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h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies in US dollars and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

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EDITORIAL

This September, the joint conference of the Chinese Association of Agricultural Machinery Manufacturers and Asian Association for Agricultural Engineering was held in Shanghai, China. The new president of the Asian Association for Agricultural Engineering is Dr. Shujun Li, the chairman of the Chinese Academy of Agricultural Mechanization Sciences and also the vice chairman of the Chinese Association of Agricultural Machinery Manufacturers.

The secretariat of the Asian Association for Agricultural Engineering was formerly based at AIT in Thailand for about 20 years but, from this July with the leadership of new president Li, it has been moved to the Chinese Academy of Agricultural Mechanization Sciences in Beijing. It was the first international conference for him as the president of AAAE but was memorable and, indeed, a powerful conference.

After the conference, I had some time to visit the World Expo. The venue was so huge that I could only see about 20 % of the whole expo. Regardless of the numbers of people visiting, the crowd control was handled promptly. As I was driving through the highway, I saw Shanghai city growing into a large metropolis. I saw the great economic growth of China during the stay.

However, this growth has created a new food problem. As income levels rise, food consumption upgrades follow; such as the growth of meat consumption. And now China seems to have become the importer of food, instead of exporter. What's more, the urbanization of the inland area is expected in the near future.

The majority of population growth in the 21st century is that in the developing countries. There are already many problems in the cities of these countries. As the poverty groups grow with the population in the cities, it is a matter of course that the government will get the price of the food down at first as a political move. This is the reason why terms of trade differ so much between food and other products, which make young people move to the cities rather than stay in the country as low-income farmers.

In the 21st century, we need to fulfill the growing food demand with a small group of people. We must push up the agricultural productivity with limited farmland, water, and other resources. This means that a global level of agricultural mechanization is needed to help this situation.

In China, to narrow the income gap between the cities and farmlands, a great amount of political funds were used. For example, a total subsidy 300 billion yen was used for agricultural machinery. I know there are not many countries able to spend so much money, but it is a matter of fact that developing countries need aggressive financial aid from the government. We must make a move before farming becomes impoverished with the lack of labor power. This tendency can already be seen in Japan. Many 65 or older farmers are going to retire in next 10 years.

China, growing so rapidly, has overcome Japan and is becoming the world's second economic power. If this growth does not slowdown in the next 20 years, the national per capita income of Chinese will be more than that of the American today. The consumption of resources, then, would be beyond all imagination. For example, it is estimated that the consumption of paper of highly developed 1.3 billion Chinese would use up all the trees in the world. To prevent this, we should research and develop the technology to push up the productivity of each resource. Also, discussing this as a worldwide problem, we should correct the terms of trade between primary industry and other industries on a global level. Whatever happens, it is a matter of course that the development of agricultural mechanization is a must-do.

My hope for the readers of AMA is to cooperate with each other to complete this historical mission and develop agricultural machinery in the world.

Yoshisuke Kishida
Chief Editor

September, 2010

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Water Harvesting and Conservation Techniques for Dryland Crop Production in Botswana: A Review

by

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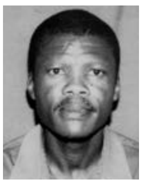

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Abstract

Water is the factor most limiting to dryland crop production in Botswana because of low and erratic rainfall and high evaporative demands. Much research work has been done on soil and water management techniques that improve and stabilize crop production in Botswana. Tied-ridging, furrow and precision strip tillage systems increased soil water storage and crop yields on sandy loam soils but did not appeal to farmers due to differences between conventional methods and additional labour and equipment required. Double ploughing, was effective in weed control and improving crop yields. Deep tillage and single mouldboard ploughing of loamy and clod-forming soils increased water infiltration and crop yields. Surface residue management and minimum tillage such as chisel ploughing are low input farming systems with a potential for the enhancement of soil moisture conditions in Botswana. The challenge is to ensure large-scale practical implementation of such technologies with a view to increase and stabilize crop yields.

Introduction

Botswana lies more or less in the centre of Southern Africa and is divided by the Tropic of Capricorn. Water is the major factor limiting dryland crop production in Botswana (DLFRS, 1980; Breyer, 1986; DAR, 1991, Racliffe *et al*., 1992). Lack of adequate water supply emanates from low average annual rainfall (200-650 mm) that is highly erratic with common dry spells during the cropping season and droughts that occur from year to year (Pike, 1971; Bhalotra, 1987). In the south-western corner, the rainfall is as low as 200 mm per year and it increases as one goes north to about 650 mm in the extreme northern part of the country. In eastern and north-eastern Botswana, rainfall occurs between October and April, is unreliable, mono-modal and averages between 450 to 600 mm per annum

(Bhalotra, 1987). The rainy season is followed by a five months (May to August), dry winter season. Runoff from high intensity rainstorms can reach 50 to 70 % of rainfall (Gibbon *et al*., 1974; DLFRS, 1980; L & WMRP, 1992) and this, combined with high evaporative demands, low infiltration rates and low water holding capacity of the soils reduce effective rainfall and crop production potential. The nature of rainfall patterns in Botswana makes dryland crop production highly risky and calls for efficient use of available water resources to stabilize the large fluctuations in crop yields.

In order to get the most effective use of variable and limited water supply, various tillage and crop management techniques can be used to modulate this water variability. The main aim of tillage is to retain rainfall where it falls on the field, to improve infiltration potential, and reduce runoff and evaporation losses. Water harvesting and conservation farming techniques that may be effectively used vary from simple and low-input intervention (double ploughing, plough and cultivate, single mouldboard ploughing and reduced tillage using disk and chisel plough instead of mouldboard plough) to more radical or complex interventions that use land engineering operations such as tied ridges and furrow, deep ripping and contouring. Once water conservation practices are put in place, cropping management techniques such as judicious planting dates, choice of crops with early-maturing, high-yielding, drought resistance or increased water use efficient crop varieties are planted. Also, agronomic practices that include application of fertilizers based on expected water supply and pest control all play an important role in improving water use efficiency and crop production yields.

The idea of effective agricultural improvement in low-input, smallholder farming is to modify the traditional production system without the need for excessive external input and high-level mechanization. Low-input tillage interventions investigated in Botswana include single ploughing, double ploughing, and plough and cultivate. Ploughing after harvest or early spring on first rains followed by second ploughing after the next appreciable rainfall (at least 15 mm of rain) and planting is referred to as double ploughing (L & WMRP, 1992; Persaud *et al*., 1992). In this system, ploughing can also be done after harvest or during winter followed by the second ploughing in spring before planting. Plough and cultivate is similar to double ploughing except that the second ploughing is done using a tined cultivator instead of a mouldboard plough. Deep tillage, surface residue management and reduced tillage promote water infiltration where rain falls on the field. Tied-ridges, furrows and strip tillage systems redistribute and concentrate rainwater at certain locations on the field and the water also infiltrates and increases soil water storage. Tied-ridges are a variation of microcatchment approach for trapping water and holding water in small depressions or blocked furrows. The small depressions retard runoff, hold water and allow it to infiltrate into the soil. Tied ridges are suitable for areas not prone to high intensity rainstorms and freely drained soils with gentle slopes.

Despite the amount of work devoted towards improving crop production, cereal grain yields under traditional farming average 350 kg ha^{-1} compared with over 1500 kg ha^{-1} under research conditions and commercial farming (IFPP, 1977; EFSAIP, 1981, DLFRS, 1985; Persaud *et al*., 1992). The factors contributing towards low production under traditional farming vary from limited use of fertilizers, poor crop management and lack of pest control measures. Even though high yielding crop varieties are generally used in traditional arable areas, the fields are located on areas that lack infrastructural development, and are on fragile soils characterised by poor fertility (Oland *et al*., 1980 and MOA, 2000).

Although less than 1 % of arable soils were rated as having high potential for dryland crop productivity (MOA, 2000), the use of modern farming techniques can raise suitability of 20 % of the land to at least moderate productivity (Radcliffe *et al*., 1992). These soils are located on areas of relatively high rainfall in the north of the country and to a lesser extent in the southeast region. Considering availability of more suitable and improved dryland farming agricultural technologies, there is much scope in improving crop production in Botswana.

A considerable amount of work on water harvesting and conservation research and related studies has been conducted in Botswana during the past 35 years. Literature of crop and soil management technologies is found in various publications and reports. The challenge is to synthesize research findings and provide farmers and producers with technologies that are likely to provide reasonable yields in worst years and good crop yields in good seasons. The synthesis developed will also strengthen the knowledge base and understanding of available technologies in Botswana.

The aim of this paper is to 1 review the effect of water harvesting and conservation techniques on soil properties and crop yield, 2 outline challenges and implications of improved technologies for arable farming, and 3 recommend crop management techniques that improve crop yields and sustainable agricultural development in the semi-arid conditions of Botswana.

Influence of Tillage on Water Infiltration

Ponded steady-state infiltration rates of uncultivated soils in Botswana varied between 11 to 330 mm hr^{-1} (Joshua, 1991). Water infiltration was lowest (191 mm hr^{-1}) and greatest (353 mm hr^{-1}) under sweep tillage and precision strip tillage (ripping to 30 cm depth in crop rows), respectively (DLFRS, 1980; Moroke *et al*., 2007). Mouldboard, chisel and disk ploughing resulted in similar infiltration rates of about 245 mm hr^{-1}. Average ponded steady state infiltration rates were 110, 140, 230 and 270 mm hr^{-1} (after 4 hours) on ferric luvisols, haplic luvisols, chromic cuvisols and cerric crenosols (Mandiringana *et al*., 2006; Moroke *et al*., 2007). Sandy loam ferric frenosols (Kalahari sand) and chromic luvisols had the greatest water infiltration rates. Steady-state infiltration rate was greatest under deep ripping and single mouldboard ploughed soils. This could be explained in part by accelerated organic matter decomposition and soil structure deterioration due to repeated tillage under double ploughing that leads to relatively rapid collapse of soil aggregates. Deep ripping and single ploughing have a better potential to relatively increase organic matter content, decrease runoff and improve soil water storage through increased water infiltration.

Soil Water Conservation

Compared with chisel and mouldboard, soil water content was greater under sweep tillage but the differences were not significant (DLFRS, 1985) (**Table 1a**). At several sites in eastern Botswana, tillage systems did not have significant effect on soil water (Carter and Miller, 1989; Carter and Miller, 1991; Persaud *et al*., 1991). Soil water content was significantly greater ($P < 0.05$) under double ploughing compared with single mouldboard ploughing (DAR, 1996). This was due to a reduced weed burden and a loosened soil profile.

Water losses by runoff from croplands can be as high as 70 % from flat-tilled land (DLFRS, 1980; L & WMRP, 1992). One alternative to flat tillage is the use of ridges aligned across the slope to hold back the slope flow and allow water to infiltrate. The tied-ridge system held water after heavy rain shower during the 1973/74 cropping season and this improved water infiltration and soil water storage (DAR, 1976). Compared with open furrows (non-tied ridges), tied-ridges improved soil water storage by 26 mm (18 %). Tied-ridges retained water on the cropland and this improved crop yield (**Table 1b**). Tied-ridges and furrows were very effective in reducing runoff and controlling local redistribution due to micro topography (DLFRS, 1985; L & WMRP, 1992). Non-levelled crop fields on traditional farms are common in Botswana (Carter and Miller, 1991; L & WMRP, 1992). Levelling of fields in combination with the use of contours or ridges promote distribution of rainwater on the field and may prevent localised flooding on one section of the field that may lead to excessive runoff losses from croplands or water logging.

Compared with cropped, fallow land increased soil water from 39 to 110 mm (181 %) (**Table 1c**). Average soil water content was greater under fallow (cultivated, ridged or chemical) compared with cropped land but was not statistically different (DLFRS, 1985).

Crop sequencing and fallow can

Table 1a The effect of tillage on soil water content and water use efficiency (WUE) of sorghum at Sebele (adapted from DLRFS, 1985)

Tillage	Total Soil Water (mm)		Evapotranspiration (mm)	WUE (kg/ha/mm)
	At planting	At harvesting		
Sweep	175.69	181.82	552.61	7.96
Chisel	153.35	169.45	562.58	7.61
Mouldboard	158.54	166.46	554.40	7.90

Table 1b The effect of tillage on total soil water (0-100 cm depth) and grain yield of cowpea and sorghum at Sebele in 1975 (adapted from DAR, 1976)

Ridge System	Soil Water Content (mm)‡		Grain Yield (kg ha^{-1})	
	At planting	At harvest	Cowpea	Sorghum
All Furrows Tied	177.9	136.6	1230	4580
Alternative Furrow Tied	162.4	132.9	910	4310
Flat	148.9	127.4	830	3170

‡Average soil water content across crops·

Table 1c The effect of cropping (maize, cover crop, and weeds) and type of fallow (cultivated, chemical and ridged) on total soil water (0-100 cm depth) at Sebele in 1969 to 1972 (adapted from DLRFS, 1985)

Treatment	Cropping System	1969/70	1970/71	1971/72
		Available Soil Water (mm)		
Cover Crop	Cropped	24.6	55.9	17.0
Maize		81.5	29.2	40.6
Weeds		12.9	53.3	36.1
Cultivated	Fallow	113.0	116.1	118.1
Ridged		112.3	100.3	118.1
Chemical		118.1	83.8	110.1
Seasonal Rainfall (mm)		312.4	671.2	613.7

be managed to increase soil water storage. Rainwater falling on fallow land can be conserved in the soil to supplement the rain that is received in the next season. In Botswana, partial fallows are essentially between post harvest to planting (May/June to November/January or early February in the North, where the growing season is longer). Full fallow is that part of the land that is not cropped for the rest of season and it could be a fraction or the whole of a farmers' field.

Weed control under fallow was achieved using herbicides and cultivation (Whiteman, 1975; DLFRS, 1980). Average soil water content under fallow was about three times greater as compared with cropped land (**Table 1c**). Compared with cropped area, the benefit of fallow in improving soil water storage increased with decreasing rainfall. When the previous seasonal rainfall was high, the effect of fallow was negligible (**Table 1c**). Besides eliminating weed competition for water and nutrients, this technique also improved infiltration of winter (late season) and early spring rains. Double ploughing, a partial fallow that increased soil water storage and improved crop yields was a recommended tillage technique for dryland farming in Botswana.

The difference between 83 and 30 mm of stored soil water at planting led to a yield difference of 1190 and 70 kg ha^{-1} of sorghum under only 108 mm of incident rainfall (DLFRS, 1985). Compared with conventional methods, sorghum grain yields were doubled due to fallow in Botswana (Whiteman, 1975). However, weed infestation, lack of labour for weeding and the thought of weeding an uncropped land has made adoption of fallow system difficult in Botswana.

Effect of Tillage on Crop Water Use Efficiency (WUE)

Considering the long-term seasonal rainfall average of 525 mm (Bhalotra, 1987; L & WMRP, 1992), it appears major crops (cowpea, maize, sorghum and millet) in Botswana would be produced quite reliably. However, high runoff and evaporation losses, low available water holding capacity and low input-management farming methods led to low WUE. Compared with traditional farming (e.g., broadcasting; low-input and minimal fertilizer use) WUE was much greater under improved crop production (row planting, fertilizer use, pest control and timely planting) (L & WMRP, 1992). Sub-optimal and harsh crop physical environment under traditional farming severely limit crops to effectively use soil water and led to low WUE (L & WMRP, 1992). Improved WUE caused crop yields in traditional farming systems to be increased.

Sorghum generally has high WUE but crops such as maize, cowpea, groundnut and watermelon may arguably be more marketable than sorghum. For example, groundnut, peanut and maize are commonly used as snacks in Botswana and can afford farmers a reasonable income. In addition, these crops may be harvested as green vegetables and do not have to reach physiological maturity, showing that they could have a very short season depending on the intended use.

Differences of WUE and crop yields between improved (relatively higher inputs) and traditional (low-input) agriculture were dramatic (L & WMRP, 1992). Traditional crop production with low plant population density had low but stable crop yields, while more intensive and improved crop production, had relatively greater but unstable crop yields. Changing from extensive traditional methods to intensive crop production (hybrids, effective weed control measures, fertilizer application based on soil test) increased WUE. Also, combined use of tillage and fertilizer use improved WUE (FAO, 1987; ICRISAT, 1989). However, there was a need for long-term investigations of how yield and WUE could be increased without sacrificing yield stability.

Effect of Tillage on Crop Yield

A series of trials comparing different tillage systems on soil properties, water conservation and crop yields were carried out mostly in eastern Botswana (DLFRS, 1980; L & WMRP, 1992, Persaud *et al.*, 1992). Conventional mouldboard ploughing on clod-forming soil (sandy loam) produced depressions that stored rainwater that acted as micro-catchments. This was so since most of the rainfall occured in few high intensity, short duration showers interspersed by periods of high evaporative demand, high run-off leading to low effective rainfall. Any form of tillage was therefore beneficial to both run-off reduction and the improvement of the hydraulic conductivity of the soil. Mouldboard and chisel ploughing consistently outyielded shallow sweep tillage (DLFRS, 1985; Willcocks, 1981; Dregne and Willis, 1983; Lal, 1985a). Thus, mouldboard ploughing on sandy loam soils produced sorghum grain yields that were similar to chisel, and disk tillage systems, which are well known water conserving tillage systems. Crop yields under disk plough and precision strip (deep ripping) were generally similar but slightly smaller than mouldboard and chisel plough (**Tables 2, 4**).

As a follow up to DLFRS tillage research, double mouldboard, and single mouldboard and cultivate ploughing (**Table 3**) were introduced and investigated. Deep ripping (variant of precision strip tillage) with crop row width of 150 cm in contrast to the standard 75 cm was recommended for further investigation (DLFRS, 1980). Compared with deep ripping, ploughing using mouldboards and chisels significantly ($P < 0.05$) increased grain yield on 2 years out of 4 (**Table 3**). However, sorghum grain yield from

Table 2 The effect of different tillage systems on sorghum grain yield from 1976 to 1979 at Sebele (Adapted from DLFRS, 1980)

Tillage System	Depth (cm)	1976/77	1977/78	1978/79	Average
		Grain Yield (kg ha^{-1})			
Mouldboard	25	2540	1610	1920	2023
Chisel	25	2370	1750	1870	1997
Sweep	10	1740	1070	900	1237
Disk	10	2120	1230	1890	1747
Precision Strip	30	1890	1530	1970	1797
LSD(5 %)		0.26	0.34	0.44	-
Rainfall (mm)		491	447	219	386

Table 3 The effect of different tillage systems on sorghum grain yield at several sites in eastern Botswana in 1988/89 (Adapted from Persaud *et al.*, 1992)

Tillage System	Sese	Tswidi	Sebele	Mahalapye	Francistown
	Grain Yield (kg ha^{-1})				
Single Ploughing[1]	688	1381	1141	1615	782
Double Ploughing[2]	640	1539	1160	1369	1094
Deep Ripping	682	841	1240	643	778
Plough & Cultivate	590	1444	1101	1439	983
Single Ploughing & WR[3]	590	1142	1456	1306	683
Rainfall (mm)	267	329	433	272	360

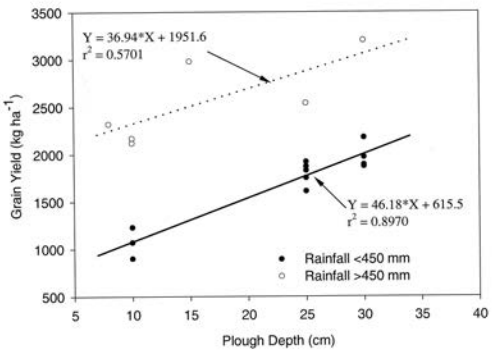
[1]Plough with mouldboard and row plant same day; [2]Post-harvest mouldboard ploughing or after first spring rains and plough again after the next significant rain and plant as in 1. [3]WR is planting on wide rows of 150 cm apart.

Table 4 Effect of tillage and surface residue on sorghum grain yield (adapted from DLRFS, 1985)

Tillage method	1976/77		1977/78		1979/80		1979/80	
	Grain Yield (kg ha^{-1})							
	−R	+R	−R	+R	−R	+R	−R	+R
MB	2.40	2.69	1.56	1.66	2.25	1.59	2.35	2.61
Chisel	2.24	2.50	1.97	1.54	1.87	1.86	2.02	2.39
Sweep	1.17	2.31	1.02	1.12	0.86	0.95	1.94	2.07
Disk	2.06	2.17	1.19	1.27	1.79	1.98	1.85	2.48
DR	1.64	2.15	1.50	1.56	1.93	2.02	2.50	2.76

-R & +R: removal and retained residues, respectively; MB: mouldboard plough and DR: deep ripping

Fig. 1 Effect of tillage depth on sorghum grain yield on luvisols at sebele between 1980 and 1985 (Adopted from DLFRS. 1985)



long-term tillage studies showed that deep ripping performed poorly compared with disk, mouldboard and sweep tillage systems (Persaud *et al.*, 1992). Weed infestation was a serious problem on deep ripped plots, particularly when rainfall was good. Since crop population density is a function of yield, lower population density and weed infestation under deep ripping were among the factors that led to lower grain yield.

The value of deep tillage (> 20 cm) in increasing crop yield was reported on sandy loam, clod-forming soils at Sebele (DLFRS, 1980; Willcocks, 1984). With the range of tillage depth evaluated, it was demonstrated that sorghum grain yield increased with tillage depth (**Fig. 1**) but varied with type of tillage system (**Tables 2, 3**). Further analysis indicated that the benefit of deep tillage increased with increasing rainfall (**Fig. 1**). The improved crop performance on deeply tilled soils tended to be more related to lower bulk density or improved root bed and soil water storage (DLFRS, 1980; DLFRS, 1985; Persaud *et al.*, 1992). Although tillage depth influenced crop performance, the type of tillage equipment used was also important and this was also true for shallow tillage. Both disk and sweep ploughs tilled the soil to a depth of 10 cm but sorghum grain yield under disk was significantly greater ($P < 0.05$) than sweep in 3 out of 4 years (DLFRS, 1980).

Generally, it is accepted that increased tillage depth increase crop yield as the soil texture becomes lighter (Baver, 1966; Gibbon *et al.*, 1974; Willcocks, 1979; Bornman *et al.*, 1989). Sub-soiling or deep tillage of clayey soils accomplishe very little benefits in terms of crop yield but if needed, it should be done when the soil is dry to ensure maximum shattering of the soil (DLFRS, 1980). Kalahari sands (regosols and arenosols) are characterised as friable, medium to coarse-textured soils. DLFRS (1980) and Persaud *et* *al*. (1992) recommended that only a shallow tillage operation is required to control weeds before planting. However, weed control using herbicides are as effective.

Tied ridges concentrate rainwater on cropped land, reduce runoff and can produce yield benefits in dry years (DLFRS, 1985c L & WMRP, 1992). Tied ridging significantly ($P < 0.05$) increased sorghum grain yield in both wet and dry seasons (**Table 1b**). Tied ridges and furrows were very effective in reducing runoff and restricting local redistribution due to micro topography (DLFRS, 1985; L & WMRP, 1992).

Fallowing allows the soil to accumulate nutrients and water reserves leading to improved yields of subsequent crops (Rowland, 1993). Whiteman (1975) showed that water conservation by fallowing improved crop yields by more than 100 %. Sorghum grain yield was significantly greater ($P < 0.05$) after bare fallow than after crop cover, weed and maize crop (Whiteman, 1975). Chemical weed control during fallow was more effective in water conservation than mechanical tillage and ridging (Whiteman, 1975).

During the May to August dry winter period, soil commonly dries out to near permanent wilting point unless there are late rains. Under these conditions, partial fallow is suitable for dryland conditions in Botswana where crop performance under double mouldboard ploughing is good (Persaud *et al*., 1992; DAR, 1996). In this system, post-harvest or early spring ploughing at first rains is done to control weeds, improves water infiltration that recharges the soil profile and soil water storage. Second ploughing and planting is conducted at the next sufficient rainfall. Once planted, the crop benefits from weed free seedbed and sufficient stored soil water often ensure good establishment (Persaud *et al*., 1992; DAR, 1996). In contrast, post harvest or early spring allowed a flush of nitrogen to occur at planting and become available to young crops. Grain yield under deep ripping and conventional tillage with wide row spacing (150 cm row spacing) were about the same (Persaud *et al*., 1991), probably because of comparable plant population density.

Although deep ripping is an ideal water harvesting technique for semi-arid Botswana, this tillage system did not perform better than tillage systems that included conventional, double ploughing, plough and cultivate, and chiselling. Chisel ploughing resulted in crop yields that were comparable to double ploughing, a tillage system recommended for crop production in Botswana. Chisel ploughing is a minimum tillage technique that disturbs the soil less and retains more crop residues on the soil surface. Conservation farming using chisel ploughing could reduce tillage costs, facilitate timely completion of tillage operations, and conserve soil and water and bio-diversity under the dryland crop production conditions in Botswana.

Maintenance of crop residues on the soil surface all year round protects the soil against soil erosion, improves water infiltration and reduces evaporation and runoff losses. Average positive increase in sorghum grain due to presence of crop residue was 31, 15, 14, 13 and 10 % for sweep, chisel, disk, deep ripping and mouldboard tillage systems, respectively (**Table 4**). Retaining crop residue on the soil surface significantly increased mean yields across tillage treatments (DLFRS, 1985). Within individual tillage treatments, grain yield increases were greatest for sweep, deep ripping, and disk tillage. Only mouldboard and chisel ploughing showed inconsistency in increasing sorghum grain yield due to presence of surface residues (**Table 4**). DLFRS (1985) reported that surface residue cover was not uniform after tillage operations and this probably caused decreased grain yield in some years.

Conclussions

The lack of good arable land coupled with low and erratic rainfall limit dryland crop production in Botswana. Research findings show that there is much scope for agricultural development and that Botswana has the capacity to produce surplus grains at economic levels. However, there is a need to use the most productive land and practise the most water efficient techniques available.

Among improved water use technologies are water harvesting and conservation (e.g., tied-ridges and surface residues), reduced tillage and surface residue management. High management inputs such as fertilization, pest control and tillage are needed to optimise the use of rainwater. Bare fallow as full or partial (double ploughing) system, has some measure of built in yield stability and has shown a great potential in Botswana.

On Kalahari sands, weed control before planting using herbicides or shallow cultivation was the only tillage required for crop production. Minimum tillage using chisels or disks improved crop yields that were similar to conventional mouldboard ploughing on sandy loamy or clod-forming soils in eastern Botswana. On these soils, crop yields increased with depth of tillage because of reduced bulk density. The use of chisel plough was the most economic because it covered a larger path and the yields were comparable to double ploughing. Surface residues suppressed evaporation and increased water infiltration.

Recommendations

Much research on promising tied-ridging and deep ploughing technologies needs to be continued both on-farm and at research stations.

The use of minimum tillage, crop residue and partial fallow combined with short season and appropriate crop management techniques would increase water use efficiency of dryland crops in Botswana.

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Accessibility Index of Indian Tractors - A Case Study

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Abstract

Tractors that are intended to be used by Indian farmers must be designed based on anthropometric data of male agricultural workers to enhance efficiency, comfort and safety of the tractor drivers. The arrangement of controls on a tractor is the crucial deciding factor for the comfort and efficiency of tractor drivers. The quantitative method of Banks and Boone (1981) to compare the alternate controls arrangement was followed to study the accessibility indices of five Indian tractors. The location of controls from the seat reference point (SRP) and their ranked frequency of use for the tractors were determined to calculate the accessibility index. The accessibility indices for the tractors were negative and ranged −0.350 to −0.025. It was observed that the control arrangements on the tractor were not within easy reach of Indian drivers. Therefore, it may be concluded that frequently operated controls on the tractors should be located in or very close to optimum reach area of the operators for better tractor workplace design.

Introduction

The basic concept in the application of human factors to the system design is the "human machine system". It can be defined as the study of human abilities and characteristics that affect the design of equipment, systems and jobs. It is an interdisciplinary activity based on human engineering, psychology and anatomy of the operator. The main aim is to improve the efficiency, comfort and safety of operators. In our day to day life we find ourselves in contact with physical facilities that have a relationship to our basic physical features and dimensions while working with machines. These facilities might be chairs, desks, work areas, controls for tractors or machines, and clothing. We know from general experience that the comfort, safety and performance of people are greatly affected by the extent that the "facilities fit" to the user. Equipment that is intended to be used by people must be designed and/or selected according to anthropometric principles if it is to function satisfactorily. Thus, it is crucial that engineers involved in the design of "people equipment" understand the use of anthropometric techniques in their design. The wide range in size and ability of humans make the designer's task challenging.

The tractor designer must consider the great variation of users and attempts should be made to accommodate a large proportion of operators. However, human beings must not only fit spatially in a man-machine-task system but also be able to move and function dynamically. It requires additional room for the operator to ingress, egress, move, turn, reach, and operate controls. Although static body dimensions are helpful for certain design purposes, dynamic and functional dimensions are more useful for most design problems. The dynamic and functional dimensions must consider the location and movement of operating controls as well as the forces to be exerted and the direction and frequency of the movements.

Anthropometric data are available as a ready reference in western countries for scientific experiments to improve the comfort and safety of the tractor operators. However, available Indian anthropometric data are not sufficient (Patel *et al*., 2000). Studies from the western countries underline the importance of ergonomic consideration for improving the safety and comfort of tractor operator. Lehmann (1958) studied the relative positioning of brake and clutch pedals, foot rest, steering column and steering wheel. Dupuis (1959) investigated the strain on the tractor operators during operation of different controls. He observed that the operator shifted the gear lever and operated the clutch pedal, brake pedals and hydraulic control lever of a front mounted loader 230, 100 and 250 times, respectively during an hour. He concluded that the efficiency and comfort of the operator could be improved with a properly designed tractor workplace. Tiwari (2001) reported that tractor drivers operated the hydraulic control lever 224 times, shifted gears and operated the clutch pedal 210 times and operated brake pedal 100 times in an hour during ploughing operation. Yadav (1995) reported mean frequencies of 72, 148, 230 and 436 for operation of clutch pedal, brake pedals, draft control lever and viewing backward, respectively, by the tractor drivers over a period of one hour.

Liljedahl *et al*. (1959) studied the forces required to steer wheel type farm tractors. Matthew and Knight (1971) suggested that the vertical distance of the pedal should vary with the type of task and should not be more than 400 mm. McCormick (1976) recommended the design feature of vehicle cabs. Matthews (1977) suggested that better control design required less physical effort to operate the controls. A survey in Bedfordshire was conducted by Barber (1978) to determine the correlation between the characteristics of the tractor seat/workplace and operator subjective opinions. Whyte and Barber (1985) investigated the nature of tractor driving and postural changes required for agricultural operations. Gite and Yadav (1989) collected anthropometric data of agricultural workers from Central India and suggested the use of data for farm machinery design on the basis of 5th, 50th and 95th percentile values of workers. Arude and Tiwari (1999) studied control locations in popular Indian tractor models and tractor operator activities while performing ploughing operations. Mehta *et al*. (2003) reported that horizontal and vertical leg reach of the operators in a tractor seat are interrelated and specified the limits for location of tractor control pedals.

In India, about 13 leading tractor manufacturers sell around 260,000 tractors per year. The size, shape and location of controls on these tractors vary based on hp of the tractor and research input of individual tractor manufacturers. However, the tractors are operated by Indian agricultural workers. The scientific information about the accessibility of controls on these tractors by Indian operators based on anthropometric consideration is meager. A good tractor design requires that important controls are easily accessible to operators. The designer must consider the great variation in anthropometric parameters of users and their attempt should be such that it can accommodate large proportion of operators. Therefore, the quantitative method given by Banks and Boone (1981) to compare the alternate controls arrangement on automobiles was followed to study the accessibility index of some of Indian tractors.

Theoretical Considerations

Accessibility index (Banks and Boone, 1981) is a function of the correlation between distance from operators to controls and ranked frequency of use of controls during operation of the tractor. This index considers three important factors:

The convenience of reaching the control as determined by the reach envelope for a particular size person.

The frequency of use from a subjective evaluation on the part of the users.

The relative position to the operator so that controls used most frequently should be closer to the operator.

The Accessibility index can be calculated by the equations given below.

$$r = \frac{N\sum XY - \left(\sum X\right)\left(\sum Y\right)}{\sqrt{\left[N\sum X^2 - \left(\sum X\right)^2\right]\left[N\sum Y^2 - \left(\sum Y\right)^2\right]}} \quad \text{.......}(1)$$

$$I = r - \sum^{S}\left[\frac{\sum^{n}\hat{f}}{\sum^{N} f}\right] \div S \quad \text{................................}(2)$$

where,

I = Accessibility index,

r = (Pearson) co-relation between distance from the operator to control(X) and the ranked frequency of use (Y),

n = number of controls outside the reach envelope,

N = total number of controls,

f = rank of each control within the envelope,

$\hat{f}$ = rank of each control outside the envelope, and

s = number of operators used to collect the data.

The accessibility index ranges between −2 and +1. The closer the index approaches +1, the better the control arrangement on the tractor is within the reach of the drivers.

Materials and Methods

The five most popular Indian tractors of different makes, models and sizes; viz T_1 (45 kW), T_2 (56 kW), T_3 (26 kW), T_4 (34 kW) and T_5 (26 kW), were randomly selected for determination of accessibility indices. The location of controls on the tractors from the operator was determined with respect to seat reference point (SRP). Seat reference point (SRP) is defined as the point in the central longitudinal plane of seat where the tangential plane of the lower back-rest and horizontal plane intersect (IS 11806, 1986). The Seat index point (SIP), as per ISO 5353 (1984), is the intersection on the central vertical longitudinal plane passing through the seat central line of the pivot axis between the human torso and thigh. The SRP was located at the seat using the SRP device. The SIP location was determined at 140 mm forward and 90 mm above to the SRP. After locating the SRP and SIP, the distance of controls, viz hydraulic control lever, brake pedals, clutch pedal, foot accelerator pedal, steering wheel, hand accelerator lever, gear shifting lever, differential lock pedal, PTO lever, and start/stop knob/switch, were measured using a 3 D digitiser (**Fig. 1**).

Fig. 1 Measurement of three dimensional coordinates of clutch pedal on the tractor (T_3)

To find the frequency of use of different controls, a subjective evaluation on the part of users was required. Based on studies conducted by Dupuis (1959), Yadav (1995) and Tiwari (2001), the ranked frequency of use of the hydraulic control lever, brake pedals, clutch pedal, foot accelerator pedal, steering wheel, hand accelerator lever, gear shifting lever, differential lock pedal, PTO lever and start/stop knob/switch were 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10, respectively, and the same rankings were used for the study. The rankings were given based on frequency of operation of these controls. The hydraulic control lever on Indian tractors is used most frequently during implement operation by tractor operators. Hence, its frequency of use was ranked one. Similarly, the ranked frequency of use of the start/stop button was 10, as it was used the least during the tractor operation.

The number of controls either outside (n) or inside the reach envelope were decided by subjective evaluation of tractor controls by the operators. Reach envelope denoted the closed area where operators can work or move without stretching their body parts.

Table 1 Horizontal distances of controls from the SRP and ranked frequency of use of different tractors

Controls	Ranked fre-quency of use (Y)	Horizontal distances of controls on tractors from SRP (X), mm				
		T_1	T_2	T_3	T_4	T_5
Hydraulic levers	1	300	360	340	370	320
Brake pedals	2	900	860	920	845	720
Clutch pedal	3	850	850	910	840	650
Foot accelerator pedal	4	850	840	890	-	-
Steering wheel	5	600	740	700	660	640
Hand accelerator lever	6	680	670	690	790	800
Gear shifting lever	7	420	900	830	550	410
Differential lock pedal	8	600	660	700	910	760
PTO lever	9	300	660	560	470	390
Start/Stop switch / knob	10	650	650	700	750	615

Results and Discussion

Control arrangement on a tractor governs the degree of operators fatigue and his safety during operation on different terrains. Accessibility index reflects the overall workplace of tractors for Indian operators. **Table 1** shows the horizontal distances of controls on the tractors from SRP and ranked frequency of use of these controls. The Pearson correlation (r) for the selected tractors were determined based on distance from the operator to control (X) and the ranked frequency of use (Y) using **Eqn. 1**. The calculated Pearson correlation coefficients were 0.29, 0.042, 0.053, 0.072 and 0.0055 for tractor models, viz. T_1, T_2, T_3, T_4 and T_5, respectively. The accessibility indices (I) for the tractors were calculated using **Eqn. 2** and were −0.15, −0.33, −0.35, −0.025 and −0.33 for the tractors T_1, T_2, T_3, T_4 and T_5, respectively. Accessibility indices were negative for the selected tractors. This might be due to the fact that the tractors met the BIS requirements for control location, which was based on ISO standard.

Accessibility indices were −0.33, −0.35 and −0.33 for the tractor models T_2, T_3, and T_5, respectively. The higher negative values of accessibility indices showed poor control arrangements on the tractors. This indicated that most of the controls (lower ranked frequency) on these tractors were not within the reach envelope and were not easy to reach by drivers. Hence, the drivers were not comfortable in operating controls on these tractors. They must move forward or bend sideways to operate the controls. The calculated accessibility indices for the tractors T_1 and T_4 were −0.15 and −0.025, respectively. As the accessibility index for the tractor T_4 approached zero, it indicated that the arrangement of controls on the tractor was comparatively better suited to the selected drivers. Hence, most of the controls on this tractor lie within the reach of the operators. The calculated accessibility index for the tractor T_3 was minimum (−0.35), i.e. maximum value towards the negative side of the index. It highlighted that important frequently operated controls on the tractors were not within easy reach of the operators. Although the tractors T_2 and T_3 had enough space for the movements of the operators, but most of control arrangements were not within the reach envelope. Similar results were obtained for tractor T_5.

Accessibility indices of the selected tractors ranged from −0.025 to −0.35 and it may be concluded that control arrangement on these tractors were not comfortable for Indian drivers. This may be because most the Indian tractor manufacturers opted the design parameter from the guidelines provided by ISO standard, which was adopted by the BIS due to lack of anthropometric data of Indian operators. Therefore, it may be concluded that frequently operated controls on tractors should be located in or very close to optimum reach area of the operator for the best design. Controls located outside this area will be more difficult to operate. The controls should not be located outside the maximum reach area unless their frequency of use was very low. It was also observed that the range of dimensions presented in the Indian standard was very large. Therefore, it is required to refine the BIS standard based on anthropometric data of Indian agricultural workers. It was also felt that tractor manufacturers should also provide adjustment in controls locations.

Conclusions

The following conclusions may be drawn from the study.

- There was wide variation in control arrangement on different makes and models of Indian tractors.
- The accessibility index is an objective method to quantify the control arrangements on a tractor with respect to the operator.
- The accessibility indices for the selected Indian tractors were negative and ranged from −0.35 to −0.025. This indicated that control arrangements on the tractor were not within easy reach of Indian operators.
- The frequently operated controls on the tractors should be located in or very close to optimum reach area of the operator for better tractor workplace design.

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Sleeve Boom Sprayer - II : Performance Evaluation of a Tractor Mounted Sleeve Boom Sprayer for Cotton

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Abstract

Efforts have been made to design and develop a sleeve boom sprayer for cotton which could be operated with a 30-35 hp tractor. The blower performance of the sleeve boom sprayer was evaluated for different blower speeds, viz. 1,841 rpm, 2,035 rpm, 2,133 rpm and 2,362 rpm, for five stagger angles, viz. 8º, 16º, 24º, 32º, and 36º with an impeller of cambered, tapered and flat undersurface made from two different materials, FRP and aluminium. The sleeve performance was evaluated for different sleeve angles, viz. −15º, 0º, 15º and 30º and for nozzle angles of 25º, 35º and 45º.

Air velocity and power consumption of the developed blower had a linear and quadratic relationship, respectively, with the blower speed. The droplet density increased with increase in air sleeve angle, either in the positive or negative direction to zero degrees air sleeve angle. Better values of VMD were obtained with 30º sleeve angle and 35º nozzle angle. The maximum mean droplet densities at almost all positions within the plants were with a nozzle angle 35º.

These performance parameters fulfilled the requirements for spraying of cotton. The sleeve boom sprayer performed satisfactorily at a blower speed of 2,133 rpm with cambered type blades set at 36º when the sleeve was set at an angle of 30º and the nozzle at an angle of 35º.

Introduction

A significant factor, with increased use of pesticides, is that high efficiency must be maintained during application in order to use only the minimum amount of pesticide for adequate control and minimum contamination to the environment. Many types of application equipment are available that have the ability to store, meter, atomize and distribute pesticides with more accurate deposition for the control of targeted pests. Considerable effort has been made in recent years to develop a spraying system, mainly through modifications of air stream configuration, to reduce the loss (Pergher *et al.*, 1977). Air assisted spraying has received a lot of attention due to the claim of high drift reduction, improved canopy penetration to the lower side of the leaves, faster application rate and quick, easy pest

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control (Anonymous, 1997). The sprayers were also modified by providing an adjustable air outlet to direct the spray to converge onto the canopy. Such configuration reduced the drift loss from 15 to 50 percent and improved deposition efficiency (Furness and Pinczewski, 1985). In India, very few research studies have been made on air sleeve boom spraying system on orchards. In field crops like cotton, due to vegetative growth, the adjacent plants get intermingled with each other, which resist the penetration of spray deep into canopy and, on the lower side of the leaves, when sprayed with a conventional boom sprayer. Thus, the total pest on plants can not be controlled, resulting in poor productivity. Hence, a sleeve boom spraying system was developed and evaluated.

Materials and Methods

Test Set-up for Laboratory Tests

A wind tunnel was designed and fabricated following AMCA (1987) standards for testing the blower. The blower was run at four speeds; 1,841 rpm, 2,035 rpm, 2,133 rpm and 2,362 rpm. In the test set-up, speed of the blower was dependent upon gear ratio. Hence a uniform speed interval could not be obtained. In order to get different air velocities, the blade stagger angles were varied. To decide these levels, an initial test was conducted with a impeller. The stagger angle was increased from 0º to 40º at 10º intervals and air velocity and discharge were measured. These values were increased up to 30º and decreased afterwards. Hence, stagger angles of 8º, 16º, 24º, 32º, and 36º were selected. Initially blades were fixed to the impeller at 8º. Similar procedures were adopted for the tests with the remaining blades, speeds and stagger angles. The laboratory experiments were conducted to study sleeve performance with different air sleeve angles and nozzle angles for droplet density and droplet size on different plant positions. Sleeve angles of −15º, 0º, 15º and 30º; and nozzle angles of 25º, 35º and 45º were used. A false floor arrangement was fabricated from 2 mm thick M.S. sheet with an arrangement to place the cotton plants at a recommended spacing of 900 mm in a single line. The spraying height was 80 cm. To facilitate the evaluation of spray penetration into the canopy of cotton plants, glossy papers were stapled onto the leaf in different plant locations, i.e. top position, upper leaf surface (TU); top position, lower leaf surface (TL); middle position, upper leaf surface (MU); middle position, lower surface (ML); bottom position, upper leaf surface (BU) and bottom position, lower leaf surface (BL). Royal blue indigo dye was mixed with water to prepare coloured spray solution. The tractor was operated at 1.5 km/h for spraying in the laboratory. The glossy papers were taken for further analysis using a droplet image analyzer.

The field test of sleeve boom sprayer was conducted on NH-44 cotton variety planted at 90 cm × 90 cm spacing in the field. The plot size was 75 m × 15 m. The average plant height, spread diameter and leaf density 90 days after planting were 90 cm, 85 cm and 380 leaves per plant, respectively. The sleeve boom sprayer used for this field experiment is shown in **Fig. 1**. While operating the blower with the sleeve boom sprayer in the field, two taper shaped PVC sleeves of 5 m length were fixed on two outlets of the blower. The tractor was operated length wise at 1.5 km/h forward speed (average) along the wind direction in the morning hours to take care of drift. Coloured dye was used for spraying. The spray droplets were collected on glossy papers placed at various positions in the plants on both sides of leaves. The analysis was done using a droplet image analyzer.

Fig. 1 The sleeve boom sprayer

Results and Discussion

Performance Evaluation of Blower of Sleeve Boom Sprayer

The blower was operated at four different speeds, five blade stagger angles and with six types of blades in the laboratory and its performance was studied for air velocity at the blower outlet and power consumption of blower.

Effect of Blower Speed on Air Velocity and Power Consumption of Blower

Analysis of variance revealed that the blower speed had a significant effect on air velocity and power consumption. **Fig. 2a** shows the relationship of blower speed with air velocity. The slope of the curves shows that the air velocity increased linearly with the increase in blower speed from 1841 to 2362 rpm within tested range of impeller blade types and stagger angles. Dhande (1991), Jaiswal (1996) and Das (1997) reported similar findings for an air-assisted orchard sprayer. A maximum air velocity of 35.75 m/s was obtained at 2,362 rpm, which was followed by 35.51 m/s at the same speed of 2,362 rpm. Higher air velocities were reported at 2,362 rpm as compared to other tested speeds. The data were analyzed to develop a relationship between air velocity and impeller speed. The relationship was found to be linear (**Fig. 2a**) and expressed as:

$V = a + bN$................................(1)

where

V = air velocity, m/s;

N = impeller speed, rpm; and

a and b are the regression coefficients.

Fig. 2b shows the relationship of blower speed with input power. The slope of the curves shows that the input power increased with the increase in blower speed from 1,841 to 2,362 rpm within tested range. This might be because as the blower speed increased; the incoming air pressure on the blade surface might have increased, resulting in an increase in power consumption of the blower. Khade (1991), Jaiswal (1996) and Das (1997) reported similar findings for an orchard sprayer. The data were analyzed to develop a relationship between input power and impeller speed. The relationship was quadratic (**Fig. 2b**) and expressed as:

$P_{in} = a + b\,N + b_1 N^2$...............(2)

where

P_{in} = input power, kW;

N = impeller speed, rpm; and

Fig. 2 Effect of Impleller Speed on (a)Air Velocity (b) Power Input to Blower

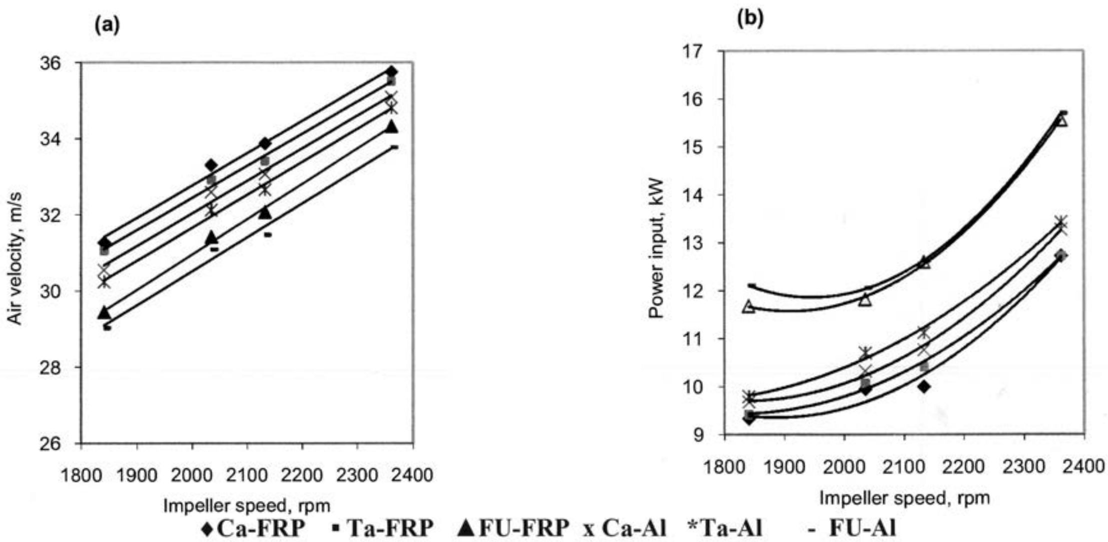


Table 1 Regression coefficients for relationship of blower speed with air velocity and input power at blower speed 2,133 rpm

Impeller type	Regression coefficients		R^2	Computed-F
	a	b × 10^{-2}		
Air velocity				
Ca-FRP	8.15	69.59**	0.98	239.96**
Ta-FRP	8.14	68.34**	0.98	279.24**
FU-FRP	7.45	66.26**	0.99	372.70**
Ca-Al	8.28	66.88**	0.98	282.11**
Ta-Al	7.67	67.40**	0.99	293.36**
FU-Al	7.34	64.52**	0.98	266.07**
Input power				
Ca-FRP	6.22	1.39**	0.95	57.62**
Ta-FRP	6.22	1.46**	0.95	59.83**
FU-FRP	5.88	1.99**	0.96	83.16**
Ca-Al	6.16	1.56**	0.96	83.92**
Ta-Al	6.10	1.65**	0.97	97.48**
FU-Al	5.94	2.00**	0.96	92.80**

** Significant at 1% level, Regression coefficients are tested on t-values a, b and b1 are the regression coefficients.

The power consumption for the required air velocity and air discharge generating impeller (Ca-FRP) was 10.00 kW at a blower speed of 2,133 rpm and at 36º blade stager angle, which was within the limit of available power for operating the sleeve boom sprayer (11 kW). A regression coefficient for air velocity and power consumption is given in **Table 1**.

Effect of Impeller Blade Type on Air Velocity and Power Consumption of Blower

The performance of the blower was evaluated in a wind tunnel using different types of impeller blades, viz. Ca-FRP, Ta-FRP, FU-FRP, Ca-Al, Ta-Al and FU-Al. Analysis of variance indicated that the impeller type had a significant effect on air velocity and power consumption of blower. The maximum air velocity of 35.75 m/s was obtained with the impeller with Ca-FRP blade which was followed by 35.51 m/s by Ta-FRP impeller, followed by 35.10 m/s by Ca-Al impeller. These higher values were obtained at maximum operating speed of blower (2,362 rpm) and blade stagger angle of 36º.

The power consumption of the blower with the impeller of Ca-FRP blades was comparatively lower than the other impellers. It increased with blower speed. The higher power input values were reported at blower speeds of 2,362 rpm. The power consumption of the blower corresponding to the required air velocity of 2,362 rpm was beyond the power availability of tractor (11 kW). Hence, the next operating speed of 2,133 rpm was selected, which produced the required air velocity at blade stagger angle of 36º. The power consumption of blower (10 kW) with the impeller of Ca-FRP blades at 36º stagger angle and at blower speed

Fig. 3 Comparative air velocity and power input of blower with different impellers

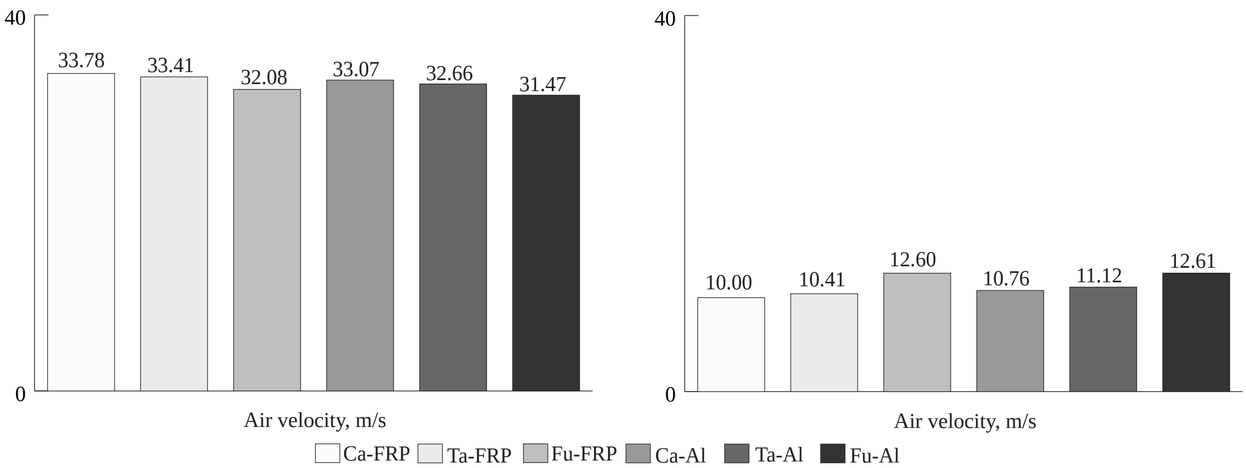
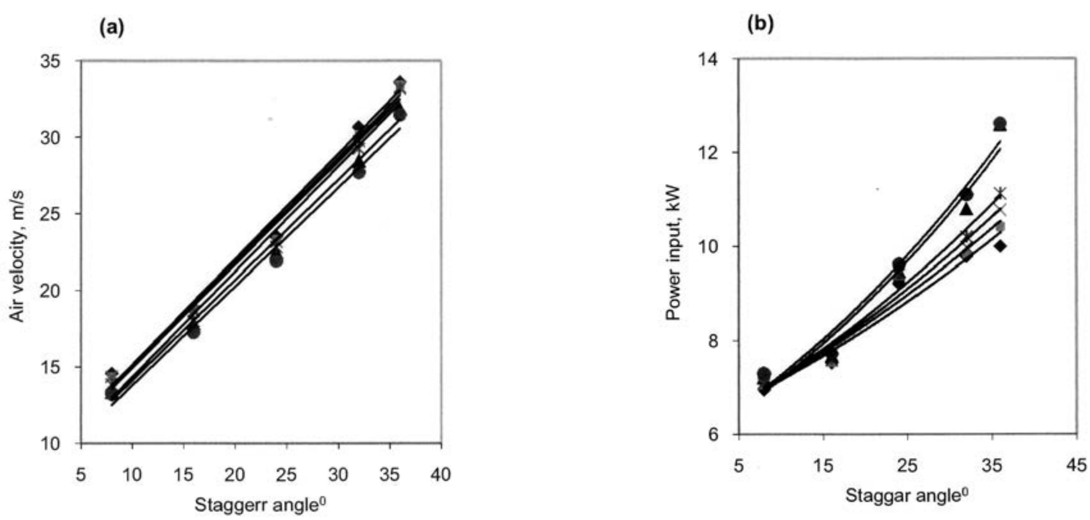


Fig. 4 Effect of blade stagger angle on (a)air velocity (b)power input to blower



of 2,133 rpm was 4.1 percent lower than Ta-FRP impeller (10.41 kW), which was followed by 10.76 kW by the Ca-Al impeller. The comparative performance of all the impellers at these parameters is shown in **Fig. 3**. It was concluded that the blower should be operated at blower speed of 2,133 rpm, stagger angle of 36º with Ca-FRP impeller.

Effect of Blade Stagger Angle on Air Velocity and Power Consumption of Blower

The impeller blades were set at predetermined stagger angle levels ranging from 8º to 36º and air velocity and power consumption of the blower were measured. Analysis of variance showed that the stagger angle had a significant effect on air velocity and power consumption. The effect of stagger angle on air velocity has been plotted in **Fig. 4a**. It indicates that air velocity increased with the increase in stagger angle. As the stagger angle increased more incoming air velocity at the inlet might increase the air velocity at blower the outlet. Das (1997) reported similar findings for an orchard sprayer. A maximum air velocity of 35.75 m/s obtained at 36º by impeller with Ca-FRP blade at 2,362 rpm speed, which was followed by 35.51 m/s at 36º stagger angle with Ta-FRP blade at blower speed of 2,362 rpm. Higher air velocities were obtained by the impeller set at 36o stagger angle within the tested range. **Fig. 4a** shows the linear trend of air velocity with stagger angle and may be expressed as:

$$V = a + b\zeta \qquad (3)$$

where

V = air velocity, m/s;
ζ = stagger angle, degree; and
a and b are the regression coefficients.

The power input increased with increase in stagger angle (**Fig. 4b**). At higher stagger angles, increase in incoming air pressure might have increased the resistance offered by blade surface. This might have increased the power consumption of blower. An increase in power consumption of orchard sprayer with stagger angle was also reported by Das (1997). The minimum power consumption was obtained at 8º stagger angle (6.97 kW) with a maximum (11.58 kW) at 36º stagger angle at a blower speed of 1,841 and 2,362 rpm, respectively. Considering the power limitations, the next operating blower speed selected was 2,133 rpm, stagger angle of 36º, and

Table 2 Regression coefficients for relationship of blower speed with air velocity and input power at 36º stagger angle

Impeller type	Regression coefficients		R^2	Computed-F
	a	b × 10^{-2}		
Air velocity				
Ca-FRP	11.02	0.0092*	1.00	6,592.94*
Ta-FRP	10.18	0.0094*	1.00	4,211.09*
FU-FRP	7.93	0.0096*	0.99	2,181.89*
Ca-Al	9.88	0.0093*	1.00	13,984.3*
Ta-Al	8.71	0.0097*	0.99	1,079.95*
FU-Al	5.34	0.0105*	0.99	2,669.72*
Input power				
Ca-FRP	-322.05*	0.56*	0.99	322.92*
Ta-FRP	-358.04*	0.57*	0.99	2,102.41*
FU-FRP	-256.79*	0.49*	0.99	573.04*
Ca-Al	-365.31*	0.56*	0.99	1,402.68*
Ta-Al	-366.96*	0.56*	0.99	404.86*
FU-Al	-307.58*	0.51*	0.99	905.40*

** Significant at 5% level, Regression coefficients are tested on t-values

Table 3 Model summary and regression coefficients for combined effect of blower speed,stagger angle and impeller on air velocity

Impeller type	Regression coefficients							Regression constant	Computed-F
	x	y	x_2	$x_3 \times 10^{-4}$	$x_4 \times 10^{-8}$	$x_5 \times 10^{-4}$	$x_2 \times 10^{-8}$		
Ca-FRP	0	0	0	1.56*	0	0.039*	0	11.27	1,741.72**
Ta-FRP	0.004*	0	0.009*	1.29*	0	0	0	2.47	3,342.16**
FU-FRP	0.004*	0	0.007*	1.54*	0	0	0	2.03	4,356.42*
Ca-Al	0	0	0	−3.29*	−0.638	0.18*	21.06*	11.63	4,596.89**
Ta-Al	0.001*	0	0	1.25*	−0.119*	0.076*	0	4.79	3,059.16**
FU-Al	0	(−0.26)*	0	0	−0.464*	0.143*	11.06*	10.72	3445.47*

** Significant at 1 percent level * Significant at 5 percent level the type of impeller as Ca-FRP.

The effect of stagger angle on input power is shown in Figure 4b An exponential trend was found as shown below:

$P_{in} = ae^{b\zeta}$ ....(4)

where

P in = Input power of blower, kW;

ζ = stagger angle, degree; and

a and b are the regression coefficients.

A regression analysis was performed and the regression coefficient for air velocity and power consumption for stagger angle is given in **Table 2**.

Combined Effect of Blower Speed, Stagger Angle, and Impeller Type on Air Velocity and Power Input

Multiple stepwise regression analysis was performed to develop a combined relationship among the air velocity, blower speed and stagger angle for all types of impellers. The equation of the following form was obtained:

$V = C + N(x) + \zeta(y) + \zeta^2 (x_2) + N\zeta(x_3) + N^2\zeta^2(x_4) + N\zeta^2(x_5) + N^2 \zeta(x_6)$ ....(5)

where

V = Air velocity, m/s;

N = Impeller speed, rpm;

ζ = Stagger angle, degree;

C = Constant; and

x, y, x_1, x_2, x_3, x_4, x_5 and x_6 are regression coefficients.

The model summary and the regression coefficients for the above are presented in **Table 3**.

The equation shown below was obtained for the combined effect of blower speed and stagger angle for all types of impellers on the input power of the blower (P_{in}).

$P_{in} = C + N^2 (x_1) + \zeta(y)$ ....(6)

The model summary and the regression coefficients for above are presented in **Table 4**. The higher values of R^2 (**Fig. 5**) between the calculated and observed air velocity and input power showed that **Eqns. 5** and **6** fit the air velocity and input power within the tested range of blower speed and stagger angles and impeller type.

Performance Evaluation of Sleeve Boom Spraying System

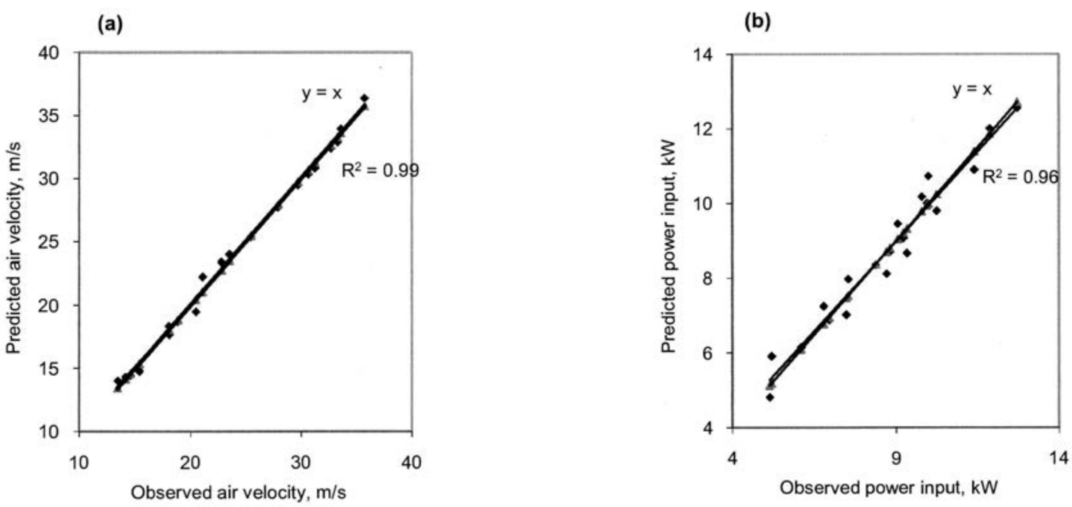
The developed sleeve boom was operated at four different sleeve angles and four nozzle angles in the laboratory and its performance was studied for droplet density and droplet diameter (VMD) obtained at various locations in cotton plants.

Table 4 Model summary and regression coefficients for combined effect of blower speed, stagger angle and impeller on input power of blower

Impeller type	Regression coefficients		Regression constant	R^2	Computed-F
	$x_1 \times 10^{-8}$	y			
Ca-FRP	177.67**	0.138**	−2.31	0.96	196.94*
Ta-FRP	179.81**	0.140**	−2.33	0.96	210.76*
FU-FRP	186.37**	0.189**	−3.01	0.92	91.30*
Ca-Al	179.36**	0.144**	−2.25	0.96	225.33*
Ta-Al	182.37*	0.149**	−2.37	0.96	201.48*
FU-Al	185.03**	0.194**	−2.97	0.91	84.22*

** Significant at 1 percent level * Significant at 5 percent level

Fig. 5 Correlation between observed and predicted (a) air velocity (b) power input



Effect of Sleeve Angle on Droplet Density and Droplet Diameter (VMD)

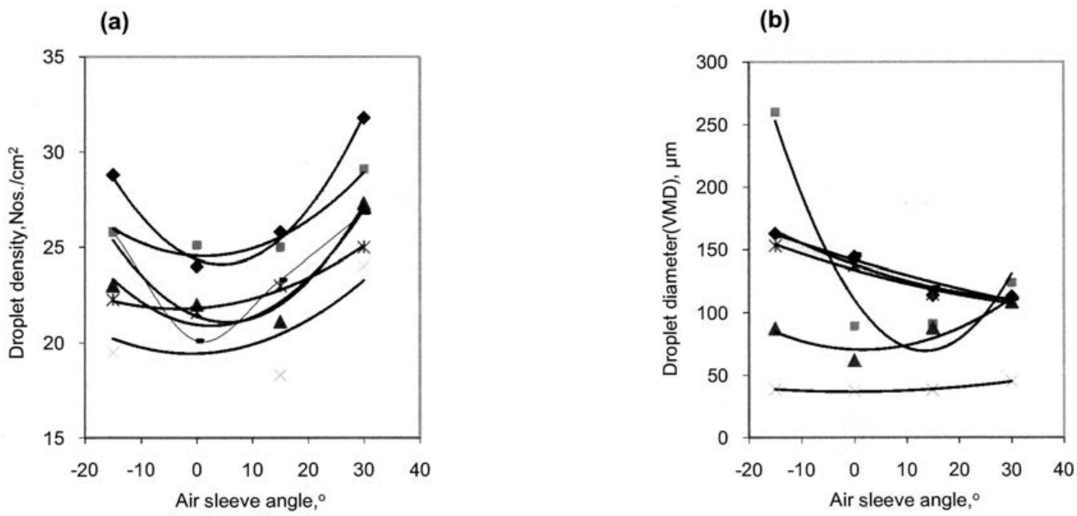
The sleeve was set at different angles (−15º, 0º 15º and 30º). Its effect on droplet density and droplet diameter was studied. The droplet density and droplet diameter at different sleeve angles are plotted in **Fig. 6**. The trend of the curve (**Fig. 6a**) showed that the droplet density increased with increase in air sleeve angle either in the positive or negative direction to zero degrees air sleeve angle. This trend was found similar in almost all positions of the plant. The maximum droplet density obtained through the plant canopy on the upper leaf surface on the target plant was at 30º air sleeve angle and minimum mean droplet density was observed with an air sleeve angle of 0º. Air velocity acting vertically downward (0º) showed lower deposition as compared to other sleeve angles. The reason behind this phenomenon was that plant leaves offered more resistance to spray laden air to penetrate deep into canopy when air was entering vertically downward. The results showed that, due to an air sleeve angle of 30º, the number of droplets deposited at the top position upper and lower surface, middle upper (MU) and bottom position upper leaf surface was within the range of droplets recommended for effective control of pests.

The trend in **Fig. 6b** shows that the droplet diameter (VMD) increased with increase in sleeve angle from 30º to −15º for upper leaf surface for top, middle and bottom position of plant. It increased with increase in air sleeve angle either in positive or negative direction to 0º air sleeve angle for lower leaf surface for different plant positions. The maximum VMD was observed due to the position of air sleeve set at −15º angle at top leaf surfaces and minimum VMD was observed at 0º sleeve angle at lower leaf surface. The values of VMD were observed as an effect of air sleeve angle of 30º at top position at upper and lower leaf surfaces, middle upper surface of plant and bottom position at upper and lower leaf surface were very close to opening size of stomata on leaf (100 micron). The lower leaf surfaces at middle position had attained the lowest deposition. This might be due to vigorous entrainment of air with spray thoroughly resulting in disintegration of the droplets. The higher impact of attacking air in the inclined direction and reflected air from ground sur-

Table 5 Data on field evaluation of tractor mounted sleeve boom sprayer

Plant position	Leaf surface	Droplet density, No./cm^2	Droplet size, µm VMD	Volume ml/cm^2	Deposition index
Top	Upper	26.52	120.1	2.30×10^{-5}	1.81
Top	Lower	22.88	123.0	2.22×10^{-5}	1.67
Middle	Upper	21.10	107.4	1.30×10^{-5}	1.05
Middle	Lower	12.4	75.8	2.60×10^{-5}	0.2
Bottom	Upper	21.2	114.2	1.44×10^{-5}	1.22
Bottom	Lower	14.2	88.8	5.55×10^{-5}	1.43

Fig. 6 Effect of air sleeve angle on (a)droplet density (b) droplet diameter



face toward plants might have resulted into more deposition at upper and lower plant positions compared with the middle one. Therefore, the sleeve angle of 30º was selected for field evaluation of the sprayer.

Effect of Nozzle Angle on Droplet Density and Droplet Diameter (VMD)

The nozzle angle was set at 25º, 35º and 45º and the effect on deposition of droplets at six different plant positions was studied. The effect of three different nozzle angles on droplet density at different plant position is shown in **Fig. 7a**. The maximum droplet density was deposited at top position of the plant and upper leaf surface as an effect of nozzle angle 35º. It was also observed that droplet density increased with increase in nozzle angle from 25º to 35º and decreased with further increase in nozzle angle from 35º to 45º. The maximum mean droplet densities at almost all positions were observed with nozzle angle 35º.

Fig. 7b shows that the droplet diameter (VMD) observed as an effect of nozzle angle set at 25º was very close to the size of stomata opening on the leaf. The values were significantly lower than the value of VMD obtained as an effect of a 35º nozzle angle at the upper surface of the leaf, i.e. top, middle, and bottom position and at the lower leaf surface for the bottom position. The droplet diameter (VMD) was increased on the upper leaf surface at the top, middle and, bottom position. However, it increased initially and further increase of nozzle angle resulted in a decrease of droplet diameter on the lower leaf surfaces. The higher value of VMD observed on the lower leaf surfaces was due to an effect of the 35º nozzle angle and at upper leaf surfaces due to an effect of nozzle angle of 45º. The lower leaf surfaces at the middle position had the lowest deposition. The higher impact of attacking air in the inclined direction and reflected air from the ground surface toward the plant might have resulted into more deposition at the top and bottom plant position compared with middle one.

However, there was a significant difference in the value of VMD at four locations of the plant as discussed above, the value of the VMD as an effect of the 35º nozzle angle was close to the opening size of the stomata on the leaf as compared to the value of VMD obtained as an effect of nozzle angle set at 45º. However, droplet density observed at nozzle angle 35º was within the range of the recommended values. Therefore, the nozzle angle of 35º was selected for field evaluation of the sprayer.

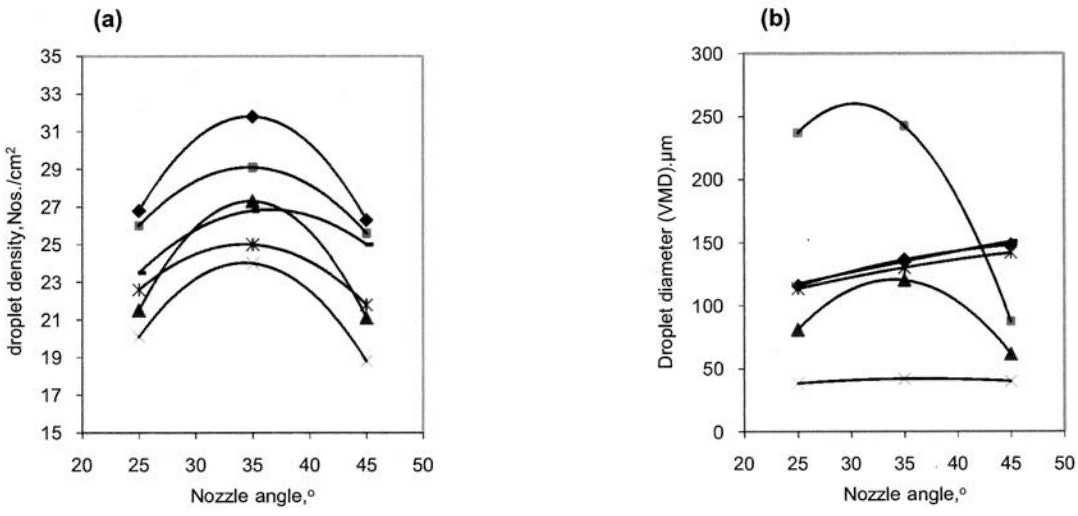
Field Performance of Sleeve Boom Spraying System

The newly developed blower with tractor mounted sleeve boom sprayer was tested in a cotton field (variety NH-44). Its performance was evaluated with an impeller with Ca-FRP blades set at 36º stagger angle and at blower speed of 2,133 rpm. The results obtained on droplet density, droplet size, deposition of spray volume and deposition index are presented in **Table 5**.

The highest droplet density was obtained on the top position of the plant, which was followed by the middle position and bottom position (**Table 5**). The droplet density on the upper and lower leaf surface at the top position of the plant and the upper leaf surface on the middle and bottom position was within the range. The data also revealed that the VMD on top position at the lower and upper leaf surface and also at the upper leaf surface on the middle and bottom position of the plant were within the limit.

The deposition index value indicated that the maximum values were on the top position of the plant at the upper leaf surface followed by lower

Fig. 7 Effect of nozzle angle on (a)droplet density (b) droplet diameter



leaf surface and lower leaf surface at the bottom position. However, these were slightly higher except at the upper leaf surface on the middle and bottom positions of plants.

Conclusions

It can be concluded that the air velocity of the developed sleeve boom sprayer increased with increase in blower speed linearly. A quadratic relationship was observed between input power and blower speed. The blower with impeller of Ca-FRP type consumed relatively less power (10 kW) at 2,133 rpm. The developed sleeve boom sprayer exhibited better deposition efficiency with the impeller of Ca-FRP blades set at 36º stagger angle, operated at 2,133 rpm blower speed by setting the sleeve at an angle of 30º and nozzle angle of 35º. During the field trial, the droplet density and volume mean diameter indicated that the newly developed sprayer performed satisfactorily in the field when operated with a medium sized tractor.

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Influence of Crop and Machine Parameters on Conveying Efficiency and Inclination of Maize Stalks in an Experimental Fodder Harvester

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Abstract

An experimental fodder harvester was developed for investigating the effects of inclination of the conveyor, number of conveyor belts, conveyor belt speed and crop height on conveying efficiency and inclination of stalk during the process of conveying maize stalk. The harvester consisted of a main frame, trolley assembly with crop holder, drive for trolley, supporting frame, fodder harvesting mechanism and power transmission system. The investigation was carried out with three levels of inclination of conveyor, viz. 0, 10 and 20º, three levels of conveyor belts, viz. 2, 3 and 4, three levels of conveyor belt speed viz., 1.5, 1.62 and 1.75 ms^{-1} and three levels of crop height, viz. 1.5, 2.0 and 2.5 m. The selected levels of variables were optimized for achieving the maximum conveying efficiency with minimum inclination of stalk for conveying.

Introduction

The performance of a fodder harvester is assumed to be optimum when the cut stalks are conveyed in a vertical position until discharged at the outer end into the windrow perpendicular to the direction of motion as well as the energy requirement to cut the crop stalks (Pandey, 1998; Devnani, 1998 and Prasad, 1998). The efficiency of the cutting unit is usually expressed in terms of conveying efficiency and deflection of the crop with respect to the vertical plane during the conveying process (O'Dogherty and Gale, 1986; O'Dogherty and Gale, 1991). In this paper, the effect of inclination of the conveyor, number of conveyor belts, conveyor belt speed and height of crop on conveying efficiency and inclination of the stalk during the process of conveying maize and sorghum stalk in the experimental fodder harvester is assessed.

Review of Literature

Inclination of the conveyer is an important factor that affects the conveying efficiency of the crop (Rangasamy, 1981). The cut plants must be transferred in a vertical position until discharged at outer end into windrow at a right angle to the direction of motion. The plants are conveyed in a vertical position. Also gathering and collecting of standing crops toward the machine is achieved without the panicle coming into contact with moving parts of the machine, which, in turn, minimize the shattering losses (Prasad, 1998; Devnani, 1998; and Pandey, 1998). For best cutting and minimum uncut area left in the field after the cutting operation, the ratio of cutter bar speed and the forward speed of the machine must lie between 1.2 to 1.4 (Das, 1998). The speed ratio of 1.026 between Vs cos? (where, Vs is peripheral velocity of conveyor or star wheel and ? is angle of inclination of star wheel) and forward speed of machine is recommended for the proper operation (Das, 1998 and Pandey, 1998).

Methods and Materials

The performance of the harvester was expressed in terms of conveying efficiency and inclination of stalk with respect to the vertical plane during the conveying process of the crop. The lifting and gathering mechanism consisted of a row crop divider fitted with a lugged 'V' belt, pressure spring and the star wheel. The star wheels for each row were driven by the lugs attached to the conveyor belt, thus, guiding the crop to the cutter bar. The quality of conveying and windrowing of cut stalk was highly influenced by the speed of the conveyor belt, number of conveyor belts and height of the crop. Also, higher velocity of conveyor belts resulted in higher shattering losses. Hence, the inclination of conveyor, number of conveyor belts, conveyor belt speed and height of crop were identified as pertinent machine, crop and operational variables for investigation with symbols as indicated below.

1 Inclination of conveyor (θ)
2 Number of conveyor belts (N)
3 Conveyor belt speed (V)
4 Height of crop (H)

The levels of variables selected for conveying sorghum using the experimental fodder harvester are furnished below.

An experimental fodder harvester was developed for investigating the influence of crop and machine parameters on conveying efficiency and deflection of the crop (**Fig. 1**). The experimental setup consisted of a main frame, trolley assembly with crop holder, drive for trolley, supporting frame, fodder harvesting mechanism and power transmission system.

Evaluational Parameters

The efficiency of a fodder harvester is usually expressed in terms of the force and energy required for cutting, efficiency of the conveyor and orientation of the stem. The performance of the fodder harvester is assumed to be optimum for the combination of selected variables, which results in minimum cutting force, minimum cutting energy and the maximum conveying efficiency.

The conveying efficiency of the experimental fodder harvester was computed based on the following expression.

$$E_c = \frac{N_o}{N_i} \times 100 \quad \text{...........................} (1)$$

where

E_c = Conveying efficiency, percent

N_i = Number of stalks fed to experimental fodder harvester

N_o = Number of stalks conveyed and windrowed

The inclination of the stalk was the angle between the stalk and the imaginary vertical line during the process of conveying along the conveyor board. To measure the inclination of the stalk for investigation of the orientation of the stalk to the conveyor board during the process of conveying, vertical lines were marked on the conveyor board at intervals of 200 mm from the one end of the cutter bar. The inclination of stalks was recorded using a digital video camera. From the video clip, the frame was captured when the stem crossed each vertical line marked over the conveyor board with help of POWER DVD software. The captured picture was exported to AUTOCAD 2002 software for measuring the angle between the stalk and each line marked over the conveyor board as shown in **Fig. 2**. From the measured inclination of the stalk, the orientation of the stem during the process of conveying was represented with a schematic diagram as shown in **Fig. 3**.

A. Machine Parameters	
I. Inclination of Conveyor	**3 levels**
1. Inclination angle (0º)	(θ_1)
2. Inclination angle (10º)	(θ_2)
3. Inclination angle (20º)	(θ_3)
II. Number of Conveyer belts	**3 levels**
1. Two	(N_1)
2. Three	(N_2)
3. Four	(N_3)
B. Operational Parameters	
I. Conveyor belt speed	**3 levels**
The following three levels of conveyor belt speed were calculated from the optimized cutter bar speed of 2.0 ms^{-1}	
1. 1.50 ms^{-1}	(V_1)
2. 1.62 ms^{-1}	(V_2)
3. 1.75 ms^{-1}	(V_3)
II. Height of the Crop	**3 levels**
1. 1.5m	(H_1)
2. 2.0 m	(H_2)
3. 2.5 m	(H_3)
Replications	3
Total number of treatments = θ × N × V × H × R = 3 × 3 × 3 × 3 × 3 = 243	

Results and Discussion

A total of 243 randomly replicated experiments were conducted using the experimental fodder harvester with selected levels of variables. The conveying efficiency and the inclination of the stalk were recorded for all treatments. The effect of selected levels of variables on the evaluation parameters were analyzed and presented below.

Effect of Inclination of the Conveyor on Conveying Efficiency for a Maize Stalk 1.5 m High (H_1)

The effect of inclination of the conveyor on conveying efficiency of the experimental fodder harvester is shown in **Fig. 4**. The increase in inclination of the conveyor from 0º (θ_1) to 10º (θ_2) had negligible effect on conveying efficiency at all selected levels of conveyor belt speed. Further increase in inclination to 20º (θ_3) reduced the conveying efficiency irrespective of number of conveyor belts. The effect of conveyor belt speed on conveying efficiency was insignificant at all selected levels of inclination of conveyor and number of conveyor belts. The increase in number of conveyor belts from 2 (N_1) to 4 (N_3) improved the conveying efficiency at all selected levels of conveyor belt speed and inclination of conveyor. In general, 10º (θ_2) inclination of

Fig. 1 Experimental fodder harvester

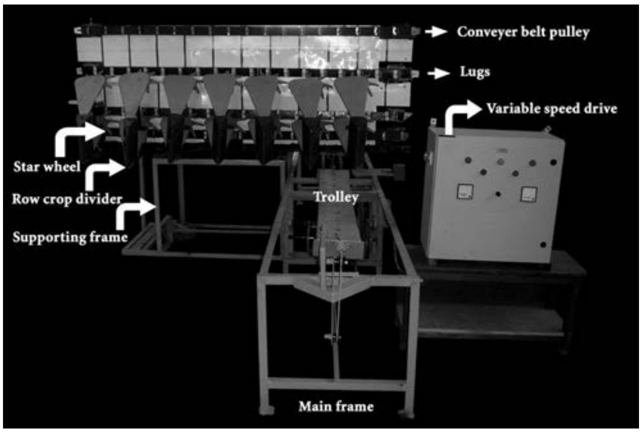


Fig. 2 View of a picture exported to AUTOCAD 2002 software for measuring the angle between the crop stalk and each line marked over the conveyor board

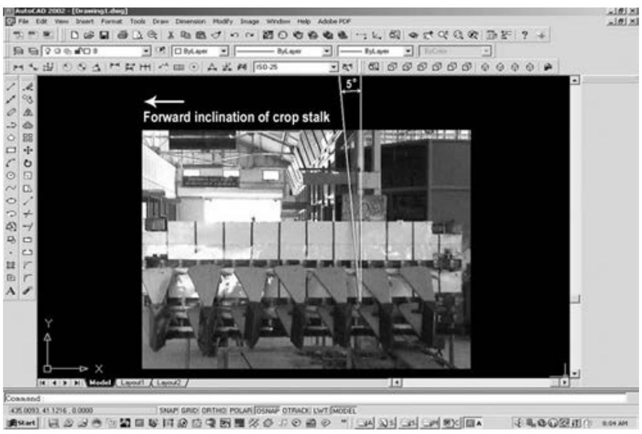


Fig. 3 Inclination of the stalk during the conveying process

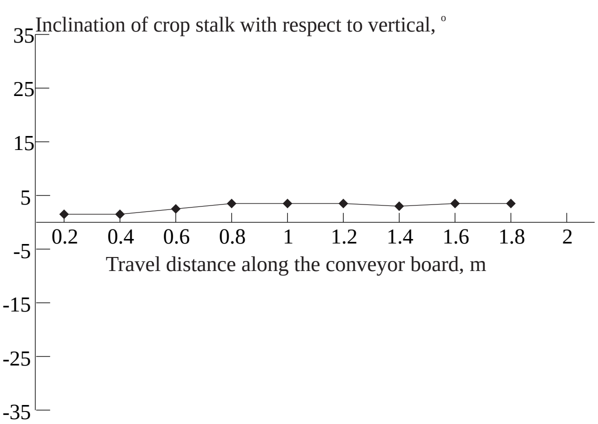
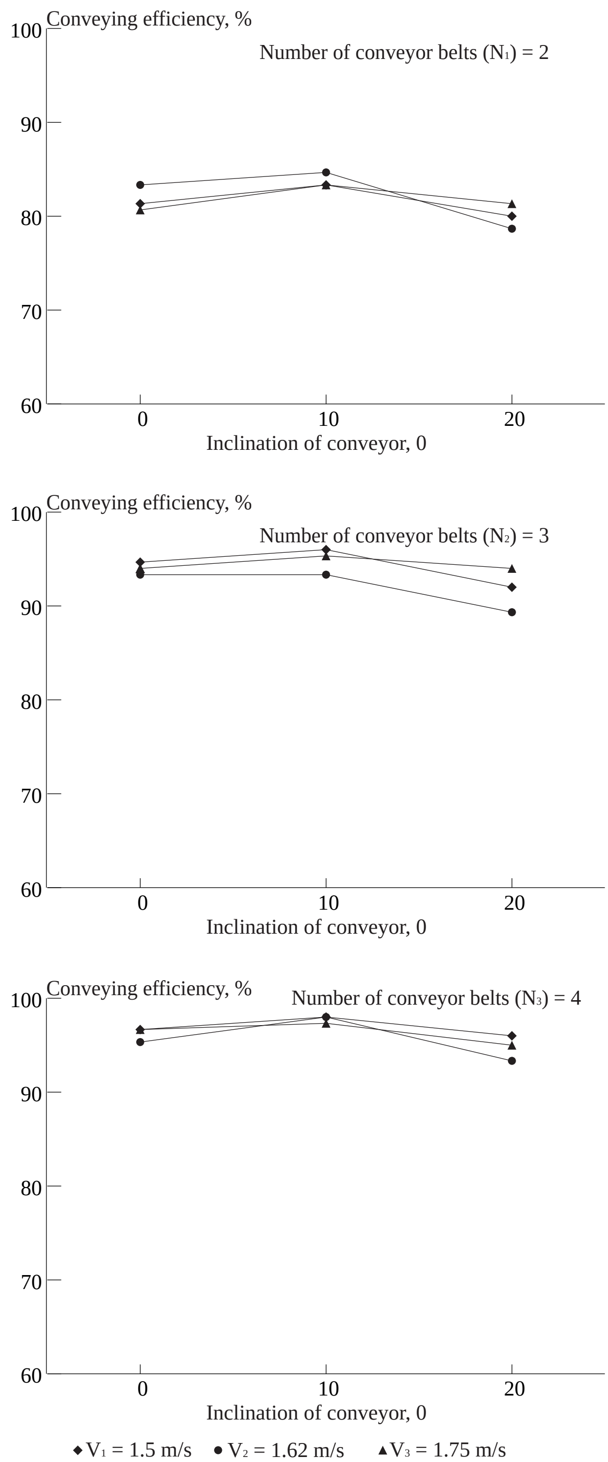


Fig. 4 Effect of inclination of conveyor on conveying efficiency at selected levels of conveyor belt speed and number of conveyor belts for 1.5 m high maize stalks (H_1)



conveyor recorded maximum conveying efficiency irrespective of conveyor belt speed and number of conveyor belts. Increase in conveyor belt speed had no effect on conveying efficiency. Increase in number of conveyor belts from 2 (N_1) to 4 (N_3) resulted in 17.6, 15.7 and 16.8 percent increase in conveying efficiency at 1.5, 1.62 and 1.75 ms^{-1} conveyor belt speed, respectively, for 10º (θ_2) inclination of conveyor. The maximum conveying efficiency of 98.0 percent was registered at 10º (θ_2) inclination of the conveyor and

Fig. 5 Effect of inclination of conveyor on conveying efficiency at selected levels of conveyor belt speed and number of conveyor belts for 2 m high maize stalks (H_2)

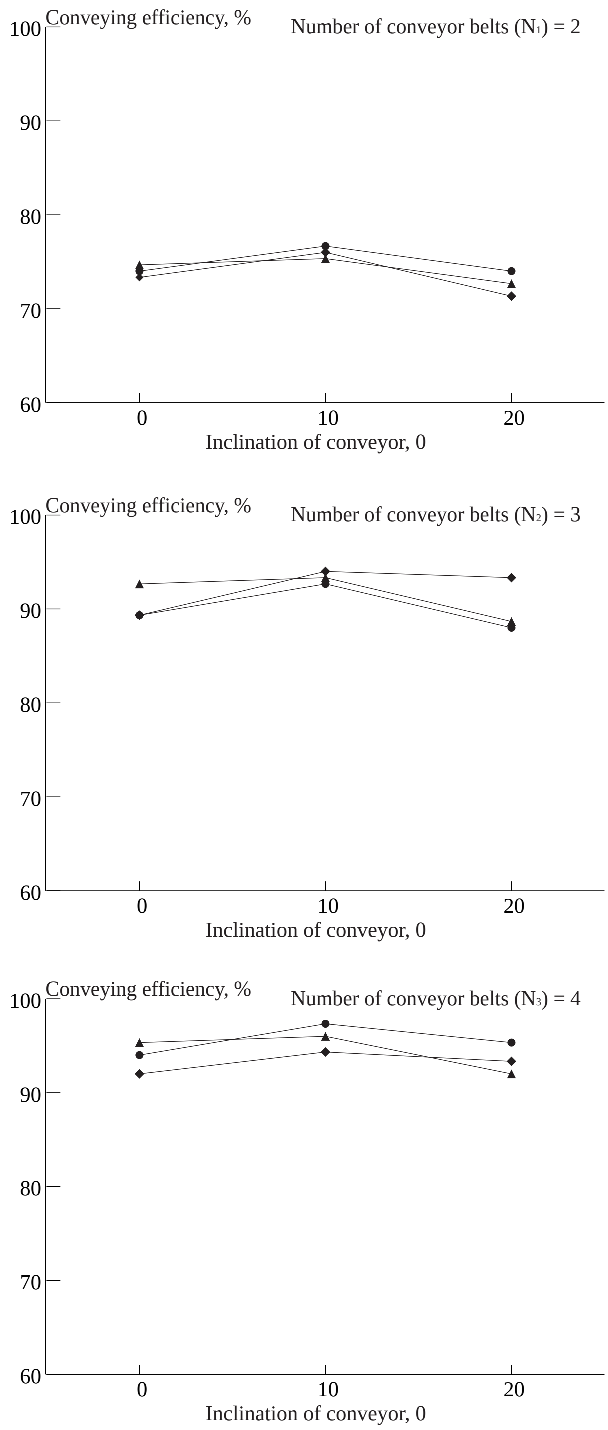
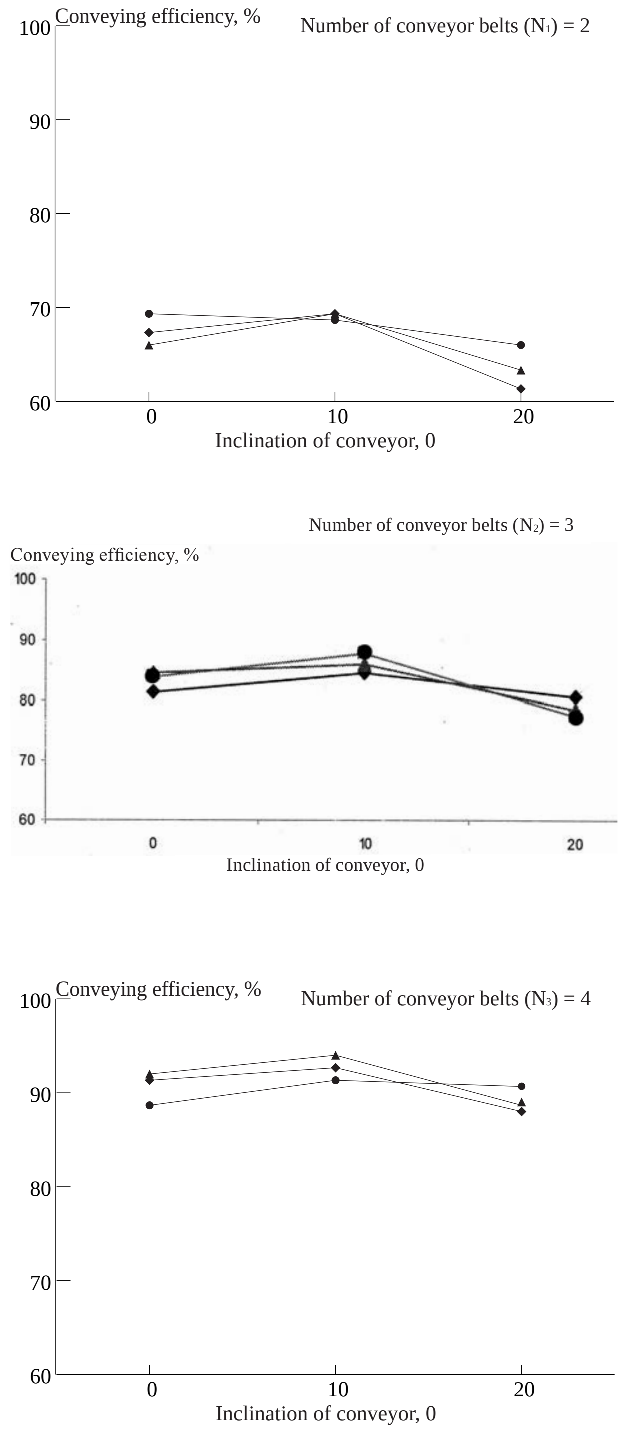


Fig. 6 Effect of inclination of conveyor on conveying efficiency at selected levels of conveyor belt speed and number of conveyor belts for 2.5 m high maize stalks (H_3)



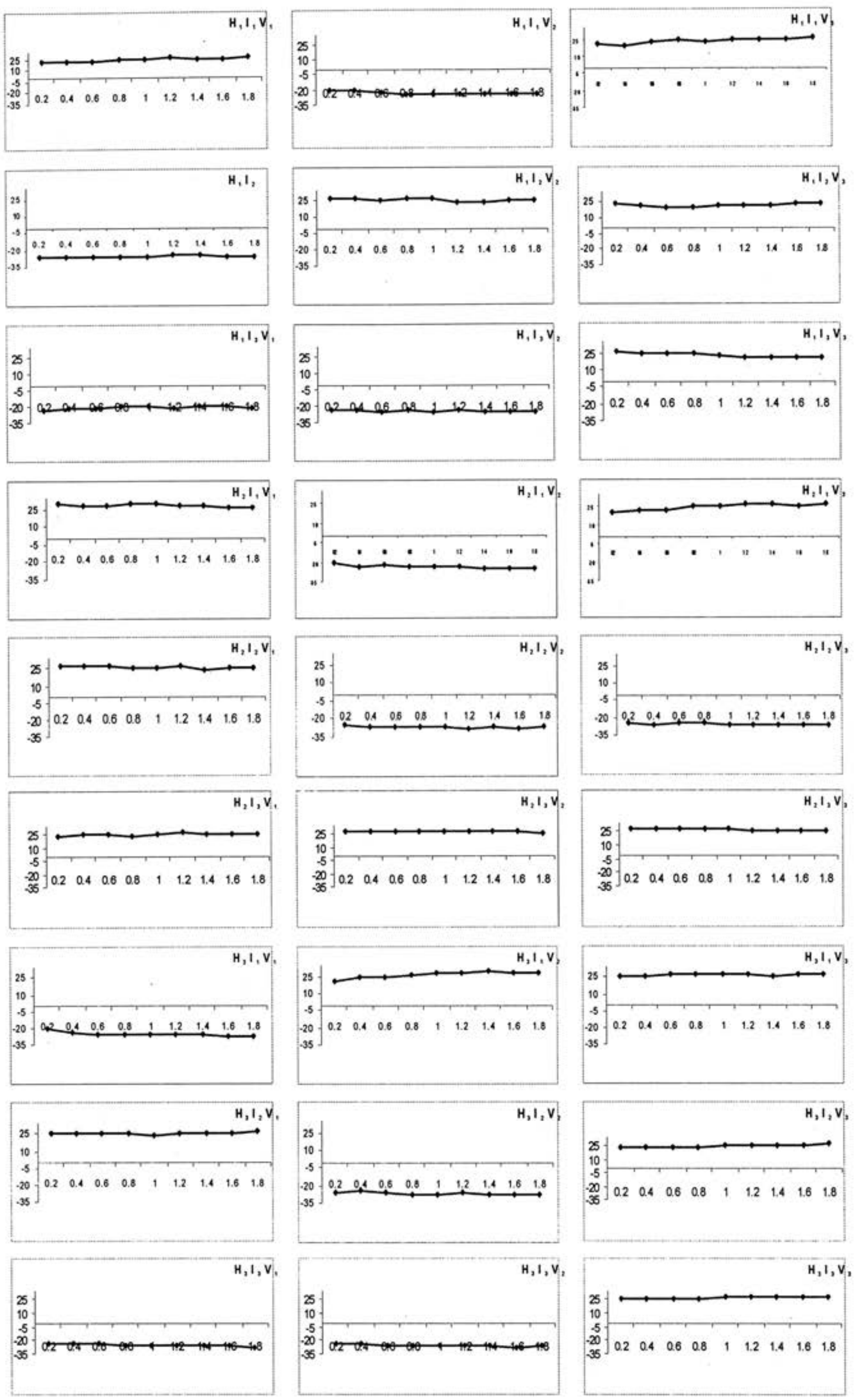
◆ V_1 = 1.5 m/s ● V_2 = 1.62 m/s ▲ V_3 = 1.75 m/s

1.62 ms^{-1} (V_2) conveyor belt speed with 4 (N_3) conveyor belts.

Effect of Inclination of Conveyor on Conveying Efficiency for Maize Stalk 2.0 m High (H_2)

The relationship between conveying efficiency and inclination of conveyor is shown in **Fig. 5**. A similar trend as that of 1.5 m (H_1) high crop was exhibited. The maximum conveying efficiency was 10º (θ_2) inclination of conveyor at all selected levels of conveyor belt speed. Effect of conveyor belt speed was negligible on conveying efficiency. Increase in number of conveyor belts from 2 (N_1) to 4 (N_3) resulted in 24.1, 27.0 and 27.4 percent increase in conveying efficiency at 1.5, 1.62 and 1.75 ms^{-1} conveyor belt speed, respectively, for 10º (θ_2) inclination of conveyor. The maximum value of conveying efficiency was observed as 97.33 percent with the combination of 1.62 ms^{-1} (V_2) conveyor belt speed, 10º (θ_2) inclination of conveyor and 4 (N_3) conveyor belts.

Fig. 7 Inclination of maize stalks along the conveyor board for two conveyor belts (B1)



Effect of Inclination of Conveyor on Conveying Efficiency for Maize Stalk 2.5 m High (H_3)

The relationship between conveying efficiency and inclination of conveyor is shown in **Fig. 6**. A similar trend as that of 1.5 (H_1) and 2.0 m (H_2) high crop was exhibited. The maximum conveying eff+iciency was 10º (θ_2) inclination of conveyor at all selected levels of conveyor belt speed. Increase in conveyor belt speed had no significant effect on conveying efficiency. Increase in number of conveyor belts from 2 (N_1) to 4 (N_3) appreciably increased the conveying efficiency by 33.7, 33.0 and 35.6 percent at 1.5 (V_1), 1.62 (V_2) and 1.75 ms^{-1} (V_3) conveyor belt speed, respectively, for 10º (θ_2) inclination of conveyor. The maximum value of conveying efficiency of 92.67 percent was registered at 10º (θ_2) inclination of the conveyor and 1.5 ms^{-1} (V_1) conveyor belt speed with 4 (N_3) conveyor belts. Comparing **Figs. 4, 5** and **6**, it was inferred that increase in height of crop from 1.5 to 2.0 m resulted in reduction of conveying efficiency at selected levels of inclination of conveyor, conveyor belt speed and number of conveyor belts.

Statistical analysis of the data was

performed to assess the significance of the variables viz., number of conveyor belts (N), inclination of conveyor (θ), conveyor belt speed (V) and height of crop (H) on conveying efficiency for maize stalk. There was a significant difference among the treatments. The individual effect of the variables viz., number of conveyor belts (N), inclination of conveyor (θ) and height of crop (H) were significant at the 1 percent level of probability. Individual effect of conveyor belt speed (V) was not significant. The order of significance for the treatment effect was highest for number of conveyor belts and height of crop (H) on conveying efficiency for maize crop.

Inclination of Stalk

The influence of the selected variables on inclination of stalk during the conveying process along the conveyor board was analyzed and presented below. The inclination of stalk, as it traveled across the conveyor board, did not systematically change with respect to the distance of travel.

The initial orientation at the starting point was almost maintained through out the travel. This might have been because there was no change in the relative position of the flight of lugs that held the cut stalks during conveying. Also, there was no jumping of stalks once they were held in a particular set of lugs. However, the average inclination of stalks changed with selected levels of variables examined under this investigation. A sample graph showing variation in inclination of maize stalks 1.5 (H_1), 2.0 (H_2) and 2.5 m (H_3) high at selected levels of conveyor belt speed and inclination of conveyor with two conveyor belts (N_1) is shown in **Fig. 7**. The inclination was either in a positive (forward) or negative (backward) direction with respect to the direction of conveying. The point of interest was to investigate the average inclination irrespective of direction and hence the data on inclination of maize and sorghum stalks were normalized by taking the root of squared values and these values were used for analyzing the influence of all selected variables on inclination of stalk during the conveying process.

Conclusion

The maximum conveying efficiency was registered for 10º inclination of conveyor for the selected levels of conveyor belt speed. Increase in conveyor belt speed from 1.5 to 1.75 ms1 had no significant effect on conveying efficiency. For 10º inclination of conveyor, increase in number of conveyor belts from 2 to 4 increased the conveying efficiency by 33.0 to 35.6 percent for the selected levels of conveyor belt speed. Increase in height of crop from 1.5 to 2.0 m resulted in reduction of conveying efficiency for the selected levels of inclination of conveyor, conveyor belt speed and number of conveyor belts. The statistical analysis revealed that the order of significance was the highest for number of conveyor belts followed by height of crop, inclination of conveyor and conveyor belt speed on inclination of maize and sorghum stalk. The maximum conveying efficiency of 94.0 percent and minimum inclination of 2.44º for combination levels of 10º inclination of the conveyor, 2.5 m height of crop, 1.5 ms^{-1} conveyor belt speed and four conveyor belts was optimized.

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A Hand-Operated Rotary Type Cleaner-Cum-Grader for Black Pepper and Cardamom

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Abstract

A rotary sieve type cleaner-cum-grader was developed and evaluated for black pepper and cardamom. This unit is suitable for removing impurities from the dried black pepper and cardamom and grading them into three grades. The grader was evaluated with black pepper and cardamom at different speeds, viz., 15, 25 and 35 rpm at 12-14 % (w.b.) moisture content. The samples from feed and various outlets were manually analyzed and the effectiveness of the grader unit was estimated. The capacity of the unit was 200 and 150 kg/h of black pepper and cardamom, respectively with grading effectiveness of 0.88 and 0.89. The sieves on the rotor of the unit could be changed according to the variety and grade specifications, and could also be made suitable for other crops by changing the sieves. The cost of the unit is approximately Rs.10,000/- and the cost of operation per quintal is Rs.40 and 30, for pepper and cardamom, respectively.

Introduction

Black pepper (Piper nigrum) and cardamom (Elettaria cardamom), popularly known as king and queen of spices, are native to evergreen rainforests of Western Ghat forests regions in India. India is the largest producer, consumer and exporter of both black pepper and cardamom. Besides India, pepper is produced in Vietnam, Indonesia, Brazil, Malaysia and Sri Lanka. Kerala alone contributes about 90 and 60 % of the country's production of pepper and cardamom, respectively. Apart from Kerala, pepper and cardamom are also cultivated in the beautiful hill districts of Karnataka and Tamil Nadu. In Kerala, pepper is mostly grown as one of the component crops under high-density multispecies cropping systems in the homesteads. Both these important spices, essentially crops of humid tropics, require heavy and well-distributed rainfall and high temperature for good growth.

Pepper becomes ready to harvest in about 6-8 months after flowering. Well matured but unripe berries are harvested by climbing on the Erythrina and silver oak trees to the height of 9-11 m, on which the pepper vines are trained. The green pepper berries after threshing are dried, mostly by sun drying in the plantation on cement floors. It takes about four days to dry the green pepper to a final moisture content of 8-10 % from the initial moisture content of about 70 % (w.b.). Car-

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damom capsules are harvested at appropriate maturity and dried in traditional kilns. In the conventional kiln, cardamom capsules are dried for 24 to 36 hours to get the final product (Pruti, 1993).

The dried pepper is cleaned to get rid of extraneous matter such as dirt, dust, stones, stalks, leaves, etc. The ungarbled black pepper contains pinheads, immature pepper and large berries. Broken pepper and light pepper grades are separated pneumatically; pin heads that are associated with garbled pepper are separated by sieving. The market value can be increased by the removal of unwanted foreign material. A magnetic separator is used to remove metallic contamination such as iron fillings and stray nails. Vibratory conveyors with inclined decks, in combination with air classification, are used for efficient destoning of spices (Ramanathan and Rao, 1974). The manual separation of the black pepper is time consuming and inefficient. Also, the method of separation using vibratory or reciprocating screens and aspirators are difficult since the dried pepper is of low weight.

Cleaning of cardamom by removing the discoloured and split capsules, along with other impurities, is done manually. The grading of dried capsules as per AGMARK specifications (grades specified by the Agricultural Marketing Department, Government of India) using round sieves is done generally. Mostly 7 mm round holed sieves are used for grading. Two types of sieve arrangements are used for grading of cardamom at the plantation level. Fixed bed sieves of this size are mounted on a frame and the cardamom to be graded is placed and agitated manually. In another model, the whole arrangement of sieves of this size that holding the cardamom to be graded is made to hang with a rope arrangement and manually reciprocated. By these methods, it is only possible to collect the underflow and over flow from the sieve. At the plantation level, it is necessary to remove both smaller and larger impurities including broken berries and capsules along with size grading according to AGMARK specifications to get higher returns. The grades of pepper and cardamom based on the AGMARK size grade specifications are given in **Table 1**.

To achieve grading of pepper and cardamom into three grades and separation of impurities, a rotary

Table 1 Grade specifications for black pepper and cardamom

Grade specification	Size, mm
Black pepper	
Tellichery Garbled Black pepper Special Extra Bold (TGSEB)	4.75
Tellichery Garbled Extra Bold (TGEB)	4.25
Tellichery Garbled (TG)	4
Malabar Garbled Black pepper (MG)	3.75
Malabar Ungarbled Black pepper (MUG)	< 3.75
Cardamom	
Mixed Extra Bold (MEB)	7
Mixed Bold (MB)	6
Mixed Superior (MS)	5
Mixed Shipment 1 (MS 1)	4
Mixed Shipment 2 (MS)	4
Mixed Light (ML)	3.5

Fig. 1 Hand operated rotary cleaner-cum-grader. For black pepper

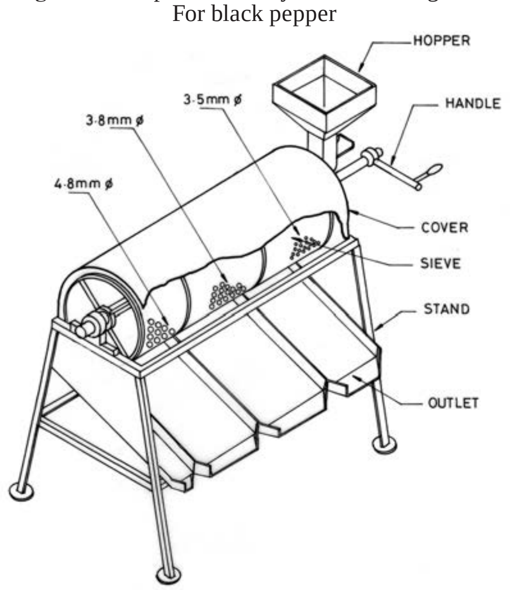
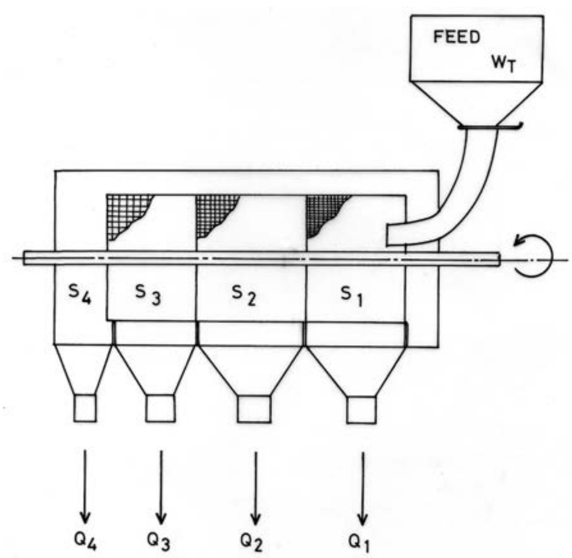


Fig. 2 Schematics of the cleaner-cum-grader



screen cleaner-cum-grader has been developed and evaluated, in this reported study.

Materials and Methods

Construction and Operation

A hand operated rotary type cleaner-cum-grader developed by Viswanathan *et al*. (1994) for grading sesame was modified and evaluated for cleaning and grading of pepper by Heartwin Amaladas *et al.* (2004). The same unit was modified and evaluated in this study for cleaning and grading pepper and cardamom. The unit, as shown in **Fig. 1**, is consisted of a rotor 1.35 m long and 400 mm diameter. The rotor was divided into three 450 mm segments with provision to place any sieves. A screw was provided inside the rotor for easy conveying of the feed materials to the sieve perforations. At the centre of the rotor, a shaft was provided to mount the rotor on two bearings and rotate with a handle. A feed hopper to hold about 15 kg of pepper or 25 kg of cardamom was placed at the feed inlet with appropriate side slopes for easy feeding into the sieves. Four inclined outlets were provided for the collection of impurities and cleaned products. A semi-circular cover was provided above the sieve assembly to avoid spilling of the material when the sieve assembly was rotated.

The unit had three round sieves, 3.5 mm, 3.8 mm and 4.8 mm diameters, which are the sieves required by the AGMARK specifications for the grades, 2, 1 and bold, respectively. For grading cardamom into three additional grades, viz., extra bold, bold and superior, sieves with round holes of 5.0, 6.0 and 7.0 mm were used.

Cleaning and Grading Efficiency

The cleaner-cum-grader cleaned and graded the dried pepper into 4 fractions as pinheads, grade-I (cleaned), grade-2 (cleaned) and grade-3 (cleaned). According to Chang (1986), let W_T be the total mass of the feed to be cleaned and graded, and W_1, W_2, W_3 and W_4 be the masses of the individual fractions of the feed material corresponding to the sieve sizes S_1, S_2, S_3 and S_4 used in the unit.

After cleaning and grading, the fraction of the feed material obtained through the product outlets may be Q_1, Q_2, Q_3 and Q_4 (**Fig. 2**).

Hence,

$$W_1 + W_2 + W_3 + W_4 = W_T \quad (1)$$

$$Q_1 + Q_2 + Q_3 + Q_4 = W_T \quad (2)$$

Let q_1 be the mass of fraction of the material other than the required size available in the fraction Q_1. Similarly q_2, q_3 and q_4 are the fractions available in Q_2, Q_3 and Q_4.

Hence, the purity of the product obtained at different outlets after cleaning and grading is:

$$P_1 = \frac{Q_1 - q_1}{Q_1} \quad (3)$$

$$P_2 = \frac{Q_2 - q_2}{Q_2} \quad (4)$$

$$P_3 = \frac{Q_3 - q_3}{Q_3} \quad (5)$$

and

$$P_4 = \frac{Q_4 - q_4}{Q_4} \quad (6)$$

The fraction yield, ratio of material in the fraction to the initial mixture, obtained through the outlets were:

$$Fr_1 = \frac{Q_1}{W_T} \quad (7)$$

$$Fr_2 = \frac{Q_2}{W_T} \quad (8)$$

$$Fr_3 = \frac{Q_3}{W_T} \quad (9)$$

and

$$Fr_4 = \frac{Q_4}{W_T} \quad (10)$$

Let a_1, a_2, a_3 and a_4 be the fractions of each size corresponding to the sieves S_1, S_2, S_3 and S_4 in the total feed as:

$$a_1 = \frac{W_1}{W_T} \quad (11)$$

$$a_2 = \frac{W_2}{W_T} \quad (12)$$

$$a_3 = \frac{W_3}{W_T} \quad (13)$$

and

$$a_4 = \frac{W_4}{W_T} \quad (14)$$

Therefore, the degree of extraction, ratio of component in the yield fraction of the same component in the initial mixture were:

$$Ex_1 = \frac{Q_1 - q_1}{W_1} = p_1 = \frac{Q_1}{W_1}$$

$$= p_1 \frac{Q_1/W_T}{W_1/W_T} = p_1 \frac{Fr_1}{a_1} \quad (15)$$

Similarly,

$$Ex_2 = p_2 \frac{Fr_2}{a_2} \quad (16)$$

$$Ex_3 = p_3 \frac{Fr_3}{a_3} \quad (17)$$

$$Ex_4 = p_4 \frac{Fr_4}{a_4} \quad (18)$$

The overall effectiveness for the n-component mixture into n-fractions (Chang, 1986 & Visvanathan *et al*., 1994) was evaluated by the completeness of the extraction of each component in a pure form as:

$$E = \sum_{i=1}^{N} Fr_i \left(\frac{p_i - a_i}{1 - a_i}\right) \quad (19)$$

Based on the **Eqns. 1** to **18**, for the system of 4 component mixtures into 4 fractions, the effectiveness of separation was calculated from **Eqn. 19**.

Evaluation

The grader was evaluated with dry pepper at a moisture content of 8-10 % (w.b.) in a plantation in Yercaud, Salem District, Tamil Nadu, India. The same unit with sieves changed according to the grade specifications for cardamom was evaluated at Cardamom Research Station, Kerala Agricultural University, Pampadumpara, Kerala, India. During the evaluation trials, the rotor was rotated at different speeds, viz., 15.25 and 35 rpm. The samples from feed and discharge from various outlets were manually analysed using hand sieves. The hand sieves were made of the same sieves, S_1,

S_2, S_3 and S_4, used in the grader. The various factors required for the estimation of the effectiveness of the grader were calculated from the analysis of the samples of various outlets.

The overall effectiveness of separation of the grader unit was calculated as,

$$E = \sum_{i=1}^{N} Fr_i \left(\frac{p_i - a_i}{1 - a_i}\right)$$

where
E = effectiveness
p_i = purity of the product
a_i = fraction of each size corresponding to the sieves
Fr_i = fraction yield

Results and Discussion

Hand sieves made of the same sieve used in the graders were used to separate the feed into fractions corresponding to the sieves S_1, S_2, S_3 and S_4. The weights and values of various terms of the above equations were recorded in **Table 2** and **3**, for black pepper and cardamom, respectively. These values were substituted in **Eqn. 19** and the effec-

Table 4 Speed of operation, capacity and effectiveness of the cleaner-cum-grader for pepper and cardamom

Speed of operation, rpm	Capacity, kg/h	Effec -tiveness
Cardamom		
15	150	0.89
20	180	0.64
25	210	0.77
Pepper		
15	200	0.88
25	235	0.84
35	260	0.73

Fig. 3 Overall view of the hand-operated rotary type cleaner-com-grader for blak pepper and cardamom

Table 2 Values of various terms used in the estimation of effectiveness of grading pepper

Speed, rpm	S_i	Opening size, mm	W_T	W_i	Q_i	q_i	P_i	Fr_i	a_i	Ex_i	Effec -tiveness
15	S_1	3.5	10	0.02	0.28	0.1	0.643	0.028	0.02	0.9	0.88
	S_2	4	10	0.08	0.49	0.3	0.388	0.049	0.08	0.237	
	S_3	4.8	10	0.46	2.48	0.14	0.942	0.248	0.47	0.497	
	S_4	> 4.8	10	0.43	7.38	0.64	0.913	0.738	0.43	1.568	
25	S_1	3.5	10	0.025	0.34	0.18	0.47	0.034	0.03	0.64	0.81
	S_2	4	10	0.14	0.52	0.22	0.577	0.052	0.14	0.214	
	S_3	4.8	10	0.5	3.75	0.21	0.944	0.375	0.5	0.707	
	S_4	> 4.8	10	0.34	5.58	0.76	0.863	0.558	0.34	1.416	
35	S_1	3.5	10	0.025	0.21	0.2	0.047	0.021	0.03	0.04	0.77
	S_2	4	10	0.086	0.46	0.25	0.456	0.046	0.09	0.244	
	S_3	4.8	10	0.482	3.23	0.1	0.967	0.323	0.45	0.691	
	S_4	> 4.8	10	0.405	5.89	0.79	0.866	0.589	0.41	1.259	

Table 3 Values of various terms used in the estimation of effectiveness of grading cardamom

Speed, rpm	S_i	Opening size, mm	W_T	W_i	Q_i	q_i	P_i	Fr_i	a_i	Ex_i	Effec -tiveness
15	S_1	5	7.7	0.05	0.035	15	0.57	0.006	0.014	0.244	0.89
	S_2	6	7.7	0.015	0.13	20	0.846	0.019	0.097	0.165	
	S_3	7	7.7	1.7	0.26	5	0.98	0.22	0.742	0.29	
	S_4	> 7	7.7	5.8	0.15	12	0.92	0.75	0.248	2.67	
20	S_1	5	7.7	0.05	0.03	20	0.33	0.006	0.014	0.142	0.64
	S_2	6	7.7	0.25	0.23	20	0.913	0.032	0.097	0.301	
	S_3	7	7.7	3	0.095	5	0.947	0.389	0.742	0.496	
	S_4	> 7	7.7	4.4	0.075	25	0.66	0.571	0.258	1.46	
25	S_1	5	7.7	0.55	0.035	20	0.428	0.007	0.014	0.214	0.77
	S_2	6	7.7	0.17	0.16	10	0.937	0.022	0.097	0.212	
	S_3	7	7.7	2.27	0.095	5	0.947	0.295	0.742	0.376	
	S_4	> 7	7.7	5.2	0.085	15	0.823	0.675	0.248	2.153	

tiveness was calculated for different rotor speeds viz. 15, 25 and 35 rpm. The capacity and effectiveness of the grader evaluated with pepper and cardamom are given in **Table 4**.

The overall effectiveness of the manually operated cleaner-cum-grader was in the range of 0.89 to 0.64 and 0.88 to 0.73 in the speed range of 15 to 25 rpm, for the cardamom and pepper, respectively. The capacity increased from 150 to 210 and 200 to 260 kg/hour in the same speed range for cardamom and pepper, respectively. The effectiveness decreased with increase in speed of operation. However, the effectiveness of separation is important for value addition and to obtain a higher value for the produce.

Thus, the higher effectiveness of 0.89 and 0.88 with grading capacity of 150 and 200 kg/hour is possible for cardamom and pepper, respectively. The cost of the unit is Rs.10,000/- and the cost of operation per quintal is Rs.40 and Rs.30, respectively for pepper and cardamom.

The overall view of the equipment is shown in **Fig. 3**.

The advantages of this type of cleaner-cum-grader are:

- Can be made to suit any crop by changing the sieves.
- This unit can be operated with out dependency on electricity.

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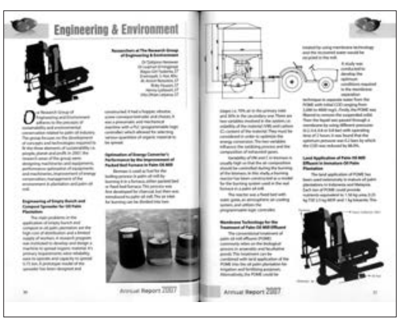

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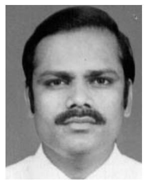

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Abstract

The knapsack type pneumatic cotton picker was developed and evaluated on ergonomic aspects by determining the energy expenditure, cardio-vascular load and cardio-respiratory stress. Six subjects were selected for the study and they were standardized and calibrated with an electrical ergometer to compute the VO_2 maximum value. Heart rate and oxygen consumption were determined using polar heart rate monitor and oxylog. Average heartbeat at the 6th and 15th minute was recorded for the calculation. The heart rate of subjects increased steadily from beginning of the operation and stabilized in the range of 121.0 ± 4.6 beats/min after the 6th minute of operation. The average oxygen consumption was 0.53 and 0.45 l/min for machine and manual picking, respectively. Average energy expenditure for operation of the cotton picker was 11.16 kJ/min and the operation of the machine could be graded as 'moderately heavy'. The average percent VO_2 max (29.7 %) was less than that of the acceptable work load (AWL) limits of 35 percent. Thus, the cotton picker proved its superiority with respect to physiological cost of operation.

Introduction

Cotton, the 'white gold' enjoys a predominant position among all cash crops in India. Cotton is an important raw material for the Indian textile industry, constituting about 65 percent of its requirements. Cotton is cultivated on 9.53 million ha with a production of 31.0 million bales of 170 kg, at an average productivity of 553 kg/ha in 2007-08 (Anon, 2008). In India, all cotton is hand picked by human labour involving about 1,565 man-h/ha (Goyal, 1979). Manual cotton picking is not only tedious work but also ten times costlier than irrigation and about twice that of the weeding operation (Ahmed *et al.*, 1987).

Cotton picking is one of the major labour intensive operations in cotton cultivation consuming the lion's share of the expenditure. Since the varieties used in India require cotton picking at several stages, the use of mechanical cotton pickers is not feasible as in the case of the defoliated picking method. Hence, the only option available is the selective picking method. It is very hard to realize a mechanically operated selective picker. Keeping the practical facts in view, a pneumatic knapsack cotton picker was developed.

With increased appreciation of ergonomics in recent years, scientists are generally becoming aware of the needs in its usefulness in solving problems and promoting health and safety of people at work. Extensive research is needed to examine the intensity of work load of farm activities in order to have a detailed examination of an operators' work in terms of physical and postural stresses as well as occupation related to health problems. The information in the above direction will be of great importance to minimize drudgery and, consequently, promote health and well being of the operator. Since man forms an integral part during operation of any machine, ergonomic data needs to be developed for further design improvements for higher work output with minimum human effort. Thus, the present study was conducted for the ergonomic evaluation of the knapsack cotton picker by determining the energy expenditure, cardiovascular load and cardio-respiratory stress of the subjects selected for operation of the machine at the Department of Farm Machinery, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, India.

Materials and Methods

Description of Cotton Picker

The knapsack cotton picker was developed to suit a one-man operator. The prime mover was mounted with the aspirator directly on the shaft. A polypropylene container of 25 litre capacity was fixed on the frame as the cotton collection drum. The circular cotton filter 100 mm diameter and 225 mm high made of nylon mesh was fitted inside the collection drum, vertically, on a suitable flange to restrict the entry of cotton inside the aspirator. A 25 mm diameter polyvinylchloride hose 1,200 mm long was fixed on the top of the collection drum with a tank nipple as pick-up pipe. The eye of the impeller was connected to the bottom of the collection drum with a 75 mm diameter duct that was sealed air tight. The backrest arrangement was provided with a cushion and belt to carry the unit easily and safely. The specification of the knapsack cotton picker is given in **Table 1**. **Fig. 1** shows the knapsack cotton picker.

Selection of Subjects

The selection of subjects in the ergonomic investigation, plays a vital role. For the ergonomic study, the subject should be medically fit to undergo the trials and also they should be a true representative of the user population. Since maximum strength/power can be expected from the age group of 25 to 35 years, (Gite and Singh, 1997), six subjects (farm workers) in the age group of 25 to 35 years were selected. Bio-clinical analysis of the blood of the workers selected was carried out for blood sugar, blood urea, hemoglobin, and serum cholesterol for identifying hypertension ailments and hypothyroid diseases and urine analysis for diabetes. It was ensured that all were free from respiratory, cardiac, and other ailments. The subjects were standardized and calibrated with the help of a bicycle-ergometer to compute the VO_2 max. The anthropometrical data and other details of the subjects are given in **Table 2**.

Table 1 Specification of cotton picker

Overall dimensions (length × width × height), mm	520 × 400 × 1000
Power source	Engine, 0.82 kW
Type of aspirator	Axial flow type (centrifugal fan)
Speed of impeller (maximum, minimum), rpm	5,500, 2,500
Type of collection drum	Polypropylene container
Capacity of collection drum, l	25
Type of cotton filter	Nylon mesh
Dimension of cotton filter (diameter × height), mm	100 × 225
Diameter of pick up pipe, mm	25
Number of operator	1 man
Field capacity of picker, kg/day	60

Table 2 Anthropometric and metabolic parameters for subjects (n=6)

Particulars	Subject							
	S1	S2	S3	S4	S5	S6	Mean	SD
Age, year	27	32	28	34	28	26	29.2	3.1
Stature, cm	172.1	168.6	167.0	166.3	168.4	163.6	167.7	2.8
Weight, kg	75	80	72	66	54	63	68.3	9.3
Heart rate, beats/min	73	73	75	72	69	71	72.2	2.0
BMR, kCal/day	1,508	1,632	1,578	1,094	1,184	1,051	13,41.2	260.2
VO_2 max, l/min	1.92	2.28	1.97	2.12	2.19	2.24	2.1	0.1
Breath rate, No./min	16	15	14	17	15	14	15.2	1.2
HR max, beats/min	190	191	194	188	179	188	188.3	5.1
Blood pressure, mmHg	118/ 79	119/ 80	120/ 80	120/ 80	122/ 80	120/ 81	119.8/80.0	1.3/ 0.6

Fig. 1 Knapsack type pneumatic cotton picker

Test Procedure

Subjects were asked to report in the laboratory at 8:00 a.m. and an initial rest period of 30 minutes was provided. Subjects abstained from smoking and taking any food as long as they were in the laboratory. Heart rate and oxygen consumption were recorded using Polar heart rate monitor and Morgan Oxylog-II, respectively, for calculating the basal metabolic rate (BMR) of the subjects. Subjects were allowed to exercise with the bicycle-ergo meter in a psychometric chamber at a pedal frequency of 100 rpm for different workloads between 40 to 200 W. In each workload, the heart rate and oxygen consumption were noted at the 6th and 15th minute because the heart rate increases rapidly in the beginning and reaches a steady state by the end of the 6th minute (Davis *et al*., 1964). The values of heart rate for each subject from the 6th to 15th minute of operation were used to calculate the mean value of heart rate for determining the physiological responses of the subjects. Subjects were given complete information about the experimental requirements so as to enlist their full cooperation for conducting the trials precisely.

Field Evaluation

The subjects were familiar with the operation of the cotton picker. They were given initial rest and heart rates were recorded before starting the work. Actual work was started at 9:00 a.m. and continued till 4.00 p.m. with one hour lunch break. Before conducting the trials, the cotton picker was put in proper test condition. One subject was allowed to operate the machine at a time. They were allowed to continue the operation till they got 'fatigued'. Then, they were provided ten minutes rest after which they again started the work. Procedure was replicated thrice. The subjects were given treatments at random to avoid bias from such things as effect of training, weather, or other such variables.

Physiological Cost of Operation

The evaluation was carried out in terms of heart rate and oxygen consumption, energy cost of operation, and acceptable work load.

Heart rate and oxygen consumption

Heart rate and oxygen consumption rate are the two pertinent parameters for assessing the energy required for performing various types of operation (Curteon, 1947). During the ergonomic evaluation of the cotton picker in the field, oxygen consumption was measured with the Oxylog-II apparatus and heart rate was measured using the Polar heart rate monitor in ambulatory position. Selected subjects were given adequate practice to get acquainted with the gadgets. Each experiment was replicated twice. The energy expenditure was computed by using the calorific value of 20.93 kJ/l of oxygen (Anon., 1987). The fatigue factor (the ratio of heart beat rate to respiration rate) was used as an index of cardio-respiratory stress (Moitra *et al*., 1974).

Energy cost of operation

The heart rate values at resting level after the 6th and 15th minute of operation were taken for determination of physiological responses of the subjects. The energy cost of operation of the cotton picker was computed by multiplying the oxygen consumed by the subject during the trial period with the calorific value of oxygen. During any physical activity, there was change in physiological response depending upon the work load and the maximum values which could be attained

Fig. 2 Heart Beat Response of Subjects During Cotton Picking with the Picker

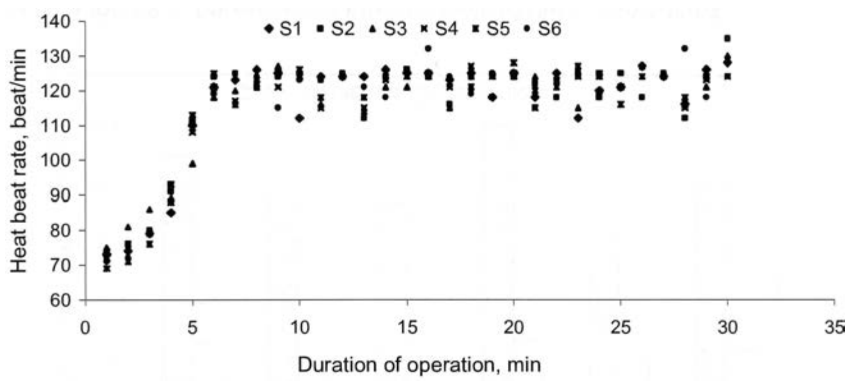
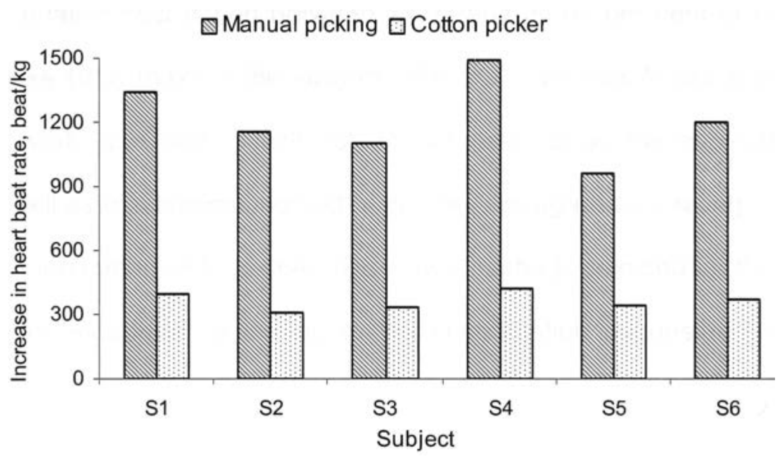


Table 3 Heart rate response of the subjects



in normal healthy individuals up to VO_2 max. However, at this extreme work load, a person could work only for a few seconds. The acceptable work load (AWL) for Indian workers has been worked out as the load consuming nearly 35 percent of the VO_2 max (Saha, *et al*., 1979) for prolonged operation. Therefore, the percent VO_2 max was computed to ascertain whether the operation of cotton picker was within the acceptable work load.

Results and Discussion

Heart Rate and Oxygen Consumption

The mean heart beat of the 6th and 15th minutes was recorded for the calculation. The heart rate of subjects increased steadily from beginning of the operation and stabilized in the range of 121.0 ± 4.6 beats/min after 6th minute of operation as shown in **Fig. 2**. The heart rate response of the subjects selected for the study for the cotton picking activity under the manual method and using the cotton picker is furnished in **Table 3**. The working heart rate was higher (102.5 ± 3.6 beats/min) for the mechanical method as compared to the manual method (97.3 ± 4.8 beats/min), where as the physiological cost was lower (364 ± 40 beats/kg of cotton) for the mechanical method than the manual method (1208 ± 186 beats/kg) (**Fig. 3**). The study was spread over thirty days and the mean values of increase in heart rate over rest were adopted for the comparison of different trials to eliminate the effect of different days as well as the time of day for the experiment.

The mean increase in heart rate over rest was 25.2 ± 3.9 and 30.3 ± 3.3 beats/min in the manual method and mechanical methods, respectively. The mean output capacity (i.e., quantity of cotton picked per thousand heart beats) was 0.844 ± 0.13 beats/kg under the manual method and 2.78 ± 0.30 beats/kg using the cotton picker. Therefore, 232.2 ± 32.6 percent increase in productivity over the manual method was achieved by using the cotton picker, and, thus, the cotton picker proved its superiority in respect of physiological cost of operation. The field capacity of the cotton picker was determined as 40 kg/day as compared to 10 kg/day for the manual method. Thus, the findings show that the cotton picker gave good productivity with lesser physiological cost. The heart rate of the workers was also within the permissible limits as per physiological norms. This reference was verified by the subjective opinion of the workers who participated in the study.

Energy Cost of Operation

The average work pulse rate of the subjects varied from 89 to 107 beats/min. The lowest and highest values of heart rate were recorded for subject 5 for the manual method of picking and subject 4 for picking with cotton picker, respectively. The variation in work pulse rate in a particular operation among all subjects was small. The energy expenditure

Table. 3 Heart rate response of the subjects

Subject	Working heart rate (HR), beats/min		Increase in HR over rest, beats/min		Increase in HR/kg of cotton, beats/kg		Output, kg/1000 beat		Increase in productivity over manual method, %
	Manual method	Cotton picker	Manual method	Cotton picker	Manual method	Cotton picker	Manual method	Cotton picker	
S1	101(73)	106	28	33	1,344	396	0.744	2.53	240.4
S2	97 (73)	99	24	26	1,152	312	0.868	3.21	270.3
S3	98 (75)	103	23	28	1,104	336	0.906	2.98	229.0
S4	103 (72)	107	31	35	1,488	420	0.672	2.38	254.7
S5	89 (69)	98	20	29	960	348	1.042	2.87	175.5
S6	96 (71)	102	25	31	1,200	372	0.833	2.69	223.4
Mean	97.3 (72.2)	102.5	25.2	30.3	1,208	364	0.844	2.78	232.2
SD	4.8 (2.0)	3.6	3.9	3.3	186	39.9	0.13	0.30	32.6

N.B.: Figures in parentheses indicate resting heart rate values

Table 4 Physiological responses of subjects

Subject	Manual picking							Cotton picker						
	S1	S2	S3	S4	S5	S6	Mean	S1	S2	S3	S4	S5	S6	Mean
Oxygen uptake, l/min	0.49	0.53	0.41	0.39	0.38	0.49	0.45	0.57	0.65	0.49	0.48	0.47	0.54	0.53
Energy expenditure, kJ/min	10.26	11.09	8.58	8.16	7.95	10.26	9.38	11.93	13.6	10.26	10.05	9.84	11.3	11.16
Relative cost (% VO_2 max)	25.5	25.5	21.9	24.1	23.9	26.2	24.5	29.7	31.3	26.2	29.6	29.6	32.0	29.7

rate for all the subjects varied from 7.95 to 13.60 kJ/min. The lowest and the highest energy expenditure rates were registered with subject 5 for the manual method of picking and with subject 2 for picking with the cotton picker. Average energy consumption in both methods is given in **Table 4**.

The relative cost varied between 21.93 and 31.95 percent of the maximum oxygen uptake (VO_2 max) of the subject. The VO_2 max was less than that of the acceptable work load (AWL) limits of 35 percent for all subjects in the manual method as well as the mechanical method of picking. With respect to the rating of workload, it appeared that the cotton picking operation by the two methods selected for the study could be graded as 'moderate' according to the classification suggested by Nag *et al.* (1980).

Field Performance of Cotton Picker

The field capacity with the cotton picker and manual picking was determined for different varieties of cotton. There was a significant difference in field capacity of the machine in comparison with manual cotton picking. A skilled labourer could harvest 10 kg cotton in a day manually, whereas the machine harvested 40 kg/day. This was a four time increase in field capacity with picker compared to manual picking. A nine percent cost saving was achieved with the cotton picker besides 75.00 percent saving in time and 68.23 percent saving in energy requirement. The efficiency of the picker was 97.02 + 0.48. Picking efficiency increased with the time of picking, i.e., less in first picking (96.35 percent) and more in third picking (97.48 percent). This showed that the maturity aspect played a positive role in mechanized cotton harvesting.

Conclusion

· The mean heart rate in cotton picking trials was 102.5 and 97.3 beats/min for machine and manual picking, respectively.

· The mean oxygen consumptions were 0.53 and 0.45 l/min for machine and manual picking, respectively.

· The mean energy expenditure for the subjects for the machine picking, was 11.16 kJ/min and the operation was graded as 'moderately heavy'.

· The relative cost (percent VO_2 max) was higher for machine operation (29.7 %) than manual picking (24.5 %).

· The average percent VO_2 max (29.71 %) was less than that of the acceptable work load (AWL) limits of 35 percent. Thus, the cotton picker proved its superiority with respect to physiological cost of operation.

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Field Evaluation of Experimental Plot Drill

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Abstract

Mechanization of field operations on experimental plots is considered a key input to agricultural research. However, with the introduction of mechanized, accurate and reliable planting systems, even small yield gains made in varietal improvement may easily be noticed. The use of machines facilitates precision and timeliness in operation and reduces drudgery, which are all critical to the productivity of crops. The tractor drawn Oyjord plot drill (Wintersteiger) was evaluated for seed placement uniformity at four operational speeds (4, 5, 6 and 7 km/h) and two types of seeds [Rapeseed (Brassica juncea L.) and Pea (Pisum sativum L.)] with three levels of seed rate in each case. The experimental work was carried out at the Crop Research Centre of GBPUA&T, Pantanagar. The plot drill seed uniformity was described with respect to coefficient of uniformity and standard deviation. Results showed that an average seed drop could not be achieved in to ground wheel skid. Seed rate and speed of operation did not have significant effect on coefficient of uniformity between rows for rapeseed (Brassica juncea L.), while speed of operation had a highly significant (1 %) effect for peas (Pisum sativum L.). At 4 km/h, standard deviation was minimum (0.10, 0.14 and 0.19 at 2.5, 3.0 and 3.5 kg/ha seed rate for rapeseed (Brassica juncea L.) and 0.09, 0.10 and 0.17 at 80, 85 and 90 kg/ha seed rate for pea, respectively). The plot seed drill covered more distance than the selected test run, as per manufacturer's calibration table, where the percent variation in distance coverage was almost equal to the ground wheel skid. Therefore, in order to obtain correct seed rate, the quantity of seed for a particular distance had to be increased or distance shown in the calibration table had to be decreased in accordance with the ground wheel skid.

Introduction

Uniformity in seed spacing has been demonstrated to be a significant factor in quality and yield for crops. With uniform spacing, the roots can grow to an optimum size and fill the row space without being pushed out of the row by a neighboring root. This ensures that all of each root can be gathered from the row by the harvester. With uneven plant spacing, some roots may be too small to be gathered by the harvester, or some roots may be too large, and may be damaged by the topping implements, or the lifting wheels of the harvester (Jaggard, 1990). Traditional methods of crop planting have involved planting of excess seed and later on thinning of the resulting plants to obtain the desired plant population at uniform plant spacing. Advancements in plant establishment practices such as seed bed preparation, high quality seed, and precision planters, have provided higher and more consistent seedling emergence. As a result, crops are planted at the desired population, in contrast with planting excess seed and thinning to a desired stand population. The precision seeding offers numerous advantages to the researchers, which include lower thinning costs, reduced competition between the young plants and reduction of shock to plants during thinning (Inman, 1968). Hence, mechanization of field operations on experimental plots is considered a key input to agricultural research. However, with the introduction of mechanized, accurate and reliable planting systems, even small yield gains made in varietal improvement efforts may easily be noticed. The use of machines facilitates precision and timeliness in operation and reduces drudgery, which are all critical to the productivity of crops. Keeping these factors in view, the coefficient of uniformity for the Oyjord plot drill for two types of seed and four levels of speed was determined for evaluating the field performance of the experimental plot drill.

Materials and Methods

The experiment was conducted in the field with sandy loam soil by using the tractor drawn Oyjord Plot multi-crop seed drill at the Crop Research Centre of GBPUA & T, Pantnagar, India. The experiment included two types of seed; pea (Pisum sativum L.) and rapeseed (Brassica juncea L.), with 3 seed rates for each type of seed and 4 speeds (4, 5, 6 and 7 km/h). The experimental plot was tilled with a tractor drawn rotavator and leveled by leveler. The experimental variables were:

Independent Variables

Types of seed and seed rates;
- · Pea (Pisum sativum L.); P 5: 80, 85 and 90 kg/ha
- · Rapeseed (Brassica juncea L.); PYS 2919: 2.5, 3.0 and 3.5 kg/ha

Operational speed; 4 levels (4, 5, 6 and 7 km/h)

Dependent Variables

Seed distribution pattern: Number of seed dropped
Mechanical seed damage
Variation in distance covered
Ground wheel skid

Experimental Details

No. of Replications; 5
Fixed length: 15.21 m
Spacing: − + 4 rows 30 cm apart for both seeds.

Oyjord Plot Drill

The Oyjord plot drill had provision for sowing the seeds continuously with varying plot lengths between 1.23 to 20.81 m with the help of a variator (**Table 1**). The basic concept of the Oyjord system was star feed, which continuously fed on a rotating distributor for equal distribution of material in the corresponding seed tubes. The exact estimated quantity of seed was placed in the funnel, which rested over the cone. In conjunction with the plot length, when a lever was actuated, the seeds were uniformly distributed in all the cells of the distributor. During the operation, the star feeder rotated and the individual cells pushed the seed into the slit through a nozzle and the seed fell over the rotating distributor. A slanting notch over the rotary distributor distributed the seed equally in the desired number of rows and the seed ultimately fell in the furrow opened by double disc type furrow openers. The rotating distributor was mounted on a swivel arm beneath the cell wheel distributor and was powered by an electric motor. The rotating distributor distributed the seed by centrifugal force. A brass nozzle was located beneath cell wheel distributor, which could be easily changed according to the requirement of different seed.

For cereals and large grain seeds : Nozzle 22 mm Φ
For rape and fine-grain seeds : Nozzle 15 mm Φ

The seed outlet in the furrow opener was designed so that seed velocity was reduced considerably, which reduced seed bouncing. With the provision of the variator provided on the star feeder, it was possible to vary the plot length. The machine could be effectively utilized for planting breeder experiments that changed seed varieties in inter plots without stopping the machine intermittently at the end of a plot. The plot seed drill is shown in **Fig. 1**.

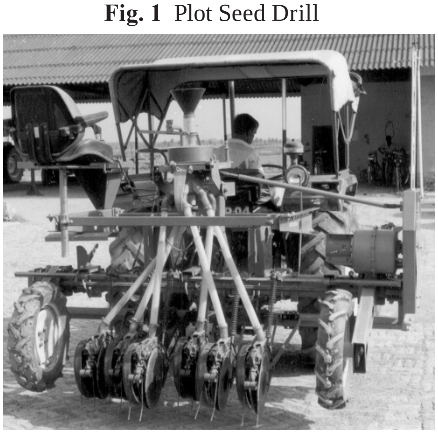
Experimental Methodology

Observations were taken on the number of seed drop, mechanical seed damage, variation in seed distance and ground wheel skid of the plot seed drill. For evaluation of the seed drill, 146.02 g of pea (Pisum

Table 1 Calibration table (Plot length, cm)

Minor gear number	Major gear number 1	2	3
1	2,081	769	304
2	2,001	765	293
3	1,921	734	281
4	1,841	704	269
5	1,761	673	257
6	1,681	643	246
7	1,601	612	234
8	1,521	582	222
9	1,441	551	211
10	1,361	520	199
11	1,288	493	188
12	1,238	473	181
13	1,189	455	174
14	1,140	436	167
15	1,091	417	159
16	1,041	398	152
17	991	379	145
18	942	360	138
19	892	341	130
20	843	322	123

Fig. 1 Plot Seed Drill



sativum L.) seed (seed rate 80 kg/ha) were placed in the funnel. The seed drill was mounted on a tractor and operated at 4.0 km/h forward speed for a distance of 15.21 m. Out of total run (15.21 m), 5 spans of 1 m length were taken at random. The number of seed dropped in each 1 m length at 10 cm intervals in each row was determined. The average value of five spans corresponding to each row and each segment, i.e. 10 cm interval, were taken. The coefficient of uniformity was calculated within each segment in each row and a split plot design was used to analyze for the effect of seed rate and speed of operation. The tests were conducted at 4, 5, 6 and 7 km/h speed of operation. After completing these tests with pea (Pisum sativum L.) seed, similar data were collected for rapeseed (Brassica juncea L.). The variation in seed dropping distance from the predetermined 15.21 m was also recorded in each case. For seed distribution pattern, Christiansen's coefficient of uniformity was calculated by using following relationships:

$$Average,\ X_a = \frac{\sum (X)}{n} \quad \text{.................(1)}$$

Christiansen's coefficient of uniformity (CU), %

$$= 1 - \frac{\sum |x - x_a|}{n\,X_a} \times 100 \quad \text{.......(2)}$$

where

X_a = Average number of seed dropped in a segment.,

n = Number of the segments

The wheel skid was calculated by the following relationship.

Ground wheel skid, %

$$= \frac{d_{th} - d_a}{d_a} \times 100 \quad \text{....................(3)}$$

where

d_{th} = 15 × π × Diameter of the ground wheel assuming half penetration of lugs into the soil, cm

d_a = actual distance covered in 15 revolution of ground wheel, cm

Results and Discussion

Seed distribution pattern for rapeseed (*Brassica juncea L.*)

The average seed drop in each segment could be 2.06, 2.45 and 2.88 at 2.5, 3.0 and 3.5 kg/ha seed rate, respectively (**Fig. 2**). But in any case, this was not achieved due to skid of the ground wheel of the plot seed drill. The average seed drop in each segment at 2.5 kg/ha was 1.85, 1.88, 1.93 and 1.87 at 4, 5, 6 and 7 km/h with standard deviations of 0.10, 0.13, 0.15 and 0.15, respectively. The average seed drop at 3.0 kg/ha seed rate in each segment was lowest (2.05) and highest (2.10) at 4 and 6 or 7 km/h, respectively, while standard deviation was highest (0.17) at 5 and 6 km/h and lowest (0.14) at 4 km/h. The average seed drop in each segment at 3.5 km/h was lowest (2.32) and highest (2.40) at 4 and 5 km/h while the high and low standard deviations were 0.19 and 0.21 at 4 and 7 km/h, respectively. The average seed drop and standard deviation in each segment are shown in **Table 2**. From **Table 2**, it is clear that standard deviation increased with increasing seed rate and speed of operation. The average seed drop might be achieved if ground wheel skid were taken into consideration, i.e., quantity of seed must be increased. Distance covered by seed drill was more and which was equal to ground wheel skid. The seed rate and speed of operation was well matched to achieve required seed rate with less variability within rows (**Fig. 2**). The coefficient of uniformity between the rows for seed rates 2.5, 3.0 and 3.5 kg/ha ranged from 87.14 to 94.74, 87.18 to 95.00 and 79.07 to 95.83 %, respectively, at 4 km/h. For 5 km/h, the coefficient of uniformity between the rows varied from 80.00 to 95.71, 82.05 to 93.62 and 83.33 to 96 % at 2.5, 3.0 and 3.5 kg/ha seed rates, respectively. The coefficient of uniformity between rows varied from 82.35 to 96.51 %, 81.08 to 93.62 % and 88.37 to 96.34 % at 2.5, 3.0 and 3.5 kg/ha, respectively, at 6 km/h speed. The coefficient of uniformity between rows ranged from 79.73 to 95.45 %, 80.95 to 96.34 % and 86.36 to 95 % at 7 km/h speed for seed rates of 2.5, 3.0 and 3.5 kg/ha, respectively. Analyses of variance for coefficient of uniformity between rows are shown in **Table 3**. The ANOVA table reveals that coefficients of uniformity between rows were not significant with seed rate and speed of operation.

Seed Distribution Pattern for Peas (*Pisum Sativum L.*)

Seed distribution pattern of peas (*Pisum sativum L.*) for different speeds of operation and different seed rates is shown in **Fig. 3**. The

Table 2 Average seed drop and standard deviation in segment of 10 cm

Type of seed and seed rate (kg/ha)		Speed of operation, km/h: 4 Mean	4 S. D.	5 Mean	5 S. D.	6 Mean	6 S. D.	7 Mean	7 S. D.	S.D. between speed
Rapeseed (Brassica juncea L.)	2.5	1.85	0.10	1.88	0.13	1.93	0.15	1.87	0.15	0.032
	3.0	2.05	0.14	2.06	0.17	2.10	0.17	2.10	0.15	0.025
	3.5	2.32	0.19	2.40	0.20	2.26	0.20	2.21	0.21	0.081
Pea (Pisum sativum L.)	80	1.40	0.09	1.44	0.12	1.47	0.14	1.46	0.14	0.030
	85	1.48	0.10	1.49	0.15	1.53	0.14	1.57	0.18	0.040
	90	1.58	0.17	1.65	0.18	1.61	0.16	1.58	0.21	0.035

average seed drop in each segment within row at 80 kg/ha was highest (1.47) followed by 1.46, 1.44 and 1.40 at 6, 7, 5 and 4 km/h, respectively. Standard deviation was lowest (0.09) at 4 km/h. The average seed drop and standard deviation in each segment are shown in **Table 2**. The average seed drop at 85 kg/ha was highest (1.57) and standard deviation was highest (0.21) at 7 km/h followed by 6, 5 and 4 km/h, respectively. The average seed drop in each segment at 90 kg/ha was 1.58, 1.65, 1.61 and 1.58 at 4, 5, 6 and 7 km/h, respectively, while standard deviations were 0.17, 0.10, 0.16 and 0.21 at 4, 5, 6 and 7 km/h, respectively. From the **Table 2** it is clear that average number of seed dropped and standard deviation in each segment were increased with increase of seed rate and speed of operation. At 4 km/h, the coefficient of uniformity between rows ranged from 88.46 to 94.83 %, 85.71 to 92.86 % and 71.43 to 95.71 % at 80, 85 and 90 kg/ha seed rates. Similarly, at 5 km/h, and 80, 85 and 90 kg/ha seed rates the coefficient of uniformity was varied from 80.00 to 94.44 %, 82.76 to 94.83 % and 80 to 94.12 %, respectively. At 6 km/h for 80, 85 and 90 kg/ha seed rates, coefficient of uniformity between the rows varied from 80.00 to 95.45 %, 78.57 to 94.12 % and 89.39 to 94.83 %, respectively. The coefficient of uniformity between rows at 7 km/h was 78.57 to 94.00 %, 77.42 to 94.83 % and 70.27 to 95.00 % at 80, 85 and 90 kg/ha seed rates, respectively. The statistical analysis between rows is presented in Table 4 and indicates that the seed rates and speed of operation have non-significant effect on coefficient of uniformity. Interactions between seed rate and speed of operation, also, have non-significant effect on the coefficient of uniformity between rows.

Ground Wheel Skid

The wheel skid increased with increasing operational speed. The average wheel skid at 4, 5, 6 and 7 km/h was 5.59, 6.79, 7.61 and 8.51 %, respectively, in the field. The statistical analysis (**Table 5**) showed that the speed of operation had significant effect on the skid of the ground wheel at 1 % level of significance.

Variation in Seeding Distance and Seed Damage

The variation in seeding distance covered by the plot seed drill in comparison to the distance claimed by the manufacturer was observed for different speeds and various types of seeds. A test run of 15.21

Fig.2 Distribution of average number of seed dropped for rapeseed (Brassica juncea L.) at distances from reference point

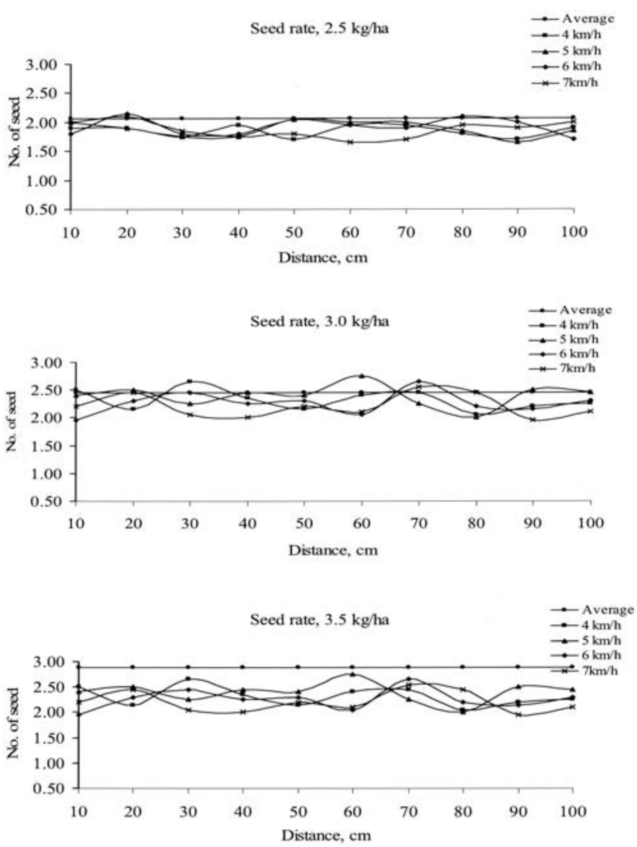
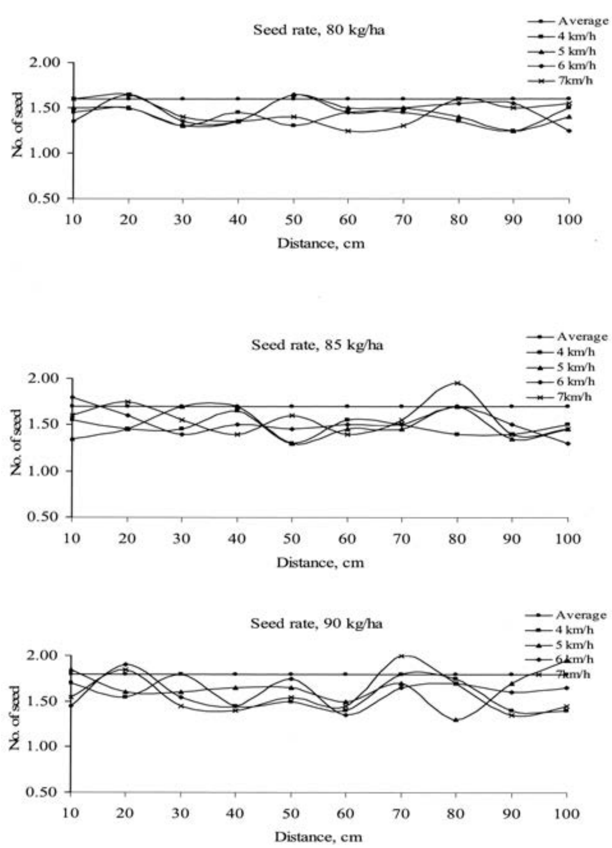


Fig.3 Distribution of average number of seed dropped for pea (Pisum sativum L.) at distances from reference point



m was selected to operate the seed drill in the field experiment. However, some variation in seeding distance coverage was observed in all cases. Variation in distance covered by seed drill was minimum at 4 km/h speed and increased with increasing the speed for all types of seeds. The average distance coverage for rapeseed (*Brassica juncea L.*) seed was 78, 101, 110 and 128 cm more at 4, 5, 6 and 7 km/h speeds, respectively, for a pre-selected test run of 15.21 m. The variation in seeding distance for peas was 90, 102, 114 and 134 cm at 4, 5, 6 and 7 km/h, respectively. The percent variation in seeding distance coverage was almost equal to the ground wheel skid percentage. From above data, the seeding distance calibration table made available by the manufacturer of the plot seed drill did not include ground wheel skid while estimating seeding distance to be covered at different lever positions. It was, therefore, necessary to determine the correct ground wheel skid before conducting an actual experiment in the field. Later on, the quantity of seed determined for a particular distance must be increased or distance shown in the table must be decreased in accordance with the ground wheel skid. The samples were collected from different furrow openers to determine the mechanical seed damage. No mechanical damage of seed was observed. This indicated that the seed metering device used in the machine worked satisfactorily with-

Fig 4 Effect of operational speed on ground wheel skid

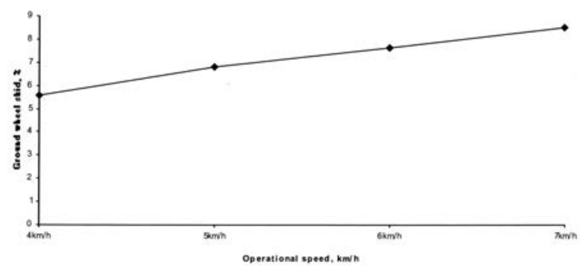


Table 3 Analysis of Variance of C.U. between rows in rapeseed (Brassica juncea L.)

Source	D. F.	S. S.	M. E. S.	F value	Remark
Segment	9	140.5417	15.6157		
Seed rate (M)	2	14.9750	7.4875	0.4981	non significant
Error (a)	18	270.5458	15.0303		
Speed (S)	3	29.9750	9.9917	0.6535	non significant
M x S	6	50.5250	8.4208	0.5508	non significant
Error (b)	81	1238.375	15.2886		
Total	119	1744.938			

SEM1 = 0.6130 SEM = 0.7139 SED1 = 0.8669 SED2 = 1.0096 SED3 = 1.7486 SED4 = 1.7449

Table 4 Analysis of Variance of C.U. between rows in pea (Pisum sativum L.) crop

Source	D. F.	S. S.	M. E. S.	F value	Remark
Segment	9	252.4583	28.0509		
Seed rate (M)	2	24.2750	12.1375	0.4168	non significant
Error (a)	18	524.2042	29.1225		
Speed (S)	3	115.5417	38.5139	1.7096	non significant
M x S	6	226.1583	37.6931	1.6732	non significant
Error (b)	81	1824.738	22.5276		
Total	119				

SEM1 = 0.6130 SEM2 = 0.8666 SED1 = 1.2067 SED2 = 1.2255 SED3 = 2.1226 SED4 = 2.1989

Table 5 Analysis of Variance for ground wheel skid

Source	D. F.	S. S.	M. E. S.	F value	Remark
Replication	2	0.05541992	0.02770996	0.2535841	non significant
Speed (S)	3	11.15253	3.717509	6.167254	Highly significant
Error (b)	6	0.6556396	0.1092733		
Total	11	11.86359			

SEM = .1908518 CV = 4.694972

out mechanical damage of seeds.

Conclusions

The coefficient of uniformity between rows and number of seed drop were decrease with increase in seed rates as well as operational speeds. The average ground wheel skid was 5.59, 6.79, 7.61 and 8.51 % at 4, 5, 6 and 7 km/h speeds of operation of the plot seed drill, respectively. The plot seed drill covered more distance than the selected test run as per manufacturer's calibration table where the percent variation in distance coverage was almost equal to the ground wheel skid. Therefore, in order to obtain correct seed rate, the quantity of seed determined for a particular distance had to be increased or distance shown in the table had to be decreased in accordance with the ground wheel skid.

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NEWS

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Economic Evaluation of Collection, Transport and Utilization of Straw in the Swath of Wheat Stubble

by

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Abstract

The objectives of this work were to economically evaluate the collection, transport and utilization of the straw available in the swath left by the combine harvester in the wheat stubbles and to estimate the possible benefits for the farmers. In order to achieve these objectives, data about straw availability from 15 farms in three Chilean provinces generated in a recent research work were used. For the baling, collection and transport, three models of rotobalers and three of rectangular balers, a front loader mounted on a tractor, a wagon and workers were considered; for the off?the?farm transport the local tariff of 2.2 US\$ km^{-1} was used. The Annual Equivalent Cost and the Net Present Value, at a 10 % real annual interest, indicators were used to obtain the operating costs of the tractors and machines and to evaluate the different alternatives. The results showed that the baling, collection and transport costs reached values from 17.2 to 26.1 US\$ ha^{-1}, the possible benefits for the farmers could reach values between 42.6 and 48.9 US\$ ha^{-1}, the Net Present Value could go from US\$ 18,300 to 40,500 for farms from 10 to 100 wheat hectares and the farmers could benefit from the sale of their straw including transportation up to 50 to 80 km.

Introduction

Wheat (Triticum aestivum L.) is the most important crop in Chile, considering that the annually seeded area is approximately 285,000 hectares (INE, 2007). The straw left in the stubble presents great difficulties for any tillage activity or direct seeding. This problem is greater in Chile than the other countries because the quantities of straw in the stubbles are larger, reaching often up to 8 and 9 t ha^{-1}. Moreover, the months after harvest have low temperatures that causes very slow decomposition (Mellado, 2007).

The use of fire to eliminate straw is still a very common practice, mainly because of its low cost and its phytosanitary positive effects. However, is not sustainable and the pressure to eliminate it will be unsustainable in the coming years, as it has already happened in the developed countries (Mellado, 2007). The alternatives to burn the straw have different cost/benefit relationships, and it is important and urgent to evaluate possible solutions for wheat producers.

On the other hand, previous research has shown that to leave about 3 t ha^{-1} of straw in the field is enough to protect the soil from erosion, maintain a good level of organ-

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ic matter, enhance high productivity and allow an adequate performance of the tillage implements and/or the zero tillage seeder (Mellado, 2007; Crovetto, 2002).

The biggest problem is caused by the swath of long straw, of approximately 1 m wide, left behind the combine harvester, which joins all the material cut and collected by the header. In Chile, this can vary from 3 to 6 m wide. Hetz *et al.* (2006) established that the linear density in this swath depends, mainly, on the width and height of the combine harvester cutting header, with values ranging from 0.552 to 2.686 kg m^{-1} and with an average of 1.037 kg m^{-1}. Then the amount of straw possible to collect from the swath with a baler can range from 1.5 to 4.5 t ha^{-1}, averaging close to 2.5 t ha^{-1} that are values similar to those found by Bamaga *et al.* (2003) and Neale *et al.* (1993).

The straw collected from this swath can be used for livestock, agricultural or industrial purposes. In the first uses are the winter bed and animal feed. Agricultural uses include the production of saprophytes fungi, composting and organic soil, eroded land cover and an addition to ensilage with excess of water (Crovetto, 2002). The industrial utilization includes use as solid fuel, with a contribution of approximately 14 to 15 MJ kg^{-1}. A recovery of 3 t ha^{-1} is equivalent to about 1,125 L ha^{-1} of diesel fuel (38.66 MJ L^{-1}). This use is widespread in northern Europe for heating buildings for collective use and could become a cheap fuel for drying agricultural products in Chile. Other uses include the manufacture of plastics, furfural, bioethanol, paper, insulation panels and filling in packages (Butterworth, 1985).

Several authors (López and Hetz, 1998; Ibáñez *et al*, 1994) indicate that it is essential to analyze the operating costs of agricultural machinery to establish its economic minimum intensity of use (EMIU), for making an informed judgment to decide whether the farmer should possess his own machines or should hire the mechanized services needed.

The objectives of this research were to economically evaluate the collection, transport and utilization of straw available in the swath left by the combine harvester in wheat stubble, to establish the costs of collecting and transporting to the places where it could be used and to estimate the possible benefits for the farmers.

Methodology

General Background

The research was carried out at the Mechanization and Energy Department of the Agricultural Engineering Faculty at the University of Concepción, Chillán, during 2006. The results of measurements made by Hetz *et al.* (2006) in 15 locations in the provinces of Linares, Ñuble and Malleco, south-central zone of Chile, were used. The area is located between 35º 37' Lat. South, 71º 34' Long. West and 37-59' Lat. South, 72º 49' Long. West. From these results the average value of straw available in the swath equivalent to 2.5 t ha^{-1}, dry matter basis, was used.

Collection and Possible Utilization of Straw Availablein the Swath

The specifications, price and technical characteristics of cylindrical and rectangular balers used in Chile were obtained. With these data, the effective work capacity (EWC) in ha h^{-1} of each model was established according to reasonable working speeds permitted by the density of the straw in the swath and depending on the width and cut height of the combine harvester. A tractor of 63.4 kW (85 HP) was also considered, with an operational cost of 14.94 US$ h^{-1} (Hetz and Weinlaub, 2001; Hetz *et al.*, 1998).

The use considered for the straw collected include its utilization for animal feed with a consumption of 3.5 kg per day^{-1}, bed for stabled cattle with a consumption of 67.5 kg $month^{-1}$ per animal, solid fuel with a contribution of 14 MJ kg^{-1} and generation of liquid fuel as bioethanol requiring 6 kg of straw to produce 1 L of bioethanol (Butterworth., 1985).

Bale Transportation on and off the Farm

Within the property, the rectangular bales are loaded and transported in a wagon and then transferred to the gathering place where they are loaded on a truck to be carried to the place of final use. It was established that two workers needed 15 minutes to load 100 bales of 25 kg each, generated in one hectare of wheat, at a cost of US$ 0.88 for labor. For the cylindrical bales of 600 kg, a tractor equipped with a front loader and a wagon with a 8 bales capacity for transportation to the place of collection were considered; for this activity a time of 15 minutes per hectare, for loading and transporting was established. For transportation off the farm, the local rate of 2.19 US$ km^{-1} was used, considering 30 ton trucks with an estimated capacity of 450 rectangular bales or 24 cylindrical bales.

Economic Evaluation

The economic calculations were carried out considering the effective prices of the machines, inputs and workers in July 2006, the prices were surveyed in Chilean pesos and expressed in US dollars without the Value Added Tax (VAT) (US$ 1 = Ch$ 547, July of 2006).

The economic evaluation of each one of the alternatives was carried out with the following assumptions:

· The evaluation span used was 10 year.

· The prices considered for the

machinery correspond to values of new machines.

· The interest rate for capital investment considered was 10% annual, real.
· This evaluation included the baling costs, on and off the farm transportation.
· The price of 0.03 US$ kg^{-1} was obtained by selling the straw as the benefit to the farmer.
· The project was financed with the farmer's own money.
· The alternatives were independent of each other.
· The calculation of the economic indicators Annual Equivalent Cost (AEC) and Net Present Value (NPV) were carried out under the same conditions for each alternative, because all of them provide the same service (Blank and Tarquin, 1992).

The fixed costs considered an insurance equivalent to 2% of the average between the initial cost and the recovery of the capital asset (Fundación Chile, 2003). The variable costs included the repair and maintenance calculated using the Morris (1988) equation, which estimated these costs as a percentage of purchase prices over the cumulative hours of use. The labor cost was estimated at 1.75 US$ h^{-1}. A 5 % of the total variable costs as unforeseen cost was applied (Fundacion Chile, 2003).

The AEC was calculated as proposed by Blank and Tarquin (1992). In that methodology, each cash flow in the future is calculated and then all of them are transferred to the present time (year zero) as a single actual amount. Then the AEC is calculated as the annual equivalent amount of the actual present using a capital recovery factor for the 10 years considered in this study.

To obtain the operational costs, per hour and per hectare, the hours of use per year and the EWC of each machine were used. Moreover, the price to perform agricultural mechanized services was calculated as Ibañez and Villar (1994) proposed, which considered fixed and variable costs, administration cost (10 %) and 20 % of the costs estimated above as profit.

The NPV, as the difference between income and outcome expressed in actual money, as proposed by Sapag and Sapag (2007), was calculated. The scenarios were analyzed according to the economic profitability of machinery's investment and included all costs of the process or hiring the service according to a tariff. The most likely scenario considered the more probable working conditions for collect-

Table 1 Characteristics of the roto and rectangular balers considered in this research work

Trademark and baler model		Work speed ($km\ h^{-1}$)	Bale weight (kg)	Acquisition Price (VAT included) (US$)*
Rotobaler	Mascar Rotop-2120	5.5-8.5	300	21,500
	John Deere 467	5.5-8.5	600	27,000
	Claas 250 R	5.5-8.5	600	33,000
	Average			27,167
Rectangular baler	Hesston 4570	3.5-6.0	25	18,088
	New Holland 570 W	3.5-6.0	25	17,850
	Case SBX-540	3.5-6.0	25	19,500
	Average			18,479

Source: Claas, 2006; Dercomaq, 2006; Deere & Co, 2006; Kutz, 2006; Mascar, 2006; Sigdotek, 2006; Tattersall, 2006.
* US$ 1 = Ch$ 547 (July, 2006)

Table 2 Width, speed and effective work capacity (EWC) of the balers

Baler model	Working width (m)	Work speed ($km\ h^{-1}$)	EWC ($ha\ h^{-1}$)	EWC ($h\ ha^{-1}$)
Rotobaler	3.2	8.5	2.041	0.490
	4.0	7.0	2.101	0.476
	6.0	5.5	2.475	0.404
		Average	2.205	0.457
Rectangular baler	3.2	6.0	1.441	0.694
	4.0	5.0	1.499	0.667
	6.0	3.5	1.575	0.635
		Average	1.505	0.665

Source: Made using data from Ibáñez and Villar (1994), and enterprises Claas, John Deere, Mascar, Agrícola Gildemeister, Dercomaq, Sigdotek y Tattersall Consulted 2006.

ing and transporting the straw with 2.5 t ha^{-1}, 4 m wide and 250 working hours of machinery annual use. From this scenario an optimistic and less favorable scenarios were simulated, with very good and adverse working conditions, respectively. This analysis was carried out for the three more common baler models in Chile, which included two cylindrical and one rectangular baler.

For farmers that work with their own machinery, considering a small number of wheat hectares and prairie that does not require the 250 hours of work per year of the baler, the extra hours are sold to the neighbors with the tariff calculated before.

Results and Discussion

The values presented in **Tables 1** and **2** show that the rotobalers produce much heavier bales and have, on average, a price and EWC of 47 % and 46.5 % higher than the rectangular balers, respectively.

Table 3 shows the AEC and hourly cost for each one of the six

Table 3 Annual Equivalent Cost (AEC) and hourly cost of the balers for three intensities of annual use

Trademark and baler model		AEC (US$ year^{-1})			Hourly Cost (US$ h^{-1})		
		Annual Use (h year^{-1})					
		150	250	350	150	250	350
Rotobaler	Mascar Rotop-2120	3,022	3,117	3,232	20.1	12.5	9.2
	John Deere 467	3,793	3,912	4,059	25.3	15.6	11.6
	Claas 250 R	4,636	4,782	4,960	30.9	19.1	14.2
	Average	3,817	3,938	4,084	25.4	15.7	11.7
Rectangular baler	Hesston 4570	2,541	2,622	2,720	16.9	10.5	7.8
	New Holland 570 W	2,510	2,589	2,686	16.7	10.4	7.7
	Case SBX-540	2,742	2,828	2,934	18.3	11.3	8.4
	Average	2,598	2,680	2,779	17.3	10.7	7.9

Table 4 Baling cost (US $ ha^{-1}), according to working width and hours of use per year

Trademark and baler model		Working width (m)								
		3.2			4.0			6.0		
		Annual Use (h year^{-1})								
		150	250	350	150	250	350	150	250	350
Rotobaler	Mascar Rotop-2120	9.9	6.1	4.5	9.6	5.9	4.4	8.1	5.0	3.7
	John Deere 467	12.4	7.7	5.7	12.0	7.5	5.5	10.2	6.3	4.7
	Claas 250 R	15.2	9.4	6.9	14.7	9.1	6.7	12.5	7.7	5.7
	Average	12.5	7.7	5.7	12.1	7.5	5.6	10.3	6.4	4.7
Rectangular baler	Hesston 4570	11.8	7.3	5.4	11.3	7.0	5.2	10.8	6.7	4.9
	New Holland 570 W	11.6	7.2	5.3	11.1	6.9	5.1	10.6	6.6	4.9
	Case SBX-540	12.7	7.9	5.8	12.2	7.5	5.6	11.6	7.2	5.3
	Average	12.0	7.4	5.5	11.5	7.1	5.3	11.0	6.8	5.0

Table 5 Total cost of baling. collection and transport of the bales (US $ ha^{-1}) according to working width and hours of use per year

Trademark and baler model		Working width (m)								
		3.2			4.0			6.0		
		Annual Use (h year^{-1})								
		150	250	350	150	250	350	150	250	350
Rotobaler	Mascar Rotop-2120	23.2	18.8	17.0	22.7	18.6	17.0	21.6	17.7	16.3
	John Deere 467	25.8	20.5	18.1	25.4	20.1	18.1	23.6	19.0	17.2
	Claas 250 R	28.5	22.1	19.4	28.0	21.9	19.2	25.8	20.5	18.3
	Average	25.8	20.5	18.1	25.4	20.3	18.1	23.6	19.0	17.2
Rectangular baler	Hesston 4570	26.0	20.5	17.9	25.2	20.1	17.7	24.9	19.7	17.6
	New Holland 570 W	25.8	20.3	17.9	25.0	19.9	17.7	24.7	19.6	17.4
	Case SBX-540	26.7	21.0	18.5	26.1	20.7	18.3	25.8	20.3	17.9
	Average	26.1	20.7	18.1	25.4	20.3	17.9	25.0	19.9	17.6

baler models considered in this study, with three intensities of annual use. It can be appreciated that the rotobaler models have an AEC and hourly costs of 47 %, on average, higher than the rectangular balers. It can also be seen that the AEC increases slightly with annual hours of use, but that the hourly cost decreases significantly, less than half, as it increases from 150 to 350 hours annual use, highlighting the importance of increased annual hours of use for decreasing hourly costs (López and Hetz, 1998).

Table 4 presents the baling costs in US$ ha^{-1} for different baler models, working width and annual hours of use. These values show that the rotobaler costs are similar, on the average, to rectangular balers with the same working width and annual hours of use. It can also be seen that these costs decrease slightly as the working width increases and fall with increased annual hours of use.

Table 5 shows the total costs of baling, collection and transport for three working widths and three levels of annual hours of use. These costs do not show significant differences between the cylindrical and rectangular balers for different working widths, but there is a notable decrease by increasing the annual hours of use. However, these costs, that include the collection and transport of the bales, are considerably greater than the baling cost shown in **Table 4**. For the most common situation found in the field (4 m wide and 250 working annual hours) the cost increased 171 % for the rotobalers and 186 % for the rectangular balers.

Table 6 shows that the potential revenues are, on average, 42.6 US$ ha^{-1} for the hired service and 48.9 US$ha^{-1} for farmer own machinery service in relation to the potential benefits arising from the sale of the straw collected with the farmer's own machinery for the three common baler models in the field and the tariff of the hired machinery service,. These values were estimated with 2.5 t ha^{-1} of straw in the swath and it should be remembered that this value could climb up to 4.5 t ha^{-1}, as shown by Hetz *et al*. (2006) Then, the revenues and benefits of the straw sold would increase significantly, especially for farmers who use high-tech machinery with appropriate levels of inputs timely applied to increase grain and straw production.

As for the NPV, **Table 7** shows average values for two rotobalers of 26.9 to 47.4 thousand dollars as the area increases from 5 to 100 hectares of wheat and 18.3 to 40.5 thousand dollars for a rectangular baler.

Finally, the profits or costs for baling in different field sizes, from 10 to 100 hectares, and their transportation to distances between 10 and 100 km, are shown in Table 8 for a rotobaler and **Table 9** for a rectangular baler. It can be seen that there are benefits generated for transportation distances, up to 70 and 80 km with a rotobaler and only up to 60 and 70 km for a rectangular baler. This reduction in the distance for rectangular baler arises from the higher cost of collecting and transporting the larger number of small bales. It also can be seen that the distance that provides profit increases with incrementing field sizes because of a larger economic justification of machinery ownership by the larger number of annual hours of use (López and Hetz, 1998).

Conclusions

The baling, collection and transport on-farm costs ranged, on average, between 17.2 and 25.8 US$ ha^{-1} for rotobalers and between 17.6 and 26.1 US$ ha^{-1} for the rectangular baler.

Table 6 Sales, tariff, profit and difference between owned and hired machines (US$ ha^{-1}) in the most likely scenario with 2.5 t ha^{-1} of straw in the swath

Trademark and baler model		Sales (US $ ha^{-1})	Tariff (US $ ha^{-1})	Profit by origin of service (US$ ha^{-1})	
				Hired	Owner
Rotobaler	Mascar Rotop-2120	68.6	24.7	45.7	49.8
	John Deere 467	68.6	26.7	41.9	48.3
Rectangular baler	New Holland 570 W	68.6	26.4	42.1	48.5
	Average	68.6	25.9	42.6	48.9

Table 7 Net Present Value (US$) for 10 years with 10% real annual interest, in the most likely scenario with 2.5 t ha^{-1} of straw in the swath and four wheatfield sizes

Trademark and baler model		Weathfield size (ha)			
		10	40	70	100
Rotobaler	Mascar Rotop-2120	26,097	33,139	39,856	47,221
	John Deere 467	27,675	34,313	40,951	47,589
	Average	26,887	33,726	40,402	47,404
Rectangular baler	New Holland 570 W	18,322	25,726	33,128	40,530

The potential benefits for farmers generated by the harvest and sale of wheat straw on the more probable scenario were, on average, 42.6 US\$ ha^{-1} for hired service and 48.9 US\$ ha^{-1} for owned machinery for the three more common balers in the field.

The Net Present Value, for 10 years and 10 % of real annual interest rate ranged from 26.9 to 47.4 thousand dollars, when going from 10 to 100 hectares using a rotobaler and from 18.3 to 40.5 thousand dollars using a rectangular baler, under the assumption that the baler idle time is sold to other farmers at the calculated tariff.

It is possible to obtain economical profits by selling straw considering transportation up to 70 to 80 km with cylindrical bales and from 50 to 60 km with rectangular bales. The farmer gets greater profits using rotobalers than rectangular balers.

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Table 8 Benefits or costs (US\$) in baling wheat straw using the John Deere model 467 rotobaler. Over ten wheatfield sizes (ha) and its transport to various distances

Travel distance, km	Weathfield size (ha)									
	10	20	30	40	50	60	70	80	90	100
10	302	603	905	1,229	1,530	1,832	2,137	2,459	2,761	3,062
20	258	516	773	1,075	1,333	1,590	1,850	2,152	2,410	2,667
30	214	428	642	921	1,135	1,349	1,563	1,843	2,059	2,272
40	170	340	510	768	938	1,108	1,278	1,537	1,707	1,878
50	126	252	378	614	740	867	993	1,230	1,356	1,483
60	82	165	247	461	543	625	709	923	1,005	1,088
70	**38**	**77**	**115**	307	346	384	422	616	654	693
80	−5	−11	−16	154	**148**	**143**	**139**	**309**	**303**	**298**
90	−48	−99	−148	**1**	−49	−99	−146	0	−48	−97
100	−93	−186	−280	−154	−247	−340	−433	−305	−399	−492

Table 9 Benefits or costs (US\$) in baling wheat straw using the New Holland 570 W rectangular baler over ten wheat field sizes and its transport to various distances

Travel distance, km	Weathfield size (ha)									
	10	20	30	40	50	60	70	80	90	100
10	280	583	885	1,186	1,466	1,770	2,071	2,375	2,676	2,956
20	214	473	731	989	1,205	1,463	1,720	1,980	2,238	2,452
30	148	364	578	792	941	1,155	1,369	1,585	1,799	1,947
40	82	254	424	594	676	848	1,018	1,190	1,360	1,442
50	**0**	144	271	397	415	541	667	795	921	938
60	−49	**35**	**117**	199	**152**	**234**	**316**	400	483	**433**
70	−115	−75	−37	**0**	−113	−73	−35	**0**	**44**	−71
80	−181	−185	−190	−196	−375	−380	−386	−389	−395	−576
90	−247	−294	−344	−391	−638	−687	−737	−784	−834	−1,080
100	−313	−404	−497	−590	−901	−995	−1,088	−1,179	−1,272	−1,585

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Mechanization Possibilities of Maize Cultivation in Hilly Regions of Jammu and Kashmir State of India

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Abstract

This paper describes the prospectus in amenability to maize cultivation mechanization in hilly regions of Jammu and Kashmir State based on the field experiments conducted. Based on the comparative performance of improved implements with conventional methods of maize cultivation, mechanization prospectus of different farm operations of maize cultivation have been explored and presented in this paper. Seed bed preparation with a power tiller rotary has enhanced the crop yields by 17.6 percent, in comparison to bullock ploughing due to a fine and well pulverized seed bed. Maize sowing by a rotary dibbler raised bed planter ensured a proper plant stand and produced 20-25 percent increased yield over the conventional method of sowing (broadcasting). Weeding, with the help of a wheel hand hoe and power weeder, gave a cost saving of about Rs. 1,400-1,700 per hectare over manual weeding. Similarly, harvesting and shelling by mechanical methods produced better results in terms of labour saving, cost saving and drudgery reduction. This meant that the various operations of maize cultivation need to be mechanized with suitable improved implements suitable to local conditions.

Introduction

Maize (zea mays L.) is the largest cereal crop of Jammu and Kashmir, which is grown in the high rainfall area with good drainage. Maize is being cultivated in about 3.3x 105 ha area annually. The total production of maize in the state for the year 2000-01 was 5.38 x 105 M.T. in 0.33 M ha area with an giving the average yields of 16.48 q/ha (Anonymous, 2001). To increase food production, the productivity of land and labour need to be increased substantially, which will require both higher energy inputs and better management of food production systems. Conventional practices are followed for most of the farm operations in maize, which consume maximum time, energy and cost as well as increase drudgery to the growers. High labour demands in each operation adversely affects the timeliness of operations, thereby, reducing the crop yield. Better cultivation practices, plant protection measurers and balanced fertilizer application play a significant role in augmenting the yields. Nevertheless, the adoption of improved processes and modified implements is equally important for better germination, proper plant stand and inter-culturing, which are prerequisites for good crop yields. It is the need of the hour and a challenge to change the agricultural strategy for increasing crop yields through appropriate mechanization to meet the food grain requirement of increasing population.

Research conducted by the scientists on different aspects reveals that decisively higher yield can be obtained by the vigorous introduction of improved tools and techniques. However, it is confronted by technological, economical, physical and social constraints, which must be overcome in order to achieve and maintain production at par with other leading countries producing maize. This means that the various operations needed for increasing the maize crop yield have to be mechanized, not necessarily with the costly automatic equipment, but with improved tools and implements suited to local conditions. To explore the possibility of mechanizing maize cultivation, different farm operations have been reviewed so that farmers of the region may be benefited.

Mechanization Prospectus

Seed Bed Preparation

Maize is mostly raised as a rainfed crop and, therefore, tillage operation is very important for in-situ moisture conservation. Seed bed preparation in maize plays a significant role in crop establishment (Maurya, 1988). It includes ploughing, planking, FYM application and clod breaking that consumes nearly 31 % of the total power required for cultivating maize (Singh, 1996). The choice of the type of implements for seed bed preparation will strongly affect the cost of maize production. In the hills of J & K state, farmers normally use a bullock drawn indigenous wood plough for field preparation. There is a problem of clod formation after ploughing, particularly in heavy soils. Women are engaged for breaking of clods with spade or shovels, which ultimately increase the cost of operation and drudgery. Field experiments were conducted to study the effects of the traditional bullock drawn system and the light weight rotary tiller (**Fig. 1**) on seed bed preparation. Results are presented in **Table 1**. There is a significant saving in cost, time and energy with the power tiller system.

Soil pulverization with of a light weight rotary tiller (8.2 mm) was better than bullock ploughing with an indigenous plough (15.1 mm). The field capacity of the power tiller rotavator was 2.5 times more than the field capacity of the bullock ploughing with an indigenous plough. The yield under rota-tilling twice was 17.6 % more than ploughing twice with bullocks. Hence soil pulverization played a very important role in enhancing productivity of maize.

Dibbling/ Planting

Proper crop establishment is the most crucial requirement in maize cultivation for higher yield. Farmers are still using the broadcasting method of maize sowing, which affects germination due to non uniform placement of seeds at proper depth. Also farmers apply 30-40 % higher seed rate than recommended to ensure optimum plant population. In broadcasting, it is not possible to achieve uniformity in distribution of seed. A farmer may sow seed at the desired seed rate but inter row distribution is likely to be uneven, resulting in bunching and gaps in the field. Field experiments conducted for different maize sowing methods indicate that a tractor drawn maize planter and rotary dibbler (**Fig. 2**) can save 7-8 times the labour and 40-50 % of the cost of operation over the broadcasting method (**Table 2**). Also 20-25 % higher yield was observed due to better plant germination and stand.

Weeding and Earthing up

Weeds compete with the crop plants for soil nutrients, moisture, light and space. Unless weeds are controlled in time, the crop yields are drastically affected. Hence. weeding is an important farm operation of good cultivation and

Fig. 1 Field preparation with light weight rotary tiller

Table 1 Comparison of Light-weight rotary tiller and bullock farming systems

Parameters	Power tiller system	Bullock system
	Rotavator × 2	Indigenous plough × 2
Working width, mm	480	140
Depth of operation, mm	45-81	150
Soil pulverization, mm	8.2	15.1
Effective field capacity, ha/h	0.05	0.02
Field efficiency, %	67	53.6
Labour requirement, man^{-h}/ha	20	50
Cost of operation, Rs/ha	952	1,850
Yield, q/ha	26.7	22.7

Fig. 2 Maize sowing with Tractor drawn raised planter and Manual rotary dibbler

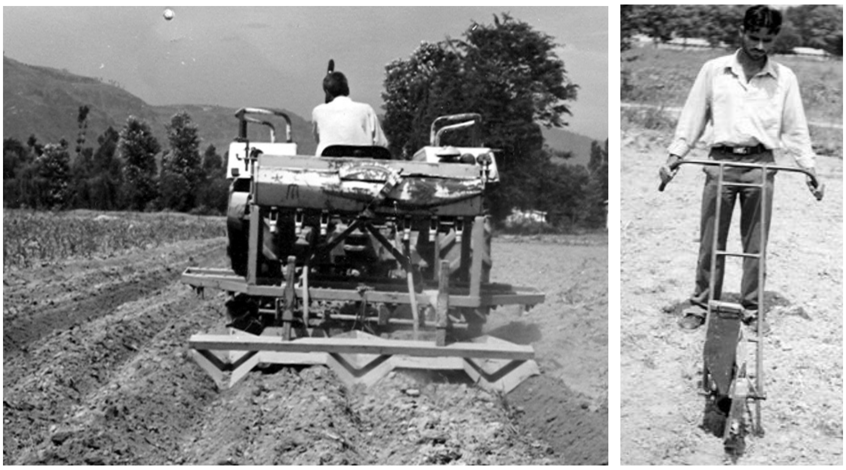

Table 2 Performance of different sowing techniques

Parameters	Methods of sowing		
	Tractor drawn raised bed planter	Manual Rotary Dibbler	Broad-casting
Seed rate, kg/ha	23	24	30
Depth of seeding, mm	51	17	15
Effective Field capacity, ha/h	0.34	0.026	0.029
Missing, %	Nil	7	-
Labour requirement, man^{-h}/ha	6	38	69
Yield, q/ha	28.2	27.1	22.6
Cost of seeding, Rs/ha	783.5	628.07	1,293

Fig. 3 Wheel hand hoe and Power weeder operation in maize

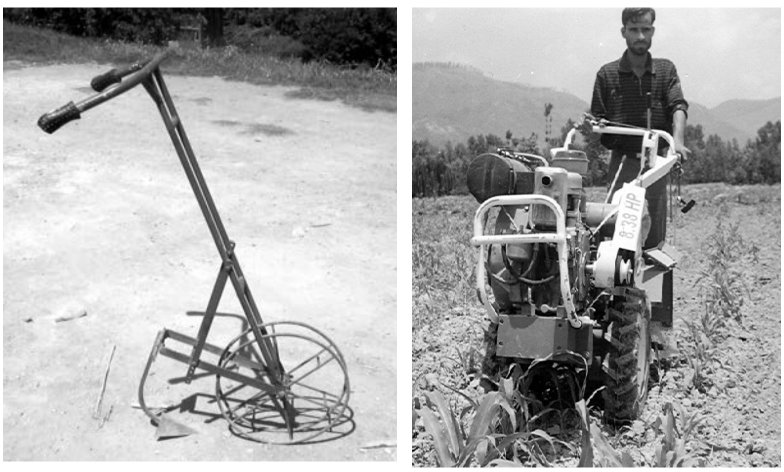

Table 3 Comparative performance of different types of weeders in maize crop

Particulars	Name of weeder		
	Wheel hand hoe (single tyne)	Power weeder	Local hand hoe (spade)
Damage of crops	3-5	5	2-3
Filed capacity, ha/hr	0.020	0.10	0.004
Weeding efficiency, %	68.5	65.5	80.1
Labor requirement, man^{-h}/ha	50	10	250
Cost of weeding, Rs/ha	438	758	2,187

Labour charges@ 70 per day for 8 hour

increasing yield. Farmers normally broadcast maize seed after field preparation. Hence, weeding/intercultural operations in maize crops are done manually by using a spade and the traditional hand hoe. The output of these tools is very low and involves great drudgery due to bending posture while operation. The newly developed wheel hand hoe can be used for efficient weeding/intercultural operations in rows. Field trials of the manually operated wheel hand hoe and power weeder (**Fig. 3**) show that these implements reduce drudgery and take less time taken compared to hand weeding. The use of these implements also results in savings of Rs 1,429-1,749 per hectare over the local hand hoe (**Table 3**). The maize crop requires at least two earthing-up operations. There is a need to mechanize this operation by introducing a suitable hand ridger/power ridger.

Plant Protection

Chemicals are widely used for controlling diseases, insects and weeds in the maize crop. They need to be applied on plants and soil in the form of spray, dust or mist. Many different kinds of sprayers and dusters are available to meet the requirements of cultivators in controlling diseases and weeds. The common type of sprayer is the knapsack sprayer (**Fig. 4**), which can be used in hilly areas. These are very common sprayer used by small and marginal farmers across the country. It is provided with a pump and a large air chamber permanently mounted in a 9 to 22.5 litre tank. One man can spray about 1/3rd area of a hectare in a day. Foot sprayer and engine mounted sprayers are also ideal for spraying operation. Manually operated dusters are quite effective for the control of pests.

Harvesting

The maize crop is harvested after normal maturity with the objective to remove maize cob and straw without loss. Optimum harvesting moisture content for maize is 25-35 percent (w.b). Rapid harvest facilitates extra days for land preparation and early planting of the next crop. Harvesting of the maize crop is traditionally done by manual methods of using a plain sickle. The traditional sickle involves drudgery and is labour intensive. The plain sickle with impact action is used for harvesting maize, which has lower capacity and higher drudgery. The self sharpening serrated sickle (**Fig. 5**) gives better performance as compared to the traditional sickle. The average field capacity of the sickle is 0.015 ha/hr. which is 40 % more than the traditional sickle. It weighs 160 gm, which is much less, as compared to the traditional sickle (200-250 gm), and reduces muscular stress. It is made of spring steel and, hence, does not require frequent sharpening of the blade. However, a power operated harvester is the need of the hour to easily harvest the maize crop with reduced drudgery.

Shelling

After harvesting, the crop is dried in sunshine to a moisture content of 15-21 percent (Afzal Maria *et al.*, 2003) and then de-husking is done by hand and shelling by either beating with sticks or hand rubbing of the de-husked cobs. In the region, de-husking is normally done manually, which is very tedious and time consuming. There is a need to mechanize this operation by introducing a suitable maize de-husker. The maize shelling by beating damages the grains whereas rubbing requires a lot of energy and time. Ergonomically, these methods of maize shelling create drudgery for the users. The low storability of maize seeds under ambient conditions is attributed to the damage occurred during shelling. Injured seeds are more likely to be damaged by volatile fungicides, insecticides than non injured seeds. Shelling of maize can be done easily and quickly with the various maize shellers (**Figs. 6** & **7**). The study conducted on use of octagonal tubular maize sheller, horizontal maize sheller and vertical maize sheller for shelling of maize indicate that a maize sheller can save about 1.5 times the labour over traditional shelling practices. **Table 4** indicates that 34.9, 35.4, and 53.9 % higher capacity can be achieved by using octagonal tubular maize sheller, horizontal maize sheller and vertical maize sheller, respectively, over the conventional

Fig. 4 Knapsack Sprayer

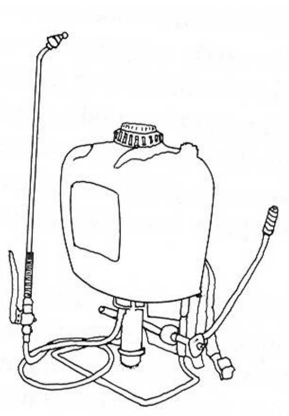

Fig. 5 Self Sharpened Serrated Sickle

Fig. 6 Maize shelling by Tubular Maize Sheller

Fig. 7 Horizontal and Vertical maize sheller

Table 4 Performance of different type of maize shellers

Type of maize sheller	Observed values				
	Moisture content, %	Shelling capacity, kg/h	Damage, %	Shelling efficiency, %	Labour requirement, man^{-h}/kg
Octagonal tubular maize sheller	16.5-22.3	15.25	2.1	98.5	0.067
Horizontal maize sheller	16.5-22.3	15.30	2.3	97.5	0.060
Vertical maize sheller	16.5-22.3	17.40	2.0	98.1	0.058
Conventional method	16.5-22.3	11.30	5.7	100.0	0.089

method. Also, grain damage is lower in maize shelling by mechanical methods (2.1-2.3 %) in comparison to conventional method of shelling (5.7 %).

Conclusion

The mechanization of maize cultivation in the region is still in its infancy, has tremendous potential and merits immediate attention. The opportunities are excellent for mechanizing the maize crop in the hills of Jammu and Kashmir state by adopting the improved tools and implements for different operations suitable for the region, which can reduce the time, cost of operation and drudgery over traditional methods. Research work in the development and dissemination of engineering technologies for mechanization of the maize cultivation for the state can play a dominant role in augmenting and sustaining the maize production. Also, application of socioeconomic and human considerations in agricultural tools and machines play a very vital role and should be given due consideration in introduction of technology in order to achieve the development of hill agriculture.

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Variability of the Performance of Lever Operated Knapsack Sprayer

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Abstract

More than 5 million Lever Operated Knapsack (LOK) Sprayers are sold annually in the world and most of them are sold in Southeast Asia. A research was conducted to find the variability of performance of LOK sprayer. Different sources contributing to variability in spraying from a LOK sprayer were investigated in the laboratory and in field conditions. The pressure and discharge was recorded by a digital pressure gauge and a flow meter, respectively, and varied in every second. An experiment was conducted in the field using three video cameras, which were placed in the front, top and side of the sprayers during operation for finding the variation in spray swaths, nozzle heights, and movement of grip, lance and nozzle, and the potential consequences. The performance of LOK sprayers were poor due to variation of parameters such as spraying pressure (CV = 20 %), flow rate (CV = 11 %), nozzle heights (CV = 60 %), forward speed of the operators (CV = 28 %), and application rate of active ingredient. Thus, the spraying pressure, discharge, swath, spray angle and spray coverage of LOK sprayer varied significantly and all of the above factors influenced an uneven spray distribution, off-target deposition, and drift.

Introduction

Pesticides are being used for protecting crops in most developing countries due to continuous increasing demands for quantity and quality of rice. These pesticides are mostly being applied using Lever Operated Knapsack (LOK) sprayers (FAO, 1994; Thornhill, 1992; Gite, 1992; Litsinger *et al*., 1980; Prasadja and Ruhendi, 1980; Ooi *et al*., 1983). More than 5 million hand operated sprayers are sold annually in the world and most of them are sold in Southeast Asia, (Matthews, 1992). The quality of a number of these sprayers, and their ability to be used to apply pesticides accurately and efficiently is of great concern due to their design and operation. The majority of the sprayers performed poorly, indicating that they are poorly designed with poor materials and mishandled by the farmers, (Mamat and Omar, 1992). It was estimated that about 50-80 % of applied pesticides wasted due to poor spray machinery and inappropriate application methods (Khan *et al*., 1997; and Heong *et al*., 1997). The variability in pumping causes a variable amount of spraying and droplet size. The stroke length can vary from time to time and from operator to operator. The forced applied on the lever can also vary, which influences spray output, swath and droplet size. Pressures can reach as much as 3 to 5 bar (McAuliffe, 1999) during lever operation and this can result in a high percentage of fine droplets. These fine droplets are less likely to penetrate the crop canopy and increase exposure to the worker. The lever strokes per minute have a great influence on spraying quality, coverage and can vary from time to time. A constant flow rate is considered as ±1.5 % of the actual flow rate (McAuliffe, 1999) and ensures accurate application of chemicals, uniform dosages and coverage, and the best biological performance of the applied chemicals. Optimum and constant pressure provides better spray droplet spectrums and less drift and non-target deposition. According to Matthews (1992) and IRRI (1992), the suggested required spraying pressure for insecticides and herbicide is 3 bars and 1 bar, respectively. To achieve the maximum recommended flow rates and operating pressure, the pump should be operated within the suggested ranges. The recommended lever strokes per minute for most LOKs are 20-30 and 10-25 by FAO (1998) and RNAM (1995), respectively. FAO (1998) reported that working pressure, maximum flow rate and variation in pressure at the nozzle should not exceed 10 % of the recommended rate. The operators of the LOK sprayers swing the nozzle from side to side during their walk through the field. The spray swath depends on the movement of the lance's swing. Maintaining a constant walking speed and constant distance between nozzle and plant tops ensures uniform distribution of spray material per unit time. Varying the walking speed or distance between the nozzle and plant tops causes uneven distribution of spray material. The distance between the nozzle and tops of the plants should be maintained at around 30 cm (IRRI, 1988). Garman and Navasero (1984), Alam *et al.* (2000), and Piggin *et al.* (2000) reported that there is a chance of overlap or missed areas during operation of LOK sprayers, and walking speed of the operator greatly influences spray application quality (Spencer and Dent, 1991). Mamat and Omar (1992) reported that 44 % of sprayers in Malaysia work below recommended pressure and discharge rates. On the other hand, more than 30 % of the sampled sprayers produced poor quality spray of less than 30 droplets/cm^2 and more than 60 % of the sprayers produced uneven spray coverage. Willam (1997) reported that most of the paddy farmers in Philippines spray by placing the nozzle 30 cm or more from the leaf surface and spraying their crop until the leaf is wet but not yet dripping, causing pollution to the soil, and finally to the water. Khan *et al.* (1997) found through investigation on spray application and safety measures in Pakistan that poor pump pressure causes bigger droplet formation and excessive drift and ultimately adds to soil pollution. They also stated that non-uniform pesticide distribution results in phytotoxicity (due to over dosing) and resistance (due to under dosing) of pests. Using the recommended pressure, flow rate, nozzle height, and spray swath are necessary for even spraying and getting maximum benefit from pesticides application. Thus, there are numerous sources of variability during operation of LOK sprayers that contribute to inadequate spray coverage, uneven distribution, inaccurate dosages, and losses of chemicals. Consequently, spray application by LOK sprayers can be inefficient, uneconomical, and contribute to pollution of the environment (Alam, *et al.*, 2000). Therefore, research was undertaken to find the variability of LOK sprayer.

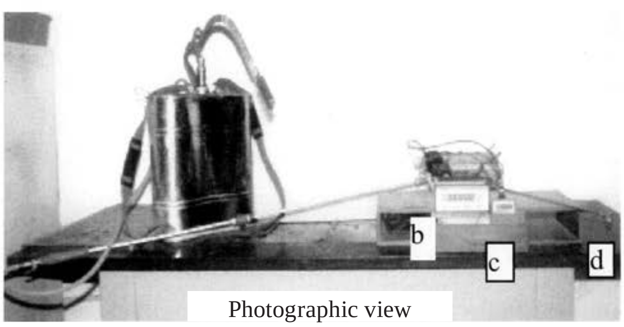
Methodology of Laboratory Experiment

Experiments were conducted in the field as well as in the laboratory to find the variability of performance of a LOK sprayer. In the laboratory, a digital flow meter (Macnaught flow meter, model M2RRP1 with Contrec, flow computer 405) and a digital pressure gauge (HHP 4100, Omega Engineering) were attached at the end of the lance. The experimental set-up in the laboratory is shown in **Fig. 1**. The instruments (flow meter and pressure gauge) were calibrated before starting the experiments. The spray angle and swath from different distances (10 cm to 60 cm) of nozzle tip were determined using a patternator.

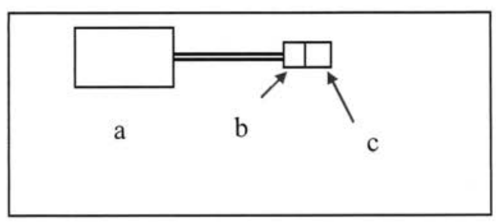
Field Experiment to Determine the Variability from LOK Sprayer

An experiment was conducted during operation in the field for finding the variation in spray swaths, nozzle heights, movement of grip, lance and nozzle by using three video cameras that were placed in the front, top and side of the sprayers (**Fig. 2**). In this experiment, operators were aware of recording. In another experiment, one video camera was used to capture the spraying operation from different angles without informing the operator. After recording, the cassette was replayed and data were collected by manual and visual methods. In the visual method, the video cassette was attached to a personal computer and

Fig. 1 Experimental set-up to measure variability of LOK spraying in the laboratory



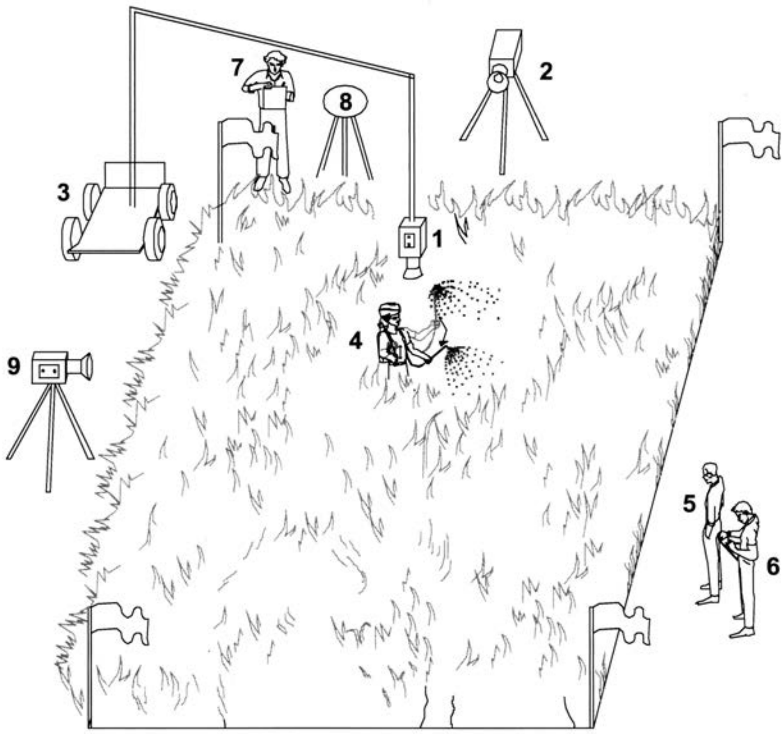
Photographic view



Block diagram

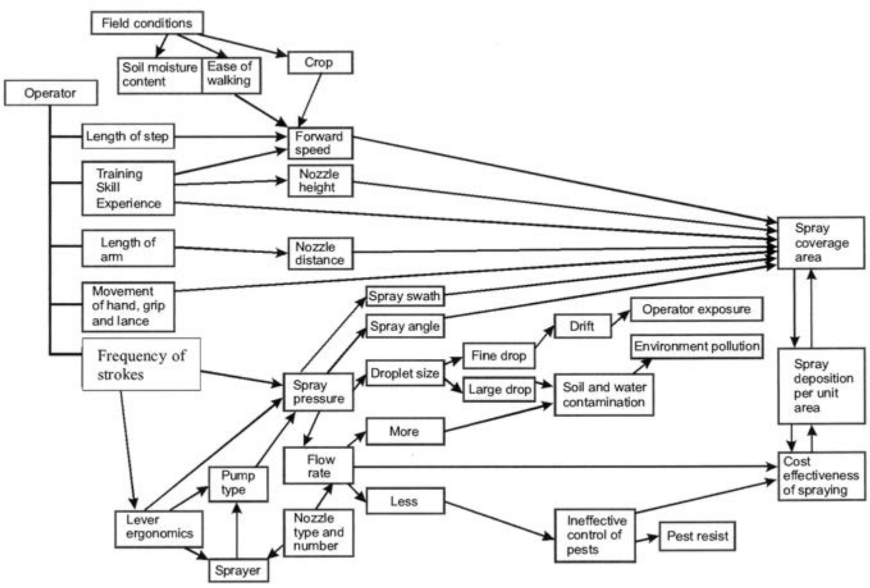
Legend: A. Spray tank, b. Flow meter, c. Pressure gauge, and d. Nozzle images were captured and stored by Ulead Media Studio software. The file was reloaded in "Corel Photo Paint" and the data were analysed. The variations of lever strokes per minute and operator speed were recorded from the field experiment.

Fig. 2 Experimental set-up to measure variability of LOK spraying in the field



Legend 1. Video camera from top, 2. Video camera from side, 3. Moveable elevator vehicle, 4. Spray operator, 5. Lever strokes counter, 6. Time recorders, 7. Person for recording relative humidity (rh), temperature (T), and wind speed (Ws), 8. Try sense device for measuring rh, T, and Ws, 9. Video camera from front

Fig. 3 Sources contributing to variability in spraying from a LOK sprayer and the potential consequences



Results

The sources contributing to spraying and the potential consequences were investigated before the laboratory and field experiments on the variability in application by the LOK sprayer. Numerous sources affected the efficiency of spraying. **Fig. 3** shows the qualitative assessment and impact of different factors on spray efficiency from a LOK sprayer.

The movement of the lever of an over-arm LOK sprayer was observed and it is shown in **Fig. 4**. Most of the time (90 %) operators maintained lever movements within the dashed area where spraying pressure (P) and flow rate (q) varied between 1.5-2.0 bars and 1.1-1.3 L min^{-1}, respectively. Spraying pressure and flow rate increased as length and speed of the lever movement increased. For a maximum length of lever movement, the spraying pressure and flow rate varied between 3.2-3.6 bars 1.6-1.7 L min^{-1}, respectively.

The top and side views of lance movement in relation to the operator are shown in **Fig. 5**. Variations in grip movements and forward speed of the operator contributed to the width of spraying. There was a change of spray width (w) in each swing of the lance when the operator was aware that his actions were being videoed. The average width of spray was 298 cm with a standard deviation (Sdt.) of 31 cm and CV of 11 %. Nozzle height varied with variation in grip position of the operator. **Fig. 6** shows the changes of nozzle height during horizontal swing of the lance. The height of the nozzle in the centre was 38 % higher than that at the open handed end and 15 % more than that at close hand end. It was also observed that the area of swath at the closed hand end was bigger than that at the open hand end. The speeds of the lance movements were also varied with position. Speed increased from

Fig. 4 Schematic diagram of lever movement of an over-arm LOK sprayer

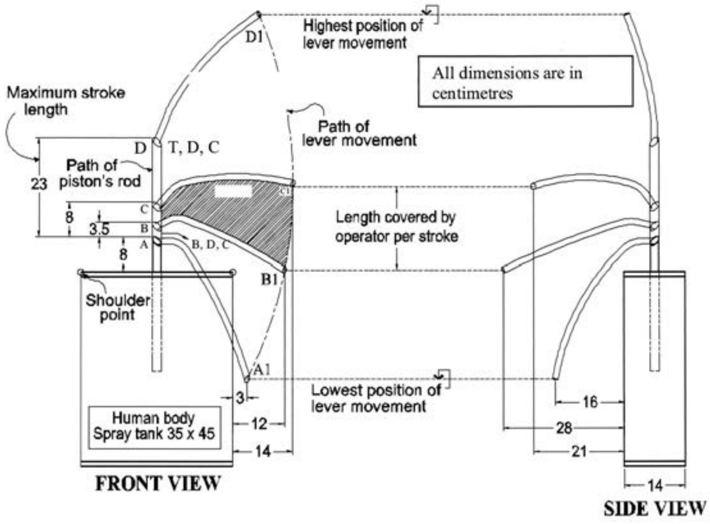


Fig.5 Movement of lance in relation to operator's body; a: Top view, and b: Side view of lane movement

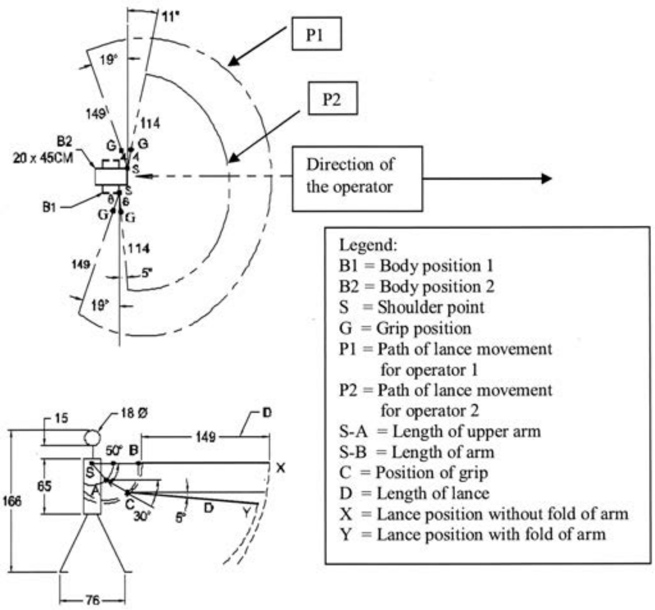
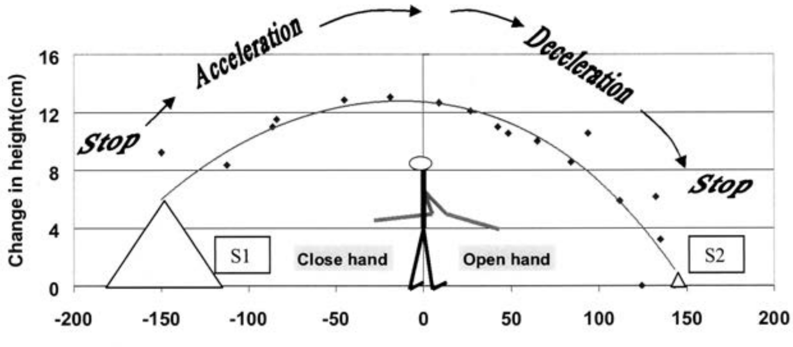


Fig. 6 Changes of nozzle height during horizontal swing of the lance



Open hand : Lance in right hand and nozzle to the right side of the body
Close hand : Lance in right hand but nozzle to the left side of the body

zero at one end to a maximum lance speed in the middle, and then decreased to the other end before stopping again.

Variations in spray swath and forward speed of the operator contributed to overlap and gaps in spraying in the field (**Fig. 7**). The gap and overlap were estimated considering a spray swath of 25 cm. A total of 13 % of the sprayed area was double dosed (i.e. overlapped) and 8 % missed during spraying by a LOK sprayer. The average lever strokes per minute (CV = 27 %), time per swing of lance (CV = 37 %), and angle of the lance (CV = 14 % for operator-1, least experienced), spraying pressure (CV = 20 %), and flow rate (CV = 10 %) varied significantly.

The CV for forward speed, strokes per minute, time per swing of lance, and angle of lance were less for the most experienced operator than for the least experienced one. The difference of means (forward speed, time per swing, and angle of lance) between least and most experienced operators was significant at the 5 % level. The average forward speed that affected the application rate of spraying varied significantly among the operators. **Fig. 8** shows the variation in amount of spray application in relation to operators and field conditions. The average spray width, and angle of lance when operators were unaware they were being filmed were lower than when they were aware of filming. The average spray width was 234 cm (Std. = 41 cm, and CV = 17 %) and angle of total rotation was 121º (Std. = 20º, and CV = 16 %) when unaware of filming.

The difference of means for the width and angle of the lance when aware and unaware varied significantly (p = 0.0000), while the means for operator speed and strokes per minute remained the same (p > 0.1). The average forward speed of the operator was 0.43 ms^{-1} (Std. = 0.11 and CV = 27 %) and stokes were 28 times per minute (Std. = 9.45, and CV = 33 %) being higher when unaware versus aware.

Discussion and Conclusion

A number of factors were identified and presented in **Fig. 3** that affected spray coverage, spray deposition, and efficiency of LOK spraying. The changes of stroke-length, grip and lance movements contributed to uneven distribution of spray, **Figs. 4-7**. Due to variation of total rotation of the lance, forward speed of the operator and height of the lance, spray concentration varied in every moment of swing of the lance, **Fig. 7**. In addition, pressure, flow rate, stroke per minute, nozzle heights, operator speed, time per swing, lance angle and spray width all varied in the use of the LOK sprayer, which contributed to uneven spray deposition. The largest sources of variation were lance angle, time per swing, spray pressure, and operator speed. Pressure varied from 1.5 to 3.6 bars, consistent with the findings of McAuliff (1999). As a result the spray was deposited on off-target (soil/drift). The mean forward speed of the operators varied considerably (e.g. 0.37 ms^{-1} and 0.54 ms^{-1}, leading to direct differences in spray delivery of up to 46 %. Garman and Navasero (1984), Alam *et al.* (2000), and Piggin *et al.* (2000) reported that there was a chance of overlap or missed areas during operation of LOK sprayers. In this study, it was found and quantified that 13 % of total sprayed area could be overlapped and 8 % missed. The CV of the forward speed of the least experienced operator was 29 % and was 14 % for the operator with the greatest experience. This result indicated that training/experience was essential for efficient spraying. T-tests also showed that the means of different spraying parameters varied significantly among operators.

Fig. 7 Gaps and overlaps in spraying due to hand movement in application

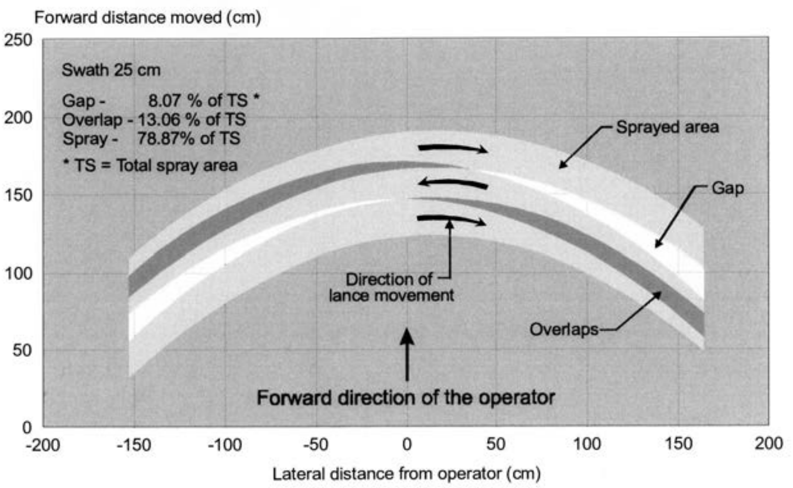
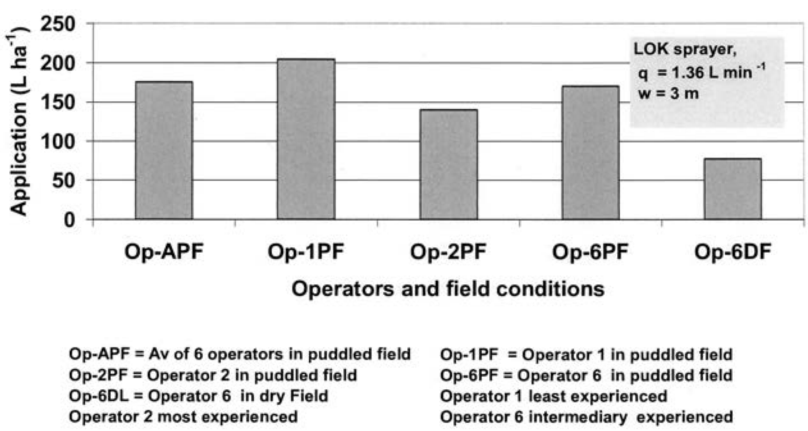


Fig. 8 Variation in amount of spray application in relation to operators and field conditions



Op-APF = Av of 6 operators in puddled field
Op-2PF = Operator 2 in puddled field
Op-6DL = Operator 6 in dry Field
Operator 2 most experienced
Op-1PF = Operator 1 in puddled field
Op-6PF = Operator 6 in puddled field
Operator 1 least experienced
Operator 6 intermediary experienced

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Optimizing Kinematic Parameters for Compost Turning Machine for Mininmum Energy Requirememts

by

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Abstract

A compost turning machine performance in terms of machine capacity, compost density, fuel consumption, energy requirements and turning cost was investigated as a function of change in the kinematic parameter (ratio of drum peripheral velocity to machine forward speed) during the compost turning operation.

From the obtained data it was concluded that:

· Machine capacity increased by decreasing the kinematic parameter.
· Compost density decreased by increasing the kinematic parameter.
· Energy requirements, as well as turning cost, were minimum at a kinematic parameter of 35.

Introduction

Mechanization of compost turning operation is considered of great importance to reduce time period to maturity, labor and cost. Different types of turning machines are available in compost fields nowadays. Among these is the self-propelled compost turning machine.

The major concerns with the compost turning operation is to mix compost materials, rebuild the porosity of the compost and release trapped heat, water vapor and gasses. This exposes all materials equally to the air at the outer surface. The compost turning machine performs complex motions. For example, a translatory motion with the machine and relative motion due to the positive drive of the turning drum. El shal and Morad (1991) stated that the combine header performance during the harvesting of standing and lodging rice have a reel kinematic parameter of 1.2 and 1.5 for standing and lodging rice, respectively, which are considered the optimum values for minimizing the header losses. Morad and El Shazly (1994) stated that the adjustment of a rotary plow kinematic parameter improved tillage performance. They also showed that a rotary plow kinematic parameter of 2-2 minimized energy requirements and improved tillage efficiency.

Morad (1995) stated that the proper adjustment of the kinematic parameter for a rotary mower during the mowing operation is of great importance to increase crop yield and decrease cost requirements. Decreasing the rotary mower kinematic parameter increased field capacity and cutting height, while field efficiency, cutting efficiency, fuel consumption and energy requirements decreased. A rotary mower kinematic parameter of 25 minimized the mowing cost.

Mohamed, *et al*. (1999) showed that, the higher values of a harvesting machine kinematic parameter are more effective in lifting lentil plants and laying them back on to the cutter bar. To avoid the shacking action of the mower cutter bar, increasing kinematic parameter values from 1.33 to 2 increased grain losses from 5.9 to 8 %. It was recommended that the lentil crop be harvested using the self-propelled harvesting machine at a reel kinematic parameter of 1.33.

Abd El-Mottaleb (2006) showed that, increasing machine forward speed from 200 to 600 m/h, measured at rotor speeds of 80, 160 and 240 rpm, increased fuel consumption from 14.9 to 19.1 (26 %), the power from 14.9 to 23.2 (26.9 %) and the energy requirements from 12.40 to 21.50 and (28.10 %) when the self propelled turning machine was used.

Fouda *et al*. (2008) showed that increasing the compost turning machine forward speed from 1,200 to 1,500 m/h increased fuel consumption from 7.5 to 10.0 lit/h. Data have shown that increasing machine forward speed from 1,500 to 2,000 m/h increased the required power from

26.5 to 35 kW at a constant turning number of four times per month and pile height of 100 cm.

This work will cover theoretical and experimental analysis on the compost turning machine kinematic parameter (ratio of drum peripheral velocity to machine forward speed) to optimize its value for the purpose of minimizing both energy requirements and turning cost.

Material and Method

Experiments were carried out at Ramsis Company for Management of Agr. Projects and Super Bio Company for compost, Sharkia Governorate to optimize the kinematic parameter of the self-propelled compost turning machine.

The raw material for producing compost was crop residues (especially rice straw). Poultry and livestock manure were also used to accelerate composting process. Added to that, a finished compost was used as a supply of microorganisms.

The Compost Turning Machine

An imported self-propelled compost turning machine was used as shown in **Fig. 1** with the specifications in shown in **Table 1**.

Kinematics of Compost Turning Machine

The blades of turning drum perform complex motions: (1) translatory motion with velocity (v) and (2) rotary motion of angular velocity (ω) around their axes (O) (Klenin *et al.*, 1985). The blades of the turning drum (**Fig. 3**) rotate in a plane coinciding with the direction of motion. The origin of the coordinate system coincides with the axis O of the shaft with the X axis along the direction of motion and the Y axis directed downward.

The extreme point on the blade (A_o) is initially on the axis X. After an interval of time, t, the axis of the shaft is displaced to the position, O_1, having covered the distance,Vt. During this interval, the blade turns through an angle (ωt). The point A_o goes to position A, the coordinates of which are obtained as follows:

$$\dot{X}_A = Vt + R \cos \omega t$$

$$\dot{Y}_A = R \sin \omega t,$$

where R is the distance from the axis of the shaft to the extreme end of the blade.

By differentiating the above equations, horizontal and vertical components of speed can be determined.

$$\dot{X}_A = V - \omega R \sin \omega t$$

$$\dot{Y}_A = \omega R \cos \omega t$$

The blades make contact with the composting windrow at a rotation angle of ωt. In this position, the blades motion is preferred to be only in the vertical direction and as a result, the horizontal component of the blades should equal zero.

$$\dot{X}_A = V - \omega R \sin \omega t_1 = 0$$

$$O_r \sin \omega t_1 = \frac{\upsilon}{\omega R} = \frac{1}{\lambda},$$

where λ is the kinematic parameter of the turning machine (ratio of rotor peripheral velocity to machine forward speed). Since sin $wt_1 \leq 1$, so $\lambda \geq 1$. This means that the blade peripheral speed should be equal to or higher than the machine forward speed.

$$\lambda \geq \frac{\omega R}{\upsilon}$$

Table 1 The self-propelled compost turning machine specifications

Made in	Model	Engine	Rotor diameter	Rotor length
Germany	Backhus 15-50	Diesel (112 kW) 150 hp	1,000 mm	4,350 mm

Fig. 1 The self-propelled compost turning machine

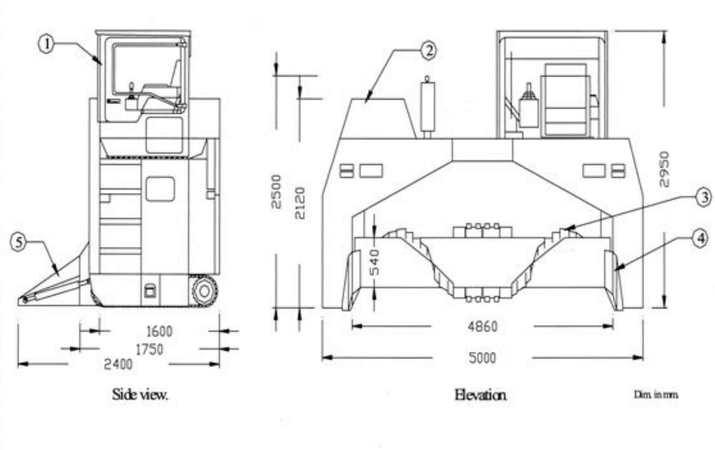
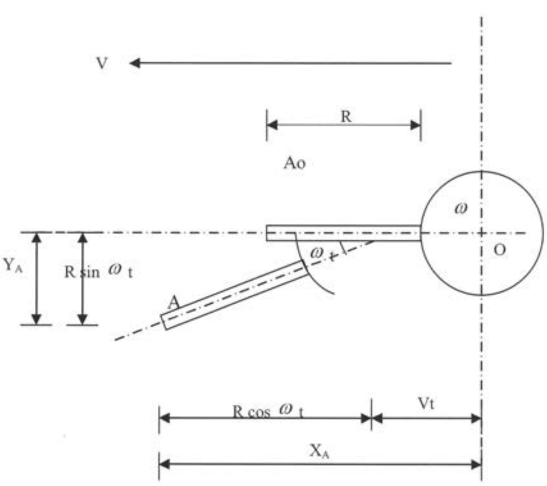


Fig. 2 Kinematics of compost turning machine



The turning pitch (S_H), according to the definition put forward by Kepner *et al*. (1975), is the amount of travel per revolution.

Hence, turning pitch = time per revolution X forward speed

$$i.e., S_H = \frac{2\pi}{\omega}\upsilon, \qquad S_H = \frac{2\pi R}{\lambda}$$

Assuming that the number of blades per course n,

$$\text{So} \qquad S_Z = \frac{2\pi R}{\pi\lambda},$$

where S_z is the turning pitch per blade.

According to this analysis, the theoretical kinematic parameter can be estimated as follows:

$$\lambda \geq \frac{2\pi R}{S_Z n}$$

The previous equation shows that the kinematic parameter as well as the turning pitch has a great effect on the compost turning machine performance. So, optimizing their values is considered of great importance for the turning machine to decrease energy requirements and increase turning quality.

For the turning machine under test, according to the previous equation, the theoretical kinematic parameter can be estimated to be $\lambda \geq 31$ taking into consideration that S_Z = 10 cm. There are three ways in which the kinematic parameter can be varied: change the rotor radius, change the peripheral velocity and change machine forward speed.

So, in the present investigation, combination of the above mentioned factors were taken into consideration to obtain different kinematic parameters for selecting the optimum value experimentally.

The experiment was conducted under conditions of constant rotor peripheral velocity of 240 rpm and five different forward speeds (2,000, 2,200, 2,500, 3,000 and 3,500 m/h), which corresponded to five different kinematic parameters of 25, 30, 35, 40 and 45.

Evaluation of the above mentioned kinematic parameters was done taking into consideration machine capacity, fuel, power, energy and turning cost.

Measurements

Compost density, ρ, was determined according to the following formula:

$$\rho = \frac{m}{\upsilon}$$

where ρ = compost density, kg/m^3;
m = compost sample mass, kg
v = compost sample volume, m^3.

Machine capacity (M. C.) (m^3/h) was determined using the following equation:

$$M.\ C. = A \times V$$

Where A = operational cross sectional area, m^3; V = machine forward speed, m/h.

Fuel consumption (F. C.) was recorded by accurately measuring the decrease in fuel level in the fuel tank immediately after executing each operation.

Turning power (T. P.) was calculated by using the following formula (Barger *et al*., 1963):

$$T.\ P. = Fc \times Cv \times \eta_{th} \times 427 \times \frac{1}{75} \times \frac{1}{1.36}\ kW$$

where
Fc = Fuel consumption, kg/s;
Cv = Calorific value of fuel, k cal/kg (Cv = 10,000 kcal/kg)
427 = Thermo mechanical equivalent, kg m/k cal;
η_{th} = Thermal efficiency of the engine, % (η_{th} = 30 % for diesel engine)

Energy requirement (E. R.) can be calculated using the following equation:

$$E.\ R.\ (W.h/ton) = \frac{T.P(W)}{M.C\ (m^3/h) \times p\ (ton/m^3)} \times \text{turning number to moturity}$$

Turning cost *(T. C.)*

Machine cost was determined using the following formula (Awady 1978)

$$c = \frac{p}{h}\left(\frac{1}{e} + \frac{i}{2} + t + r\right) + (0.9hp \times f \times s) + \frac{w}{144}$$

where c = hourly cost. P = capital investment, h = yearly operating hours e = life expectancy i = Interest rate t = Taxes and over head ratio r = Repairs ratio of the total investment Hp = Horse power of engine. f = Specific fuel consumption, lit/hp h, s = Price of fuel per liter w =Labor wage rate per month in L. E. 144 = Reasonable estimation of monthly working hours.

Turning cost can be determined using the following equations:

$$\text{Operationa 1 cost (L.E./m}^3\text{)} = \frac{\text{Mashine cost (L.E./h)}}{\text{Mashine capacity (m}^3\text{/h)}}$$

$$\text{T. C. (LE/ton)} = \frac{\text{Operationa 1 cost}}{\text{Compositing density (ton/m}^3\text{)}} \times \text{turning. number to moturity.}$$

Results and Discussion

Effect of Kinematic Parameter on Machine Productivity

The most critical factor in productivity of the turning machine is its kinematic parameter. **Fig. 3** shows the effect of the kinematic parameter on machine productivity. Results show that an increasing kinematic parameter from 25 to 45 decreased machine productivity from 2,100 to 1,600, from 2,750 to 2,100, from 3,500 to 2,550, and from 3,800 to 3,200 m^3/h under different pile heights of 60, 80, 100 and 120 cm, respectively. The increase in machine capacity by decreasing the kinematic parameter is attributed to the increase in quantity of turning materials per unit time because the decease in kinematic parameter is acquainted by an increase in forward speed.

Effect of Kinematic Parameter on Compost Density

Compost density is inversely affected by the kinematic parameter. **Fig. 4** shows that increasing the kinematic parameter from 25 to 45, decreased compost density from 590 to 480, from 610 to 490, from 630 to 500 and from 680 to 520 kg/m^3 under different pile heights of 60, 80, 100 and 120 cm, respectively. The decrease in compost density is attributed to more cutting and mixing by the rotor blades per unit volume of the disturbed compost due the high rotor velocity compared with the low forward speed. This action increased the material volume resulting in a decrease in compost density.

Effect of Kinematic Parameter on Energy Requirements

Fuel consumption, required power and energy requirements are greatly affected by the turning machine and its kinematic

Parameter, **Fig. 5**. Concerning the fuel consumption, increasing kinematic parameter from 25 to 45 pile height of 100 cm. decreased fuel consumption from 36.6 to 26.6 lit/h. As to the energy requirements, increasing kinematic parameter decreased energy requirements up to 35. With further kinematic parameter increase up to 45, energy requirements will significantly increase. When the kinematic parameter was 35, the energy requirements value was 875 W h/ton. under the same previous condition. The increase in energy requirements by increasing kinematic parameter from 35 to 45 is attributed to the increase in rotor blades knocking more compost material per unit time. The increase in the energy by decreasing kinematic parameter from 35 to 25 is attributed to the excessive load of compost material on the rotor blades added to the high impact of rotor with the compost material.

Effect of Kinematic Parameter on Turning Cost

The most critical factor in selecting a compost turning machine is the cost required for the turning operation. Results in Fig. 6 show the effect of the turning machine as well as its kinematic parameter on both hourly and turning costs. The data show that, increasing the kinematic parameter from 25 to 35 at pile height of 100 cm, decreased turning cost from 1.53 to 1.27 L.E./ton. With any further increase in the kinematic parameter from 35 up to 45, turning cost will increase from 1.27 to 1.49 L.E./ton under the same previous condition.

Conclusions

The proper adjustment of the turning machine kinematic parameter during the compost turning operation is of great importance to decrease both energy and cost.

The kinematic parameter of between 30 to 35 and pile height of 100 cm are considered the optimum

Fig. 3 Effect of kinematic parameter on machine capacity at different pile heights

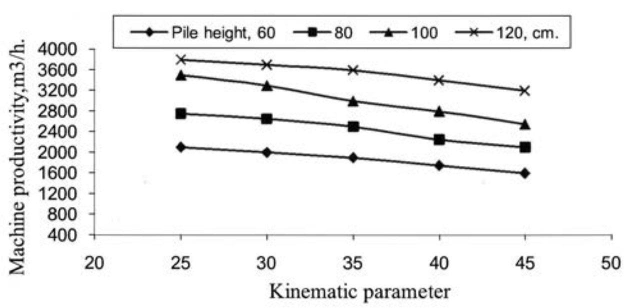


Fig. 4 Effect of kinematic parameter on composting density at different pile heights

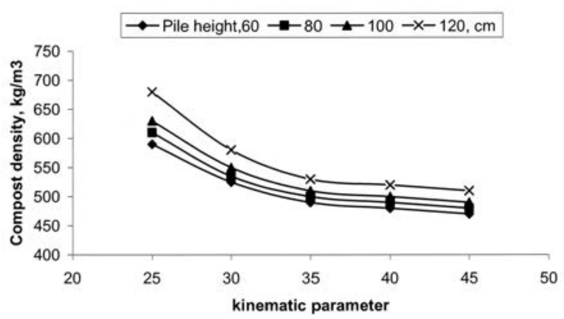


Fig. 5 Effect of kinematic parameter on fuel and energy requirements at different pile heights

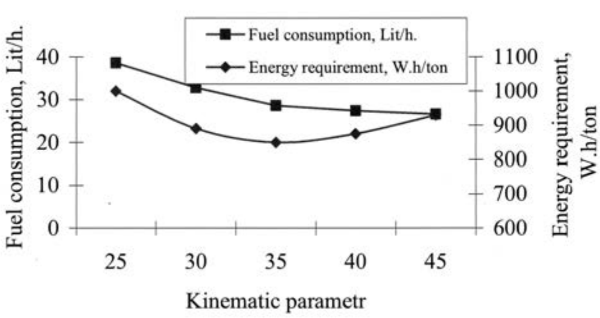
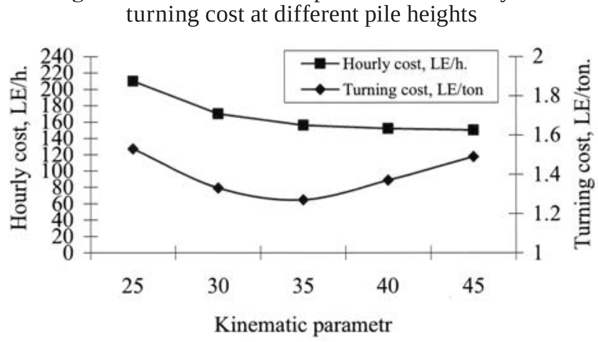


Fig. 6 Effect of kinematic parameter on hourly and turning cost at different pile heights



conditions for the compost turning operation.

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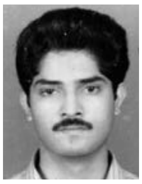
A Mechanical Dibber Planter for Selected Seeds

by



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Abstract

A mechanical dibber planter was developed for planting selected seed namely maize, redgram, and cotton. The unit consisted of six dibbers arranged radially on a dibber wheel, which actuates the seed metering mechanism and allows the seed to fall on the seed transfer cup and travel to the tip of the dibber. The dynamic performance of the dibber wheel was evaluated in a test track in terms of depth of placement of seed, pattern of seed placement, and hill spacing at forward speeds of 1.0, 1.25, 1.5, 1.75, and 2.0 km h^{-1}, dibber depth settings of 20, 35, and 50 mm, and soil moisture levels of 8, 10, 12, 14, and 16 percent (d.b.). Tests were conducted using vertisol. The dibber depth setting and forward speed influenced the pattern of seed placement. The soil moisture did not affect the number of seeds placed inside the dibbed hole. The hill spacing was strongly influenced by all the selected soil and machine parameters. A dibber depth setting of 50 mm resulted in the best performance at the forward speed of 1.0-1:25 km h^{-1} and soil moisture content of 10 percent (d.b.). From the field experiments, the frequency distribution of number of plants per hill indicated that two seedlings were germinated for maize in 75 ± 2 percent of the hills. But, three seedlings were germinated in 68.5 ± 1.5 and 62 percent of the hills for redgram and cotton, respectively. The frequency distribution of hill spacing for the three crops indicated that about 32 percent of the hills were spaced at 300 mm. About 82 ± 2 percent of the hills were spaced at a distance of 285-300 mm. The missing hills were 3-5 percent. The field capacity of the dibber planter was 0.27, 0.20 and 0.34 ha h^{-1}, respectively for maize, redgram and cotton.

Introduction

The steady increase in India's population necessitates an increase in crop production every year to meet the food demand of the country. Because of the steep increase in cost of seed, fertilizers, and migration of agricultural labourers to urban areas, the cost of food production is going up at an alarming rate. Although introduction of high yielding varieties and adoption of more stringent resource management practices has increased crop production to a certain extent, technological advancement in agriculture is a must to cope with the productivity of the land (Swaminathan, 2001). The most important agronomic practice that enhances the productivity in cultivable land is maintaining required plant population. Low seed germination percentage, seed damage, inadequate soil moisture, and improper depth of seed placement are the major factors that affect the plant population in the field. At present, the desired plant population is achieved by sowing excess seeds per unit area and thinning the crop after germination. This process is labour intensive and costly seeds are wasted, thereby, the total cost of production is increased many fold. Introduction of precision planting machinery can solve these problems apart from enhancing plant yield through better plant spacing management. At present precision planting is not popular in the country since 100 percent viable seeds are not commercially available. If precision planting is adopted at this juncture, the plant population must to be maintained through gap filling (Anon., 1999). But the gap filled seeds require 7-10 days to catch up with the earlier seedlings in the field. The life cycle is hence affected and ultimately the crop yield is reduced. Hill dropping is therefore an ultimate solution, as it takes into account the viable part of the seed, since two to three seeds are placed in a single hole. If such a hill dropping system is fitted with a dibber, it will ensure a more desirable environment by providing correct depth of seed placement and spacing. Earlier researchers investigated the dibber planting technique and its capacity to improve overall emergence of seeds in comparison with conventional planters (Heineman *et al.*, 1973;

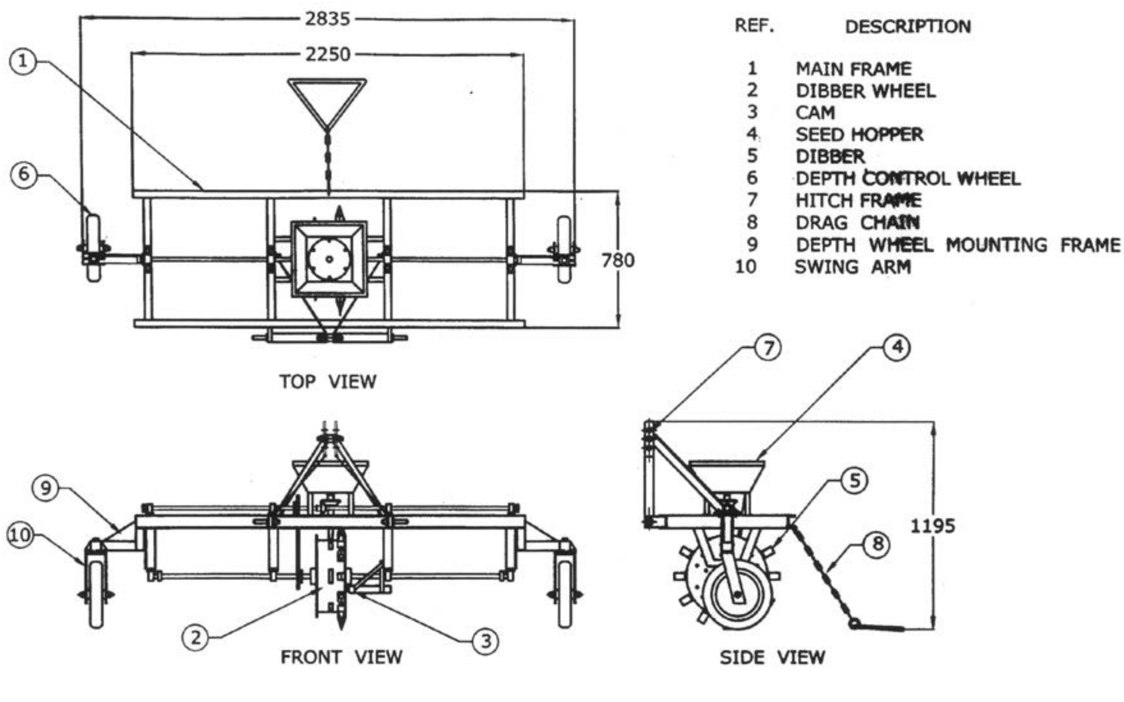
Harriot, 1974; Wilkins *et al*., 1979; Molin *et al*., 1998; Miles and Reed, 1999). The methods by which the seeds are dibbed at a predetermined depth were accomplished either by sequential delivering or by allowing the seeds to rest temporarily inside the dibber and then delivering to the dibbed hole. The sequential delivering of seeds is a continuous process by which seeds are metered, transferred, and dropped to the dibbed hole. It is a complicated process and requires simultaneous seed transferring when the holes are dibbed. The simultaneous seed transferring is achieved through pneumatic and magnetically attractive seed coating methods (Wilkins *et al*., 1979). Brown *et al*. (1994) developed a dibber drill that consisted of a dibber wheel mounted on a tool bar to punch holes in the soil and an air assisted plunger type seed metering mechanism. The dibber wheel was driven by direct contact with the ground. A compressor supplied air at 0.7 bar to transfer the seeds from the seed metering mechanism to the dibbers. The average seed emergence recorded with this drill was in excess of 70 percent compared with 41 percent for the coulter drill. But in these types of dibber planters, the delivering of seeds is intermittently disturbed due to improper synchronization caused by the wheel slippage. Also, magnetically attractive coating of seeds is costly. These problems are eliminated in the mechanical dibber planter in which seeds are allowed to rest temporarily inside the dibber just before they are dropped. Adekoya and Buchele (1986) developed a mechanical punch planter to plant maize in tilled soils. It consisted of twelve radially mounted punches on a wheel made of two continuous discs and one annular disc. The metering unit was powered by the rotation of the punch wheel. As the planter speed increased from 2.8 to 7.9 km h^{-1}, the punched hole containing only one seed decreased from 91 to 59 percent. A mechanical dibber planter consists of a seed metering unit, a seed transfer and synchronizing unit, and a dibber wheel. The research on cam operated dibber planters is still in the developing stage since little work has been done on this. Hence, such a planter was developed in this research and its performance tested for planting maize, redgram, and cotton.

Materials and Methods

Development of the Dibber Planter

A dibber planter consisting of a frame, dibber wheel, seed metering mechanism, cam, drag chain furrow closer, and depth control wheels was developed as shown in **Fig. l**. The main frame was made to support the dibber wheel, seed metering mechanism, cam, furrow closer, and depth control wheels. A three point category-I hitch was welded on the top of the frame to mount the unit to the tractor. The dibber wheel consisted of six dibbers arranged radially on a supporting disc (**Fig. 2**) of 473 mm diameter. The dibber (**Fig. 3**) was fabricated to a size proportional to the diameter of the supporting disc. Six pegs were welded on the periphery of an annular ring (**Fig. 4**) in such a way that, when assembled with the supporting disc, one peg was fixed between two

Fig. 1 Dibber planter



dibbers. The annular ring was also used to support the seed transfer cups. A covering disc was made to enclose the components of the dibber wheel. When these units were assembled as a dibber wheel (**Fig. 5**), it also acted as a ground wheel to drive the seed metering mechanism. A rectangular shaped seed box 430 × 430 × 180 mm with a 3 kg capacity was fabricated and mounted on top of the frame. The slope of

Fig. 2 Supporting disc for dibbers

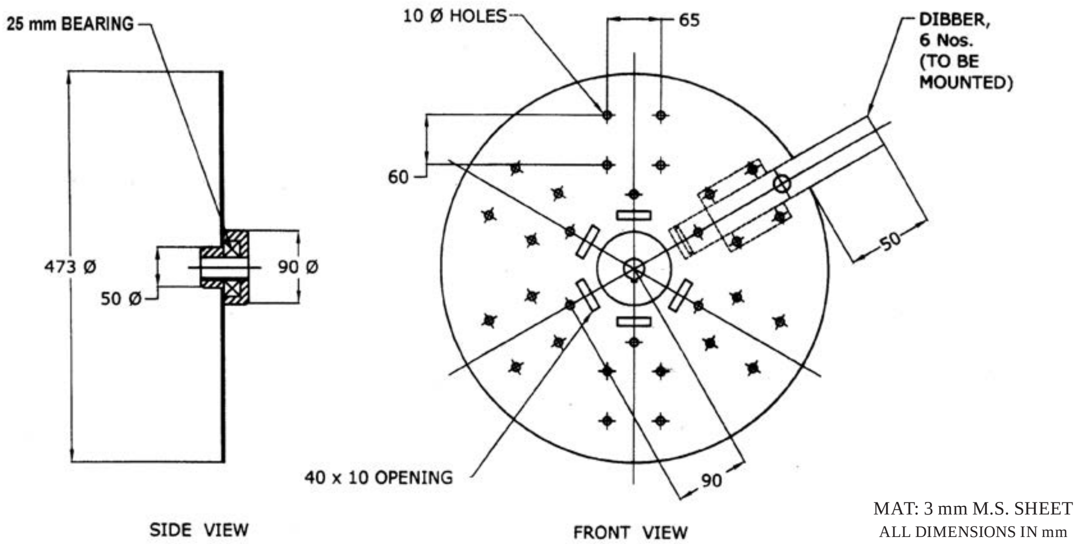
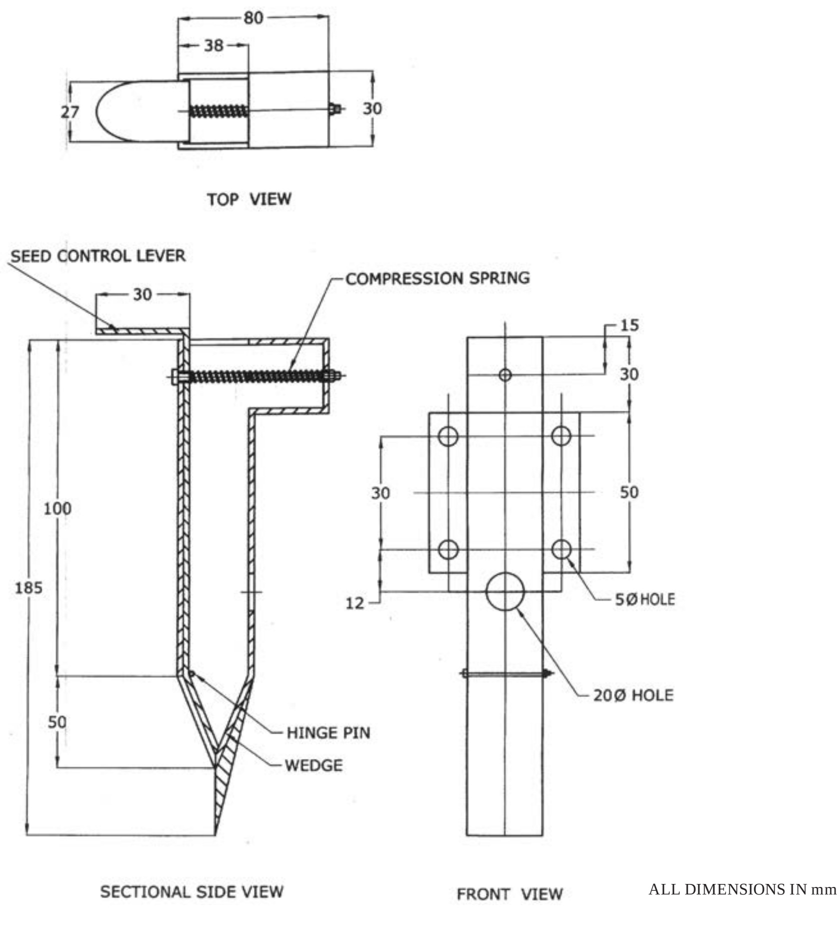


Fig. 3 Dibber



the seed hopper was maintained at 30 deg, which was greater than the angle of repose of all selected seeds, to ensure free flow. Three 240 mm diameter seed discs made of 10 mm thick mild steel plates with cell diameters of 11, 8, and 10 mm were fabricated for maize, redgram, and cotton, respectively. A 12 mm diameter circular opening was drilled on the hopper bottom to transfer seeds to the dibber wheel when it coincided with the cells. To avoid seed damage, a clearance of 1 mm was allowed between the seed disc and the hopper. The metering mechanism was driven by the dibber wheel through a chain drive and bevel gear. The speed ratio between the dibber wheel and seed metering mechanism was 1:1. A cam was fabricated for a displacement angle of 60 degrees with an outstroke-dwell-return stroke of 30-1 0-20 deg. It was mounted on the common tool bar of the main frame. The position of the cam was fixed in such a way that the seed control lever opened the dibber when it is about to penetrate, the soil. A 16 mm diameter drag chain was provided as a furrow closer at the rear side of the main frame. Two nylon tyres of 3.50-8, 4 PR were used as depth control wheels. These depth control wheels rotated universally by means of a suitable frame work that consisted of two L-shaped frames made of Indian Standard Angle of 50 × 50

Fig. 4 Annular ring with seed transfer cups

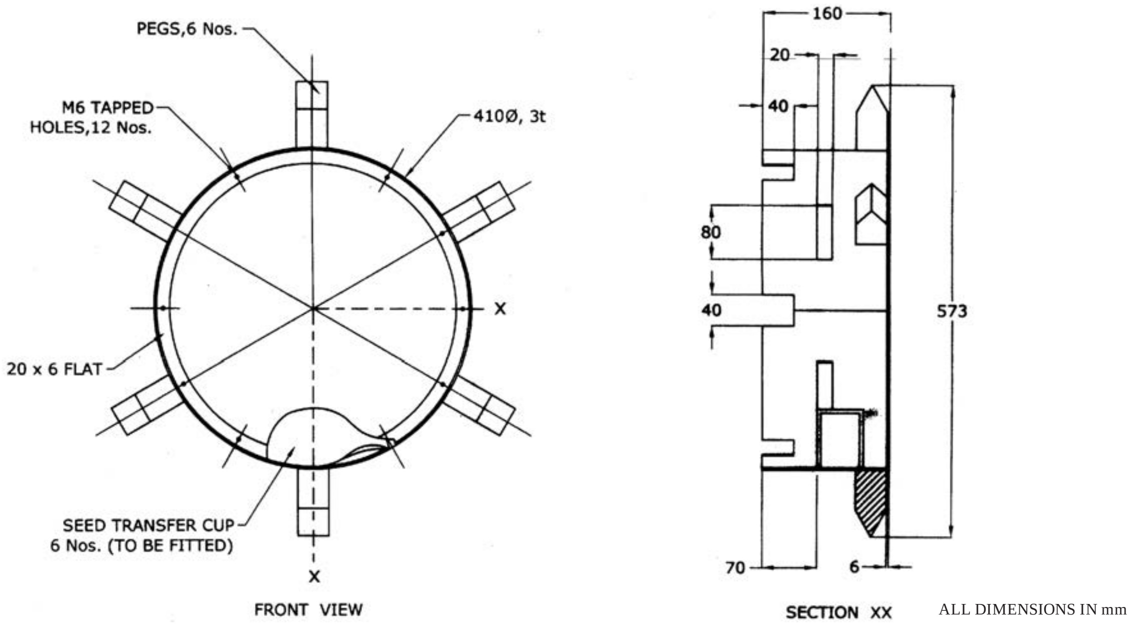
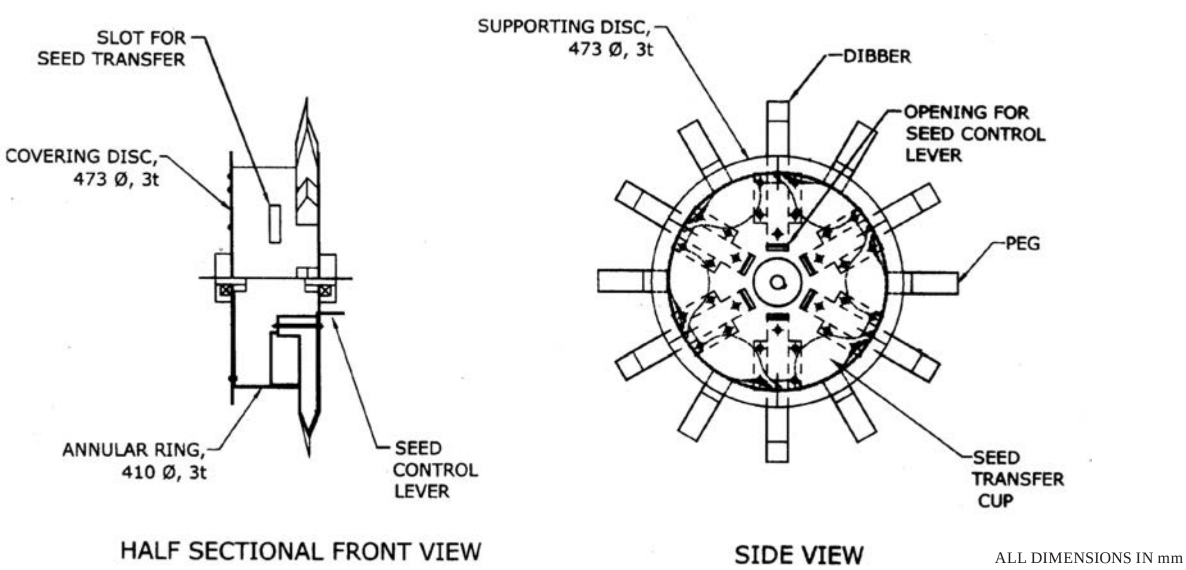


Fig. 5 Prototype dibber wheel



× 6 mm fastened on both ends of the main frame. A 60 mm diameter bush bearing and 65 mm length was welded at the end of the L-shaped mounting frame. Two swing arms pivoted through the bush by means of an axle. This arrangement avoided dragging of the depth control wheels. The depth of operation of the dibbers was varied by raising or lowering the wheels. While working, the metered seeds fell on the seed transfer cup and traveled to the tip of the dibber and rested temporarily. As the dibber entered the soil, the seed control lever (follower) came in contact with the rise portion of the cam, pushing the compression spring to open the dibber. The seed, which were resting temporarily inside the dibber were then dropped into the dibbed hole. As the dibber came out of the soil, the follower came in contact with the fall portion of the cam surface, thus, releasing the spring to close the dibber.

Testing of the Planter under Dynamic Conditions

The planter was tested under dynamic conditions on a 50 × 0.4 m, level, uniform and straight soil track. Vertisol at 8 percent (d.b) moisture content was spread in the track to a depth of 70 mm. Slip of the dibber wheel and change in the forward speed of the tractor were expected to cause significant variation in the distribution of seed, depth and pattern of seed placement, and hill spacing. After planter calibration, tests were conducted at forward speeds of 1.0, 1.25, 1.5, 1.75, and 2.0 km h^{-1}, dibber depth settings of 20, 35 and 50 mm, and soil moisture levels of 8, 10, 12, 14, and 16 percent (d.b). The depth control wheel was adjusted to the correct dibber depth setting and the depth of seed placement and pattern, and hill to hill spacing were observed as

Table 1 Factors Selected for Dynamic Test

Seed	Soil type	Speed, Kmh^{-1}	Dibber depth setting, mm	Soil moisture, percent (d.b)
Maize	Vertisol	1.00	20	8
Redgam		1.25	35	10
Cotton		1.50	50	12
		1.75		14
		2.00		16
Replication – 4				

Total number of treatments =3 × 1 × 5 × 3 × 5 = 225

Fig. 6 Effect of forward speed and soil moisture on depth of placement of seed

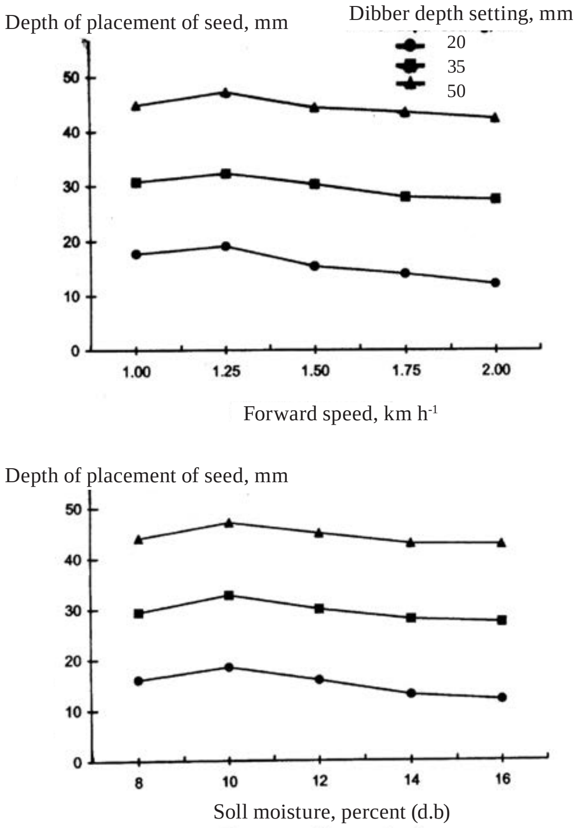
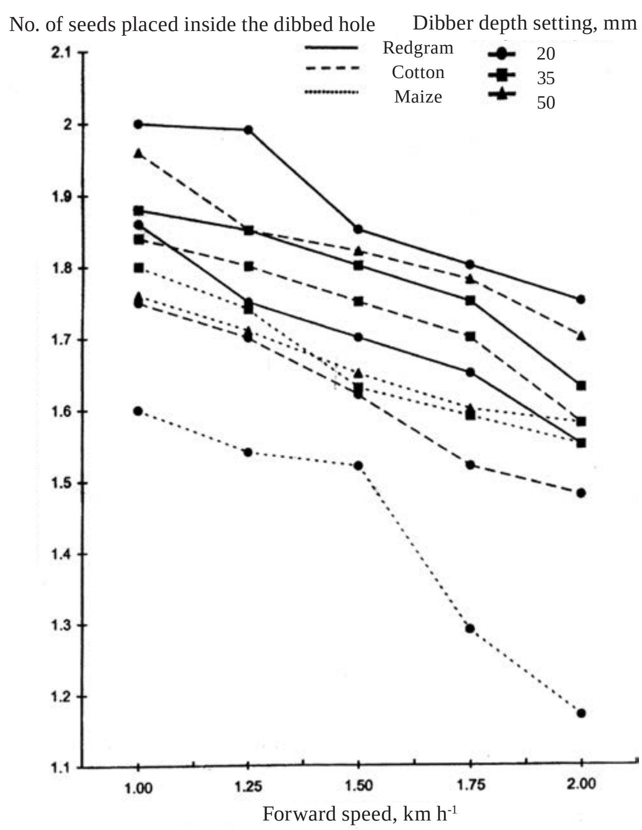


Fig. 7 Effect of forward speed on number of seeds placed insaide the dibbed hole



the dibber planter moved forward. The experiment was replicated four times. Treatment combinations are shown in **Table 1**.

Field Performance Evaluation of the Planter

A field size of 0.6 ha, each in vertisol, was prepared to a fine tilth and divided into three strips of 0.2 ha. The pre-calibrated dibber planter was used to plant maize, redgram and cotton in each plot at the optimized dibber depth settings of 50 mm. The unit was evaluated with the optimized forward speed of 1.0-1.25 km h^{-1} at 10-12 percent (d.b) moisture content. The row spacing adopted was 600 × 300, 450 × 300, and 750 × 300 mm for maize, redgram, and cotton, respectively (Anon., 1999). Life irrigation was provided immediately after planting. The seed geminated per hill and hill spacing were observed and recorded randomly in each plot at a length of 3 m at 30 locations on the seventh day of planting. The observations were statistically analysed using single factor ANOV A. The frequency distribution of the number of plants per hill and hill spacing were drawn.

Results and Discussion

Performance of the Planter under Dynamic Conditions

Predominance on Depth of Placement of Seed

The interaction of factor means indicated that, irrespective of dibber depth setting, the depth of placement of seed decreased when the forward speed was increased from 1.0 to 2.0 km h^{-1} (**Fig. 6**) (Adekoya and Buschele, 1986). A higher depth of placement of seed was observed for 1.0-1.25 km h^{-1} compared to other speeds for the dibber depth settings tested. At higher forward speeds of 1.5, 1.75, and 2.0 km h^{-1}, the release of seeds from the dibber was delayed and seeds were not placed at the centre of the dibbed hole. The depth of placement of seed was the highest at 10 percent (d.b) soil moisture content for all the dibber depth settings. At all other moisture contents, it was lower. It was found to increase as the soil moisture increased from 8 to 10 percent and, thereafter, it decreased. At 8 percent moisture content, the dibbed hole collapsed affecting the depth of placement. At soil moisture content of 12, 14, and 16 percent, the soil stuck to the dibber and affected the release of seed at the centre of the hole. Hence, it was concluded that the forward speed of 1.0-1.25 km h^{-1} and soil moisture content of 10 percent (d.b) yielded the best performance for depth of seed place-

Fig. 8 Effect of forward speed and dibber depth setting on hill spacing

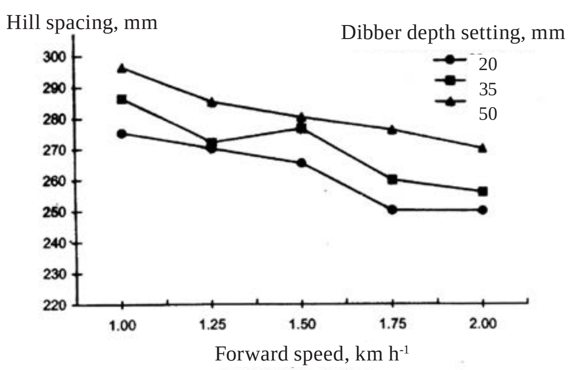


Fig. 9 Effect of soil moisture and dibber depth setting on hill spacing

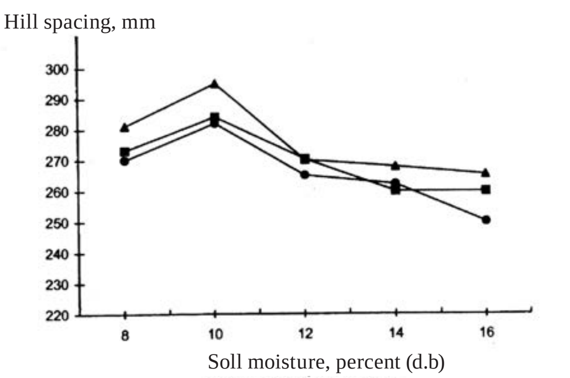


Fig. 10 Frequency distribution of number of plants per hill

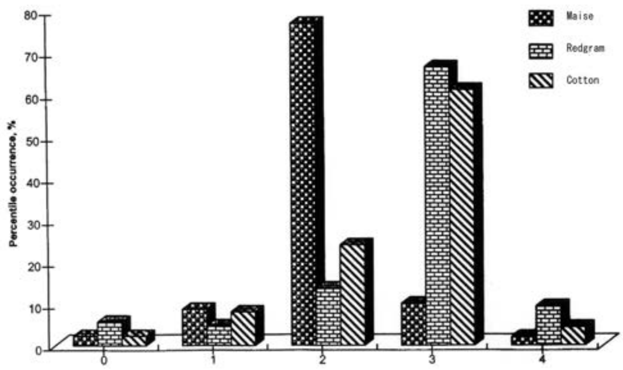
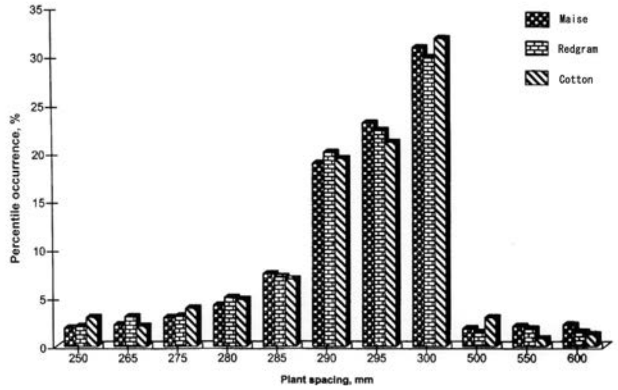


Fig. 11 Frequency distribution of hill spacing



ment.

Performance on Pattern of Placement of Seed

The factor means interaction for all the three seeds clearly indicated that the number of seed placed inside the dibbed hole (pattern of placement of seed) for all the dibber depth settings was the same (**Fig. 7**). As the forward speed of the dibber was increased, the number of seeds placed inside the hole was decreased. Hence, it was concluded that the forward speed of the dibber wheel was responsible for the pattern of placement of seed. It was also inferred that the number of seeds placed inside the hole for any particular speed was higher for redgram followed by cotton and maize. Since the spherocity of redgram was higher than maize and cotton, the transfer of metered seeds from the transferring cup to the dibber may be higher. It was concluded that among the forward speeds of the dibber wheel 1.0-1.25 km h^{-1} yielded the best placement of seed with minimum scattering. Hence, it was recommended that the planter be operated at minimum forward speed for maximum placement.

Performance on Hill Spacing

The interaction of factor means revealed that, as the forward speed was increased, the hill spacing was reduced (**Fig. 8**). This might have been due to the increased slip of the dibber wheel drive. The hill spacing was nearer the desired spacing of 300 mm as the dibber depth setting was increased. The highest hill to hill spacing of 296.5 mm was at 1.0 km h^{-1} forward speed for 50 mm dibber depth setting. The hill spacing was the highest at 10 percent soil moisture content (d.b) for all the dibber depth settings (**Fig. 9**). This might have been due to higher slip of the dibber wheel at lower moisture contents of the soil. As the soil moisture content was increased beyond 10 percent (d.b) the hill spacing was reduced. This might have been due to excessive sticking of soil to the dibber causing further reduction in traction and, hence, the hill spacing (Wells and Treesuwan, 1978). Irrespective of soil moisture content the hill to hill spacing was increased with increase in dibber depth settings. Hill spacing reduced as forward speed increased. The largest hill to hill spacing was obtained at a soil moisture content of 10 percent (d.b.) for all the forward speeds tested. In summary, a dibber depth setting of 50 mm resulted in the best performance (296.5 mm) at a forward speed of 1.0 km h^{-1} and soil moisture content of 10 percent (d.b).

Field Performance of the Dibber Planter

The field performance of the dibber planter was evaluated by sowing maize, redgram and cotton. The analysis of variance for the number of hills per three meter length of row for the three types of seed is shown in **Table 2**. The results concluded that the number of hills among the row and replication were not significant. There was no variation in the number of hills among the rows. Also there was no variation in the number of hills in a row. The mean number of hills observed per three meter length for maize, redgram, and cotton was 8.5, 9.2, and 8.5, respectively. The frequency distribution of number of plants per hill for the three crops is presented in Fig. 10. In 75 ± 2 percent of the hills, two seedlings germinated per hill for maize. Three seedlings per hill germinated in 68.5 ± 1.5 percent and 62 percent of the hills for redgram and cotton, respectively. The frequency distribution of hill spacing for the three crops is shown in Fig. ll. About 32 percent of hills were, spaced at 300 mm. A maximum number (82 ± 2 %) of hills were spaced at a distance of 285 - 300 mm. The missing hills in both the soils were minimum (3 to 5 %). Thus, the dibber planter and its mechanism worked perfectly for hill dropping of seeds. The field capacity of the dibber planter was 0.27, 0.20 and 0.34 km h^{-1}, respectively, for maize, redgram and cotton. The cost of operation of the unit was US $ 17, 22 and 13 per hectare, respectively, for maize, redgram and cotton. The cost of the planter was US $ 445.

Table 2 Analysis of variance for number of hills among the row

SV	DF	SS	MS	F
Maize				
Replication	2	0.264	0.132	< 1
No. of hills among the row	9	5.464	0.607	1.91 NS
Error	18	5.736	0.318	
Total	29	11.464		
C.V. = 6.2%, NS = Not significant				
Redgram				
Replication	2	0.266	0.133	< 1
No. of hills among the row	9	4.700	0.522	1.47 NS
Error	18	6.400	0.355	
Total	29	11.366		
C.V.= 6.5%, NS = Not significant				
Cotton				
Replication	2	0.800	0.400	1.23 NS
No. of hills among the row	9	2.533	0.281	< 1
Error	18	5.866	0.325	
Total	29	9.200		
C.V. = 6.6%, NS = Not significant				

Conclusions

The developed mechanical dibber planter distributed seeds uniformly to all the dibbers. It was concluded that it would be very effective at minimum forward speeds for dibbing of seeds. Attachment of an electronic seed metering mechanism would result in better performance of seed transfer. Fixing of pointed edges at the dibber tips would help restrict the entry of soil boulders and other materials into the dibbers. Further work should be directed along these lines.

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■■

Wireless Sensor Network for Orchard Soil and Climate Monitoring

by
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Abstract

Soil and climate monitoring plays an important role in orchard management. A wireless sensor network is an efficient approach for monitoring a large-scale orchard with densely distributed nodes. Combined with a project of facility cultivation of a local pear variety in Zhejiang province, China, a wireless sensor network combining network clustering and route enhancing is proposed with an aim to facilitate node distribution in orchard and regular network maintenance. The topology of a wireless sensing cluster, hardware and software design of wireless node and routing enhancement are elaborated. The test results show that the proposed scheme has the capability of robust data transmission, high sensing accuracy of soil and climate parameters and excellent data consistency. The design method proposed in the paper is also suitable for other farmland monitoring systems.

Introduction

The growth of fruit trees has a close a relationship with orchard soil conditions and climate change. During its growth, a fruit tree not only needs abundant sunlight and a certain level of air temperature and humidity, but also appropriate soil temperature, moisture and manure. The all-day monitoring of orchard soil and climate helps orchard management. At the present time, orchard monitoring in China is just beginning and most monitoring techniques are still in the stage of testing. As the traditional methods, including underground cabling and trolley wiring, disturb orchard cultivation, wireless techniques are gaining farmer's great interest. Although some wireless monitoring systems based on GSM or GPRS have been put into operation, it is still hard to obtain region-wide farmland information with certain density due to sparse sensing points. In the area of large scale farmland monitoring, emerging wireless sensor network (Sausen *et al*., 2008; Pappas *et al*., 2008; Chang *et al*, 2008; and Qiao *et al*., 2005) has its unique capabilities, like random deployment, flexible extension, and cost-effective field-map building. The multi-hop communication between sensing nodes not only helps form directive data transmission, but also provides feedback signal pathways to actuators in precision control (Morais *et al*., 2005).

The wireless sensor network has found its way into various fields

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such as frost prevention (Jaradat *et al.*, 2008), flood monitoring (Kuang *et al.*, 2008), soil detection (Liu *et al.*, 2008), and farmland information collection (Li *et al.*, 2008 and Zhang, 2008). When a large number of sensing nodes is distributed, the life of a network with various energy-consumption nodes will terminate ahead of schedule as some individual node exhausts its energy. Lu and Liu (2007) proposed a regional distribution density formula of sensing nodes, theoretically indicating that energy consumption rate of each node could keep balance. According to the scheme, however, it would become hard to deploy network nodes in a real field. Up to now, there is no information about how to design an application-specific convenient way to build a wireless sensor network. In this paper, combined with a project on facility cultivation of Huanghua Pear, a local variety in Zhejiang province, China, a kind of wireless sensor network integrating network clustering and route enhancing is proposed. The system has been implemented and tested for orchard soil and climate monitoring.

System Design

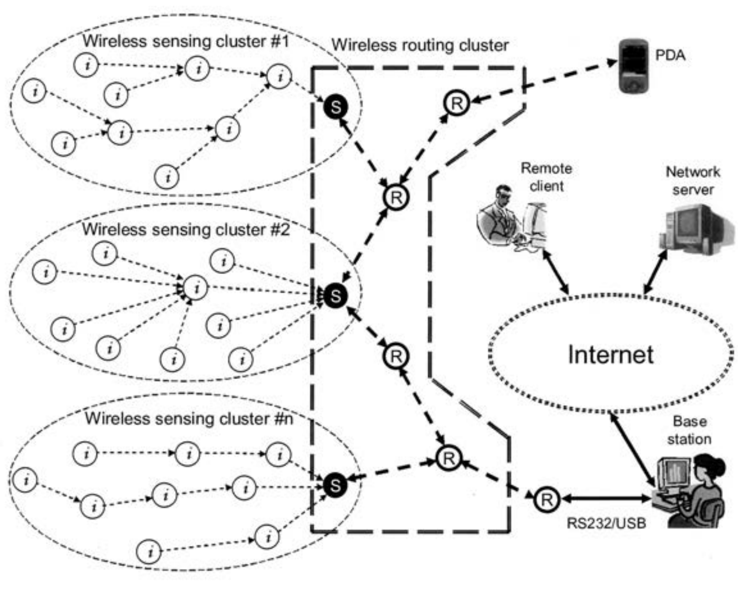
A wireless sensor network for orchard soil and climate monitoring (or orchard monitoring system thereafter) consists of wireless sensing nodes, sink nodes, routing nodes, base station, network server and remote clients (**Fig. 1**).

To facilitate network management and maintenance, the orchard monitoring system is divided into several wireless sensing clusters and one routing cluster. Functionally, each sensing cluster is a wireless sensor sub-network, which is made up of sensing nodes and one sink node . A sensing node is responsible for the collection and storage of site-specific soil and climate parameters such as air temperature and humidity, sunlight intensity, soil temperature, moisture and electric conductivity (He *et al.*, 2008). A sensing node transfers these data to sink nodes via multi-hop communication protocol. A sink node has the duties of receiving, filtering and storing the data and forwarding them to wireless routing node. The main difference between a routing cluster and a sensing cluster is that there is no sensing capability of soil and climate parameters. Routing nodes can transfer data in a bidirectional way, while a sensing node, in general, delivers data in a fixed direction. Although sensing nodes can form an ad hoc network, such a system needs extra energy support. When sensing nodes are statically deployed, it is unnecessary to adopt an ad hoc network (Dressler, 2008). Also, it is harder to test node communication in an ad hoc network. In ISM radio bands, the weak emitting power of wireless nodes leads to narrow signal coverage, which is usually less than 100 m radially. When a sink node is far away from the base station, there is no guarantee of reliable data communication between them. In this case, more routing nodes are needed to extend the network coverage. To ease regular maintenance of the network, routing nodes could be deployed along two sides of paths in the orchard. Thanks to bidirectional data transmission of a wireless routing cluster, base station(s) can statically access to the network via a nearby routing node, while mobile devices, like PDA, can dynamically apply for network access. Base station(s) and mobile devices should follow the procedure of node identification. Only those passing the identification have the right of data browsing and network supervision. Base stations with an access to the internet can upload data to network server and carry out a series of data operations. When permitted by network manager, a remote client can retrieve data from the network server.

Wireless Sensing Cluster

A wireless sensing cluster is one of basic units of an orchard monitoring system management and maintenance. The more the sensing nodes in a sensing cluster, the faster the energy consumption of sensing nodes closer to the sink node (Lu and Liu, 2007). In our design, each node uses a 4-bit encoding scheme

Fig. 1 Wireless sensor network for orchard soil and climate monitoring



so that a sensing cluster includes 16 nodes at most. A sink node is encoded as 0000, and sensing nodes are given 0001-1111, respectively. The topology of a sensing cluster can be designed as star, tree, chain or other irregular styles. Start-typed network consisting of one core node and many peripheral nodes has high reliable data links. But, due to limited radio power in a single node, its network coverage is usually small so that more star-typed subnets are cascaded to extend the network range. A core node has dual functions: data sensing and data transmission. A tree-typed network is built hierarchically so that it is convenient to manage the network. In the case of an orchard monitoring system, however, due to simple relationships between nodes and the small size of a sensing cluster, functional over-division of control program in a sensing node will become insignificant. By comparison, chain-typed networks can be easily extended with linear node links so that it is suitable to be deployed in an orchard.

Double-chain Topology

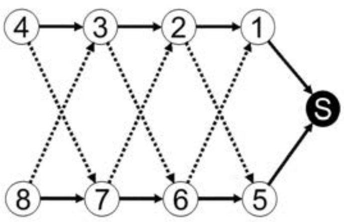
In single-chain structure, each node in system malfunction or in sleeping status has serious effect on other nodes' data transmission. In that case, network quality of service (QoS) will be seriously affected. To enhance data routing, double-chain topology is proposed in our study. As an example, a sensing cluster with 9 nodes is illustrated in **Fig. 2**. The sensing cluster is made up of eight sensing nodes and one sink node. In normal condition, the pathway of data transmission is arranged as 4-3-2-1-S and 8-7-6-5-S. Concerned with some unexpected faults in node links, an alternative pathway for each node is added, shown in dashed lines in **Fig. 2**. For instance, if node 2 happens to exhaust its power, node 3 will automatically transfer its data to node 6; meanwhile, node 3 receives the data from node 4 as well as ones from node 8. Through the double-chain network topology, wireless data links in a sensing cluster can be enhanced greatly.

Sensing Node

A sensing node usually includes several functional parts such as soil and climate parameters sensing, signal amplifying and reshaping, data processing and storing, wireless transmission and power supply, shown in **Fig. 3**. The data processing unit (DPU) consists of a low-voltage CPU (MSP430F149) and I2C EEPROMs with extra interfaces of RS232 and SPI. In general, the signals from various sensors are transformed as a uniform style of 0-2.5 V before they are input to the A/D ports A0-A7 of CPU. Affected by climate disturbance, data communication between nodes tend to be unstable. It becomes necessary to monitor chip voltage and temperature of CPU and solar-battery voltage so that base station can use these parameters to diagnose remote node when it is in fault. All of A/D data are averaged in a soft-filter and then packed into data frames according to pre-designed protocol. Finally, DPU initiates wireless transmission and delivers data to next sensing node or sink node.

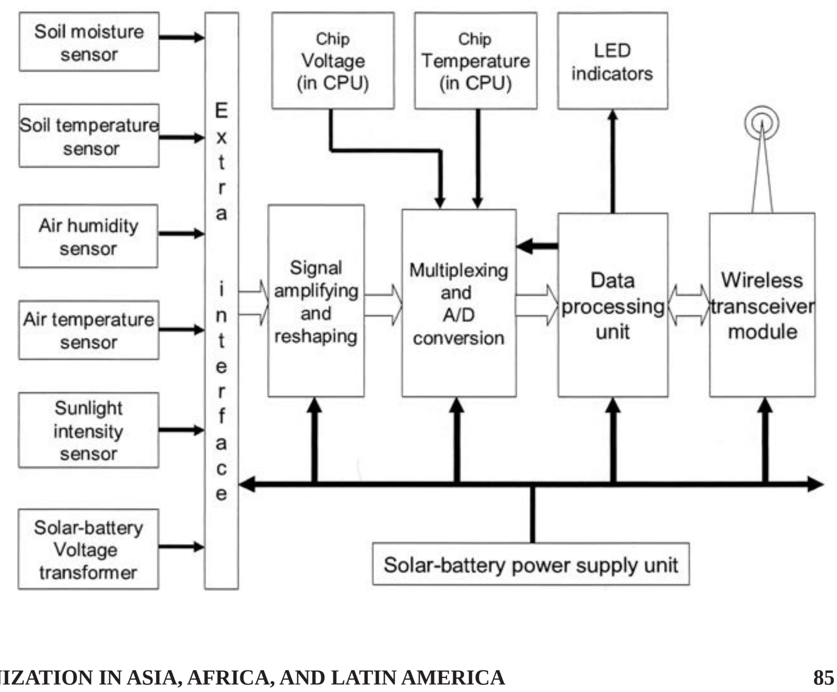
The program in a sensing node includes three modules: wireless data receiving, wireless data sending and A/D conversion. In the beginning of wireless data receiving, a wireless transceiver is powered up and initialized. In order to avoid its

Fig. 2 Double-chain network topology of a sensing cluster



(1-8:sensing node; S: sink node; solid line: main chain pathway; dash line: alternative chain pathway)

Fig. 3 Hardware elements of a sensing node



program dead-running caused by no data arrival, a down-counter for data receiving is set up. Each time the wireless data receiving module is started up, the down-counter deceases 1. If it reaches 0, the procedure of data receiving will be terminated. In addition, a node is often faced with data sending failure caused by wireless communication congestion or a partner node's off-power. In this case, another down-counter for data retransferring is added. Each time data transmission is triggered, the counter deceases 1. The procedure does not stop until the data are sent successfully or the counter reaches 0. A/D conversion could be done alternately with wireless transmission because A/D conversion of 10 channels in each round only lasts 100 ms or so. In order to reduce energy consumption, the control program in a sensing node runs once per one minute, during which the soil and climate parameters change unremarkably.

Sink Node

Sink node has two-tier tasks. One is to collect data sent from sensing nodes followed by data checking and framing. The other is to collaborate with other routing nodes to transfer data frames to base station. Besides being instructed by the base station, a sink node can do some statistical tasks; for example, to calculate average soil temperature in a region per hour. If there is a controllable device in a sensing cluster, like an electric relay for irrigation, the sink code will send a control signal to it according to the instruction from the base station. In addition, to ease fault diagnosis of network, sink a node needs to collect chip temperature and voltage of the CPU and solar-battery voltage, and send them to base station.

Routing Enhancement

Sensing clusters dispersed in a large orchard are often beyond the radio coverage of the base station, which may lead to data communication failure. Routing nodes need to be added in blind spots of the radio so that sink nodes can transfer data to the base station in the means of a relay race. Routing nodes are designed with bidirectional data transmission which provides random network access for base station and mobile devices. Different from sink node, routing node has no capability of data processing.

Base Station and Remote Access

Base station is responsible for whole-region data monitoring and network management. It can directly link to a routing node via RS232/USB interface. If it is far away from any a routing node, alternative approaches such as telephone line access, GSM or GPRS could be used. Also, if a routing node can gain access to the internet, the base station could connect with the orchard wireless sensor network by IP address. Functionally, the base station includes: collection of soil and climate parameters from all sensing clusters periodically, judgment of running status of any a node based on statistical analysis on data frames, configuration of routing nodes, data storage into and data retrieval from SQL database, data visualization, etc. If a network server is available, the base station can upload data to it through the internet periodically. A remote client permitted or licensed by the network manager can also browse or download relevant data from the network server.

Network Communication Protocol

According to network protocol hierarchy, wireless sensor network can be designed as four layers: physical layer, data link layer, network layer and application layer. The physical layer provides hardware support for data collection and wireless channels. Data link layer is responsible for the data transmission between two neighboring nodes. It is usually implemented in a wireless transceiver module. The network layer is in charge of end-to-end data transmission. It has two ways of data transmission: cut-through and store-forward. Routing node with cut-through transmission requires predetermined global routing information. It does not provide data storage. Instead, store-forward transmission needs temporary data storage in routing node. Routing pathway is decided depending on its radio links to succeeding nodes. Thus, store-forward transmission is for high reliable data communication. In this study, we adopt store-forward data transmission as the communication protocol of the orchard monitoring system. In order to learn about each wireless node's performance, we need to record the routing information of each data frame from source sensing node to base station. The structure of the data frame is designed as follows,

#, routing mark in routing cluster (4 bytes), routing mark in sensing cluster (2 bytes), sensing cluster code (1 byte), node code in a sensing cluster (half byte), frame sequence code (half byte), data sequence (22 bytes), *

A data frame of 32 bytes long starts with # and ends with *. Both source sensing node from which a data frame is sent and other nodes through which the frame is retransferred are recorded in the data frame itself. In an orchard monitoring system, the sensing cluster is encoded from 0 to 255, among which both 0 and 255 are saved for system broadcasting. The valid sensing cluster code is 1-254. Node code in a sensing cluster is 0-15, among which 0 is for sink node, 1-14 for sensing node, and 15 saved for testing. Frame sequence code is 0-15, which means there are 16 various formats of data frame. Different data frames hold different data sequence. Data sequence in a data frame holds 11 words at most. Totally, each sensing node can define 176 data (1,611).

Routing mark in the sensing cluster possesses 16 bits, each bit corresponding to a node in a sensing cluster. Routing mark in a routing cluster holds 32 bits with each corresponding to a routing node in the routing cluster. If wireless sensor network becomes larger and more routing nodes are needed, the routing mark in routing cluster would be extended with more bits. When a sensing node starts to transfer its data frame, routing marks both in the sensing cluster and in routing cluster are reset with 0. If a data frame is received by a sensing node, its corresponding bit in the routing mark in sensing cluster will be set with 1. Meanwhile, if the data frame is retransferred by a routing note, its corresponding bit in routing mark in routing cluster will be set with 1. Based on the two routing marks, the base station can learn about the routing pathway of the data frame from source sensing node to base station. Also, using these two routing marks, some statistical analyses can be done in the base station to judge how often a node participates in data transmission. Thus, these routing marks are useful in the optimization of node distribution as well as network configuration.

Evaluation of System Performance

The orchard monitoring system introduced in the study has been fabricated in laboratory and tested in our campus orchard. Sensing cluster is made up of 8 sensing nodes encoded by 1-8 and one sink node by 0. Base station connects with sink node directly through RS232, shown in **Fig. 4**. The topology structure has been shown in **Fig. 2**. The monitoring program of the base station is written in Visual Basic 6.0. **Fig. 5** shows how one data frame from sensing node 4 has gone through other sensing nodes. It took routing pathway of 4-7-6-5-0 instead of 4-3-2-1-0. This suggests that node 4 is able to select an alternative pathway automatically to forward its data in case the normal routing pathway is broken.

The wireless sensor network needs to monitor a large quantity of parameters with numerous sensors. It is important to guarantee the accuracy and consistence of these sensors. For our orchard monitoring system, the accuracy of sensors is listed in **Table 1**. The absolute errors of air and soil temperature are both less than 0.5 ºC. The relative errors of air humidity and soil moisture are lower than 3 % and 1 % RH, respectively. Sunlight intensity sensed by a silicon light cell keeps its error less than 5 %. **Fig. 6** shows the sensing consistency of air temperature in sensing node 1-4 during 2 hours. It suggests that the dynamic change of these four air temperature sensors is no more than 0.5 ºC.

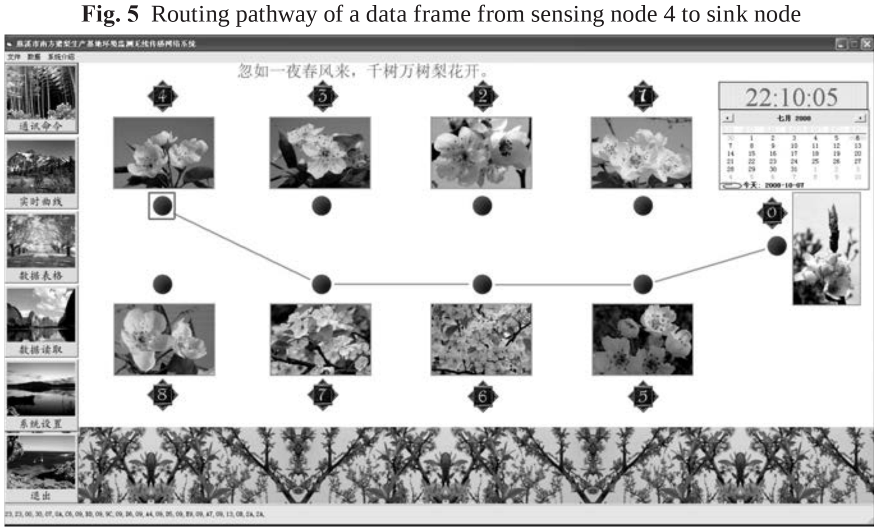
Fig. 7 shows the numbers of data frames received by the base station from sensing nodes and sink node in 3 hours or so. It suggests that the sink node (node 0) has maximum data transmission due to its direct connection with the base station. Among all sensing nodes, nodes 1 and 5 have higher data arrival rate than others. It can be explained that data transmission performance of a node has close relationship with their distance to sink node. The farther the distance, the larger the number of data lost. In order to improve data communication, two methods could be conducted: one is to revise data routing algorithm to decease radio communication conflict; the other is to reduce multi-hop times of data by redistributing nodes.

Table 1 Testing result of sensor accuracy

Items	Error
Air temperature	< 0.5 ºC
Soil temperature	< 0.5 ºC
Air humidity	< 3 % RH
Soil moisture	< 1 % RH
Sunlight intensity	< 5 %

Fig. 4 Sink node and its link to base station via RS232 interface

Fig. 5 Routing pathway of a data frame from sensing node 4 to sink node



Conclusion

Low-cost wireless sensor network based on multi-hop communication protocol is becoming an important approach for farmland monitoring. In this study, concerned with geographical feature of orchard and ease of network management, the method of dividing wireless sensor network into many sensing clusters is proposed. Each sensing cluster consists of several sensing nodes and one sink node. To transfer data from sensing node to base station effectively, routing nodes are added along the two sides of orchard paths to extend network coverage. The testing results shows that the scheme for orchard soil and climate monitoring is successful with high accuracy of data sensing and dynamic network management. The next step is to extend network coverage and collect more data for correlative analysis between soil and climate parameters with fruit yield, with the aim to provide decision-making information for orchard management.

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Fig. 6 Sensing consistency of air temperature in sensing node 1-4

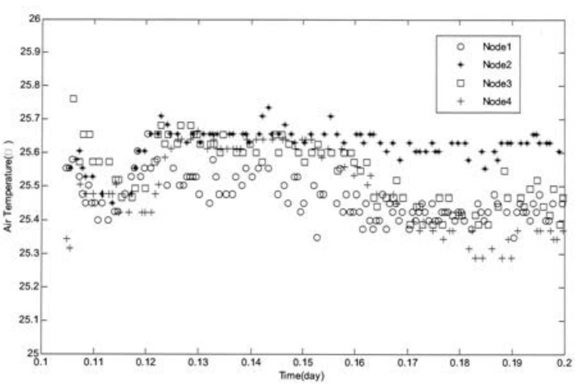
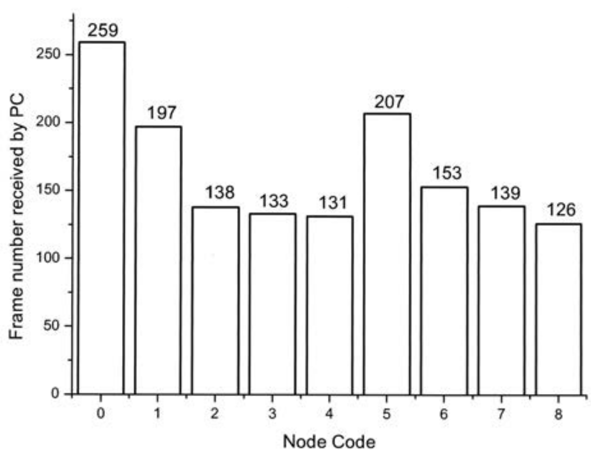


Fig. 7 Data frames received by base station from 8 sensing nodes and 1 sink node in about 3 hours



Development and Evaluation of Tractor Operated Vegetable Transplanter

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Abstract

Vegetables are a major source of protective foods in human nutrition. Also the cultivation of vegetables is one of the options to shifting from a rice-wheat rotation. One of the major hindrances in vegetable cultivation is transplanting of seedlings which requires lot of labour (244-310 man^{-h}/ha). Vegetables crops are sensitive and require a very timely operation. The imported machines are quite sophisticated and costly. So a two row semi-automatic transplanter having a picker wheel type metering mechanism has been developed and evaluated. It can transplant wash-root type seedlings of vegetables like cauliflower, tomato and chillies on the beds as well as flat fields. The plants missing were about 2 to 3 percent at a speed of about 0.8-1.0 km/h depending upon the plant to plant spacing and skill of operator. Plant mortality and yield was comparable with the manual transplanting. There is a savings of about 70-80 percent in labour requirement in comparison to manual transplanting, depending upon crop spacing.

Introduction

India is next only to China in area and production of vegetables and occupies prime position in the production of cauliflower, second in onion and third in cabbage in the world. The area under vegetable crops was about 7.05 million ha and production was about 110.27 million tones during 2005-06 (Anon, 2008). Vegetables are a major source of protective foods in human nutrition. In Punjab, total area under vegetables during 2005-06 was approximately 163 thousand hectares with a production of 2.47 million tones with an average productivity of 15.1 ton per hectare (Anon, 2007). Due to increased rate of ground water depletion, emphasis is now being laid on shifting area from rice to some other crops. Cultivation of vegetables is one of the options. One of the major problems in vegetable cultivation is transplanting of seedlings. This requires a lot of labour, which is very costly. The dependence on labour is major constraint in enhancing area under these crops. The labour requirement in manual transplanting is as high as 244 -310 man-h/ha (Chaudhuri *et al*., 2001). Vegetable crops are sensitive and require very timely transplanting operation. Labour shortage in peak season causes delay, which leads to reduced yield. (Chaudhuri *et al*., 2003). One percent missing plants in the field results in reduction in yield up to 0.6 % (Saimbhi *et al*., 1992). The transplanting in bending posture requires an extra energy expenditure of 8 kJ/min and increases the heart rate by 51 percent (Nag *et al*., 1980). The imported machines are quite sophisticated and the semi-automatic vegetable transplanter developed earlier was found to have poor performance on traditional seedlings because it had a gravity type metering mechanism (Anonymous, 2002). A two row semi-automatic planter having a picker wheel type metering mechanism was developed and evaluated. It can transplant wash-root type seedlings on the beds as well as on the flat fields.

Materials and Method

Brief Description of the Machine

The machine consisted of a frame, two lugged ground wheels, seedling tray, seat for the operator, furrow openers, compaction wheels, finger guide tunnel, picker wheel type metering mechanism and a water tank. The picking fork had a spring mounted rubber flapper, which closes while passing through the tunnel. Again these flappers open at the bottom end of the tunnel to release the seedlings in a furrow. The inclined wheel compact the soil around the seedlings. Power from the wheel is supplied to the planting mechanism through shaft, chain and sprockets. The plant spacing in the machine can be adjusted as per the requirement of agronomic practice of a particular vegetable by changing sprockets. A stationary view of machine is shown in **Fig. 1**. Isometric view of machine with detailed components is shown in **Fig. 2**. Two persons, one for each row is required to place the seedlings in the flappers when these open at the top position. The root side of the seedlings is kept towards the operator. Water is sprayed on each row by the shower provided behind the picker wheel for temporary relief to the plant. Brief specifications of the machine are given in **Table 1**.

Evaluation Procedure:

The machine was first evaluated in the laboratory to find the forward speed of the machine based on missing and optimal ergonomical parameters based on light workload (75 < HR < 100). It was observed that a person could put 30 seedlings/minute in the picking fingers (**Table 2**). Based upon this, the planter could be operated at a speed of about 1.0 km/h.

The machine was used for transplanting vegetable seedlings of chilli, brinjal, cabbage and cauliflower (**Fig. 3**). Comparative trials of each crop (three replications) were transplanted using the transplanter and using traditional manual labour. Manual transplanting was done as per university recommendations. The crop parameters of these vegetables are given in **Table 3**. Besides this, sarson (mustard) seedlings were also transplanted with transplanter on flat (45 × 26 cm) using the three-row machine and by the manual method on a flat field as per recommendation of the university (45 × 15 cm). All the vegetable seedlings were transplanted using the machine at row-to-row spacing of 67 cm instead of 60 cm since it is not possible in this mechanical transplanting due to high tread width of available tractors. A view of the crop stand of different vegetables is shown in **Fig. 4**.

Table 1 Brief Specifications of vegetable transplanter

Parameters	Specification
Type of the machine	Semi-automatic
Nursery type for which machine is developed	Bare root type
Type of metering mechanism	Picker wheel type
No of picking fingers	10
Type of pickers	Rubber flappers
Row spacing, cm	45-60 (Adjustable)
Method of changing plant spacing	By changing sprocket
Type of furrow openers	Shoe type
Watering arrangement	Two nozzles
Water tank capacity, lit	120

Fig. 1 Stationery view of tractor operated two-row vegetable transplanter

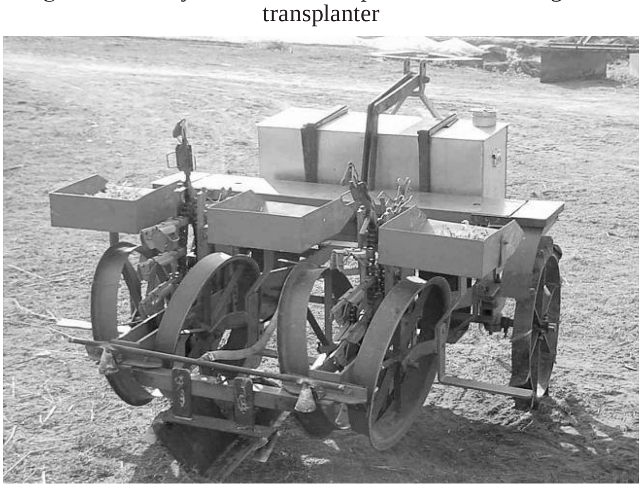

Fig. 2 An isometric view of tractor operated two-row vegetable transplanter

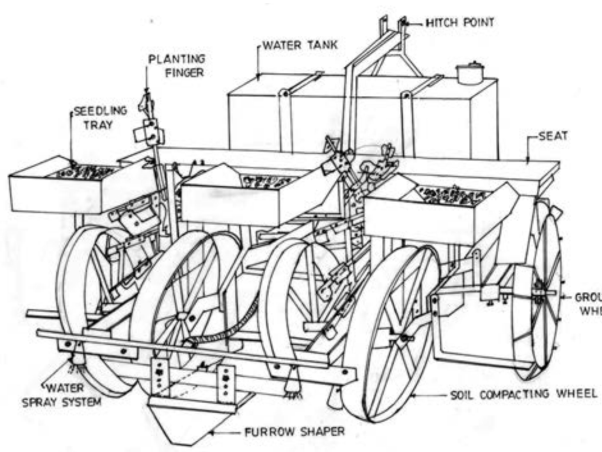

Table 2 Effect of speed of operation and position of operator seat on different physiological parameters of the subjects under laboratory condition

Speed of operation, km/h	Seedlings feedings/ min	Heart rate, bpm	Workload, watts	Stress in eyes, %	Missing, %	Postural configuration, degree
0.5	15	89.6	4.6	1.9	0.3	2.0
1.0	30	101.1	12.9	7.7	1.8	2.2
1.5	45	111.1	20.2	13.3	5.8	2.1

Table 3 Agronomic and crop parameters of vegetables transplanted

Name of crop	Variety	Age of nursery	Treatment	
			Mechanical	Manual
Chilli	Hybrid CH-1	-----	On beds 67 × 60 cm	On Ridge 75 × 60 cm
Brinjal	Pretty hybrid	30	On beds 67 × 45 cm	On bed 60 × 45 cm
Cabbage	Golden Acre Ega	36	On beds 67 × 45 cm	On Ridge 60 × 45 cm
Cauli-flower	GS-235	36	On beds 67 × 30 cm	On Ridge 45 × 45 cm
Gobhi Sarson	GSL-1	32	On flat 30 × 45 cm	On flat 45 × 15 cm

Table 4 Field performance results of 2-row vegetable transplanter

Parameters	Chilli		Brinjal		Cabbage		Cauliflower	
	TVT*	MT*	TVT	MT	TVT	MT	TVT	MT
Spacing, cm × cm	67 × 60	75 × 60	67 × 45	60 × 45	67 × 45	60 × 45	67 × 30	45 × 45
Speed of operation, km/h	0.80 -0.98							
Field capacity, ha/h	0.082-0.092							
Yield, q/ha	210.1	195.1	415.0	424.0	172.4	185.2	333.3	367.1
Plant mortality, %	2.9	1.0	7.0	7.5	0.0	0.0	1.5	2.1
Missing hill, %	0.8	0.0	3.5	0.0	2.0	0.0	3.0	0.0

*TVT-Transplanted using vegetable transplanter MT- manually transplanted

Results and Discussions

The plants missing were about 2 to 3.5 percent at a speed of about 0.8-1.0 km/h depending upon the plant-to-plant spacing and skill of operator (**Table 4**). Plant mortality was slightly more in nursery transplanting using the transplanter as compared to the manual transplanting. High mortality was observed in brinjal in both the treatments. This might have due to mechanical handling of the stem of the nursery plant. The yield of crop transplanted using the transplanter and by the manual method was 210 and 195 q/ha, respectively, for Chilli; 415 and 424 q/ha for brinjal; 333.3 and 367.1 q/ha for cauliflower and 172.4 and 185.2q/ha for cabbage. There was no difference in the yield. The apparent difference in yield was due to difference in row-to-row spacing because the mechanical operation was performed at a row-to-row spacing of 67 cm whereas the manual transplanting was at row-to-row spacing of 60 cm. However, the yield was at par with manual transplanting on the farmers' field.

The yield of gobi-sarson transplanted on flat land by manual method was 1,551 kg/ha and the crop transplanted using transplanter was 1,554 kg/ha. The crop trans-

Fig. 3 A view of cauliflower and Gobi-sarson transplanted by vegetable transplanter

Fig. 4 A view of crop stand

planted using the machine on flats had fewer plants per square meter as compared to that transplanted manually and gave the same yield due to more space availability to facilitate its growth in terms of more shoots per plant. The machine saved about 70-80 percent labour in comparison to manual sowing depending upon crop spacing. Due to low capacity of the machine the saving in cost was up to 10 percent.

Conclusions

- The machine can transplant different types of seedlings precisely and without any problem at a speed of about 1.0 km/h.
- The machine saves about 70-80 percent labour in comparison to manual transplanting depending upon crop spacing.
- The yield was at par with manual transplanting.
- The machine will act as a boom at the time of scarcity of labour.

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ABSTRACTS

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

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Optimum Tilt Angle and Orientation for a Flat Plate Solar Water Heater under Egyptian Conditions: Salah, M. Abdellatif, Prof. and Head of Agric. Enging Dept. Mansoura University, Egypt; **Nasser, M. Elashmay,** Researcher in Agric. Enging Res. Inst., Agric. Res Center, Giza, Egypt.; **Ahmed, M. Kassem**, Senior Researcher in Agric. Same.

Solar water heater (SWH) is a most widely used for different Agricultural and Industrial applications in Egypt. But, there are many parameters that affect solar water heater thermal performance. Tilt angle and orientation are considered as an important factors influencing, not only the thermal performance but also the heat energy acquired by the solar system. Four identical solar water heaters were situated on the roof of Agricultural Engineering Department to investigate under clear sky conditions the effect of tilt angle and orientation on solar water heater thermal performance. They were mounted individual on a movable frames which could be adjusted so that at any time the angle of incidence of the surface of the solar heater and the sun's rays could be set at zero. Water could be continually cycled through the SWH. After passing through the SWH, the heater water was stored in an insulated storage tank. The obtained result clarified that the solar heater which tracked the sun's rays once each half an hour from sunrise to sunset was more efficient than the other solar heaters. Overall thermal efficiencies for SWH1, SWH2, SWH3, and SWH4 were on average 72.83%, 65.85%, 61.60%, and 55.98%, respectively.

904

Supercritical Carbon Dioxide Extraction of Fungi-Converted Lipids: Meishuang Dong, City College of Zhejiang University, 50 Huzhou Street, Hangzhou 310015, P. R. China; **Mike Dong,** Department of Animal and Food

Science, Delaware University, 531 S College Ave., Newark, DE 19711, USA, **Changqing Wu,** Same.

Supercritical CO_2 extraction was investigated for the lipid recovery from canola flake, in which polyunsaturated fatty acids (PUFAs) was added by fungi conversion, including arachidonic acid (ARA, C20:4n6) and eicosapentaenoic acid (EPA, C20:5n3). Up to 92% lipids were recovered during 10 hours extraction at 5,000 psi, 50°C and 2.31×10^{-5} kg/s CO_2 flow rate. The fatty acid composition of extracted oil for the percentages of the main components, C16:0, C18:0, C18:1, C18:2, C18:3, C20:4 (ARA) and C20:5 (EPA) had no significant change during extraction. The extraction kinetics was modeled with high R^2 of 0.99 and small sum of square deviations (SSD) using Goto *et al*. (1993) model. The feasibility was demonstrated and for lipid extraction using supercritical CO_2 from fungi-converted canola flake.

911

Development and Testing of an Improved Turmeric Boiler: V.Thirupathi, Associate Professor; Department of Food & Agricultural Process Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore-03 641003, India, **R. Viswanathan**, Professor and Head, same.

In turmeric processing boiling is the first post harvest operation to be performed in the farm level. In the traditional method of turmeric boiling, cow dung slurry was used in open vessels, which leads to lower price of the produce, loss of energy, loss of time and higher labor requirement. To overcome this problem, a steam boiling type improved turmeric boiler, has been developed and the performance of the unit was tested. Capacity of the unit was 240 kg per batch and time taken for boiling is 20 minutes. Saving of time and fuel in the improved boiler were 50 and 38 percent respectively. Time taken for drying turmeric rhizomes is less when boiled in improved boiler. Curcumin, oleoresin and essential oil content were high for samples boiled in improved method.

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Vibration Characteristics of Power Weeders: K.Kathirvel, Professor, Department of Farm Machinery, Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore- 641003, INDIA, **S.Thambidurai**, Ph.D scholar, same, **D.Ramesh**, Asst. Professor, same, **D.Manohar Jesudas**, Professor and Head, same.

Power weeders have been developed for the mechanical control of weeds to alleviate the acute labour scarcity in modern agriculture. The operator of a power weeder has to endure various environments and stresses. The environment includes all the factors in the surroundings which have an effect on man-machine system. Among these factors, mechanical vibration is more important because it significantly accelerates fatigue and affects the sensitivity and reaction rates of the operator. The machine vibration of three commercially available power weeders popular among the farmers viz., power weeder operated by 7.5 kW diesel engine (PW_1), power weeder operated by 4 k W petrol engine (PW_2) and power weeder operated by 4 kW petrol start kerosene run engine (PW_3) was measured at different locations viz., engine, chassis, gear box, root of handle bar and handle using the portable PULSE multi-analyzer system (Brüel & Kjaer Type 3560 C) in stationary mode at different levels of engine speed. The machine vibration at handle for the three power weeders was measured at 1.5, 1.8 and 2.1 km h^{-1} forward speed during first and second weeding in cotton crop. The vibration mapping indicated that increase in engine speed from 1,600 to 3,200 rpm resulted in three fold increase in peak acceleration at handle of PW_1 and two fold increase for PW_2 and PW_3 power weeders in stationary mode. Vibration at the top of the engine was the highest followed by handle, gear box, chassis and root of handle bar in all the three selected power weeders. Acceleration levels varied widely and were greatly dependent on variables such as forward speed, terrain, type of power weeder and mode of operation. Acceleration levels increased with forward speed of travel under all operating conditions. In weeding mode, with increase in forward speed from 1.5 to 2.1 km h^{-1} the percentage increase in peak acceleration during first weeding was 98.8, 31.5 and 78.3 percent at the handle of three power weeders PW_1, PW_2 and PW_3 respectively. Peak acceleration on the handle is lower in second weeding than the first weeding due to damping effect of soil. Among the three power weeders, the vibration induced at selected locations was maximum for power weeder PW_3 followed by PW_2 and PW_1.

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Performance Evaluation of Reciprocating Type Grader for Black Pepper: V. Thirupathi, Associate Professor, Department of Food and Agricultural Process Engineering, Tamil Nadu Agricultural University, Coimbatore-641 003 INDIA, **R. Visvanathan,** Professor and Head, same.

Grading is done to standardize a product, to facilitate marketing, for sales appeal, for ease in quantifying, for ease in price fixing of uniform sized lot and for compliance of international or national grading standards. Black pepper is graded for commercial value and for export purpose. Grading was done based on size of the black pepper. Grading was done in a reciprocating type grader at different slope (10, 11.8 and 13.5º), stroke length (1:1, 1:2 and 1:3) and peripheral speed (113,138, 163 and 188 m/min). Maximum grading efficiency of 87.12 percent was obtained for black pepper at 163 m/min peripheral speed, 1:2 stroke length and 11.8º slope.

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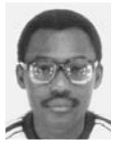
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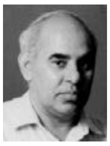
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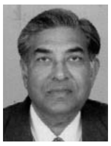
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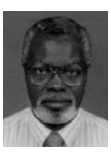
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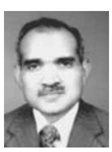
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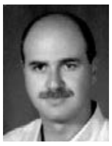
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