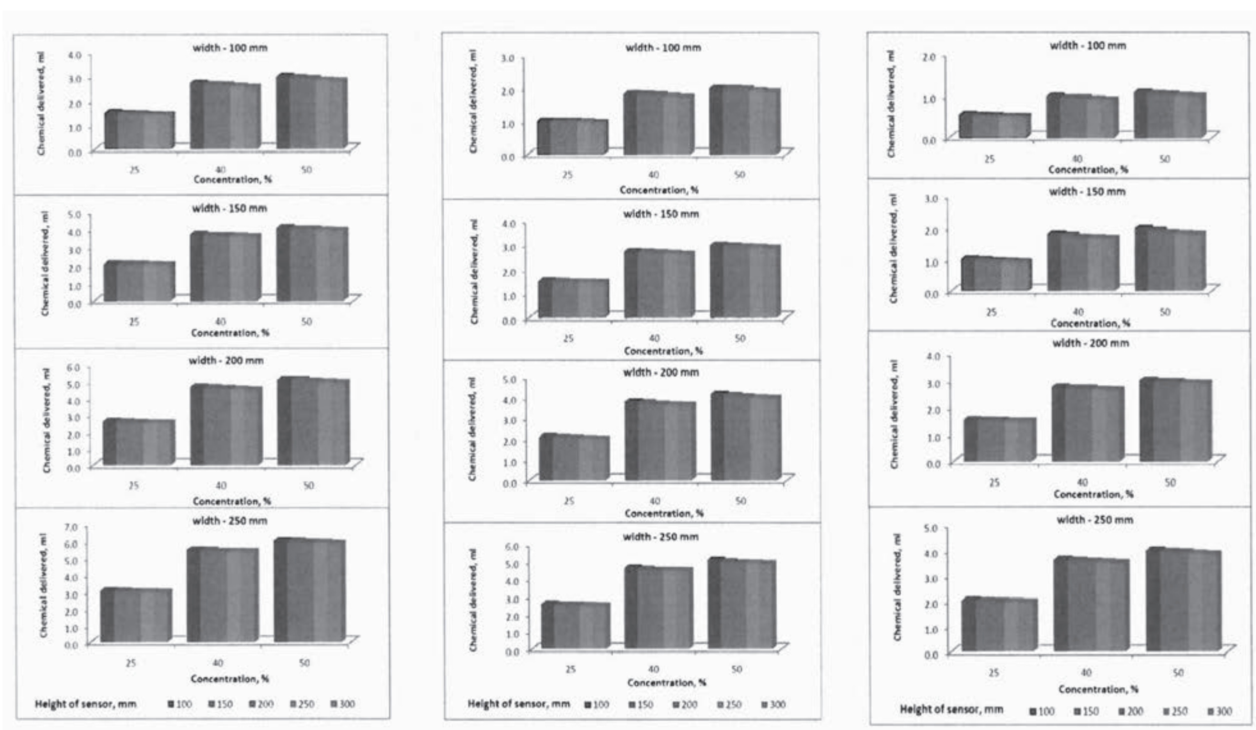

Fig. 8 Effect of concentration and height of sensor on quantity of chemical delivered for different simulation plate widths at 1.5, 2.5 and 3.5 km h^{-1}.

the amount of chemical delivered at different forward speed for different widths of simulation plats at a concentration of 50, 40 and 25 percent is presented in **Fig. 9**. The decrease in amount of chemical delivered with increase in height of sensor with all combinations with different forward speeds, width of simulation plates and chemical concentration was due to the fact that the sensitivity of the sensor decreases with increase in the distance from the reflector namely the simulation plate.

Experimental Statistical Design

To statistically verify the influence of the different independent variables on the amount of chemical delivered, all the data recorded with the experimental set up were analyzed using SAS (Statistical Analysis Software).

Analysis of variance for the amount of chemical delivered

The analysis of variance for optimum amount of chemical delivered as influenced by concentration of chemical, width of simulation plate, height of sensor above the plant canopy and forward speed of operation. From the results it is confirmed that each of the independent variables namely chemical concentration (C), width of the simulation plate (W), height of sensor (H) and forward speed (S) significantly affect the amount of chemical delivered. Also the interaction effect of the variables in pairs C × W, C × H, W × H, C × S, W × S and H × S on the amount of chemical delivered were significant. The interaction effect of the variables in combination of triplicates, C × W × S, and W × H × S on the amount of chemical delivered were significant. But the interaction effect of the variables in combination of triplicates C × W × H and C × H × S and the combination of all four variables C × W × H × S were not significant. The non - significance of the above three combinations may be due to the insignificant effect of height of sensor on the amount of chemical delivered. This indicates that the different levels of the four variables individually as well as in combinations have a great effect on the amount of chemical delivered except the combination of the height of sensor with chemical concentration, width of simulation plate and forward speed.

Conclusions

The significance of spray liquid discharge rate, concentration of the spray, width of plant canopy, height of the sensor from the canopy and forward speed of operations was quantified. The range of pressures adopted for chemical and carrier liquid produced droplets with VMD and NMD ranging between 101 to 200 μ and VMD/NMD ratio of 1.09 to 1.29 which is classified as fine spray. The Analysis of Variance for optimum amount of chemical delivered as influenced by concentration of chemical, width of simulation plate, height of sensor above the plant canopy and forward speed of operation indicated that the selected variables and their interactions

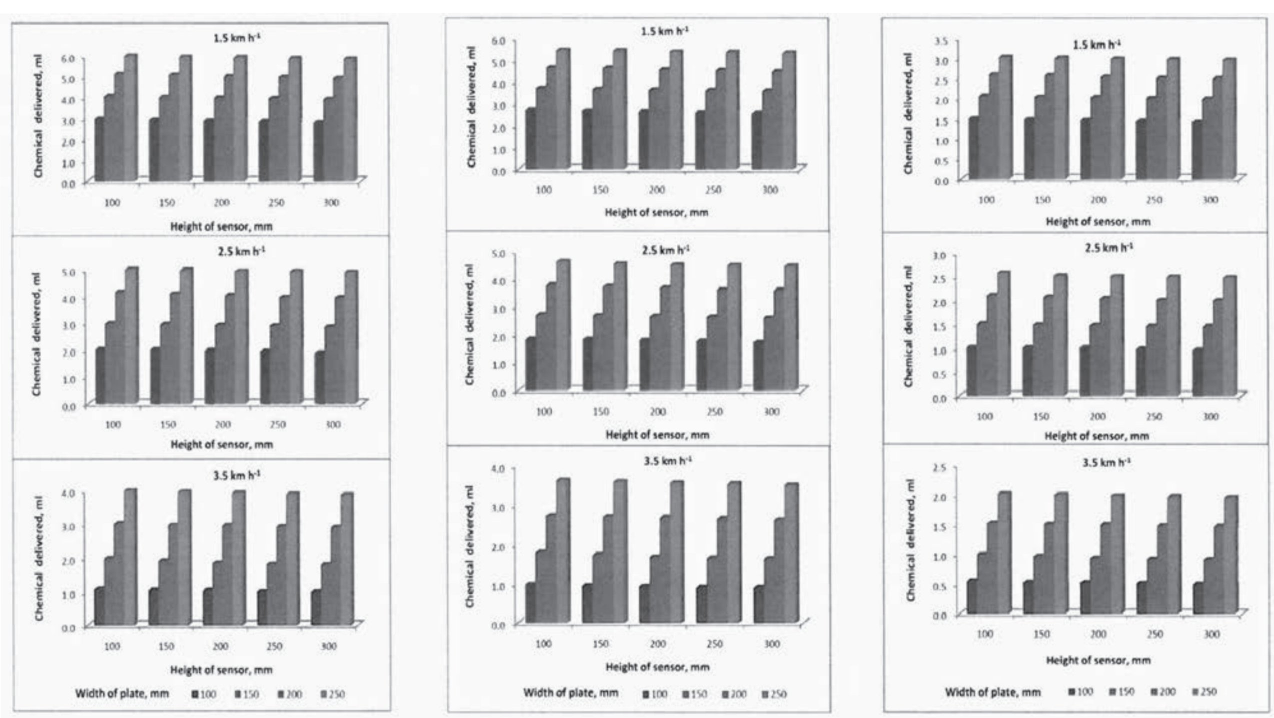

Fig. 9 Effect of height of sensor and simulation plate width on quantity of chemical delivered for different forward speeds at 50, 40 and 25 % concentration.

significantly affected the amount of chemical delivered. The mean comparison tests indicated that the minimum amount of chemical delivered (499 µl) was achieved at a chemical concentration of 25 percent, 100 mm width of simulation plate, 3.5 km h^{-1} forward speed and sensor height of 300 mm above the plant canopy.

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ERRATA

AMA Vol. 46, No. 3 Summer, 2015 Page 34 writer's position	Writer's name	Correct Position
	Tarl Berry	Postgraduate Student
	Mulugeta A.	Delele Postdoctoral Fellow

EVENT CALENDAR

◆ **CIAME 2015 –China International Agricultural Machinery Exhibition**
October 26-28, 2015, Qingdao, CHINA
http://www.camf.com.cn

◆ **ISB-INMA TEH' 2015 International Symposium**
October 30-November 1, 2015, Roma, ITALY
http://isb.pub.ro/isbinmateh.html

◆ **3rd International Engineering and Technical Education Conference (IETEC'15)**
November 1-4, 2015, Sibiu, ROMANIA
http://conferences.ulbsibiu.ro/ietec-brcebe/index.php

◆ **AgroWorld Kazakhstan**
—Central Asia's International Agricultural Exhibition—
November 4-6, 2015, Almaty, KAZAKHSTAN
http://agroworld.kz/en/

◆ **Land.Technik AgEng 2015**
November 6-7, 2015, Hannover, GERMANY
www.vdi.de/landtechnik-ageng

◆ **AGRITECHNICA 2015**
November 10-14, 2015, Hanover, GERMANY
https://www.agritechnica.com/en/

◆ **9th CIGR Section VI International Technical Symposium**
November 16-20, 2015, Auckland, NEW ZEALAND
http://www.cigrvi.com/

◆ **International Symposium Gembloux 2015**
November 25-27, 2015, Gembloux, BELGIUM
http://www.kemiz.up.lublin.pl/index.php?id=konferencje

◆ **50th Annual Convention of Indian Society of Agricultural Engineers (ISAE)**
—Symposium on Agricultural Engineering in Nation Building: Contributions and Challenges—
January 19-21, 2016, Bhubaneswar, INDIA
http://www.isae.in/AnnouncementFiles/ISAE%202016_pdf.pdf

◆ **44th Actual Tasks on Agricultural Engineering**
February 23-26, 2016, Opatija, CROATIA
http://atae.agr.hr/

◆ **ISMAB 2016**
—International Symposium on Machinery and Mechatronics for Agriculture and Biosystems Engineering—
May 23-25, 2016, Niigata, JAPAN
http://www.ismab2016.jp/

◆ **The first International Precision Dairy Farming Conference**
June 21-23, 2016, Aarhus, DENMARK
http://www.precisiondairyfarming.com/2016/

◆ **CIGR AgENG NJF 2016**
—International Conference of Agricultural Engineering—
June 26-29, 2016, Leeuwarden, NETHERLANDS
http://conferences.au.dk/cigr-2016/

◆ **ASABE 2016 Annual International Meeting**
July 17-20, 2016, Orlando, Florida, USA
https://www.asabe.org/meetings-events.aspx

◆ **AGRICONTROL 2016**
—The 5th IFAC Conference on Sensing, Control and Automation for Agriculture—
14-17 August, 2016, Seattle, Washington, USA
http://ifac.cahnrs.wsu.edu/

◆ **3rd Conference Biogas Science 2016**
September 2016, Szeged HUNGARY

◆ **VII International Conference on Agricultural Statistics (FAO)**
October 26-28, 2016, Roma, ITALY
http://icas2016.istat.it/

◆ **XIX. World Congress of CIGR**
April 22-25, 2018, Antalya, TURKEY
http://www.cigr2018.org/

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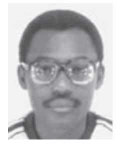
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S Tembo

-AFRICA-

Benedict Kayombo
Assoc. Prof. of Soil and Water Eng., Dept. of Agric. Eng. and Land Planning, Botswana College of Agric., Univ. of Botswana, Private Bag 0027, Gaborone, BOTSWANA. TEL+267-3650125, bkayombo@bca.bw

Mathias Fru Fonteh
Assoc. Prof. and Head, Dept. of Agril. Eng., Faculty of Agronomy and Agril. Sciences, Univ. of Dschang, P.O. Box 447, Dschang, West Region, CAMEROON. TEL+237-7774-0863, matfonteh@yahoo.com

Said Elshahat Abdallah
Assoc. Prof. of Agril. & Biological Process Eng., Dept. of Agril. Eng., Faculty of Agric., Kafrelsheikh Univ., Kafr Elsheikh 33516, EGYPT. TEL+20-473-14-8949, saidelshahat@agr.kfs.edu.eg

Ahmed Abdel Khalek El Behery
Agric Eng. Research Institute, Agril. Reserch Center, Nadi El-Said St. P.O. Box 256, Dokki 12311, Giza, EGYPT. behery28@yahoo.com

Ahmad Addo
Assoc. Prof., Department of Agril. Engg, Kwame Nkrumah Univ. of Sci. and Tech. (KNUST) Kumasi, GHANA. TEL+233-3220-60242, aaddo.coe@knust.edu.gh

Richard Jinks Bani
Lecturer & Co-ordinator, Agric. Eng. Div., Faculty of Agric., Univ. of Ghana, Legon, GHANA

Israel Kofi Djokoto
Prof., Israel Kofi Djokoto, Associate Prof. Univ. of Science and Technology, P.O.Box 420 ust, Kumasi, GHANA, profdjokoto@yahoo.com

David Kimutaiarap Some
Eng. Prof. Dept. of Agril & Biosystems Eng., School of Engg Chepkoilel University College of Moi Univ., P.O. Box: 2405-30100, Eldoret, KENYA, dkimutaisome2@gmail.com

Karim Houmy
Prof. and head of the Farm Mechanization Dept., Institute of Agronomy and Velerinary Medicine II, Secteur 13 Immeuble 2 Hay Riad, Rabat, MOROCCO. TEL+212-7-680512, houmy@maghrebnet.net.ma

Opeyemi Adeniyi Oyelade
Obtaining Doctor, Farm Power and Machinery Dept., National Centre for Agril. Mechanization (NCAM), P.M.B. 1525, Ilorin, Kwara State, NIGERIA. TEL+2348069030588, yemibamigbedjdoyelade@gmail.com

Umar Buba Bindir
Director General/CEO, National Office for Technology Acquisition and Promotion, No 4. Blantyre Street, Wuse II PMB 5074, Abuja, FCT Federal Republic of NIGERIA. TEL+234-9461-1183, ubindir@yahoo.com

Joseph Chukwugotium Igbeka
Prof., Dept. of Agril. Eng., Univ. of Ibadan,, Ibadan, NIGERIA. TEL+234-2-810-1100-4, Library@Ibadan.ac.ng

Emmanuel Uche Odigboh
Prof., Agril. Engg Dept., Faculty of Eng., Univ. of Nigeria, Nsukka, Enugu state, NIGERIA. TEL+234-042-771676, MISUNN@aol.com

Kayode C. Oni
Dept. of Agril. & Biosystems Eng., Faculty of Eng. & Technology, Univ. of Ilorin, PMB 1515, Ilorin, NIGERIA. TEL+234-803-5724708, kayoroll@gmail.com

Umezuruike L. Opara
Research Prof., S. Africa Research Chair in Postharvest Technology, Faculty of AgriSciences, Stellenbosch Univ., Private Bag X1, Stellenbosch 7602, SOUTH AFRICA. TEL+27-21-808-4604, opara@sun.ac.za

Nathaniel Gbahama Kuyembeh
Assoc. Prof., Njala Univ. Colle, Univ. of Sierra Leone, Private Mail Bag, Free Town, SIERRA LEONE. TEL+249-11-778620/780045

Abdien Hassan Abdoun
Member of Board, Amin Enterprises Ltd., P.O. Box 1333, Khartoum, SUDAN.

Amir Bakheit Saeed
Assoc. Prof., Dept. of Agric. Eng., Faculty of Agric., Univ. of Khartoum, 310131 Shambat, SUDAN. TEL+249-11-310131, absaeed5@yahoo.com

Abdisalam I. Khatibu
P. O. Box 2138, Zanzibar, TANZANIA. khatibu@zansec.com

Solomon Tembo
52 Goodrington Drive, PO Mabelreign, Sunridge, Harare, ZIMBABWE.

-AMERICAS-

Hugo Alfredo Cetrangolo
Full Prof. and Director of Food and Agribusiness Program Agronomy College Buenos Aires Univ., Av. San Martin4453, (1417) Capital Federal, ARGENTINA. TEL+54-11-4524-8041/93, cetrango@agro.uba.ar

Irenilza de Alencar Nääs
Prof., Agril. Eng. College, UNICAMP, Agril. Construction Dept.,P.O. Box 6011, 13081 -Campinas-S.P.,BRAZIL. TEL+55-19-788-1039, irenilza@agr.unicamp.br

Abdelkader E. Ghaly
Prof., Biological Eng. Dept. Dalhousie Univ., P.O. Box 1000, Halifax, Nova Scotia, B3J2X4, CANADA. TEL+1-902-494-6014, abdel.gahaly@dal.ca

Edmundo J. Hetz
Prof., Dept. of Agric. Eng. Univ. of Concepcion, Av. V. Mendez 595, P.O. Box 537, Chillan, CHILE. TEL+56-42-216333, ehetz@udec.cl

Marco A. L. Roudergue
Mechanization and Energy Dept., Agril. Eng. Faculty, Campus Chillan, Univ. of Concepcion, Chile. Vicente Mendez #595, CHILE. TEL+56-42-2208709, malopez@udec.cl

Roberto Aguirre
Assoc. Prof., National Univ. of Colombia, A.A. 237, Palmira, COLOMBIA. TEL+57-572-271-7000, ra@palmira.unal.edu.co

Omar Ulloa-Torres
Prof., Escuela de Agricultura de la Region, Tropical Humeda(EARTH), Apdo. 4442- 1000, San Jose, COSTA RICA. TEL+506-255-2000, o-ulloa@ns.earth.ac.cr

Pedro Paneque Rondon
Assoc. Prof., Universidad Agraria de La Habana,


H A Cetrangolo


I de A Nääs


A E Ghaly


E J Hetz


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G C Bora


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Indra Mani


C R Mehta


A M Michael


B S Pathak


V M Salokhe


G Singh


S R Verma


Kamaruddin Abdullah


M Behroozi-Lar


Saeid Minaei


A M Abdul-Munaim


B A Snobar


J H Chung


In-Bok Lee


M Z Bardaie


Enkhbayar Gonchigdorj


M P Pariyar


H P W Jayasuriya


A D Chaudhry


Alamgir A Khan


A Q A Mughal


Rafiq ur Rehmen


N A Abu-Khalaf


R M Lantin


R P Venturina


S A Al-Suhaibani


A M S Al-Amri


S Illangantileke


S F Chang


T S Peng


S Krishnasreni


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Y Pinar


I Haffar


N Hay


P V Lang


T H Katardjiev


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Retirement Co-editors` Name List

Co-editor`s name	Nationality	Inaugural year	Retired year
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Chau Van Khe	Vietnam	1972	1980
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Shahansha-Uddin Choudhury	Bangladesh	1973	1991
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T. Touggaard Pedersen	Denmark	1975	1990
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Naresh Chandra Saxena	India	1980	1988
Paris Andereou	Lebanon	1980	1984

Co-editor`s name	Nationality	Inaugural year	Retired year
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Harry D. Henderson	Lebanon	1984	1985
Mohammad Afzal	Pakistan	1984	1994
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Back Issues

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

(Vol.45, No.1, Winter, 2014-)

◇ ◇ ◇

Vol.45, No.1, Winter 2014

◇ ◇ ◇

Vol.45, No.2, Spring 2014

◇ ◇ ◇

Vol.45, No.3, Summer 2014

◇ ◇ ◇

Vol.45, No.4, Autumn 2014

■■

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The Editorial Staff of the AMA requests of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process:

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Priority in the selection of article for publication is given to those that –

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j. Convert national currencies in US dollars and use the later consistently.
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