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EDITORIAL

First of all, I would like to wish all the readers of AMA a happy new year.

Time flies so fast that 11 years has already passed since the beginning of 21st century. That is to say, 1/10th of the 21st century has already passed. As the times go by, the world keeps changing, showing no sign of slowing down. It is changing in various areas with happy and catastrophic incidents, along with joys and sorrows. Though we've had a happy time enjoying delicious meals celebrating a new year, we should not forget that there are still millions of people suffering from hunger in the world.

There are many reasons for this problem, including conflicts and political matters. However, the basic point is how to establish a new system to supply enough food for the exploding population. In spite of the growing population, there are no more lands left to develop. We have been cutting down forests to obtain more farmlands, but it has started to show its limitation. The deforestation problem in Brazil and other Amazon regions is especially raising a controversy nowadays. I think the best solution is to stop cutting down the forests that play such a significant role in the whole vital ecological system on Earth.

The most important agricultural technology in the 21st century is to increase the productivity per unit land; that is to say, improve the land productivity. There are some costly technologies such as agricultural facilities, but the basic point is how to make best use of solar power and obtain maximum sustainable yields. To establish such an earth-friendly technology, accurate working agricultural machinery is very important, along with related hardware. To accomplish a particular task at a particular place and time, mechanization must replace human work. We need new mechanization for this.

Agricultural mechanization is the most effective way to improve land productivity. It plays the most important role in the agricultural technologies of the 21st century, and we must show continuous efforts to develop this technology. Agriculture has regional characteristics and, at the same time, there are general characteristics that cover all agriculture. To be successful, we need various agricultural mechanizations suitable for each region. We need many experts to develop various types of agriculture suitable for various regions, and we also need many manufacturers to create the machines and make use of the newly developed technology.

Looking at the agricultural machinery industry from a global point of view, there are few large sized manufacturers making engines, tractors, and combines. Also, there are millions of manufacturers making other machinery, though small and tiny. We need these small, but yet powerful, companies to realize the idea I have shown. These small but numerous manufacturers can develop machinery suitable for each region. There are countries promoting political rules for tractorization, but most of the countries tend to ignore the importance of the operating machines themselves. To make agricultural mechanization successful, political rules must be established that will allow the small manufacturers to grow more efficiently. You might need a global backup for this.

With the development of computer technology, people began to design machines using the computer. However, to make machines suitable for each region, farming data are needed for the various regions. When the data are available, machines can be made that will be suitable for any region, even at a faraway place. We should promote the informatization of machine design. We need to develop a system to get the farming data of the world quickly. Today, you can use the internet to get any information from any place. We need to make good use of this new information-communication technology to develop the agricultural mechanization suitable for today. I would like to cooperate with the people of the world to develop a system that can produce and supply enough food for all people.

Yoshisuke Kishida
Chief Editor

January, 2011

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Development and Evaluation of Tractor Operated Sub Soil Coir Pith Applicator

by

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Abstract

Subsoil mulching with coir pith is a new concept. Deep loosening of soil and placement of coir pith in the subsoil layers as mulch directly below the crop rows would improve the root zone, which would not re-compact during subsequent years. The unique property of coir pith to hold 7-8 times its weight in moisture helps to improve moisture status of the root zone. A prototype subsoil coir pith applicator was developed. The coir pith applicator placed the coir pith at a depth of 15 to 30 cm below ground level. This technique ensured that the coir pith filled trenches are not dispersed by subsequent ploughing, thus, preventing the dispersion and disintegration of the coir pith.

The subsoil coir pith applicator was built around a chisel plough, which formed the tool for loosening the soil and also provided the frame for mounting the attachment. Coir pith was fed from a hopper through a rotary vane type feeding device and was funneled into the furrow bottom. A pair of furrow opener wings opened the furrow behind the chisel plough for placement of the subsoil mulch. The coir pith was fed by a vane type metering device rotated by a ground wheel. This arrangement ensured uniform placement of coir pith inside the furrow. The performance of the machine and the effect of subsoil mulching on crop growth was investigated in terms of soil moisture distribution, crop attributes *viz.*, height of the plant, number of leaves, number of sympodial branches, number of lateral roots, lateral root spread length, root length, number of bolls and yield. It was observed that the subsoil mulching opened up a triangular furrow in which the coir pith was placed to a depth of 15-30 cm at an application rate of 24 t ha^{-1} and at row to row spacing of 0.75 m. The effect of subsoil mulching was compared with chisel ploughing and control treatments. The soil moisture at 15-30 cm under the subsurface mulched plots was significantly higher than that of the other two treatments. All the indices of plant growth *viz.*, height of the plant, number of leaves, number of sympodial branches, number of lateral roots, lateral root spread length and root length were significantly higher under sub soiled mulched plots than that of the other two treatments. The yield of cotton in sub soiled mulched plot was 46.4 and 29.4 % higher than the chiseled and control treatments. The yield of cotton in the chiseled plot was 13.2 % higher than that of the control treatment.

Introduction

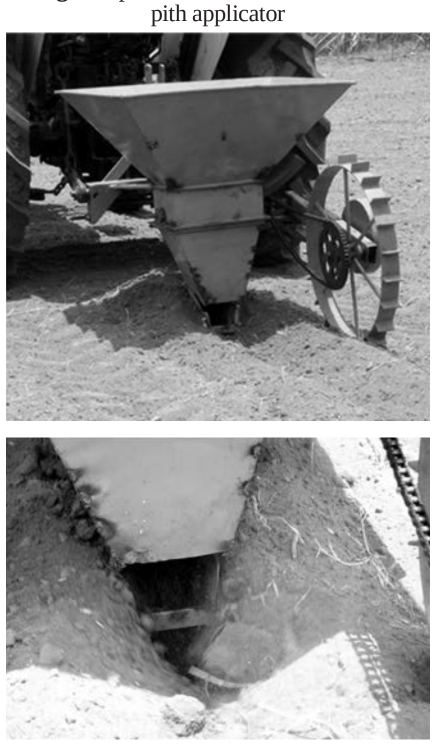
Coir pith has excellent physical and chemical characteristics that make it an ideal material for incorporation into soil as an amendment. The water retention properties of this material have resulted in its increasing use as a growth medium in nurseries. It is a biologically degradable material and recent advances in composting of coir pith have made it possible to modify its chemical structure and convert it into organic manure. The abundant availability of coir pith waste create waste disposal problems for the coir fiber industries on one hand and, on the other hand, makes it attractive to be used as a soil amendment. The objective of subsoil mulching is to improve the root zone environment in the subsoil layers. Deep tillage loosens the subsoil and facilitates deep penetration of roots into subsoil layers that remain moist. However, the effect of deep tillage is not permanent and the soil recompacts due to natural processes and due to the traffic induced compaction. Incorporation of coir pith as a subsoil mulch could prevent recompaction of subsoil. Presence of organic material in the subsoil could also make the subsoil biologically active and enhance root growth into subsoil layers. This would increase the moisture and nutrient availability in the root zone. Since coir pith is highly resistant against biological degradation, the subsoil mulching can have long term effect, compared to surface incorporation. Subsoil placement of mulch would prevent it from being dispersed during subsequent tillage operations. Hence, the mulched trenches would remain as porous channels across the subsoil layers.

Review of Literature

Gupta and Gupta (1983) conducted a field experiment for two years to find the effect of grass mulching on growth and yield of legumes and reported that, out of five levels of application rates (0, 3, 6, 9, 12 t ha^{-1}), 9 t ha^{-1} of grass mulch resulted in an increase of 200 percent in the average production of legumes. Rathore *et al.* (1988) investigated the tillage and mulching effects on water use, root growth and yield of rainfed mustard and chick pea and reported that the application of straw mulch significantly increased root weight by 3-5 percent and 13-15 percent in mustard and chick pea, respectively. Mulching increased crop yield by 27.5 percent for chickpea and 30.7 percent for mustard. Increase in plant height, straw yield and number of pods per plant for chick pea was 5.9, 39.6 and 16.3 percent, respectively, whereas, for mustard crop, it was 3.4, 23.7 and 5 percent. Veerabadran (1991) investigated the effect of composted coir pith application on growth and yield of rainfed sorghum in black soils and reported that the application of composted coir pith at the rate of 20 t ha^{-1} significantly increased the root length, plant height, grain yield, and straw yield by 27.3, 18.5, 83.1 and 57.7 percent, respectively, when compared to no compost application. Khalilian *et al.* (2002) investigated the effect of application rates of composted municipal solid waste injected into sub soil at 15-45 cm depth in cotton crop for 3 years and reported that all the application rates (8.1, 18, 24.5 t ha^{-1}) of compost significantly increased cotton yield when compared to no compost application in all the three years. The

Fig. 1 Tractor operated subsoil coir pith applicator

Fig. 2 Operational view of subsoil coir pith applicator



increase in yield of 23-44 percent was proportional to the application rates.

Methods and Materials

Subsoil Coir Pith Applicator

The prototype subsoil coir pith applicator was built around a chisel plough which formed the tool for loosening the soil and also provided the frame for mounting the coir pith applicator. Coir pith was fed from a hopper through a rotary vane type feeding device and was funneled into the furrow bottom. A pair of furrow opener wings opened the furrow behind the chisel plough for placement of subsoil mulch. The unit consisted of a chisel plough, furrow opener, ground wheel, feed hopper, rotary vane type feeding device. The unit is shown in **Fig. 1** and the operational view of the unit is shown in **Fig. 2**. The cost of the unit was Rs. 15,000 and an area of 0.60 ha could be covered per day. The specifications of the sub soil coir pith applicator are furnished in **Table 1**.

Table 1 Specifications of tractor operated subsoil coir pith applicator.

Details	Value
Over all dimensions (L × B × H), mm	1800 × 1000 × 1200
Chisel plough	
Width of share, mm	25
Lift angle of share, °	20
Length of share, mm	150
Type of mounting	Category I or II
Furrow opener	
Type of furrow opener	Wing type
Width behind standard, mm	50
Maximum width, mm	140
Feeding device	
Hopper capacity, kg	37
Rotor diameter, mm	180
Rotor length, mm	340
Ground wheel assembly	
Diameter of ground wheel, mm	790

The performance of the machine and the effect of subsoil mulching on crop growth was investigated. The experiment was conducted for a rainfed cotton crop. The variety of cotton was MCU 12. The duration of the crop was 150 days. The seed rate was 7.5 kg ha^{-1}. The field was completely randomized into 12 plots. The performance of the unit was compared with chisel plough and conventional method. The treatments of the investigation were:

T_1 = Subsoil coir pith
T_2 = Chisel ploughed
T_3 = Control
Replications = 4 (Observations recorded at two locations in each replication)

The size of each plot was 4.5 × 21.0 m.

Evaluation1 Parameters

The efficacy of the sub soil coir pith application was evaluated in terms of the following parameters.

a). Soil moisture content
b). Crop biometric observations viz., height of the plant, number of leaves, number of branches, number of lateral roots, lateral root spread length, root length, number of bolls
c). Yield of cotton crop
d). Machine parameters viz., area covered and field efficiency

Soil Moisture Content

Soil samples were collected randomly at 15 cm and 30 cm depth, respectively, by using a screw auger from subsoil coir pith, chiseled plough and control plots at periodic intervals from the date of sowing. The moisture content was calculated on wet basis. After taking initial weight, soil samples were placed in the hot air oven by maintaining an oven temperature of 65 ºC for 24 hours. The dried weight was measured. The soil moisture content was calculated using the following relationship.

Soil moisture (%) = [(Weight of wet soil sample − Weight of oven dried soil sample) / Weight of wet soil sample] × 100

Crop Biometric Observations

From the each treatment of the experimental plots, five totally healthy plants per replication were selected and labeled for recording the biometric observations viz., height of the plant, number of leaves, number of branches, number of lateral roots, lateral root spread length, root length and number of bolls. The height of the plants was measured by using a foot rule and other biometric observations are recorded by counting manually at regular intervals of 15 days of crop growth.

Yield of Cotton Crop

From the each plot, the cotton was picked manually and the weight cotton was recorded.

Machine Parameters

The field performance of different implements used for land preparation to bring the soil into a fine tilth condition was recorded in terms of area covered, field efficiency, speed of operation and depth of operation.

Results and Discussion

Height of the Crop

The height of the cotton crop was measured from the ground level to the tip of the plant at 30 day intervals after sowing for five plants per replication. The mean values are furnished in **Table 2**.

The cotton crop was significantly higher in the sub soiled coir pith mulched treatment on 60 and 120 DAS than T_2 and T_3. The order of ranking for the height of the crop was T_1, T_2 and T_3.

Number of Leaves

The number of leaves in five plants per replication was counted at 30 day intervals after sowing and the mean values are furnished in **Table 3**.

Even though the number of leaves in the cotton crop was on par in the three treatments, the order of ranking for number of leaves was T_1, T_2 and T_3.

Number of Branches

The number of sympodial branches in five plants per replication was counted after 60 DAS at 30 day intervals and the mean values are furnished in **Table 4**.

The number of sympodial branches in cotton crop was significantly higher in sub soiled coir pith mulched treatment on 120 DAS than T_2 and T_3. The order of ranking for the height of the crop was T_1, T_2 and T_3.

Number of Lateral Roots

After adequate moisturing and loosening the soil with a crow bar, the cotton plant was pulled out. The pulled out plants were used for recording the root parameters. The number of lateral roots of pulled out plant was counted. The number of lateral roots for five plants per replication was counted at 30 day intervals after sowing and the values are furnished in **Table 5**.

The number of lateral roots of the cotton crop was significantly higher in sub soiled coir pith mulched treatment during the crop growth period than T_2 and T_3. The order of ranking for the number of lateral roots was T_1, T_2 and T_3.

Lateral Root Spread Length

The lateral root spread length of the pulled out cotton plant was measured by spreading the cotton crop on a glass plate. The lateral roots spread length for five plants per replication was measured at 30 day intervals after sowing and the mean values are furnished in **Table 6**.

The lateral root spread length

Table 2 Height of cotton crop in trial field

Treatments	Operation	Height of cotton crop, cm			
		30 DAS	60 DAS	90 DAS	120 DAS
T_1	Subsoil coir pith mulching	15.50	53.25	77.00	111.00
T_2	Chisel ploughing	13.25	38.77	74.60	100.12
T_3	Control	9.72	35.25	56.75	73.75
	S.E.D	1.11	3.15	3.96	5.59
	LSD	2.38	6.77	8.48	11.98

Table 3 Number of leaves in cotton crop in trial field

Treatments	Operation	Number of leaves in cotton crop				
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1	Subsoil coir pith mulching	8	38	97	145	183
T_2	Chisel ploughing	8	32	81	130	150
T_3	Control	7	20	54	105	109
	S.E.D	1.0	3.0	7.7	11.8	14.2
	LSD	2.1	6.5	16.5	25.3	21.2

Table 4 Number of sympodial branches in cotton crop in trial field

Treatments	Operation	Number of sympodial branches		
		60 DAS	90 DAS	120 DAS
T_1	Subsoil coir pith mulching	7	16	23
T_2	Chisel ploughing	8	15	19
T_3	Control	4	9	17
	S.E.D	0.8	2.1	2.0
	LSD	1.8	4.5	4.2

Table 5 Number of lateral roots of cotton crop in trial field

Treatments	Operation	Number of lateral roots of cotton crop			
		30 DAS	60 DAS	90 DAS	120 DAS
T_1	Subsoil coir pith mulching	13	17	19	22
T_2	Chisel ploughing	8	12	14	17
T_3	Control	6	10	13	15
	S.E.D	0.4	0.5	0.5	0.4
	LSD	0.8	1.0	1.1	0.9

of the cotton crop was significantly higher in sub soiled, coir pith mulched treatment during the crop growth period than T_2 and T_3. The order of ranking for the number of lateral roots was T_1, T_2 and T_3.

Root Length

The root length of the cotton crop was measured at periodic intervals and the values are furnished in **Table 7**.

The root length of the cotton crop was significantly higher in the chisel ploughed field treatment during the crop growth period than T_1 and T_3. The order of ranking for the number of lateral roots was T_2 , T_1, and T_3.

Soil Moisture Content

The soil moisture content at different growth stages (31-124 DAS) for 0-15 cm and 15-30 cm in the three treatments is furnished in **Table 8** and **9**, respectively, and the moisture distribution pattern is represented in **Fig. 3** for 0-15 cm and 15-30 cm depth, respectively.

The variation in soil moisture content in 0-15 cm depth between the treatments was not significant on 7, 38, 69, 98 and 124 DAS. But the effect of subsoil mulching was clearly reflected by significantly higher moisture retention in sub soiled coir pith mulched plot for 15-30 cm depth than chisel ploughed and control treatments. The order of ranking for sub soiled moisture retention was T_1, T_2 and T_3. The moisture content at 0 to 150 mm depth in all the three treatments became equal after heavy rains indicating that the soil reached field capacity. However, at the same time, the sub soil layers showed higher moisture in the T_1 treatment over T_2 and T_3 treatments, thus, indicating that the

Table 6 Lateral root spread length of cotton crop in trial field

Treatments	Operation	Lateral root spread length, cm			
		30 DAS	60 DAS	90 DAS	120 DAS
T_1	Subsoil coir pith mulching	13.0	15.0	16.0	18.2
T_2	Chisel ploughing	9.0	10.5	12.0	14.0
T_3	Control	7.0	8.5	11.7	14.0
	S.E.D	0.14	0.26	0.25	0.31
	LSD	0.29	0.55	0.53	0.66

Table 7 Root length of cotton crop in trial field

Treatments	Operation	Root length, cm			
		30 DAS	60 DAS	90 DAS	120 DAS
T_1	Subsoil coir pith mulching	11.26	15.33	18.66	24.70
T_2	Chisel ploughing	10.16	17.50	20.50	26.50
T_3	Control	9.60	14.30	18.01	23.92
	S.E.D	0.12	0.22	0.11	0.24
	LSD	0.26	0.44	0.23	0.52

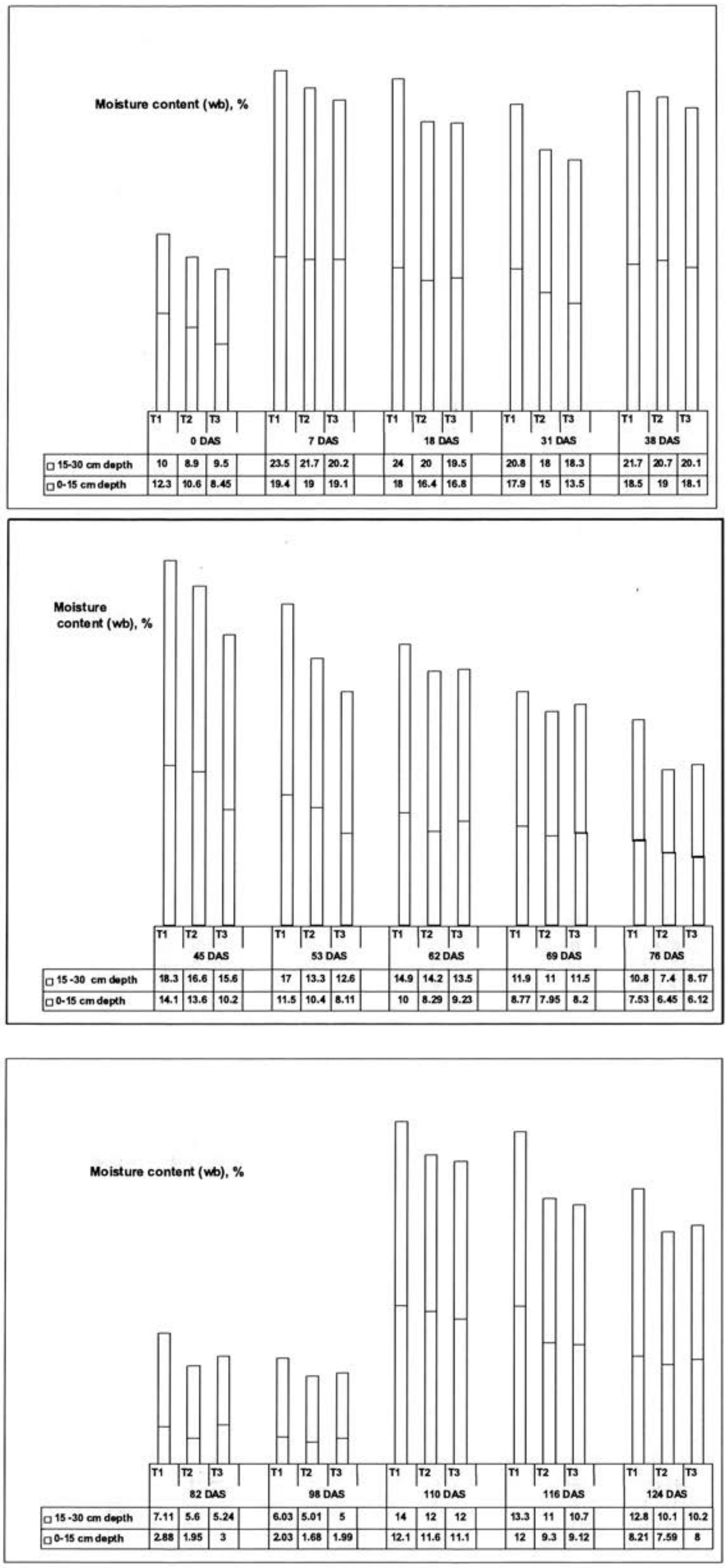
Table 8 Soil moisture content at different growth stages (31-124 DAS) for 0-15 cm

Treatments	Operation	Soil Moisture content in 0-15 cm depth, %			
		31 DAS	62 DAS	98 DAS	124 DAS
T_1	Subsoil coir pith mulching	17.9	10.0	2.03	8.21
T_2	Chisel ploughing	15.0	8.29	1.68	7.59
T_3	Control	13.5	9.23	1.99	8.00
	S.E.D	1.21	0.39	0.15	0.85
	LSD	2.59	0.83	0.32	1.82

Table 9 Soil moisture content at different growth stages (31-124 DAS) for 15- 30 cm depth

Treatments	Operation	Soil Moisture content in 15-30 cm depth, %			
		31 DAS	62 DAS	98 DAS	124 DAS
T_1	Subsoil coir pith mulching	20.81	14.91	6.03	12.80
T_2	Chisel ploughing	18.03	14.21	5.01	10.12
T_3	Control	18.25	13.51	5.00	10.2
	S.E.D	0.75	0.85	0.46	0.44
	LSD	1.60	1.82	0.98	0.94

Fig. 3 Soil moisture content recorded in the trail field during the crop growth period



sub soil layers of coir pith mulched plots absorbed higher moisture. The effect of the sub soil coir pith mulching was obvious during the drying phase of the soil and the sub soiled mulched plots showed higher moisture content than the other treatments. The effect was more pronounced in the sub soiled layers. After a long spell of drying between the 39th and 114th DAS, the soil moisture in the top soil layers became equal. However the moisture in the sub soiled plots was slightly more than that of chiseled and control plots.

The number of bolls was counted for five plants per replication in the cotton crop 75 DAS at 15 day intervals and the mean values are furnished in **Table 10**.

The number of bolls in the cotton crop was significantly higher in the T_1 and T_2 plots as compared to the control.

Crop Yield

The picking of cotton was done periodically and the values are furnished in **Table 11**.

The yield of cotton in the sub soiled mulched plot was 46.4 and 29.4 % higher than the chiseled and control treatments. The yield of cotton in chiseled plot was 13.2 % higher than the control treatment. The higher yield in sub soiled mulched and chiseled plots when compared to the control, may be attributed to the improved moisture storage in the root zone.

Conclusions

The performance of the subsoil coir pith applicator and the effect of subsoil mulching on cotton crop growth was investigated in terms of soil moisture distribution, crop attributes viz., height of the plant, number of leaves, number of sympodial branches, number of lateral roots, lateral root spread length, root length, number of bolls and yield.

1. The soil moisture at 15-30 cm under the subsurface mulched plots was significantly higher than that of the other two treatments.
2. All the indices of plant growth viz., height of the plant, number of leaves, number of sympodial branches, number of lateral roots, lateral root spread length and root length were significantly higher under sub soiled mulched plots than that of the other two treatments.
3. The yield of cotton in sub soiled mulched plots was 46.4 and 29.4 % higher than that of chiseled and control treatments.
4. The yield of cotton in chiseled plots was 13.2 % higher than that of the control treatment. The higher yield in the sub soiled mulched and chiseled plots, when compared to the control, may be attributed to the improved moisture storage in the root zone.
5. The coir pith applicator was suitable for loosening the sub soil and placing the coir pith at 30 cm depth.
6. The applied coir pith acted as soil conditioner, sub-surface mulch and rooting medium.
7. The applied coir pith improved the physical properties of soil and helped retain water.

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Table 10 Number of bolls in cotton crop in trial field

Treatments	Operation	Number of bolls			
		90 DAS	105 DAS	120 DAS	150 DAS
T_1	Subsoil coir pith mulching	8	11	16	30
T_2	Chisel ploughing	5	7	12	19
T_3	Control	5	8	11	12
	S.E.D	0.3	1.0	2.4	3.2
	LSD	0.7	2.1	5.3	6.1

Table 11 Yield of cotton crop in trial field

Number of picking (DAS)	Yield of cotton, kg ha^{-1}		
	Sub soil coir pith mulched (T_1)	Chisel ploughed (T_2)	Control (T_3)
1 (130)	82.0	33.5	39.7
2 (150)	326.5	215.3	188.9
3 (165)	778.0	640.5	582.0
4 (178)	128.3	127.0	87.3
Total	1,314.8	1,016.3	897.9

Decision Modeling for Mechanization Strategies of Rice Cultivation in Chhattisgarh, India

by
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Abstract

The scarcity of water is a critical limitation for sustainable productivity of rainfed rice in Chhattisgarh State of India. Amongst the available possible alternatives to overcome the problem of unsustainable rice yield, direct row seeded rice cultivation was more promising to sustain water scarcity during dry spells. The research created information on machinery inventory and utilization and source wise energy use patterns for various operations in rainfed rice cultivation. It was predicted that by use of mechanical power, seedbed preparation and sowing operation might be completed before onset of monsoon. Timeliness of sowing of rice crop can utilize every unit of rain in growing season. According to available resources, the developed model permitted suggestions for making decision for adoption of rice crop establishment technique.

Introduction

Chhattisgarh State of India comes under dry and sub humid climate. It is an area of small and marginal farmers. The success or failure in rice production is directly related to the economy of the farmers of this category. Rice is a labour and water intensive crop. Fujisaka (1991) emphasized that Biasi (Beusani) is a common crop establishment practice in rainfed lowland rice areas of eastern India. Biasi is used in dry seeded lowland fields to control weeds. But Biasi reduces, not only the weed population, but also the rice plant population. Jacobi (1974) conducted studies on tillage for low land rice in Orissa noticed that rainfall pattern is one of the important problems for timeliness of the soil tillage operation. Gupta *et al.* (1992) reported that drill seeding in dry soil makes the use of a mechanical seed drill feasible. It improves soil structure since puddling is minimized. Lower labour cost is the major advantage of direct seeding. The method eliminates seedbed preparation, care of seedlings in the seedbed, pulling seedlings and hauling and transplanting operations. The savings in labour may substantially reduce production cost, particularly in areas where labour cost is high. Also direct seeded rice may mature 7-10 days earlier than transplanted rice. This saving in time is important; especially where multiple cropping patterns are used. Verma *et al.* (2002) conducted studies on a row seeding implement and found that yields of row seeded rice (3-3.5 t/ha) are more as compared to broadcast seeded rice (2.4-2.7 t/ha).

In transplanting, seedlings are first raised in the seedbed before they are planted in the puddled field. Physiologically, proper age of seedlings for carrying out transplanting is 15-20 days. Exceeding this age will cause high transpiration from seedlings and consequently affect the yield adversely. Again, it has been claimed that best yield is obtained by transplanting the seedlings the same day on which these are removed from the nursery bed (Biswas, 1981). Thus, timeliness of transplanting is a very important factor, influencing productivity of rice. The average yield of rice in Chhattisgarh State is very low (1.2 t/ha) as compared to other Indian states like Punjab, Tamilnadu and West Bengal where average yields of rice have reached up to 3.5-4.0 t/ha. (**Fig. 1**). Frequent dry spells cause failure of rice production. It results in great instability in rice yield and land use intensity. Once a crop has failed, there is an acute shortage of employment for the rural people. Direct seeded and transplanting methods are the most commonly practice of rice cultivation.

The direct seeding method is in use in both upland and low land.

Due to uncertainty about the rainfall and limited resources farmers always face the problem as to which rice cultivation method to adopt. Some of the merits and demerits of prevailing rice cultivation's practices of Chhattisgarh are given in **Table 1**.

The unsustainability and low rice yield under rainfed condition are associated with many supportive constraints such as natural, biological, physical and socio economic.

Natural Constraints

Rainfall Variability

Based on analysis of rainfall data of the last 25 years it was perceived that about 50 % of rainfall occurs in a few storms that last for a total of 20-30 hours, which is hardly 1 % of the total number of hours in rainy season when rice is grown. A large amount of water from these storms is lost by runoff, seepage and deep percolation. The remaining 99 % of crop growing period depends on the remaining 50 % of rainfall, which is not well distributed. Variability in rainfall and evaporation is shown in **Fig. 2**.

Complex Performance of Soil in Different Moisture Regimes

Rice is grown in loam, silty clay loam and clay soil. Due to the presence of clay and iron oxide in the soil of Chhattisgarh, it becomes very sticky when soil moisture content is above 18 % and very hard when the moisture content is reduced to 7 % or less. Under this situation working with animate power and traditional implements is difficult.

Biological Constraints

Low crop production is due to the use of the traditional variety, although the 65 % of the area is covered under High Yielding Variety (HYV). But these varieties are suitable for irrigated conditions and transplanted rice. When these varieties are used in the rainfed condition the yield is seriously reduced.

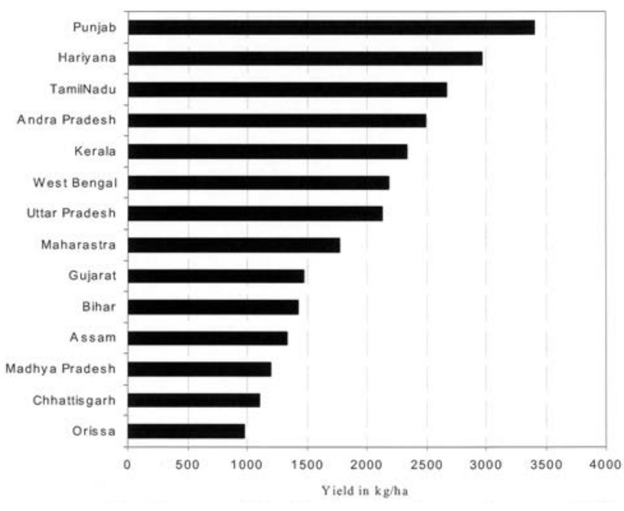
Management Constraints

When the season peaks for transplanting, biasi and weeding, there is a shortage of labour, as these operations are still performed by human labour for all categories of farmers. Transplanting and direct seeded rice are not sown in rows, so control of weeds is not possible with the mechanical weeder. Due to drudgery involved in agricultural operations, particularly in rice cultivation and rapid industrialization in Chhattisgarh, the availability of agriculture labour is very limited.

Table 1 Merit and demerits of rice cultivation practices in Chhattisgarh

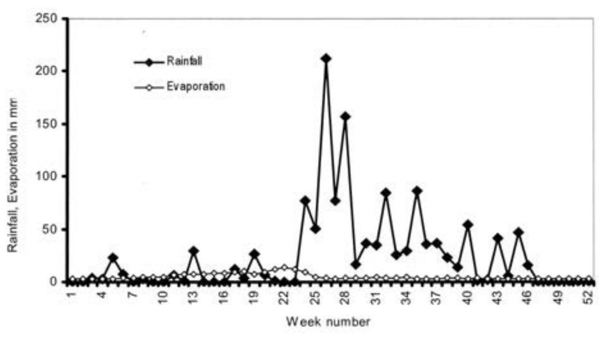
Cultivation practices	Merits	Demerits
Direct seeded *Broadcast Biasi*	Less labour requirement. Yield is stable under uncertain rain. Cost of cultivation is low. Drought risk avoided.	High weed infestation. Low yield as compare to transplanted rice. Wild rice infestation High seed rate.
Row seeding	Rice yield is closed to transplanted rice Mechanical weed control Drought risk avoided	Needs well-prepared field. Needs efficient row seeding and weeding implement.
Transplanting	High yield, less weed infestation control against wild rice.	High energy and input cost. Need water management Labour intensive job.

Fig. 1 Average yield of rice in major rice growing state of India



Source: Directorate of Economics and Statistics, Government of India 2005-06.

Fig. 2 Weekly average rainfall and evaporation for Chhattisgarh, India



Materials and Methods

To achieve the objectives of the present study benchmark surveys were conducted in selected villages of Chhattisgarh. The energy use patterns in direct seeded and transplanted rice cultivation were collected. Participatory Rural Appraisals (PRA) conducted in Chhattisgarh plane, particularly in Durg, Rajanandgaon, Janjgir and Raipur Districts during 1995-97, were used as secondary data. On the basis of these survey reports and PRA experiences, experiments were conducted in the experimental fields of the Faculty of Agricultural Engineering, Indira Gandhi Agricultural University, Raipur, Chhattisgarh, India during the year 1997-2001. The information obtained was used as primary data to determine the energy use in rice cultivation. The data generated through these experiments were used in decision modeling for mechanization strategies of rice cultivation in Chhattisgarh.

Due to diversity in economical status of farmers, there is a broad difference amongst farmers for adoption of technology. Under the category of resource rich farmers almost all the agricultural operations are performed by the machine. Whereas, small and marginal farmers depend upon animate power for rice cultivation. To understand the problem of the mechanization gap, a problem diagram is shown in **Fig. 3**.

Decision Modeling in Rice Crop Establishment Technique for Sustainable Yield

For unsustainable rice production, the experimental results and energy survey reports show two possibilities to overcome the drought problems:

a) To increase area under irrigation
b) To advance the crop schedule by dry seeding of rice

With available information and analysis of these two possibilities, the first possibility seems to be difficult. The irrigation projects are expensive and present a lot of social and economic problems. Also, the rate of increase in irrigated land per year since 1965-66 has been

Fig. 3 Problem diagram for unsustainable rice production

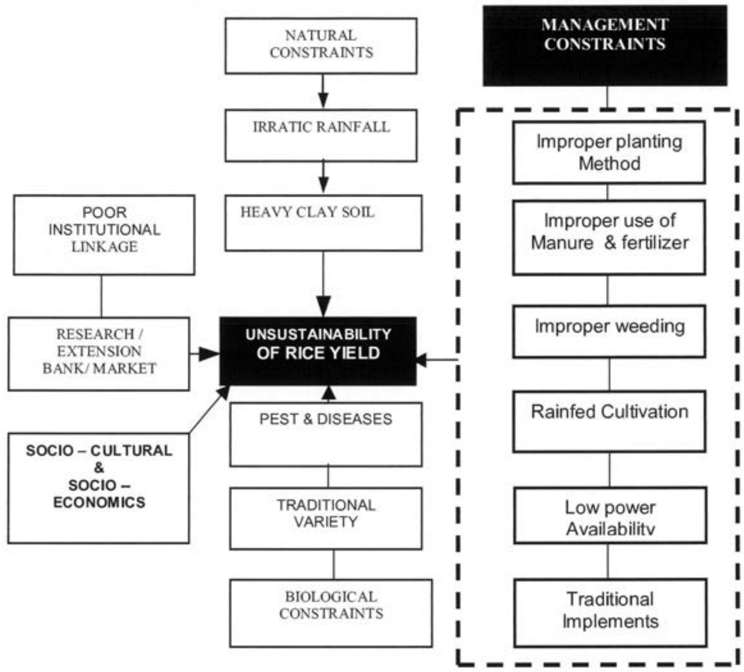
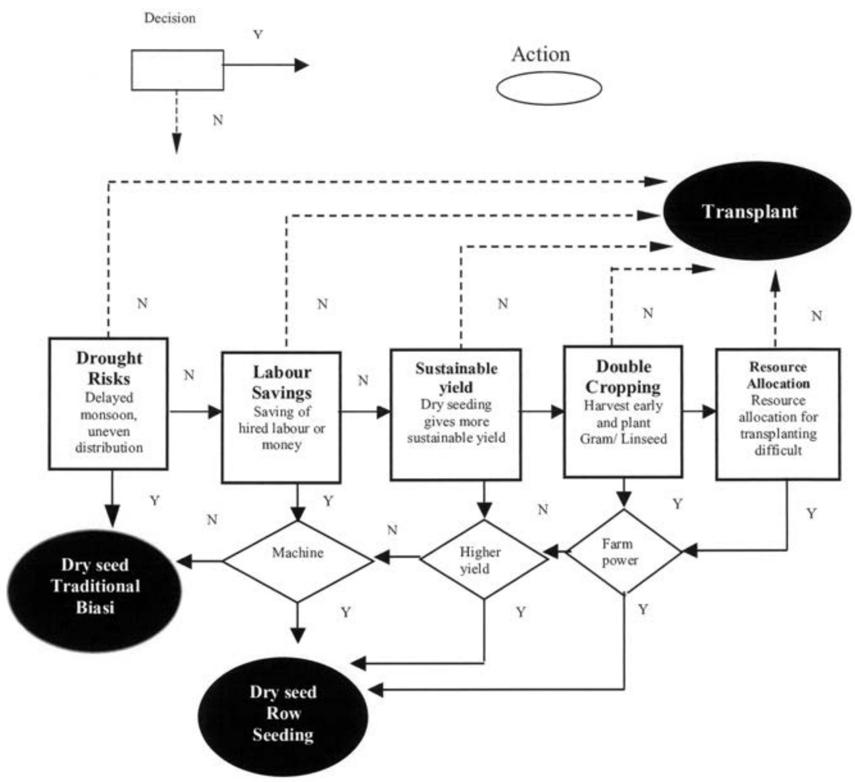


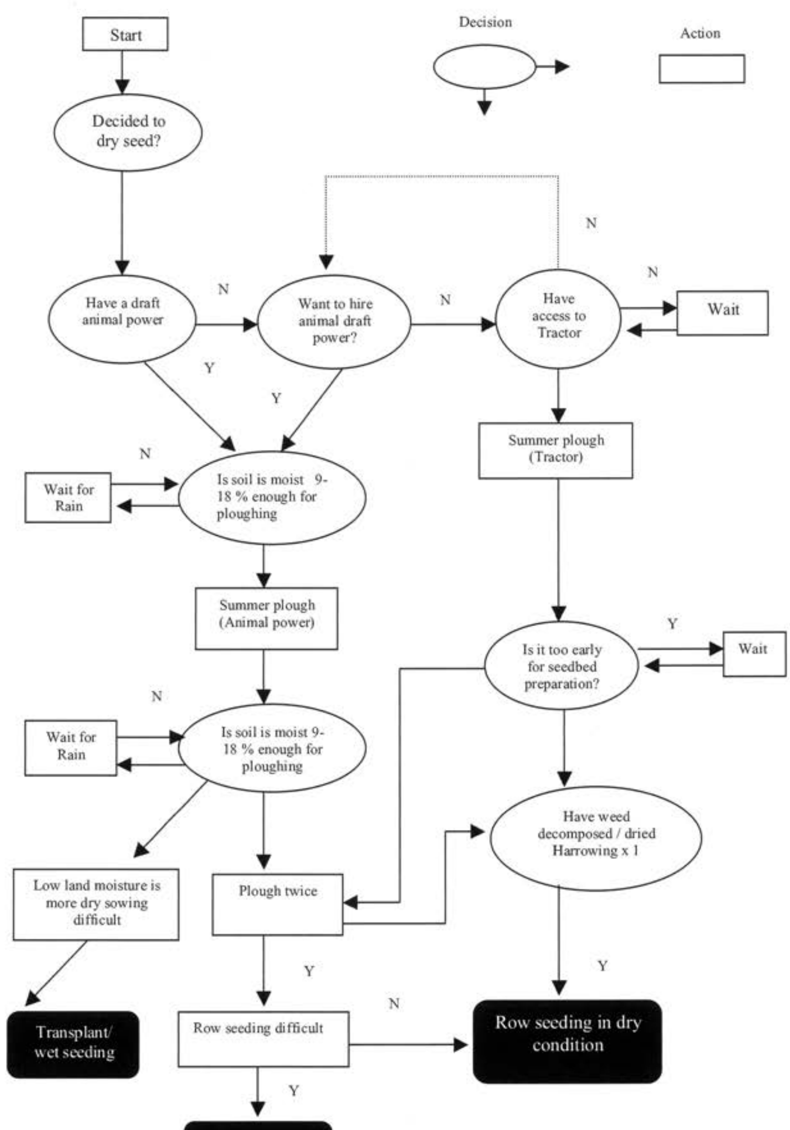
Fig.4 Rice crop establishment decision model for dry seeding



only 0.44 % of the total cultivated land. The second possibility is more promising because of proper management of land, water and other available resources. The decision-making process and particularly the implementation of the decision to switch from traditional broadcast biasi and transplanting to dry seeding is rather complex.

The idea of a three-stage model of rice crop establishment decisions is used for Chhattisgarh rainfed rice cultivation. The first stage of the model deals with the motivation and externalities involved in the decision-making process. (**Fig. 4**). First priority has been given to the drought risk. Labour saving, sustainable yield double cropping depends on the machinery management and availability. Energy efficient machinery and mechanical power availability are the major factors in deciding between row seeding and direct broadcast seeding.

Fig.5 Implementation of rice crop establishment technique



In the second step, as the dry seeding had already been decided in stage I, the systematic model was considered in a time sequence. The main problem a farmer faced was how to prepare land before monsoon rains. It could be solved by the use of improved implements and mechanical power. At the same time, seed could be sown in the rows with a seed drill with seeds 4-6 cm below the soil. Because of the seed depth, these seeds germinated when there was sufficient rainfall, up to 120-140 mm. Thus, the crop utilized every drop of the monsoon rain. Where as, in the traditional biasi system, up to 200-275 mm water was needed for crop germination. In direct row seeding, there was no need of the biasi operation. However, biasi was only possible when there was an accumulation of 5 to 10 cm water in the field. By the direct row sowing, germination of rice started about 15 days in advance in comparison to the traditional system. It was found by many of the researchers that, in terms of total water requirement, direct row seeded rice required 550-600 mm of water. In the traditional method 700-800 mm of water was required. So, by the advance in cropping schedule, direct row seeded rice gave a more sustainable yield(**Fig. 5**).

Energy Studies in Experimental Field

The soil of the experimental field was silty clay loam having 21.4 % sand, 40.3 % silt and 38.3 % clay. On an average the initial bulk density and cone index for the depth of 0-150 mm was 1.60 g/cc and 8.87 kgf/cm^2 respectively at an average moisture content of 16.7 %. The experiments included animal drawn and tractor drawn farming situations, traditional method (by using traditional implements) and the improved method. The area of each plot was 20 × 40 m^2. The measurement of draft, speed and operational time for each operation were done separately. The recommended doses of fertilizers were applied on the basis of soil fertility of the experimental plot. The crops were grown under rainfed conditions. Observation on germination, tillering and yield were recorded. The energy equivalence for direct and indirect sources suggested by Binning *et al.* (1984) was used.

Results and Discussion

Energy Use and Cost of Production in Rice Cultivation Practices

Energy and cost of production for cultivation of rice in direct seeded (broadcast biasi and row seeding) and transplanting method is given in **Table 2**.

The cost of cultivation was higher for transplanted rice. Comparison of the rice crop establishment method showed lower energy consumption (1,597 MJ/ha) and lower cost of operation (Rs. 2,668/ha) for direct seeded rice. In Chhattisgarh, a majority of farmers use direct seeded crop establishment method because of lower cost and less risk from drought. The cost of production of the transplanted method was 1.5 to 2 times higher than the direct seeded method. In both systems of cultivation (row seeding/transplanting), energy and cost requirement for weeding were about 40 % less than broadcast seeded and random transplanted rice. The reason was due to use of the mechanical weeder between the rows. The energy requirement in harvesting, threshing and transportation mainly depended upon the performance of the crop. However, the total direct energy and cost of cultivation in row seeded, direct sown rice by the use of improved implements were 3,988 MJ/ha and Rs 7,158/ha, which were about 33 % and 21 %, respectively, less than the traditional method. It was interesting to note, particularly in the tillage operation by the use of a tractor, that time of operation and cost of cultivation could be reduced about 90 % and 42 %, respectively, in comparison to animate farming. The similar results were also observed for the threshing operation by the use of an electric operated thresher over threshing by animal treading. The cost of threshing for animal treading and electric thresher were Rs. 450/t and Rs. 265/t, respectively.

Average Energy Consumption in Rice Production in Chhattisgarh

Energy use and cost of production in various rice cultivation practices in Chhattisgarh were compared on the basis of specific energy, energy productivity and labour productivity(**Table 3**).

For production of 1 kg of rice by the traditional broadcast method required the highest energy (4.9 MJ/kg). In comparison to the traditional broadcast method, direct row seeded

Table 2 Total energy use and cost requirement for rice cultivation

Particular	Direct seeded				Transplanted			
	Broadcast Traditional (A)		Row Improved (B)		Random Traditional (C)		Row Improved (D)	
	Energy MJ/ha	Cost Rs/ha	Energy MJ/ha	Cost Rs/ha	Energy MJ/ha	Cost Rs/ha	Energy MJ/ha	Cost Rs/ha
Farm operation (Direct energy)								
Land preparation	1,600.6	2,674	1,417.6	2,365	1,924.9	3,093	2,485.3	2,774
Sowing/Nursery	471.2	806	180.3	303	-	312	-	296
Transplanting	-	-	-	-	838.9	1,695	945.7	1,890
Interculture	1,830.1	3,646	1,069.6	2,183	480.2	1,980	269.6	550
Plant protection	-	183	11.0	183	14.6	208	15.8	208
Fertilizer application	23.0		23.0		23.0		30.0	
Water Management	49.0		49.0		58.8		58.8	
Harvesting	432.3	1,103	487.9	1,245	405.8	1,035	414.3	1,057
Transportation	200.5	421	242.0	518	271.1	603	386.1	615
Threshing	565.2	1,072	508.4	900	646.3	1,210	432.2	900
Sub Total (I)	5,171.9	9,905	3,988.8	7,697	4,663.6	9,136	5,037.8	8,290
(Direct energy)								
Seeds	1,528.8	660	1,293.6	440	808.5	275	808.5	275
Fertilizer	5,604.0	1,597	5,604.0	1,597	5,604.0	1,597	5,604.0	1,597
Superior chemicals	-		30.0	100	59.7	200	60.5	200
Sub Total (II)	7,132.8	2,257	6,927.6	2,137	6,472.2	2,072	6,473	2,072
Total (I) + (II)	12,304.7	12,162	10,916.4	9,734	11,135.8	11,008	11,510.8	10,362

rice required 36 % less energy. By the experimental results, it is clear that one MJ of energy row seeded rice can yield highest as compare to the other method.

Comparison of Yield and Agronomic Parameter

The same variety of rice MW-10 (short duration 100-110 days) was sown in all the experimental fields during the years 1997 to 2001. The effect of various treatments on average germination, tillering and yield are given in **Table 4**. Germination rate, tillering and yield were maximum for the improved method. The direct row seeded method gave highest yield of rice (3,488 kg/ha) followed by row-transplanted rice (3,004 kg/ha), traditional random transplanted (2,805 kg/ha) and lowest in traditional broadcasted biasi method (2,509 kg/ha). The average yield for the improved method was 28 % more compared to the traditional direct sown broadcast method. More yield under improved conditions was due to better tilth, better germination rate, higher numbers of tillers per unit area, and healthy plants because of proper utilization of fertilizer and row to row seeding that also promotes better sunlight penetration.

Energy Out put- Input ratio

The energy available from grain and straw represents the energy output, where as energy consumed in various operations represents energy input (Gupta *et al.*, 1994). The total direct and indirect energy (including seed, fertilizer and chemical energy) and energy out put input ratio are given in **Table 5**.

Total energy use in direct sown rice was in the range of 10,000 to 12,000 MJ/ha with output energy of 73,760 to 102,540 MJ/ha. Energy output-input ratio varied from 5.99 to 9.39 and 7.28 to 7.72 for direct sown and transplanted rice.

Table 3 Average energy consumption in rice production in Chhattisgarh

Particulars	Direct Seeded		Transplanted	
	Broadcast Biasi	Row seeding	Random	Row
Total energy (MJ/ha)	12,304.7	10,916.4	11,135.8	11,510.8
Yield (kg/ha)	2,509	3,488	2,805	3,004
Specific Energy (MJ/kg)	4.90	3.12	3.97	3.82
Energy productivity (kg/MJ)	0.204	0.320	0.252	0.261
Labour Input man-days/ha	244.3	183.2	204.00	154.10
Labour productivity (kg/man.day)	10.27	19.00	13.75	19.41

conclusions

On the basis of experimental results, direct row seeded rice crop establishment technique was found suitable for drought risk and more sustainable yield amongst the other rice cultivation practices use in Chhattisgarh. The row seeding

Table 4 Effect of system of cultivation on crop parameters

Cultivation System	Germination (Plant /m^2)	Tillering (Tillers / m^2)	Average height of plants (cm)	Average height of panicle (cm)	Grain yield (kg/ha)	Straw (kg/ha)
Direct sown						
Traditional (Broadcast)	57	181	67	18.3	2,509	3,051
Improved (Row seeded)	85	236	75.8	22.8	3,488	4,176
Transplanted						
Traditional (Random)	41	258	70.2	19.3	2,805	3,318
Improved (Row)	46	270	71.8	20.7	3,004	3,581

Table 5 Out put-input ratio for traditional and improved methods for rice cultivation

Cultivation System	Energy out put MJ/ha × 10^3			Energy input MJ/ha × 10^3		Energy out put-input ratio	
	Grain	Straw	Total	Direct + energy input tillage to threshing	Direct + indirect energy from tillage to threshing	Tillage to threshing	Total (direct + indirect)
Direct sown							
Traditional (Broadcast)	36.9	38.1	75	5.17	12.30	14.26	5.99
Improved (Row seeded)	50.3	52.2	102.5	3.98	10.91	25.76	9.39
Transplanted							
Traditional (Random)	41.2	41.5	82.7	4.66	11.35	17.74	7.28
Improved (Row)	44.1	44.8	88.9	5.07	11.51	17.53	7.72

method of rice cultivation is most effective in view of energy saving and better yield as compared to traditional broadcast biasi system of cultivation of rice. Row seeding by seed drill saves about 40 to 45 % of energy for weeding operation as compared to traditional broadcasting system.

In transplanted rice, puddled seedbed preparation and transplanting of rice seedling was reported as the most energy intensive operation, consuming 42 to 48 % and 15 to 18% of total energy used in field operation. Initial energy input and cost input of transplanted method of rice cultivation was higher than direct seeded rice. Transplanted rice was more susceptible to drought and more dependent on availability of water. Once the monsoon breaks, reduction of rice yield was very high. Frequent dry spells, monsoon breaks and uneven distribution of rainfall were common features of rice cultivation in Chhattisgarh. Under these circumstances, direct seeded rice cultivation practice was found as an alternative to the broadcast biasi system.

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Effects of Different Cleaning Systems and Storage Duration on the Internal and External Quality of Sugar Beets

by

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Abstract

The objectives of this study were to determine the effects of three different cleaning systems that were adopted for sugar beet loading, unloading and cleaning machines, on sugar beet external (physical properties) and internal quality properties depending on storage duration. The cleaning systems were the rollenrost cleaning system (Y_2), the star-shaped gear (rollenrost) + brush cleaning system (Y_3), the fingered (chained) cleaning system (Y_4) and the control (Y_1). External quality values measured were weight change, root breakage and surface injury. Internal quality values were polarization, invert sugar and extract sugar yield. Weight losses, invert sugar increases, polarization and extract sugar yield values decreased depending on silo storage times.

Introduction

During the harvest of sugar beets, dirt on the beet, particularly on root cracks, not only increases transportation costs but also causes labour and time losses in the washwater canals of sugar production factories resulting in worsening of operating values in fabrication and decrease of yield. The soil also creates a good sprouting and rotting environment under rainy conditions. Beets broken or injured during harvest, loading, unloading and transportation are unsuitable for storage in silos. Such beets have high respiratory activity, and cause high sugar loss in the silo as they get infected and decay in a short time.

Smed *et al*. (1996) suggested that sugar loss resulting from tail breakage was 2-3 %, and sugar loss resulting from crown wastage was 6-16 %. Steensen (1996) suggested that 41 % breakage, 86 % bruising and 34 % cracks occurred in sugar beets during loading, unloading and cleaning. He also suggested that (1) 0.7-0.8 % loss was seen in sugar content due to one-week storage resulting from respiration in mechanically harvested beets; (2) there was 10-20 % more sugar loss compared to non-injured or less injured beets having tail and body breakages and heavy surface injuries; (3) there was a sugar loss of 1-1.3 % resulting from washing; and (3) heavily injured beets reached 50 % of this value.

Van der Linden (1996) suggested that rollenrost and axial rolls used together with the brush system reduced dirt-caused wastage by 30-50 % on an average, whereas breakage and injury losses were the same with conventional systems. He stated that rollenrost and brush systems were more effective in root cleaning, whereas the axial rolls were more effective in cleaning dirt and green leaves. He also suggested that pressurized air was effective in reducing dirt-caused wastage but that it came with a high cost.

Sugar beet harvesting in European countries is completely by harvesting machinery. After the harvest, beets are subjected to a preliminary cleaning operation by cleaning machinery in order to prevent field soil transportation to beet acceptance centers and obtain cleaner beets. Although the usage of cleaning machinery varies by country, the percentage is about 90 %. Dirt and leaves on the beet are reduced, but some bruises might occur during such operations. Bruises on the beet (surface injuries, cracks, bumps, tail breakages) may cause increased silo storage and operational losses. When the lifted beet is put into the silo, it consumes some of the sugar it has accumulated. So, it has to be instantly processed.

According to data of the Turkish Sugar Factories Co. Inc. for the year 2006, 6.4 million tons of beets were processed by sugar factories (T.Ş.F.A.Ş., 2006). Daily beet processing capacities of factories was 106.8 thousand tons. An average of 60 days was needed to process existing beets with such processing capacity. Therefore, beets harvested in Turkey must be stored in silos from October 20, when beet lifting generally starts.

According to survey results of Regional Beet Offices of Turkish Sugar Factories Co. Inc., in 2006 there existed a total of 7,712 machines on beet planting fields with 7,519 pieces of one-row haul type, 174 pieces of one-row self-running, 6 pieces of two-row self-running and 13 pieces of six-row self-running combine beet harvesters. Moreover, according to data obtained from State Statistics Institute (SSI), 10,400 pieces of beet lifting machines were used in sugar beet agriculture (Anonymous, 2008). Ninety seven percent of beet harvest machinery was one-row haul-type and use of one and two-row self-running machinery was on the rise.

Harvesters generally have fingered cleaning systems. Machine harvest percentage is about 35 % in sugar beet agriculture. Machine harvest tends to increase; however, increase is not sufficiently fast in the currently applied beet buying system due to factors such as low capacity of factories and small amount of land owned by farmers. Use of post-harvest cleaning machine is not yet widespread. There are 233 mobile beet unloading, cleaning and loading machines in the 25 sugar factories owned by Turkish Sugar Factories Co., Inc. Percentage of machine unloading is 76 % (T.Ş.F.A.Ş., 2006). Unloading machines are mostly used in post-harvest beet cleaning and these machines have star-shaped gear (rollenrost) cleaning system (Y_2). The most important factor determining the cleaning efficiency of beet unloading machines is the moisture ratio of dirt coming with the beet. In measurements made in 2004, 2005 and 2006, when the study was conducted, moisture ratio of the dirt was 26 %, 25 % and 30 %, respectively.

Sugar beets are cleaned using three different cleaning systems after harvesting and efficiencies of cleaning systems and external and internal quality values of beets were studied in this research. External quality values studied in the research were root weight, root breakages, surface injuries, weight losses, crack amount, whereas internal quality values studied were polarization, invert sugar and extract sugar yield.

Materials and Methods

Climatic Properties of the Region

Ankara has typical terrestrial climate characteristics, that is, warm and arid weather in summer months

Fig. 1 Rollenrost cleaning system

and cold and rain in winter months. Annual rainfall is at a low value of 367 mm. The warmest period is between July and August, whereas the coldest period is in January. Average temperature is between 10 to 13 °C, and average monthly rainfall is between 11 to 55 mm. with a highest recorded temperature of 41.4 °C, and the lowest recorded temperature of −32.2 °C. The number of frost days in a year is 60 to 117 days, on the average, and the number of days of snow varies from 10 to 70. Although the dominant wind changes depend on topographical structure, it is in the southwest direction in the region of Etimesgut where the study has been conducted. March and April are the months of strong winds. Based on the values of many years, the average pressure value of Ankara is 912.7 mb and the highest and lowest recorded pressure values are 936.5 mb and 882.6 mb, respectively (Anonymous, 2006b).

Rollenrost Cleaning System

Currently, the star-shaped gear cleaning system is widely used in mobile beet unloading, cleaning and loading machinery in varying horizontal and vertical row numbers depending on the capacity of the machine. The system has a cleaning area of 1.5 m^2 (**Fig. 1**) and contains 10 rows of shafts on rollenrost produced from 10 pieces of GG 25 cast iron. Diameter of star-shaped gears is 200 mm, and the distance between the gears on the shaft is 75 mm, with a distance between shafts of 190 mm revolving at 120 min^{-1}.

Star-Shaped Gear (Rollenrost) + Brush Cleaning System

Five rows of the brush system have been mounted on the system in order to increase the efficiency of the star-shaped gear system on cleaning efficiency. The brush layout has a diameter of 400 mm. The brushes are mounted on to the star-shaped gear system, and revolve at 120 min^{-1} (**Fig. 2**). The distance between the brush axis and the star-shaped gear system has been set to 200 mm, and the brushes revolve in the opposite direction to the star-shaped gear cleaning system.

Fingered (Chained) Cleaning System

The Armer Salmon Hippo (origin United Kingdom) beet cleaning machine has been used in this system (**Fig. 3**).

Sample beets were of the Fiona sugar beet variety originating from Germany KWS (Kleinwanzlebener Saatzucht AG.-Einback). They were

Fig. 2 Front and side view of rollenrost + brush cleaning system

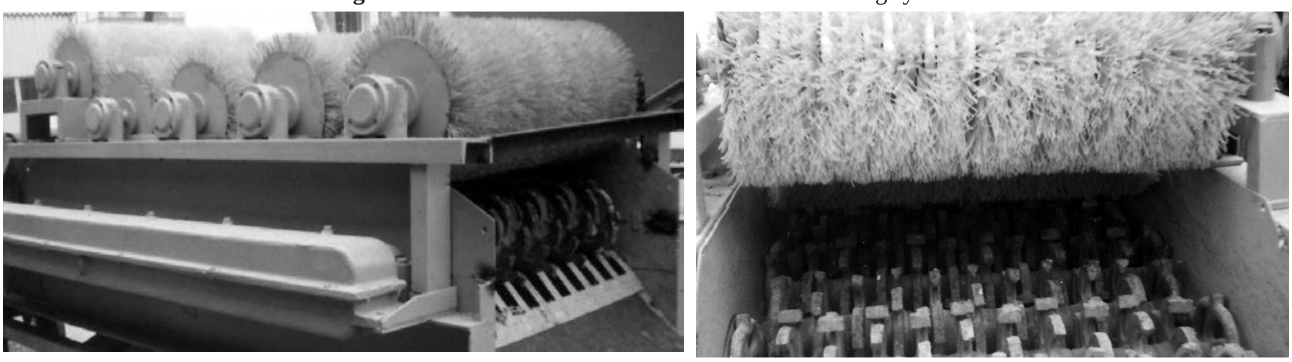
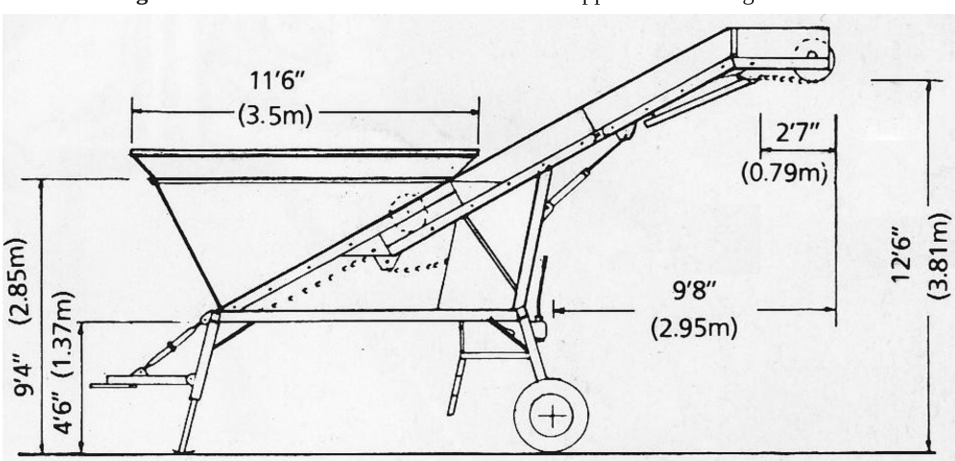


Fig. 3 Schematic view of the Armer Salmon Hippo beet cleaning machine



Hopper length:3.5 m
Hopper width: 3.2m
Hopper height: 3.05m
Hopper capacity: 4m^3
Folded length: 7.2 m
Wheel base: 2.4 m
Engine power: 6kW
Wheels: 750 m × 16 × 8 ply

obtained during 2005-2006 at the Etimesgut Trial Station from plantings made on an area of about 0.2 ha. Harvest was made on October 20, which was the date Ankara Sugar Factory started general lifting. The trial was established with five repetitions in random blocks according to factorial trial order. Five hundred samples each (5 × 100) were taken from beets harvested by three-furrow beet lifting methods. The samples were analyzed for the determination of their previous internal and external quality values. And the remaining beets were passed through three different systems according to the test method recommended by IIRB (International Institute for Beet Research) for the determination of operational qualities of beet cleaning and loading machinery. They were then put into a silo with a volume of about 1,000 m^2 (600 t) in 50 sacks (**Fig. 4**) (Vandergeten *et al.* 2004). In the study, the measured external quality values were weight change, root breakage and surface injury and the internal quality values were polarization, invert sugar and extract sugar yield. Variance analysis and F test were applied on the study outcomes in accordance with the trial plan. No double comparison was made where the F value was insignificant among the methods. Double comparisons, in cases where the F value was significant, were made using the Duncan multiple comparison method.

Three different cleaning systems were used in the study. These systems were;

Y_1. Field (Control)
Y_2. Star-shaped gear (rollenrost) cleaning system
Y_3. Star-shaped gear (rollenrost) + brush cleaning system
Y_4. Fingered (chained) cleaning system.

Beets were then put into the silo in sections so that there would be 10 sacks of machine-filled beets and 10 sacks of field-filled beets. Every 15 days, beets (40 sacks) were taken out of the silo and reanalyzed for quality. Total silo time was established as 75 days. Beet samples in bags were taken out of the silos at the end of 15, 30, 45, 60 and 75 day periods, weighed, and analyzed for their internal quality.

The beet silo was placed in an east-west direction so that the longer side would be in the southern

Fig. 4 Silo dimension and placements plan of the sample sacks in silo

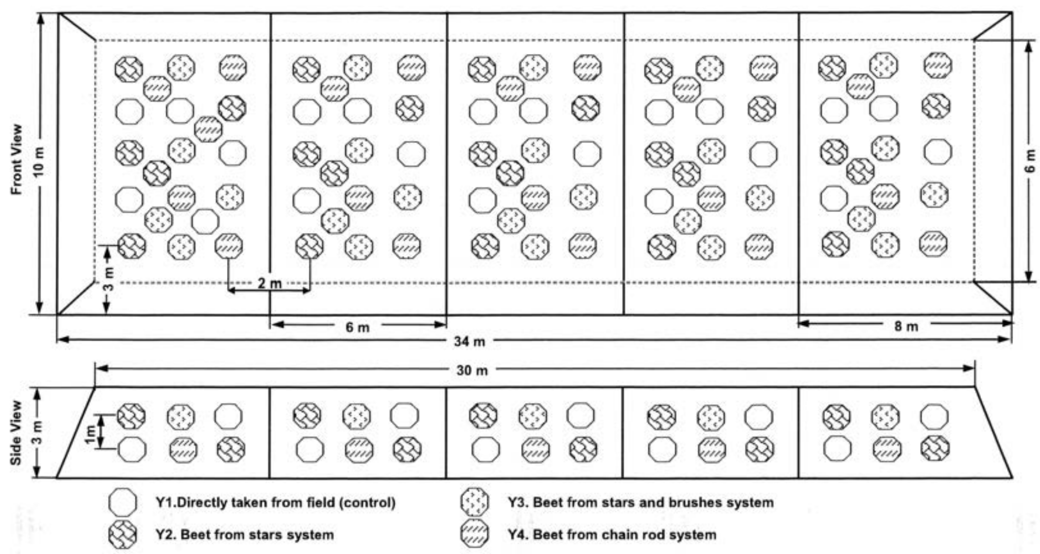
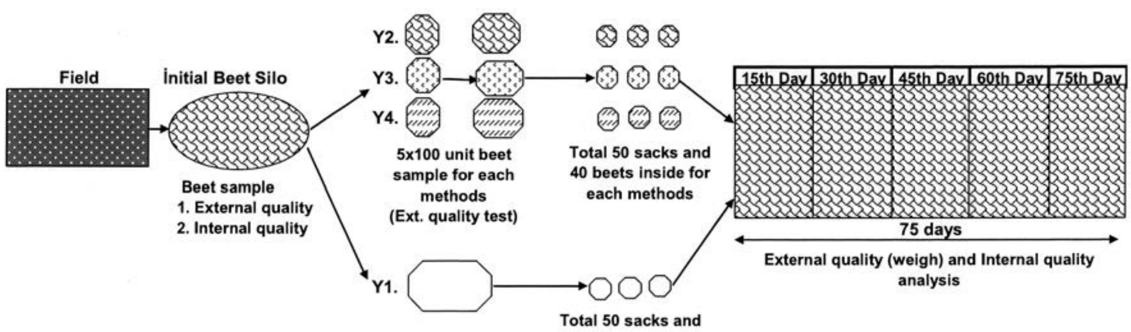


Fig. 5 Flow chart of the application of the beets from the field to silo



direction. The silo dimension was planned to be 34 × 10 m, and 3 m high. Silo dimensions and silo placement layout of sample bags are given in **Fig. 4**. The flow chart of the practice carried out from taking beets from the field to the silo is given in **Fig. 5**.

Results

Results are given in the tables. An evaluation was made by measuring beet diameters, surface damages, root breakages and cracks, if any, before and after the machine, in order to obtain knowledge on the physical properties of studied beets. Internal quality values of beets were measured by analyzing beet samples taken in 15-day periods from beets put into the silo. Findings relating to internal and external quality values are given below.

Beets

Distribution of the 6000 beet diameters measured during the three years of the study is given in **Fig. 6**. Beet diameters are between 50-150 mm, and are parallel in all of the three years.

Root Breakages

According to root diameters measured in the study, the biggest change occurred in Y_3 and Y_4 methods (**Fig. 7)**. Machine handling gave the highest increase in the 25-50 and 50-75 mm values in these two methods. Accordingly, it can be concluded that root breakages occurred mostly in these two methods.

Surface Damages

According to methods implemented, the highest number of injuries in number and area on the beet surface occurred in the Y_3 method (**Fig. 8**). This method was followed by Y_4, with the least number of injuries occurring in the Y_2 method.

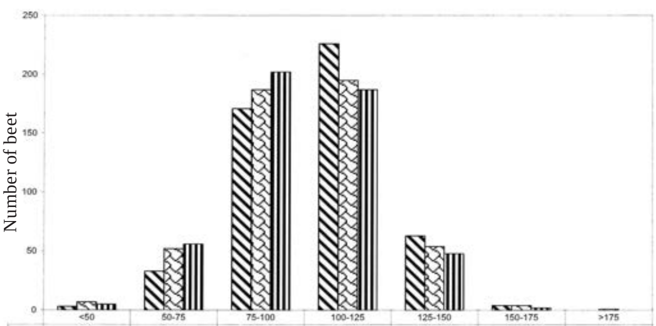
Crack on Beet Surface

As in surface injuries, the highest number of cracks occurred, again, in the Y_3 method. This was followed by the Y_2 method with the least number of injuries occurring in the Y_4 method (**Fig. 9**).

Weight Losses

The highest weight loss among the methods, depending on silo storage time, was in the Y_1 method by 64 %. While the weight loss in all meth-

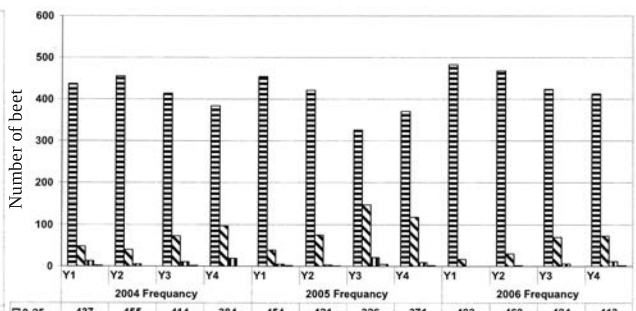
Fig. 6 Greatness distribution of the sample beets



	<50	50-75	75-100	100-125	125-150	150-175	>175
2004	3	33	171	226	63	4	0
2005	7	52	187	195	54	4	1
2006	5	56	202	187	48	2	0

Beet diameter (mm)

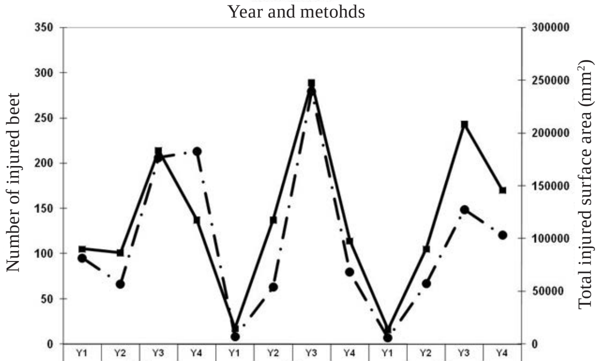
Fig. 7 Root diameters distribution of the beets before and after the cleaning systems



	Y1	Y2	Y3	Y4	Y1	Y2	Y3	Y4	Y1	Y2	Y3	Y4
	2004 Frequancy				2005 Frequancy				2006 Frequancy			
0-25	437	455	414	384	454	421	326	371	483	468	424	413
25-50	48	40	73	97	39	75	148	118	17	30	70	73
50-75	13	5	11	19	5	3	21	9	0	2	6	12
75-100	2	0	2	0	2	1	5	2	0	0	0	2

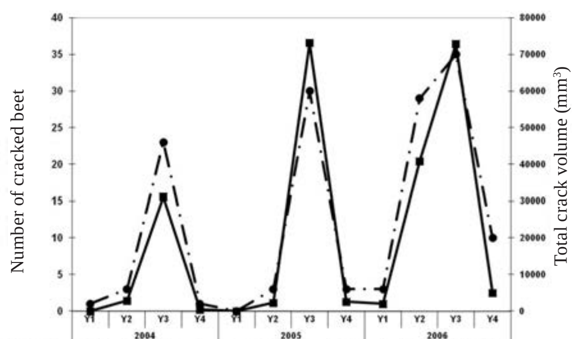
Root diameter (mm)

Fig. 8 Injury on the beet surface according to the methods applied



	Y1	Y2	Y3	Y4	Y1	Y2	Y3	Y4	Y1	Y2	Y3	Y4
	2004				2005				2006			
Injured beet	105	101	214	137	17	137	289	114	16	105	243	170
Surface area (mm²)	81571	56850	176658	182428	6914	54007	239456	68275	5783	57266	127536	103175

Fig. 9 Fissures on the beet surface according to the methods applied



	Y1	Y2	Y3	Y4	Y1	Y2	Y3	Y4	Y1	Y2	Y3	Y4
	2004				2005				2006			
Cracked beet	1	3	23	1	0	3	30	3	3	29	35	10
Crack vol. (mm³)	70	2800	31167	405	0	2340	73131	2640	1980	40824	72858	4945

ods tended to increase, other than the Y_4 method, until the 45th day, it decreased thereafter and a value close to the weight loss obtained on the 15th day was proportionally observed on the 75 th day (**Fig. 10**). Upon comparison of obtained values with the initial weight, the highest weight loss among the methods was in the Y_3 method by 44 % at the end of the 75th day. This was followed by the Y_2 method with 30 % and the Y_4 method with 26 %. The lowest weight loss among the methods, depending on beet storage time in the silo, was in the Y_4 method. Though the difference among the methods with regards to weight loss was statistically insignificant, the difference between the Y_4 and Y_1 methods was found meaningful at 1 % ($P < 0.01$).

Polarization Values

The polarization value increased between the start date and the 15th day due to water loss of beets, and a decreased in all methods after the 15th day depending on silo storage time (**Fig. 11**). Highest actual polarization values were observed in the Y_4 method, and although 18.20 % polarization value was obtained at the end of 75th day, the highest loss during silo storage silo occurred in this method by 5.5 %. The lowest loss during the silo storage was in the Y_2 method by 2.8 %. The Y_3 method showed the second highest change at the end of the 75th day by 4.2 % in return for a polarization value of 17.67 %. From a polarization perspective, the difference between Y_4 and Y_3 was found meaningful at 1 % ($P < 0.01$).

Invert Sugar Values

Upon examination of invert sugar values of expressing transformation of sucrose (a disaccharide obtained from sugar beet) into glucose and fructose (each a monosaccharide); although the highest actual value was on the 75th day reel in the Y_3 method by 1.04, the highest increase according to 15th day values was in the Y_1 method by 278 % (**Fig. 12**). This was followed by Y_3 at 256 %, Y_4 at 234 % and Y_2 at 202 %. The difference among the methods on the 30, 45, 60, and 75th days was found significant at 1% ($P < 0.01$).

Extract Sugar yields

When the extract sugar yield values expressing sacked sugar were examined, it showed a decreasing trend depending on silo storage time. Giving the highest sugar amount on the 15th day of 4.86 kg/50 beets value, the Y_3 method showed the highest fall at the end of 75th day with a change of 18 % (**Fig. 13**). Again, showing the second highest yield of 4.42 kg/50 beets on the 15th day, the Y_2 method showed the second highest fall with a change of 15 %. Giving the second highest extract sugar yield value on the 15th day by 4.50 kg/50 beets, the Y_4 method was the method showing the lowest fall with a change of 13 %. Extract sugar yield value expressing sacked sugar is an important indicator for profitability and its change is not desirable. However, depending on cleaning efficiency during loading, unloading and cleaning operations starting from harvesting, extract sugar yield value decreased during silo storage time due to the dirt, leaves and injuries on the beet. In fact, many factors played a role in this change, and post-harvest operations played a role encouraging change.

Discussion

According to 2006 data, a total of 5.3 million tons of beets was unloaded by beet unloading machines in beet buying centers of sugar factories in Turkey. However, dirt valuing 796 thousand US Dollars (1 US$ = 1.18 TL) dirt was returned to the farmer (Anonymous, 2006a). Increase of cleaning efficiency of beet unloading machines prevented paying for soil and sugar losses due to dirt during the factory process from a sugar factory perspective, and encouraged retaining of soil on the field and protection of agricultural

Fig. 10 Average weight loss

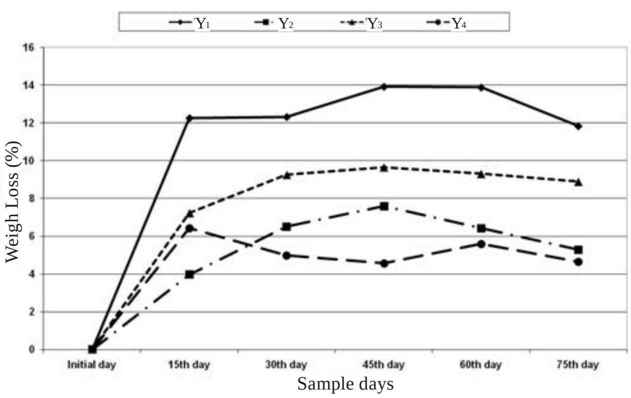
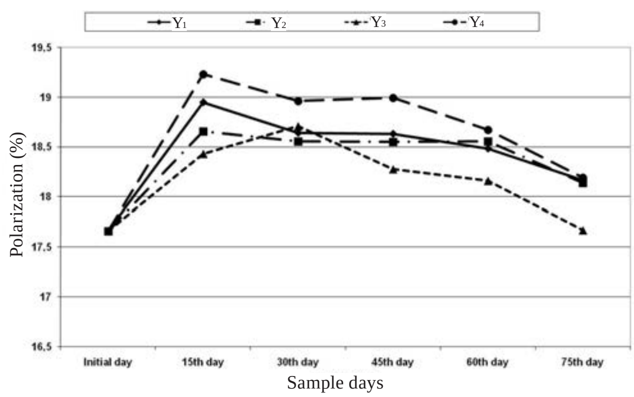


Fig. 11 Average polarization values



areas from a farmer perspective.

When one gram of dirt enters into the sugar production process, 1.5 billion protozoa (single-celled), 51 thousand metazoa (many-celled) and 50 thousand nematoda (larvae) will be taken into the process in addition to 100 thousand algae, 600 million bacteria, 400 thousand yeast in every dm^3 of the soil (Azar, 1997). Microorganisms and bacteria received at the factory by beet washwater, dirt sticking to poorly washed beets and bruised beets cause sugar loss. For example; 109 Bacillus Stearother Mophilus bacteria contained in one ml syrup cause 100-160 mg sugar loss in one hour. And, the sugar loss in the syrup containing 6-7 million bacteria in one millimeter is 0.1 %. In other words, sugar loss is 7 tons in a factory with a beet processing capacity of 7,000 tons/day. Moreover, beets must be cleaned from dirt, correctly stored in silos and well washed to ensure minimum bacteria entry into the factory in order to prevent infection-originated sugar loss (Durukan, 1992).

According to 25 sugar factories that belong to Turkish Sugar Factories Corporation with average process data for 2005, 2006 and 2007, electricity consumption per one ton of beets is 30.21 kWh and per one ton of sugar is 222 kWh. Water cost for cleaning and processing is 26.65 US$ (unpublished campaign evaluation notes of Turkish Sugar Factories Corporation, 2007). In European countries, electricity consumption per one ton of beets is; 14.8 kWh in Denmark, 14.7 kWh in Sweden, 16.7 kWh in Finland and 23.3 kWh in Poland. The countries have electricity consumption per one ton of sugar of 198, 183, 178 and 263 kWh, respectively (Bericht, 2005). Except Poland, the electricity consumption in Turkey is much more than the other countries.

With this purpose, efficiency of three different cleaning systems was studied in this research. According to study results, weight losses and invert sugar values increase and polarization and extract sugar yield fall depending on silo storage times. The highest decrease in polarization values among the methods occurred on the 75th day and, from the point of total losses, the highest fall was in the Y_4 method, which had the highest cleaning surface area. From an actual perspective, highest invert sugar values were in the Y_3 and Y_4 methods by 1.04 and 0.98 at the end of the 75th day. Results parallel to polarization and invert sugar values were found with regards to extract sugar yield. There is more area for physical contact with the beets in the Y_3 and Y_4 methods for beet cleaning, and beet is cleaned better. Upon cleaning, injuries, cracks, and breakages increase on the surface of biological material, depending on physical contact. The cleaning procedure used, though creating an advantage during the initial 15 day period with regards factory processing values, caused an increase of invert sugar and weight loss values and an increase in sugar losses during the subsequent period.

With regards to extraction, reduction of dirt on beets received at the factory by half will result in 50 % reduction in the biological treatment pool and energy costs in wastewater pool volume (Ülkü, 1992).

As a result, if the benefits made by better beet cleaning are supported by shortened processing time, then higher gains may be made by sugar factories. Otherwise, sugar losses will increase and the amount of sugar produced will tend to fall.

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Fig. 12 Average invert sugar values

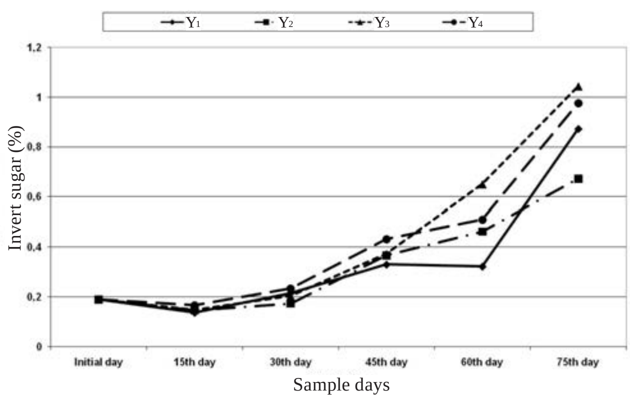
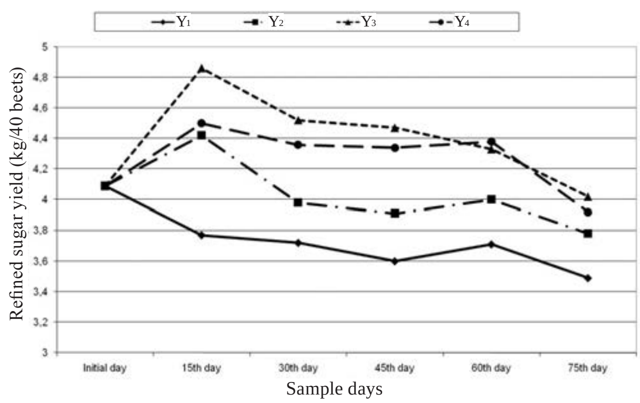


Fig. 13 Average refined sugar yield values



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Design and Development of an Experimental Cotton Picking Aid: Part I

by

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Abstract

An experimental cotton picking aid was designed and developed for picking cotton from cotton bolls. In order to generate required suction pressure on the boll, a suitable blower size was selected based on the minimum force required to pick the boll. This force was theoretically computed as 3.6 N for picker end diameter of 25 mm. A suitable cyclone separator was designed for collecting the bolls. For the selected air flow rate of 0.076 m^3/s through the cyclone, area of inlet duct, exit pipe along with the inlet and exit velocity through the cyclone were also computed at an air velocity of 15 m/s (through suction pipe). An electro magnet was designed to increase the picking rate. The minimum current required to operate the electro-magnetic valve was computed as 4.26 A. Losses in the system like friction losses and pressure losses at various sections of the developed machine were also computed in order to find out the total pressure loss. The total pressure loss was computed as 111.7 mm of H_2O. Finally, a prototype of the machine was developed and tested according to theoretical design computations. The power and fuel consumption of the developed prototype was also measured.

Nomenclature

A	Area of inlet, m^2	h_w	Head of water column, m
A_1	Area of inlet duct, m^2	h_m	Head of mercury column, m
A_2	Area of exit pipe, m^2	H	Magnetic field strength, AT/m
A_s	Surface area of cyclone exposed to the spinning fluid, m^2	I	Current in the bar, A
a	Area of magnetic core (= 2.139×10^{-4} m^2)	l	Length of connecting pipe, m
B	Flux density (= 1.1 Wb/m^2 assumed)	l	Length of picking pipe (2.5 m)
d'	Diameter of connecting pipe, m	l_a	Length of air gap (= 10 mm)
d	Diameter of picking pipe (50 mm)	N	Number of turns (= 2,000)
D_c	Diameter of cyclone, m	P	Pressure created, N/m^2
f	Coeff. of friction (= 0.0143), which is a function of reynolds number (R_e).	r_e	Radius of exit pipe, m
F	Force in Newton, N	r_t	Radius of circle to which the centre line of the inlet is tangential, m,
g	Acceleration due to gravity, m/s^2	S_m	Specific gravity of mercury (13.6)
h	Head created by air column, m	S_w	Specific gravity of water (1)
h_f	Head loss due to friction in pipe (= 54.5 m)	u_1, u_2	Inlet and outlet duct velocity, m/s
		V	Velocity of air in sleeve, m/s

Greek letters

μ	Viscosity of air (1.807×10^{-6} kg/sm at 20 ºC)	α	Constant (0.000000056 at 20 ºC)
ρ	Density of air, kg/m^3	β	Constant (0.1189×10^{-9} at 20 ºC)
μ_0	Viscosity at 0 ºC (0.000017)	ΔP	Cyclone pressure drop, millibars
σ	$4\pi \times 10^{-7}$ (H/m)	ρ_f	Gas density, kg/m^3

Introduction

Cotton is cultivated in about 60 countries around the world. USA, Russia, China, India, Brazil, Pakistan, Turkey, Egypt, Mexico and Sudan are major cotton producing countries accounting for nearly 85% of total production of the world cotton (Anon., 2000). Despite its enormous production, cotton picking is still practiced manually in India. It is not only a tedious operation but about ten times more costly than the cost of irrigation and about twice the cost of the weeding operation (Prasad and Majumdar, 1999). A previous study (Sandhar, 1999) showed that cotton requires about 1560 man-h per ha for hand picking in India and an adult person can pick about 15-20 kg/day of seed cotton. Whereas a single row spindle type picker can achieve an average of 870-2180 kg/day. Anonymous (1977) developed a knapsack vacuum cotton picker. A laboratory model of blower fan for creating a vacuum in the picking zone for the development of a pneumatic cotton picker was fabricated and tested. Idiyatullin *et al.* (1984) developed a cotton harvester fitted with electrical drivers for its pneumatic conveyor and harvesting system. Efficiency was improved by extending working time, improved layout, reduced component weight and more complete power utilization. Fouad and Wahaby (1988) reported the development of a 5 HP cotton picker designed to meet requirements of small farmers. It worked on the principle of suction and was operated by one man. Singh and Malhotra (2000) developed a knapsack type cotton picker using lightweight and durable material. Preliminary laboratory tests were performed and the suction pressure was measured. Maximum suction developed was 400 mm of water and pressure drop due to various leakages was 50 mm of water. However, a lot of time was wasted when the electric cable had to be dragged to the fields and caused lots of damage to the crop due to frequent movement of cable in the fields. Murugesan *et al.* (2004) designed and developed a shoulder mounted power driven cotton picker. The terminal velocity of seed cotton was 3.2 m/s. The cotton-picking system developed had four systems; namely, pure suction, venture suction, single picking brush-cum-suction and counter rotating brushes-cum-suction. The last device fared better for picking cotton from the fully opened cotton bolls.

At present, two types of cotton pickers (pickers and strippers) are commercially available for mechanical cotton picking. However, mechanical cotton pickers are not yet suited in India because prevalent cotton varieties have staggered picking period and require two or three pickings. Moreover, defoliation is necessary prior to mechanical picking. Therefore, a mechanical cotton picking aid has been designed and developed. The use of picking aid will not only be useful in minimizing drudgery involved in hand picking but will also enhance the picking speed thereby saving costly labour.

Materials and Methods

Theoretical Design of Experimental Cotton Picking Aid

Theoretical design was formulated (1) by designing the minimum force required to pick the cotton boll; (2) by designing a suitable cyclone separator; (3) by estimating the total pressure losses in the system; (4) by designing an electro-magnetic valve system for automatic operation and (5) by selecting the suitable size blower.

Minimum Force Required to Pick the Cotton Boll

The maximum suction pressure created by the blower across the orifice meter installed at the picking end pipe was measured in terms of head of mercury column using a U-tube mercury manometer, which was 50 mm of mercury (h_m). This was later converted to suction pressure created by air using the following relationships (Kumar, 1998):

$$h_w = 12.6 \times h_m \quad (1)$$

$$h_{air} = h_m \times 12600 \quad (2)$$

$$h_{air} = 50/1000 \times 12600 = 630\ m$$

Fig. 1 View of cyclone separator

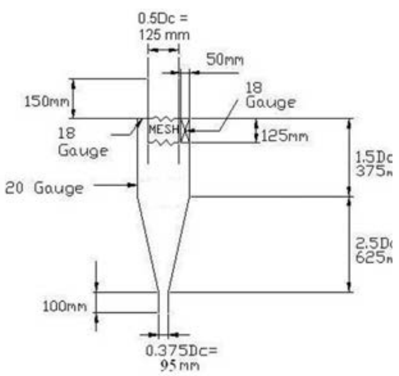
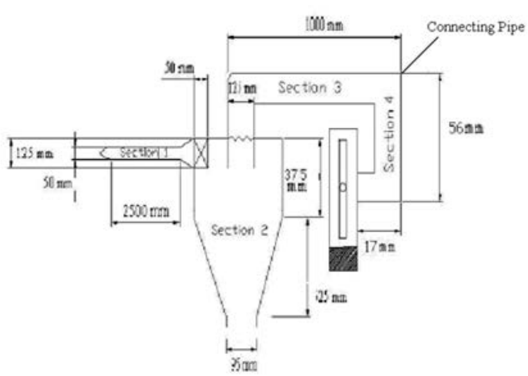


Fig. 2 Various sections causing pressure losses



$P = \rho \times g \times h = 1.2 \times 9.81 \times 630$
$= 7416.4\ N/m^2$ ....(3)
$F = P \times A$ ....(4)
For picker end diameter of 25 mm
$F = 7416.4 \times 3.14 \times (0.025)^2 / 4$
$= 3.6\ N$

Design of Cyclone Separator

Sinnott (1998) suggested that the inlet velocity range of a cyclone separator should be between 9-27 m/s. Therefore, a velocity of 15 m/s was arbitrarily selected for the design. Other dimensions of the cyclone were then scaled as shown in **Fig. 1** for the maximum air flow rate (Q_a = 0.076 m^3/s) ensuring intake velocity of (V_i =15 m/s):

Area of inlet duct, *at 15 m/sec* = $Q_a / V_i = 5.067 \times 10^{-3}\ m^2$........(5)

Also, recommended duct area = $0.5\ D_c \times 0.2\ D_c$......................(6)

From **Eqn.5** and **6**

$D_c = 0.225\text{-}0.25\ m$

Area of inlet duct,

$A_1 = 0.5\ D_c \times 0.2\ D_c = 6250\ mm^2$ ....(7)

Inlet duct velocity,

$u_1 = Q_a / A_1 = 12.16\ m/s$.........(8)

Area of exit pipe,

$A_2 = \pi \times (r_e)^2 = 12265.6\ mm^2$.(9)

Similarly, exit duct velocity,

$u_2 = 6.19\ m/s$

Estimation of Pressure Losses in the System

Friction Losses

The friction losses due to airflow were estimated using pipe flow equations as given by Bansal (2002):

h_f *for picking pipe* = $\frac{4flv^2}{d2g}$ ..... (10a)

h_f *for connecting pipe* = $\frac{4flv^2}{d'2g}$ (10b)

$R_e = Vd / v$ .... (11)

$f = \frac{0.0791}{(R_e)^{1/4}}$

for R_e varying from 4,000 to 10^6 .... (12a)

$f = 0.0032 + \frac{0.221}{(R_e)^{0.237}}$

for R_e *up to* 4×10^7 .... (12b)

Where $v = \mu / \rho$ .... (13)

For a gas $\mu = \mu_0 + \alpha t - \beta t^2$..... (14)

$v = \frac{1.807 \times 10^{-6}}{1.2}$

$= 1.5058 \times 10^{-6}\ m^2/s$

Pressure Losses

Pressure losses due to various sections and bends in the machine (**Fig. 2**) were computed as given:

Pressure loss in picking pipe (section 1):

Flow rate $q = \frac{\pi \times d2 \times v}{4}$........(15)

(For picking pipe diameter used = d and for connecting pipe diameter used = d')

At a given flow rate q (0.076 m^3/sec), velocity in the pipe V is computed as 38.7 m/s.

Also, pressure loss in the pipe is $= pgh_f = 641.5\ Pa = 66\ mm\ of\ H_2O$......................................(16)

Similarly, pressure loss in sections 3 and 4 have been computed and shown in **Table 1**.

Pressure drop in cyclone separator (section 2):

Sinnott (1998) has given the following equation for pressure drop due to cyclone:

$\Delta p = \rho_f \times$ « $\langle u_1^2\{1 + 2\o^2\ [2 \times (r_t / r_e) - 1]\} + 2u_2\rangle^2 / 203$»......... (17)

$\Delta p = 4.09$ *millibar* $= 42.64$ *mm of* H_2O

Pressure losses occurring in section 3 and 4 due to bends and various required parameters for their measurement are shown in **Table 2**. Total pressure losses of the system due to section 1, 2, 3 and 4 and at bends is the sum of all the losses as shown in **Table 3**.

Design of Electro-Magnetic System for Valve Operation

The force required to open the valve was 68.6 Newtons. The designed electro-magnetic valve and the coil arrangement is shown in **Fig. 3a** and **Fig. 3b**.

Theraja (1999) has given the following equation to determine the actual force required to lift the valve

Table 3 Pressure loss due to various sections and bends

Pressure loss in	Pressure loss (mm of H_2O)
Section 1	66.00
Section 2	42.60
Section 3	0.202
Section 4	0.114
Curve bend	0.55
Two 90° bend	2.20
Total	111.70

Table 1 Various parameters and pressure losses in section 1, 2, 3 and 4

Section	l (m)	d (m)	q (m^3/s)	V (m/s)	R_e	f	h_f	Ploss (mm of H_2O)
1	2.5	0.05	0.076	38.7	1,285,031.2	0.0143	54.5	66.0
2	1	0.25	0.076	-	-	0.008	-	42.64
3	1	0.127	0.076	6	506,043.2	2.9×10^{-3}	0.167	0.202
4	0.56	0.127	0.076	6	506,043.2	2.9×10^{-3}	0.094	0.114

Table 2 Various parameters and pressure losses at bends provided in section 3 and 4

Bend in	d' (m)	q (m^3/s)	V (m/s)	r/d	K	Ploss (mm of H_2O)	No. of bend(s)	Total Ploss (mm of H_2O)
Section 3	0.127	0.076	6	0.5	0.25	0.55	One	0.55
Section 4	0.127	0.076	6	-	0.50	1.10	Two	2.20

(f_v):

$$f_v = 1.5 \times \frac{B^2 a}{2\sigma} Newton \text{.............} (18)$$

$$B = \sigma \times H = \frac{\sigma \times N \times I}{l_a} \text{...........} (19)$$

σ is taken as $4\pi \times 10^{-7}$ (H/m)

Length of the inner rod (L_1) and outer rod (L_2) were 70 mm and 15 mm.

Hence, from **Eqn. 19**, *I = 4.26A.*

Selection of the Suitable Blower Size

A centrifugal blower of 55 cm size (outer casing) and operating range of 3,500-5,500 rpm was selected. During the operation, the variation of a mercury manometer column was between 35-50 mm. The selection also included all the pressure losses in consideration within the machine as computed above. The centre of the blower was joined to the outlet of the cyclone separator through a duct and flexible pipe. The blower was run with the help of a belt and pulley arrangement operated with the tractor PTO. A set of four pulleys were used to provide the desired rotational speed of the blower fan.

Development of Designed Prototype

The developed cotton picking equipment consisted of different parts.

Picking Pipe:

A flexible picking pipe of about 2.5 m length and smooth from the inside was used as a picking pipe. The diameter of the picking pipe was 50 mm to avoid the clogging of cotton bolls.

Picker end Diameter:

Four different sizes of picker end diameters were selected out of the sizes available in the market. These were 20, 25, 32 and 40 mm. These were of plastic and could be easily attached and detached.

Mechanical Valve:

The basic concept behind the design of the valve was to open and close the air supply as per requirement for picking the cotton bolls. It also blocked the air supply when picking was not being done. The picking system was connected with a 50 mm diameter ball type mechanical valve. One end of the valve was joined to the inlet of the cyclone separator and other end to the picking pipe. The other function of the valve was to minimize the trash content, which was generally higher during mechanical picking of the cotton crop. The closing and opening of the valve was controlled with a lever operated by the worker. It was further designed to be operated with an electro-magnetic switch. However, due to non-availability of

Table 4 Specifications of experimental cotton picking aid

SN	Parameters	Specification
General	Type of aid	Mechanical
	Power Source	Tractor and Motor
Overall dimensions	Length, mm	1,500
	Width, mm	1,000
	Height, mm	1,600
Cyclone collector	Diameter, mm	250
	Length, mm	1,000
	Length of upper cylinder, mm	375
	Length of cone, mm	625
Mechanical valve	Type	Ball
	Size, mm	50
Blower type		Centrifugal
Picking pipe	Length, mm	250
	Diameter, mm	50
	Size of pipe joining fan and cyclone, mm	127
Size and num-ber of bends		127 mm, 3

Fig. 3a A view of electro-magnet

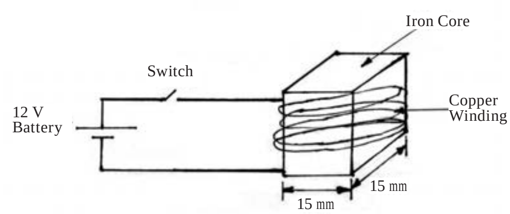


Fig. 3b A View of coil arrangement in mechanical valve

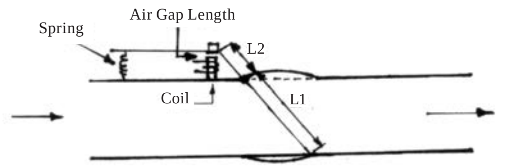
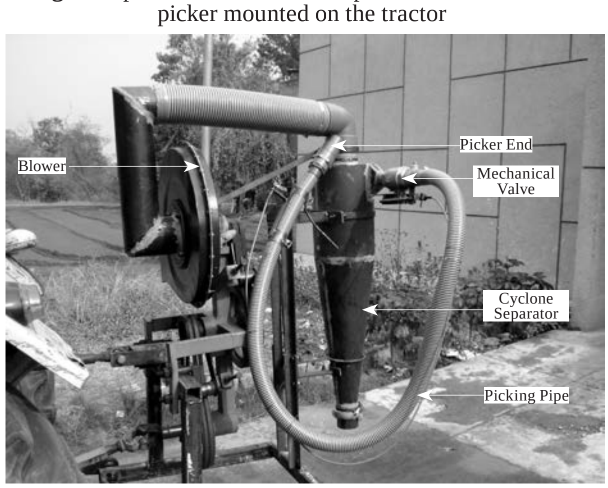


Fig. 4 A pictorial view of developed mechanical cotton picker mounted on the tractor



a switch, the operation of the valve was done manually during initial experiments.

Cyclone Separator:

The cyclone separator was fabricated using mild steel sheet of 18 gauge thickness. The inlet of the separator was joined to the mechanical valve and outlet to the blower with a flexible pipe and steel ducts. Diameter of the separator was 250 mm and height of the cyclone separator was 1,000 mm. Cotton was collected at the lower portion of the separator while the air was discharged through the separator from the blower outlet. There were two mesh sizes fixed at the outlet of the separator, which allowed only air to pass through the blower and not the cotton. Size of the holes on lower mesh was 5 mm and of the upper mesh 8 mm. The cyclone separator was fixed with clamps, which in turn was welded to the angle iron (38.1 mm × 6 mm) and was further welded on the machine frame.

A view of the fabricated cotton picker machine mounted on the tractor is shown in **Fig. 4**. Description and other details of the developed machine are also shown in **Table 4** and in **Figs. 5** and **6**.

Results and Discussion

Power and Fuel Consumption

Power and fuel consumption of the developed picking aid was measured at different suction pressures. A 3-phase wattmeter and energy meter was used for the measurement of power consumption and a one liter fuel tank was clamped just above the fuel injection pump for fuel consumption measurement. The effect of suction pressure on power consumption and fuel consumption for open and closed valve condition is shown in the **Table 5**. For a closed valve, minimum fuel consumption and power consumption at suction pressure of 35 mm of Hg were 1.92 l/h and 5.15 kW, respectively, and maximum fuel consumption and power consumption at suction pressure of 50 mm of Hg were 2.22 l/h and 7.25 kW, respectively. For open valve at suction pressure of 35 mm of Hg, minimum fuel consumption and power consumption were 1.98 l/h and 5.39 kW and maximum fuel consumption and power consumption at suction pressure of 50 mm of Hg were 2.34 l/h and 7.65 kW. With an increase in suction pressure, power and fuel consumption also increased for open as well as closed valve condition. A graph was plotted for power consumption and fuel consumption against different suction pressures (**Figs. 7** and **8**).

Table 5 Effect of increasing the suction pressure on power and fuel consumption

Suction pressure (mm of Hg)	Fuel consumption (l/h)		Power consumption (kW)	
	For closed valve	For open valve	For closed valve	For open valve
35	1.92	1.98	5.15	5.39
40	2.04	2.10	5.74	5.97
45	2.10	2.16	5.56	6.99
50	2.22	2.34	7.25	7.65

Fig. 5 Side elevation of experimental picking aid (all dimensions are in mm)

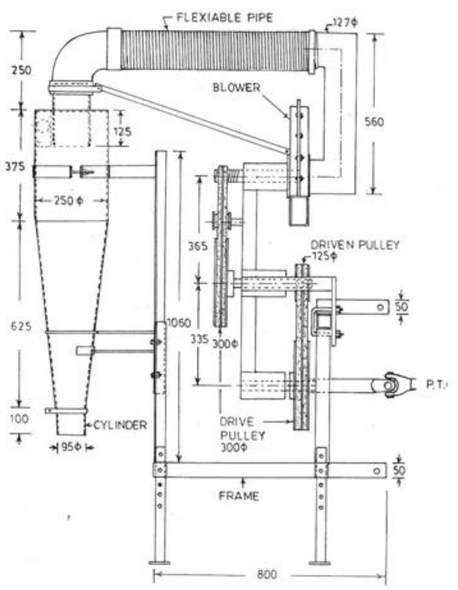
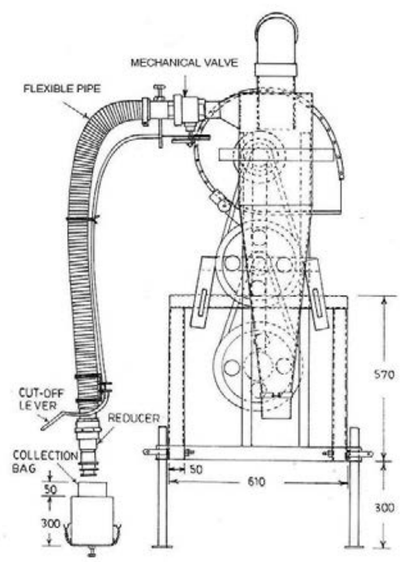


Fig. 6 Front elevation of experimental picking aid (all dimensions are in mm)



Conclusions

An experimental cotton picking aid was design and developed for picking cotton from the cotton bolls. The picking system was equipped with a 50 mm ball type mechanical valve The cyclone separator was designed for a flow rate of 0.076 m^3/s. Dimensions of the cyclone separator was scaled according to its diameter which was 0.25 m. A total pressure loss of 111.7 mm of H_2O was in the system with a maximum pressure loss of 66 mm of H_2O in picking pipe. Minimum force required to pick the cotton boll was 3.6 N. An electro magnetic system was also designed, which required 4.26 A current to develop the minimum force required to lift the valve. It was evident that fuel and power consumption of the machine was directly proportional to the suction pressure.

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Fig. 7 Effect of suction pressure on power and fuel consumption for closed valve

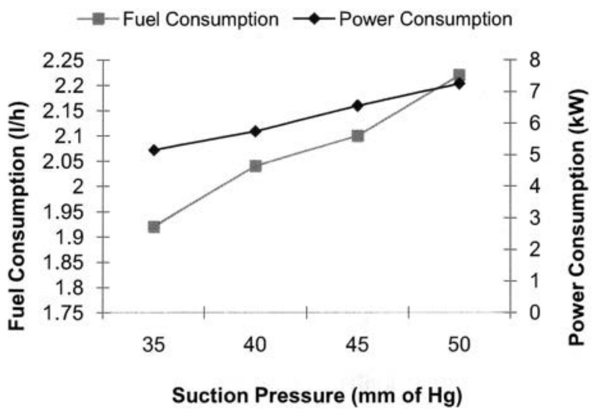
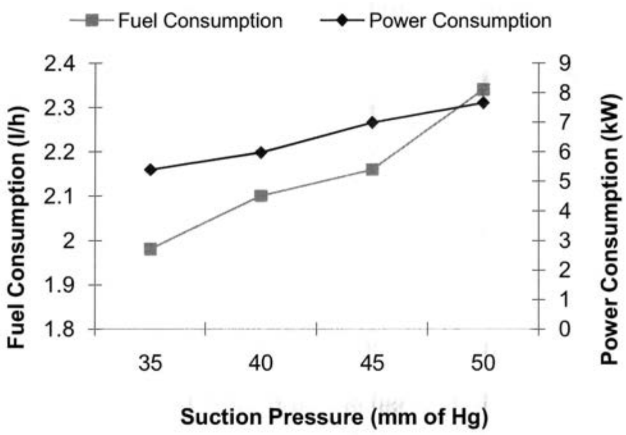


Fig. 8 Effect of suction pressure on power and fuel consumption for open valve



Noni—a Hope in a Bottle

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Introduction

Morinda citrifolia known commercially as noni grows widely throughout the pacific and is one of the most important traditional Polynesian medicinal plant. Noni is noted for its extremely wide range of environmental tolerance. It is found naturally in relatively dry to mesic sites or lowland areas in close proximity to shorelines, or as an important forest understory specie in low elevation pacific island forests and rainforests. Noni, extensive range of environmental tolerances also includes exposure to wind, fire, flooding and saline conditions. Although not considered to be invasive to a degree that threatens ecosystems noni is treated as a weed in some settings, is very persistent and difficult to hill, and is one of the first plants to colonize harsh waste areas or lava flows. All parts of the plant have traditional and/or modern uses, including roots and bark (dyes, medicine), trunks (firewood, tools) and leaves and fruits (food, medicine). Noni is well suited for intercropping within traditional agroforestry subsistence farming systems or as a monocrop in full sun. The tree has attained significant economic importance worldwide in recent years through a variety of health and cosmetic products made from its leaves and fruits.

Major Components

A number of major components have been identified in the Noni plant such as scopoletin, octoanoic acid, potassium, vitamin C, terpenoids, alkaloids, anthraquinones (such as nordamnacanthal, morindone, rubiadin, and rubiadin-1-methyl ether, anthraquinone glycoside), b-sitosterol, carotene, vitamin A, flavone glycosides, linoleic acid, Alizarin, amino acids, acubin, L-asperuloside, caproic acid, caprylic acid, ursolic acid, rutin, and a putative proxeronine (Levand and Larson ,1979 and Heinicke, 1985)

Distribution

M. citrifolia is commonly assumed to have originated in Southehrn Asia and subsequently distributed by humans or other means into the islands of the Western pacific.

The distribution of noni is pantropical at latitudes of 19ºW or S. The Indo-pacific distribution includes eastern Polynesia (Hawaii, Lime Island, Marquesas, Cook Islands), Melanesia (Fiji, New Guinea, Solomon Islands), western Polynesia (Samoa, Tonga, Rothmas and Tuvalu) and Micronesia (Pohnpei, Guam, Palau, (Marshall Islands and Northern Marianas), Indonesia, Australia and Southeast Asia. Noni has also become naturalised on the open, shores of central and South America and on many islands of West Indies, the Bahamas, Bermuda, the Florida and parts of Africa.

Botanical Description

The scientific name of Noni is Morinda citrifolia L.The botanical name for the genus was derived from the two latin words morus, mulberry, and indicus, Indian, in reference to the similarity of the fruit of noni to that of true mulberry (Morus alba). The species name indicates the resemblance of the plant foliage to that of some citrus species. It belongs to family Rubiaceae (coffee family)and subfamily Rubioideae. Noni is the common name for Morinda citrifolia L and is also called Indian Mulberry, Ba Ji Tian, Nono or Nonu, Cheese Fruit, and Nhau in various cultures throughout the world

The Noni plant is a small evergreen tree found growing in open coastal regions at sea level and in forest areas up to about 1300 feet above sea level. The plant is often found growing along lava flows. It is identifiable by its straight trunk, large, bright green and elliptical leaves, white tubular flowers, and its distinctive, ovoid, "grenade-like" yellow fruit. The fruit can grow in size up to 12 cm or more and has a lumpy surface covered by polygonal-shaped sections. The seeds, which are triangular shaped and reddish brown, have an air sac attached at one end, which makes the seeds buoyant. This could explain, in part, the wide distribution of the plant throughout the Polynesian islands. The mature Noni fruit has a foul taste and odour (Swanholm *et al*. 1959). Morinda citrifolia L is not considered to be at risk in the wild.

Associated Plant Species:

They include breadfruit (Artocarpus altilis), banana (Musa spp.), papaya (Carica papaya), plalms (e.g. betel nut palm, Arecacatechii and coconut, Cocos nucifera), pandanus (Pandanus spp.), beach hibiscus (Hibiscus tiliaceus), ti (Cordylinie fruticosa) and piper species (e.g. kava, Piper methysticum). Some of these associated species are understory and some are overstory for noni. Noni grows as a recent introduction around villages or in homegardens, in backyards and along streams and gulches.

Uses and Products

Captain James Cook of the British Navy noted in the late 1700's that the fruit was eaten in Tahiti (Cheeseman, 1903). An 1866 publication in London explained that Morinda citrifolia fruit was consumed as a food in the Fiji Islands (Seemann and Flora, 1866). Later publications describe the use of this fruit as a food throughout the Pacific Islands, Southeast Asia, Australia, and India. In Roratonga "the fruit was often eaten by the natives" (Cheeseman, 1903). Australian Aborigines were reported to be "very fond" of the fruit (Maiden, 1889). In Samoa, Noni fruit was common fare, and in Burma, the fruit was cooked in curries or eaten raw with salt (Morton,1992). Merrill (1943) described Morinda citrifolia L as an edible plant in a technical manual of edible and poisonous plants of the Pacific Islands, in which the leaves and fruits could be used as emergency food. Abbott (1992) also reported that Noni had been used as a food, drink, medicine, and colorful dye. Very young leaves are cooked as vegetables and eaten with rice in Java and Thailand; mature leaves are wrapped around fish before cooking and then eaten with the cooked fish. The terminal bud is used as food. Dried leaves or fruits are used to make infusions and teas for medicinal use.

The medicinal history and accumulated scientific studies, to date, have revealed and confirmed the Polynesian's claim of the health benefits of Noni. The medical knowledge and pharmacopoeia of the Polynesians is now believed to have been fairly complex and modern scientific and medical communities are beginning to study the plants compiled from this knowledge base. The Polynesians utilized the whole Noni plant in various combinations for herbal remedies. The fruit juice is in high demand in alternative medicine for different kinds of illnesses such as arthritis, diabetes, high blood pressure, muscle aches and pains, menstrual difficulties, headaches, heart disease, AIDS, cancers, gastric ulcers, sprains, mental depression, senility, poor digestion, atherosclerosis, blood vessel problems, and drug addiction. Scientific evidence of the benefits of the Noni fruit Juice is limited but there is some anecdotal evidence for successful treatment of colds and influenza (Solomon, 1999). Allen (1873) reported some information on the ethnobotanical properties of Noni. He said that the fruit is used as deobstruent and emmenagogue. This is one of the earliest articles on the medicinal benefits of Noni. Isabel Abbott (1985), a former botanical chemist at the University of Hawaii, stated that, "People are crazy about this plant. They use it for diabetes, high blood pressure, cancer, and many other illnesses". Bushnell (1950) reported that Noni was a traditional remedy used to treat broken bones, deep cuts, bruises, sores, and wounds. Morton (1992) gave numerous references for medicinal uses of Noni. In addition, Polynesians are reported to have successfully used Noni to treat breast cancer and eye problems. Betz (1997), stated that "Morinda citrifolia has been tested for a number of biological activities in animal and anti-microbial studies." He reports that the dried fruit has smooth muscle stimulatory activity and histaminergic effects.

Biological Activities of Noni Products

Antibacterial Activity:

Acubin, L-asperuloside, and alizarin in the Noni fruit, as well as some other anthraquinone compounds in Noni roots, are all proven antibacterial agents. These compounds have been shown to fight against infectious bacteria strains such as Pseudomonas aeruginosa, Proteus morgaii, Staphylococcus aureus, Baciillis subtilis, Escherichia coli, Salmonella, and Shigela. These antibacterial elements within Noni are responsible for the treatment of skin infections, colds, fevers, and other bacterial-caused health problems. Extracts from the ripe noni fruit exhibited moderate antibacterial properties against Ps aeruginosa, M pyrogenes and E coli, and were also shown to have moderate antibacterial properties against Salmonella typhosa, Salmonella montevideo, Salmonella schottmuelleri, Shigella paradys (BH) and Shigella paradys (III-Z) (Bushnell, 1950) .

Antiviral Activity:

Umezawa *et al*. (1992) found a compound isolated from Noni roots, named 1-methoxy-2-formyl-3-hydroxyanthraquinone, suppressed the cytopathic effect of HIV infected MT-4 cells, without inhibiting cell growth.

Anti-tubercular Effects:

Noni has been found to kill Mycobacterium tuberculosis. A concentration of extracts from Noni leaves killed 89 percent of the bacteria in a test tube, almost as effective as a leading anti-TB drug, Rifampcin, which has an inhibition rate of 97 percent at the same concentration.

Antitumor Activity:

In 1992, Hirazumi, a researcher at the University of Hawaii, reported anticancer activity from the alcohol-precipitate of Noni fruit juice (non-ippt) on lung cancer in C57 Bl/6 mice at the 83th Annual Meeting of American Association for Cancer Research. The noni-ppt was shown to significantly prolong the life of mice up to 75 % with implanted Lewis lung carcinoma compared with the control group (Hirazumi *et al*., 1994)It was concluded that the noni-ppt seems to suppress tumor growth indirectly by stimulating the immune system (Hirazumi *et al*., 1996). Improved survival time and curative effects occurred when noni-ppt was combined with sub-optimal doses of the standard chemotherapeutic agents such as adriamycin (Adria), cisplatin (CDDP), 5 fluorouracil (5-FU), and vincristine (VCR), suggesting important clinical applications of noni-ppt as a supplemental agent in cancer treatment (Hirazumi and Furus,1999). These results indicate that nonippt may enhance the therapeutic effect of anticancer drugs. Therefore it may be of benefit to cancer patients by enabling them to use lower doses of anticancer drugs to achieve the same or even better results.

Anthelmintic Activity:

An ethanol extract of the tender Noni leaves induced paralysis and death of the human parasitic nematode worm, Ascaris Lumbricoides, within a day (Raj, 1975). A botanist via Morton reported that Noni has been used in the Philippines and Hawaii as an effective insecticide (Morton, 1992)

Analgesic Activity:

Betz (1997) reported that the Noni fruit possesses analgesic and tranquilizing activites. A French research team led by Younos, tested the analgesic and sedative effects of extracts from the Morinda citrifolia plant. The extract did "show a significant, dose-related, central analgesic activity in the treated mice." They stated that "these findings validate the traditional analgesic properties of this plant." The analgesic efficacy of the Noni extract is 75 % as strong as morphine, yet non-addictive and side effect free (Younos *et al*., 1990)

Hypotensive Activity:

Dang Van Ho of Vietnam demonstrated that a total extract of the Noni roots has a hypotensive effect (Youngken, 1996). Moorthy and Reddy (1970) found that an ethanol extract of the Noni roots lowered the blood pressure in an anesthetized dog [26]. Youngken's research team determined that a hot water extract of Noni roots lowered the blood pressure of an anesthetized dog (Davison, 1927) A Hawaiian physician reported that Noni fruit juice had a diuretic effect (Asahina *et al*., 1994)

Immunological Activity:

Asahina found that an alcohol extract of Noni fruit at various concentrations inhibited the production of tumor necrosis factor-alpha (TNF-α), which is an endogenous tumor promoter. Therefore the alcohol extract may inhibit the tumor promoting effect of TNF-α (Hokama, 1993)

Mental Health and Improved High Frequency Hearing:

A small human clinical trial of the effect of TNJ on auditory function and quality of life in the patients with decreased bone mineral density and auditory function has been conducted in UIC College of Medicine, Rockford, IL. This study showed that TNJ provided a positive benefit on mental health and improved high frequency hearing. The data suggests that increased amounts or extended duration of TNJ intake may be required to affect this disorder (Langford *et al*., 2002)

Commercial Products

The primary commercial products from noni include beverages (fruit juice, juice drinks), fruit powders (for manufacture of reconstituted juice or juice drink products made from dried ripe or unripe fruits), toiletries (lotions, soaps etc.), oil (from seeds) and leaf powders (for encapsulation or pills).

Environmental Preferences and Tolerances

Climate:

Elevation range: 1-800 m, depending on latitude and environment.

Mean annual rainfall: 250-4,000 mm.

Rainfall pattern: Noni can tolerate, a wide range of precipitation patterns, including summer, winter, bimodal and uniform.

Dry season duration (consecutive months with <40 mm rainfall): At least 3-4 months depending on age, size of tree, temperature, relative humidity and soils.

Mean annual temperature:
20-35 ºC.

Minimum temperature tolerated:
12 ºC.

Soils:

Noni grows in a very wide range of soils and environments, with a notable ability to survive in harsh environments, such as those found on coral atolls or basaltic lava flows. It can also be found in solution pits or brackish tide pools near the coast, in limestone soils or outercroppings, on coral atolls, as a colonizing species of basaltic lava flows, as well as in native forests.

Soil drainage: Noni tolerates a wide range of drainage conditions including seasonal water logging, but it prefers free, well drained soils.

Soil acidity: It can grow in a wide range of acidity levels, from acidic to alkaline.

Special soil tolerances: Noni tolerates shallow, saline, sodic and infertile soils.

Tolerance

Mature, cultivated noni can easily withstand drought for 6 moths or more. Wild noni plants growing in arid conditions can spend their entire lives in conditions of perpetual drought. The plant grows well in full sun. Noni can grow in a wide range of light intensities, from full sun to over 80 percent shade. It can regenerate after fire by sprouting new foliage from roots or stems. Noni withstands and even thrives in brackish tide pools. It can also tolerate flooded conditions for long periods of time. It is very salt-resistant and tolerant of ocean salt spray. Noni is tolerant to extreme salinity in general and is thought to possibly gain nutritional benefit from the minerals contained in sea-water. Although windy areas are not advised for commercial production, noni can grow in windswept locations. However, yields and overall plant growth of noni in such areas are diminished.

Abilities

It has the ability to regenerate from shoots or root suckers rather than from seed, producing small thickets or groves. Noni is not considered to be self-pruning, although the woody branches of this plant are brittle and may be relatively easily broken during overly heavy fruiting loads or during high winds. Noni plants regenerate well, even after severe pruning and may be cut back to the trunk (stumping) to promote the growth of a dense head of foliage.

Growth and Development

The growth rate is moderate, generally 0.75-1.5 m/yr, slowing as the tree reaches maturity. Noni flowering and fruiting is continuous throughout year. Fluctuations in flowering and fruiting may occur due to seasonal effects (temperature, rainfall, sunlight intensity and duration). Noni does not compete well with grasses or with grassy weeds in deep soils as an agricultural monocrop. However, it is a good forest understory plant that can tolerate very harsh conditions and plant competition from forest trees, including allelopathic species. In fact, noni is one of the few plants that can thrive beneath the canopy of iron-wood (Cstuarina equisetifolia) trees.

Propagation

Noni is relatively easy to propagate from seeds, stem or root cuttings and air-layering. The preferred methods of propagation are by seed and by cuttings made from stem verticals.

Propagation from seed:

Noni seeds are reddish-brown, oblong-triangular, and have a conspicuous air chamber. They are buoyant and hydrophobic due to this air chamber and their durable, water-repellent, fibrous seedcoat. The seedcoat is very tough, relatively thick, and covered with cellophane-like parchment layers. A single large noni fruit can contain well over 100 seeds. Only soft, ripened noni fruits should be chosen for seed collection. The seeds must be separated from the fibrous, clinging fruit flesh. First, split the fruit by hand into smaller pieces. Separate the seeds from the flesh using a strong spray of water and a firm screen or colander, washing the pulp through the screen while retaining the cleaned seeds. Rubbing the fruit fragments on the screen by hand or with a blunt object can help force the fruit flesh through the screen. It may take 15 minutes or more of vigorous washing and rubbing to detach most of the flesh from the seeds.

Scarifying the hard seedcoat by nicking or puncturing it significantly reduces germination time, improves germination percentage, and promotes uniform sprouting. Whereas, in nature the seedocat must gradually decompose before water can enter, scarification overcomes this natural seed dormancy. Using a household blender to separate seeds from the ripened flesh can also result in nicking the seedcoats, or the seeds can be suspended in water and sub-seedcoats, or the seeds can be suspended in water and subjected to short pulses of blending.

Noni seeds can be dried and stored, but the length of time they will remain viable is not known. After cleaning, spread the seeds out on newspaper and dry them in the shade or indoors for 2 or 3 days. Store the seeds in an airtight container at room temperature.

Fresh noni seeds can be planted immediately after extraction from the fruit. Some growers soak the seeds until they start to germinate, then plant them in containers, while others plant fresh seeds without pre-soaking treatments. Some growers just plant fruit fragments containing seeds directly into the field soil.

Noni seeds require hot, wet conditions for optimum germination. Unscarified seeds need several months to a year before natural germination takes place, but this period can be reduced to a month or so using heat. The seeds can tolerate temperature of 100ºF (38 ºC) perhaps even higher. Select the warmest spot in the nursery or greenhouse to germinate noni seeds or heat can be supplied using nursery heating pads.

Generally noni seedlings are grown in pots in full sun for a minimum of 9-12 months before they are transferred to the field. Seedlings up to a year old or more may also be planted. If noni plants are transplanted too young they are most susceptible to weed competition, mechanical damage, and slug attack.

Seedling and young plants grown from cuttings can be given liquid fertilizer once a month, or a controlled release fertilizer less often (depending on the formulation's release period). Balanced formulations such as 14-14-14 that also contain micronutrients (minor elements) are advised. Young plants also respond well to applications of dilute, liquid foliar fertilizers. As plants become established, granular, rapidly soluble formulations can be used. Noni is relatively salt-tolerant, and fertilizer burn is uncommon under normal conditions.

Vegetative Propagation:

Cultivation of noni plants from stem cuttings (verticals or laterals) reduces the time required to obtain plants that are ready for transplanting. Cuttings from stems and branches will sprout roots readily under the proper conditions.

Select vigorous plants for propagation. Remove a branch or stem and check for fresh sap flow from the wound. If the sap flows readily, cuttings could be made from these materials. If sap does not ooze from the cut end, discard the material and select another plant, another location, or perhaps wait for a better time of year. Sap flow indicates a vigorous, actively growing plant with relatively high reserves of energy.

Insert the cut end of the freshly cut noni stem into a pot containing a general-purpose growth medium. Rooting hormones should improver or accelerate rooting of vegetative cuttings, but it is not necessary. As with seed germination, bottom heat enhances rooting, and an artificial, pathogen-free medium is preferred to untreated agricultural field soil. Select a location with partial shade and keep the cuttings well watered until rooting occurs. After rooting, move the plants into full sun and begin fertilizer applications.

Noni plants may also be produced by air layering or by digging up plants that have sprouted from the root system of a mature plant.

Site Selection

Avoid locations where other crops have been planted recently, due to the susceptibility of noni to root-knot nematodes. Select a site in full or partial sun with well drained, well aerated soil. Avoid heavy soils, compacted areas, and flood-prone sites. Prepare a hole about the size of the pot and transplant carefully. In rocky locations, "rip" the land (disturb or plow the subsoil) before grading to prepare a flat or gently sloping field.

Pruning

Less than 3 years old plants should be pruned back after or during their first production of fruits. In the flowering years, the pruned plants will become bushy and, because noni trees can reach a height of approximately 20 ft, growers may wish to prune the plants to facilitate picking.

Nutrition and Fertilizer

Young seedlings and transplants are given controlled-release fertilize formulations, while older, mature plants are given rapidly available granular formulations. Fertilizer should be applied away from the trunk at the "drip line" of the plant, the area where water drips from the edge of the leaf canopy.

Noni plants of all ages respond well to sprays of foliar fertilizer. Noni flower and fruit production is very responsive to sprays of high-phosphorous foliar fertilizers (e.g., 10-45-10) and products (e.g., seaweed emulsions) containing nitrogen and minor elements.

Noni should be fertilized frequently using smaller amounts of fertilizer, rather than infrequently using larger amounts. In high-rainfall areas, young plants up to a year old can be given 1/2 pound per month of balanced fertilizer (14-14-14), and more mature plants can be given up to 1 pound per month.

Effective organic fertilizers for noni cultivation include crushed coral, dolomite, K-mag 7-7-7, and composted chicken manure and macadamia nut husks. Some locations will benefit from yearly applications of lime, about 1 pound per plant.

Irrigation

Noni thrives with moderate irrigation and can survive extended drought once established and mature. When plants are less than 2-3 years old and conditions are dry, irrigate once or more a week, applying up 10 gallons per plant; for older plants, irrigate less frequently. Overwatering can accelerate damage from root-knot nematodes, cause root rot, and leach fertilize nutrients beyond the root zone.

Plant diseases

Black Flag of Noni:

A severe leaf and fruit blight occurs in the Puna district of the island of Hawaii. The disease is caused by the pathogen, Phytophtora botryose. Symptoms include a black leaf and stem blight, stem or branch dieback, and a chocolate-colored or black fruit rot. The disease is favored by prolonged periods of wet weather. Control measures include pruning, weed control, and field sanitation.

Sooty Mold:

Sooty mold is a black, superficial growth of a nonparasitic fungus that utilizes the sugary exudates produced by soft-fungus insects such as scales and aphids. Sooty mold can easily be wiped off leaves by hand. Heavy infestation of the fungus can reduce photosynthesis, resulting in poor plant growth and reduced fruit size and quality. A soapy water spray can control sooty mold.

Noni Root-knot Disease:

Noni root-knot is a disease of the roots caused by root-knot nematodes, Meloidogyne species. Above-ground symptoms include reduced vigor, plant stunting, and yellowing. Affected roots can be galled, swollen, cracked, and rotten. This disease can be minimized by using nematode-free transplants and by adding organic soil amendments such as composts containing chicken manure. Moderate irrigation and fertilizer use will also minimize the damage and reduce the magnitude of secondary root rot by saprophytic fungi and bacteria.

Stem Rot:

In stem rot, tissues at the base of the plant decay, resulting in stunted plants. The initial plant symptom is wilt, including leaf flagging, and drop. The disease arises from a complex of multiple causes including predisposing stresses (root-knot nematodes, flooding, stem injury) and stem-girdling decay by a soilborne fungus, Sclerotium rolfsii. Planting pathogen-free plants, selecting appropriate sites, and avoiding plant stress can minimize the occurrence and severity of stem rot.

Insect Pests

Pest attacks on cultivated noni can cause significant damage. Pests known to attack noni in Hawaii include aphids (Aphis gossypii), ants, scales (the green scale), mites (eriophyid mites), whiteflies (fringe guava whitefly), and slugs. Pest outbreaks are favored by monocultures of noni. Thus, intercropping with other species of nonhost plants can minimize the overall severity and frequency of pest attacks.

Eliminate weeds that are alternate hosts of noni pests to prevent outbreaks. Significant weed hosts of noni pest are identified by periodic inspections of both noni pests nearby weeds for the presence of pests such as aphids, scale, and whitefly. These and other soft-bodied insects can be effectively controlled with sprays of insecticidal soaps and oils. Mites can be controlled by pruning affected leaves and by applications of approved pesticides, such as sulphur. For slugs and ants, apply a temporary barrier at the base of the noni plant, such as copper tape (for slugs), or a sticky substance such as pine tar (for ants).

Weeds

Noni transplants are susceptible to competition from weeds such a Guinea grass and sensitive grass (Mimosa pudica). Young noni plants should be weeded by hand until the stem is sufficiently large to withstand potential mechanical injury from mowers or string trimmers. Although weed mats can suppress weeds, they also inhibit granular fertilizers from penetrating to the roots zone, and heat can accumulate under the mat, which may favour nematode reproduction. Once noni plants are well established, competition from weeds is less damaging than when the plants are young. Care should be taken to eradicate weeds that are hosts of root-knot nematodes. They may be identified by inspecting their roots for the presence of the characteristic galls and swellings. Noni is susceptible to attack by dodder (Cuscuta sandwichensis), a parasitic weed. Dodder should be manually removed from infested noni plants.

Harvesting and Yield

Noni plants can begin to bear fruit about 9 months after planting. Fruits can be harvested at this early stage, although they generally are small and few. Some farmers choose to forgo harvest during the first and second years in favour of pruning back the branches instead. This pruning results in a bushy plant with more vertical and lateral branches and ultimately produces greater fruit yield.

In Hawaii, noni fruits may be harvested year round, although there are seasonal trends in fruit production that may be affected or modified by the weather and fertilizer applications. Fruit production may diminish somewhat during winter months in Hawaii. The expected yield from mature, healthy plants is 250-500 pounds per plant per year, depending on nutrition and plant spacing. However, yields at some locations can exceed 500 pounds per plant per year with good crop management. Fruits may be picked just before they begin to ripen fully and turn completely whitish-yellow on the tree. These fruits are suitable for shipping and will continue to ripen en route unless measures are taken to retard ripening. For processing locally, fresh fruits are picked when ripe, just before they fall naturally from the tree. Juice can be squeezed directly from the ripened fruits or allowed to drip from the fruits and ferment as in the traditional method.

Agroforestry/Environmental Practices

Although noni regrows well after pruning. Noni plants are generally not managed for mulch production in agroforestry situations. It is well suited for home gardens. A single plant is sufficient to meet the needs of one or more families. Noni can be used for boundary markers due to its persistence and ability to survive harsh conditions and extended periods of drought. The fruits and leaves are useful as animal feed or fodder (pets and livestock). Ripe fruits are a natural source of food for birds, rodents and insects. The flower nectarines are very attractive to honeybees. Noni is tenacious enough help to stabilize lands in harsh or unstable coastal environments. Although the naturalized, M. citrifolia (the wild and cultivated noni types) is considered by many to be a beautiful plant with shiny green foliage, some object to its use as an ornamental plant due to the strong and sometimes offensive odour of ripened fruits and because the fallen fruits attract many flies and other insects. The cultivated M. citrifolia variety 'Potteri' is a beautiful and functional ornamental plant with small fruits and green and white variegated leaves.

Conclusion

Morinda citrifolia assumed to have originated in Southern Asia has been used in folk remedies by Polynesians for over 2000 years, and is reported to have a broad range of antibacterial, antiviral, antifungal, antitumor, antihelminthic, analgesic, hypotensive and immune enhancing effects. The noni plant has the ability to survive in harsh environments and a wide range of acidity levels. It has rapid regeneration ability and can be propagated from seed, stem or root cuttings and air layering. Owing to its therapeutic and nutritional value, it can be considered as one of the most important medicinal plants.

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Studies on Standardisation of Spacing and Transplanting Depth for a Self Propelled Rice Transplanter

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Abstract

A field experiment was conducted during March-June 2008 at wetland in Tamil Nadu Agricultural University to optimize the spacing and depth of transplanting in rice cultivation using a self propelled rice transplanter (Yanmar 6 row). The treatment consisted of 4 levels of hill spacing (30 × 32 cm, 30 × 22 cm, 30 × 18 cm and 30 × 16 cm) in the main plot and depth of planting (manual, 2 cm and 4 cm depth) in the sub plot. Higher DMP (24,231 kg ha^{-1}), root length (16.63 cm), number of panicles m^{-2} (862 m^{-2}) and grain yield (7,167 kg ha^{-1}) were produced when transplanting was done at 30 × 22 cm spacing (15 hills m^{-2}). Among the depth of planting, increased plant dry matter production (17,498 kg ha^{-1}), root length (17.28 cm), number of panicles m^{-2} (812 Nos. m^{-2}), filled grains panicle1 (113), panicle length (22 cm) and grain yield (7,667 kg ha^{-1}) were produced in 4 cm depth.

Introduction

Food security to the people is the key issue pressing the scientists, bureaucrats and politicians around the world. Among the food grains, rice is one of the important stable foods for the world population. Almost 90 % of the world's rice is produced in Asia. In India, rice is the major crop and occupies the largest cropped area of 44.2 Mha with a total production of 87.5 Mt and an average productivity of 1.9 t ha^{-1} (Natarajan *et al.*, 2008). To meet the growing demand required for the population, the rice yield has to be doubled. SRI is a method of cultivation in which higher yields are obtained with less seed, less water and judicial application of fertilizer.

In all rice growing regions of the country, there is acute shortage of human labour during the rice transplanting period and in many cases this delays transplanting, leading to reduced yield and less profit. So, transplanting by labour is becoming difficult in terms of economics, though it is the effective means of rice cultivation. In the SRI method of cultivation, manually marking of the plot is done before transplanting to ensure proper spacing. Then labourers transplant one or two young rice seedling in each grid of the marking. This method of planting requires careful planting on the grid which is difficult for the workers who do not normally follow proper spacing in planting and maintain seedling population per hill. Moreover, in the conventional method of planting, 25-30 day old seedlings are transplanted, whereas, in the SRI method of transplanting, 15 day old seedlings are transplanted (Berkelaar, 2001; Willem and Kassam, 2006).

Mechanization has become a necessity to reduce drudgery in farm operations including women farm workers. In order to overcome difficulties faced by the workers in transplanting the seedling, it is felt that a rice transplanter should be developed for rice planting. In India various types of rice transplanters (imported from eastern countries, viz. Japan, Korea, China, etc.) are used by the farmers. Spacing is very important for optimum plant population per unit area and will be reflected on the yield of the crop. Depth of planting is very crucial for getting uniform establishment. The correct planting depth is one that places the seed where it can imbibe water for germination but not desiccate thereafter. In the SRI techniques 12-15 day old seedlings are transplanted and mechanical weeding is done 10 days after transplanting. It is often necessary to plant deeper to protect from mechanical damage. But. it should be standardized for getting higher yield. Hence, a field study was conducted to standardize the spacing and depth of planting with a self propelled six row Yanmar transplanter.

Materials and Methods

A field experiment was conducted at wetland in Tamil Nadu Agricultural University during March-June 2008 with medium duration rice cultivar ADT 43 to optimize the spacing and depth of planting with a self propelled six row Yanmar rice transplanter. The experiment was laid out in a split plot design and replicated thrice. The main plot was comprised of 4 levels of plant spacing (30 × 32 cm, 30 × 22 cm, 30 × 18 cm and 30 × 16 cm) and sub plots comprised of depth of planting (manual, 2 cm and 4 cm). Rice seedlings of 15 days old were used for transplanting. Other management practices like weeding, fertilization and irrigation were done according to standard procedure followed for SRI techniques.

Results and Discussion

Effect of Treatment on Growth Attributes

Transplanting younger seedlings at an optimum spacing facilitates use of mechanical weeding and permits greater root growth, better tillering and provides other favourable conditions for better growth, especially soil aeration (Kumar and Shivay, 2004). Significantly higher DMP (Dry Matter Production) was produced by a wider spacing of 30 × 22 cm. DMP at harvest was 32.72 and 48 % higher in 30 × 22 cm spacing (**Table 1**) over 30 × 32 cm spacing and 30 × 16 cm spacing due to the obvious reasons of optimum plant population, better land area and availability of nutrients, water and energy. Koma and Sinv (2003) opined that with more resources available to the plants, more tillers were produced with more growth above the ground for effective photosynthesis. Wider spacing (15 hills m^{-2}) enabled plants to receive radiation twice that of densely spaced ones. Light reached even lower leaves, which also contributed to production of assimilates for plant growth and development (Mahender Kumar, *et al*., 2007).

Depth of planting is very crucial for getting uniform establishment. The correct planting depth is one that places the seed where it can imbibe water for germination but not desiccate thereafter. In the SRI techniques, 12-15 day old seedlings were transplanted and mechanical weeding was done at 10 days after transplanting. It was often necessary to plant deeper to protect from mechanical damage. Higher DMP of 17,498 kg ha^{-1} was produced by 4 cm compared to 2 cm depth of planting due to roots that had strong anchor-

Table 1 Effect of spacing and depth of planting on growth, yield attributes and yield of rice

Treatments	DMP (kg ha^{-1})	Root length (cm)	Number of panicles (Nos. m^{-2})	Filled grain $panicle^{-1}$ (Nos.)	Panicle length (cm)	Grain yield (kg ha^{-1})
Spacing						
30 × 32 (10 hills m^{-2})	6,301	15.20	635	93	20	6,287
30 × 22 (15 hills m^{-2})	24,231	16.63	862	99	20	7,167
30 × 18 (18 hills m^{-2})	15,114	15.57	783	98	21	6,930
30 × 16 (21 hills m^{-2})	20,699	15.62	635	119	24	6,283
S.Ed.	510.29	0.62	20.23	3.37	1.06	205.54
CD (0.05)	1,029.72	1.28	41.02	6.91	2.16	415.22
Depth of planting						
Manual	15,124	13.94	658	89	20	5,635
2 cm depth	17,136	16.05	716	105	21	6,697
4 cm depth	17,498	17.28	812	113	22	7,667
S. Ed.	410.99	0.73	20.96	2.54	1.02	310.13
CD (0.05)	826.91	1.47	40.29	5.16	2.04	638.44

age with soil when planting depth increased. It enabled the plants to take nutrient and water from a deeper layer. Shallow depth of planting leads to a shallow rooting pattern and also most roots are distributed in top layer, and roots become shallower with the wider spacing (Zhu Defeng *et al*., 2002).

Root length (**Table 1**) was higher (16.63 cm) with 30 × 22 cm spacing (15 hills m^{-2}). Transplanting at a wider spacing (15 hills m^{-2}) provided ample light intensity and soil volume, which encouraged luxurious growth of roots and tillers supporting synergically. About 60 % of photosynthates formed in the shoots were translocated to roots for its growth, which pervasively explored soil for water and nutrient to supply to the aerial parts (Mahender Kumar *et al*., 2007). Planting the seedlings at 4 cm depth produced lengthier roots of 17.28 cm than other methods of planting.

Effect of Treatment on Yield Attributes and Yield

The number of panicles m^2 (862 m^{-2}) was significantly higher in 30 × 22 cm spacing (**Table 1**). The enhanced availability of resources under wide spaced rice and optimum population per unit area could have allowed more productive tillers to be produced. The number of total tillers increased exponentially as the number of phyllochrons (leaf number) advanced (Zhu Defeng *et al*., 2002). More total tillers ultimately produced more productive tillers. The number of filled grain $panicles^{-1}$ (119 $panicle^{-1}$) and panicle length (24 cm) were significantly higher with 30 × 16 cm spacing. This was due to fewer productive tillers m^{-2} produced under this spacing and led to more allocation of source in limited sink. Enhanced root growth increased DMP and led to higher productive tillers that, ultimately, led to higher grain yield (7,167 kg ha^{-1}) under 30 × 22 cm spacing.

More panicles m^{-2} (812 m^{-2}), filled grain $panicles^{-1}$ (113 $panicle^{-1}$) and grain yield (7,667 kg ha^{-1}) was higher when seedlings were planted at 4 cm depth. Better root growth and shoot growth under this treatment ultimately led to higher yield attributes and crop yield. Incorporation of farm yard manure, green manure and green leaf manure should be done at 5 cm depth. When seedlings were planted at the 4 cm depth, roots could get nutrients easily with less energy. This resulted in better shoot and root growth.

Conclusion

In the SRI techniques 12-15 day old seedlings were transplanted and mechanical weeding was done at 10 days after transplanting. So, seedlings were at very young stage. It was often necessary to plant deeper to protect from mechanical damage by a weeder. So, transplanting the seedling at optimum spacing of 30 × 22 cm (15 hills m^{-2}) and at 4 cm depth was the ideal spacing and depth for higher yield under the SRI with transplanter.

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Musculoskeletal Discomfort and its Reduction in Cotton Cultivation

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Abstract

Haryana rural women have been shouldering responsibility with men in agricultural activities. They undertake the most strenuous activity in cotton cultivation; i.e. cotton picking where farm women spend maximum time (11.15 hrs/day). The majority of respondents complained of physical hazards during picking cotton as felt fatigued (4.85) and pain in body parts (4.81). Introduction of improved methods; i.e. using cot bag resulted in less grip fatigue (6.7 %). Regarding musculo-skeletal discomfort, women reported less pain in the upper back (47.9 %), shoulder joint (50.0 %), and thighs (47.3 %) using cot bag. Cot bag improved efficiency of the worker and decreased drudgery by lowering their stress, thus, making it a user friendly bag.

Introduction

Women have made a significant contribution to the nation's agricultural production. In rural areas, about 60 percent of agricultural operations like transplanting, weeding, harvesting, storage of grains are handled exclusively by women while in other jobs they share the work with men. In Haryana state, harvesting of wheat and cotton crops exhibit an eye-catching picture of quantum of work being performed by rural women. These activities are physically arduous and, thus, place farm workers at potential risk of musculoskeletal disorders like osteoarthritis of hips and knees, low back pain and neck upper limb complaints. (Walker-Bane and Palmer, 2002). Sharma *et al.* (2000) also emphasized that long hours of squatting and bending posture by women in farming activities led to problems like backache and muscle pain. Hence, there is a need to develop and implant the suitable tools and technologies that suit the requirement of women for harvesting cotton.

Though there are various farm implements to reduce work load there are a few tasks like cotton picking/ collection where there is still the old method; i.e. picking cotton by hand and collecting cotton in their traditional way; i.e. in a dupata bag. This creates lots of biomechanical stress on the shoulder and wrists of the worker. Moreover, falling and picking of cotton pods from the ground make them bend very frequently and exert additional stress on the back muscles. Therefore, the present study was undertaken to find out the most strenuous activity in cotton cultivation and introduce suitable technology to minimize their musculo-skeletal discomfort.

Methodology

The study was undertaken in rural areas of Haryana state, India where cotton is the major cash crop. A total of 150 farm women constituted the sample. Data were collected regarding performance of women in various cotton cultivation activities in relation to time spent per day and total man days for each activity. The average time spent was the actual time spent, whereas, average man days was derived by multiplying average time spent on an activity per day with the average number of days that particular activity was carried out and dividing it by 8 (since 8 hours are considered to be equivalent to one man day). Health hazards (viz., physical, mechanical and environmental) in various activities were determined and the most strenuous activity was identified. For the experimental study 20 respondents were selected from the previous sample.

The improved method; i.e. cot bag for picking the cotton, was introduced. This cot bag was developed in the department of Family Resource Management under All India Coordinated Research Project on Home Science on Ergonomics of Farm Women's Drudgery (AICRP 2002). Intervention of this cot bag was done in rural areas of Haryana State, India to minimize the hazards of women in cotton picking.

Biomechanical stress in the form of grip fatigue and musculoskeletal problems were assessed before and after introducing the improved method. Grip fatigue was measured by a Grip dynamometer. This grip strength at rest (S_r) and after the work (S_w) was taken separately for the right and left hand and calculated by the following formula.

$$\text{Grip fatigue (\%)} = [(S_r - S_w) / S_r] \times 100$$

For musculo-skeletal discomfort a human body map was used to identify incidences of musculo-skeletal discomfort in different parts of the body (Corlette and Bishop 1976) on a five point scale ranging from very severe pain (5) to very mild pain (1) and their mean scores were calculated.

Results and Discussion

Background Information of the Respondents

Results revealed that a majority of the respondents (62.0 %) were in the age range of 36-50 years followed by respondents under the age group 20-35 years (27.3 %), having joint family system (55.3 %), having more than 10 members in the family (54.0 %). Only one third could read and write (33.3 %) followed by those who were primary pass (32.6 %). A majority of the respondents (62.7 %) had a low level of mass media exposure (**Table 1**). Cent percent respondents were engaged in farming sector. They were actively involved in performing a number of agricultural activities like sowing, weeding, picking and harvesting. Farm women were performing these activities along with men.

Time Spent and Man Days:

Table 2 reveals that cotton picking was the main activity on which women spent the most of their time.

Fig. 1 Women picking cottons

Fig. 2 Women using cot bag

Dimensions of Cot bag: Length- 50" Functional length- 32" Ready width- 48" Neck width- 6"

Table 1 Socio-personal and economic profile of the respondents

Parameters	Total (N=150)
Age	
20-35 yrs	41 (27.3)
36-50 yrs	93 (62.0)
Above 50 yrs	16 (10.6)
Family type	
Nuclear	67 (44.6)
Joint	83 (55.3)
Family size	
Less than 5 members	10 (6.66)
5-10 members	58 (38.66)
More than 10 members	82 (54.66)
Education of the respondents	
Illiterate	23 (15.3)
Can read & write only	50 (33.3)
Primary	49 (32.6)
Secondary	28 (18.6)
Occupation of the respondents	
Agriculture	150 (100.0)

Figures in parentheses depict percentages

The average time spent per day on cotton picking was 11.15 hours/day followed by weeding (8.06 hrs/day). The number of man days spent annually on cotton picking was highest; i.e. 58.45 man days.

Health Hazards:

The health hazards felt by farm women while performing selected agricultural activities during cotton cultivation were assessed. The health hazards were categorized as physical, mechanical and environmental hazards and are presented in **Table 3**.

It is evident from the Table that cotton picking was the most strenuous activity under cotton cultivation. A majority of the respondents complained about physical hazards like they felt fatigued as the mean score was highest up to 4.89 in cotton picking. Similarly farm women felt pain in body parts as the mean score was 4.81 followed by headache/fever with a mean score 4.28 while performing the activity.

The experimental study was conducted on 20 farm women and their biomechanical stress was studied before and after introducing the improved cot bag for cotton picking.

Biomechanical Stress

Biomechanical stress included the muscular fatigue and feeling of pain in the muscles of body. Muscular stress included grip fatigue of hand muscles and, Musculo-skeletal discomfort.

Grip fatigue

The grip strength was measured before and after the cotton picking experiment in the existing as well as the improved method; i.e. using cot bag. **Table 4** shows the difference between these two values that was used as a measure for grip fatigue. Results revealed that grip fatigue was more (9.5 %) after performing the activity with the existing bag. Whereas, use of the cot bag resulted in less fatigue of grip muscles (6.7 %). This was due to less pressure on the wrists, shoulders and upper arms. It further revealed that improvement in grip strength (29.5 %) was observed using the cot bag over the existing bag.

Musculo-Skeletal Discomfort

Musculo-skeletal discomfort was determined on a human body map with a five point scale ranging from mild pain (1) to very severe (5) as shown in **Table 5**.

Mean scores were calculated for existing and improved cot bag to compare the difference in pain reported. While picking cotton maximum pain was reported in the finger (4.6), upper back (4.8), shoulder joint (4.8), and upper arm (4.2). The improved bag resulted in reduction in pain reported in various parts of body. Gomez (2003) studied prevalence and predictions of joint pain in farmers. Most prevalent pain was in the lower back (41.0 %), neck/shoulder (35.0 %), knees (29.0 %), hands/wrists (28.0 %) and hips (15.0 %). As depicted in **Table 5** the reduction in pain was maximum in the upper back (47.9 %), shoulder joint (50.0 %), thighs (47.3 %), mid back (44.4 %) and upper arm (28.5 %) after use of the improved method (cot bag). Gandhi (2005) evaluated a pick bag and found that there was a decrease in energy expenditure (2.6 %), total cardiac cost of work (TCCW) and physiological cost of work (PCW) (2.8 %).

Conclusions

Cotton picking was the most

Table 2 Time spent per day and number of man days spent annually by farm women in cotton cultivation (N=150)

Activities	Time spent/ day(hrs)	Average man days
Preparatory tillage	5.45	7.10
Sowing	6.40	15.32
Weeding	8.06	35.98
Picking	11.15	58.45

Table 4 Percent change in grip fatigue while using improved method with cot bag over existing method (kg) n = 20

Parameters	Existing method			Improved method		
	Right	Left	Average	Right	Left	Average
At rest	27	25	26	27	25	26
After work	24	23	23.5	25	23.5	24
Grip fatigue (%)	11.0	8.0	9.5	7.4	6.0	6.7

Percent improvement in grip strength −29.5 %

Table 3 Health hazards faced by farm women in cotton cultivation (Mean Score) N=150

Activity	Health hazards							
	Physical			Mechanical`		Environmental		
	Fatigue	Pain in body parts	Headache	Accident	Injury	Heat stroke	Allergy	Skin problem
Preparatory tillage	2.87	2.96	2.96	1.65	1.98	2.78	1.93	1.87
Sowing	3.26	2.89	3.09	1.73	1.87	3.13	2.28	2.73
Weeding	4.12	3.96	3.68	3.53	3.28	3.99	3.97	3.58
Cotton picking	4.89	4.81	4.28	0.56	0.96	4.28	4.46	4.83

Table 5 Incidence of musculo-skeletal discomfort using existing and improved cot bags

n=20

Body parts	Existing bag	Improved bag	Significant reduction (%)
	Mean Score		
Head	4.1	-	100
Neck	4.4	3.4	22.7
Shoulder joint	4.8	2.4	50.0
Upper arm	4.2	3.0	28.5
Elbows	1.6	1.2	25.0
Lower arm	1.8	1.8	-
Low back	3.2	2.6	18.7
Wrist/hands	3.8	1.9	50.0
Buttocks	1.3	1.2	7.6
Upper leg/ thigh	3.8	2.0	47.3
Knees	3.2	3.2	-
Calf muscles	4.4	4.4	-
Ankles/feet	4.5	4.5	-
Upper back	4.8	2.5	47.9
Mid back	3.6	2.0	44.4
Fingers	4.6	4.6	-

strenuous and time consuming activity. Farm women spent more than 11 hours per day and 58.45 man days annually for this activity. Regarding occupational health hazards, it was found that cotton picking was most strenuous regarding physical parameters followed by environmental and then mechanical parameter. By introducing the improved method (cot bag) grip fatigue was decreased up to 6.7 %. Regarding musculoskeletal discomfort, women reported less pain in the upper back, shoulder joints (47.9 % each) and thighs (47.3 %). Hence, cot bag was found better than the existing bag as it increased the efficiency of the women and decreased the drudgery by lowering her stress, thus, making it a user friendly bag.

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Animal Powered Transmission System: An Alternative Energy Source for Small Agro Processing Machines





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Abstract

Draught animals are a dependable source of energy for agriculture but their power has not been fully utilized. To enhance utilization, animals may be employed for operating small agro-processing machines through rotary power. A power transmission system was developed for this purpose. The system consisted of a set of crown, pinion and spur gears. The initial speed of rotation of animals was stepped up in the ratio of 1:125. A final drive shaft consisting of pulleys, fly wheel and a ratchet was provided to transmit power. The power was transmitted from the gear box to this final drive shaft through an underground shaft encased in a pipe for operation of different agro-processing machines. The ratchet disengages the under ground shaft and the final out put shaft as the animals stop or slow down avoiding hammering on the hind legs of animals. The flywheel was provided for smooth running of agro-processing machines and uniform supply of power. The system was tested for different loads by applying load through an animal loading car. The system worked satisfactorily up to a draught of 125 kgf. Different agro-processing machines, namely; maize sheller, grain cleaner, flourmill and chaff cutter were operated by the power transmission system and their performance was evaluated. The draught requirement of the selected machine was well within the draught capacity of the animals.

Introduction

Animal traction continues to increase in many parts of the world, particularly those where there are significant numbers of smallholder farmers. Animal power will continue to be important for food security, self-reliance and poverty alleviation. Animal power is a renewable natural resource that can assist, not only in production, but also in land and water management and resource conservation. All countries, whatever their degree of industrialization and urbanization, can benefit from ecologically sustainable power sources. The animal power is especially suitable for the expansion and intensification of subsistence farming.

Draught animals are a major source of motive power for small farmers in India. Bullocks, buffaloes, camels, horses, mules and donkeys are common draught animals. These animals perform different field operations and are also used for rural transportation. The draught animals supplied 14.5 percent of total farm power in India (Singh, 1999). Use of animals as a source of energy is very dominant in the country and will continue to be so for many more years (Srivastava, 2000). In past years, animal power has been a neglected option,

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but governments, planners, agencies and the private sector are now taking it more seriously. Animal power should become an integral part of national development strategies, including those relating to food security, resource conservation, rural transport and employment. Work animals should be seen as ecologically and economically appropriate in rural areas. They should be seen as coexisting effectively with motorised systems to enhance the quality of community life.

Draught animals will continue to be used in Indian agriculture, which is a time tested animate source of energy for sustained agriculture in the face of dwindling reserves of the non-renewable source of energy (Yadav, 2001). Moreover draught animals being the holistic source of rural power need to be maintained, improved and used efficiently for local business developments through entrepreneurship for higher economic returns, besides cultivation operations and transport. It is estimated that liquid fuel and natural gas would exhaust by 2,050 and coal by 2,250 at the present rate of use. These predictions and their consequences are applicable to India as well (Sukhatme, 1997). The annual use of draught animals varies greatly. It ranges from about 300 to 1,500 hours annually. The annual utilization of draught animal power could be increased by developing animal powered agro processing machines. This type of activity may increase the annual utilization of animals by 1,000-1,500 hours (Srivastava, 1989).

Hallikery *et al.* (1995) developed a power conversion unit that consisted of an old gearbox of a Zetor tractor. Further increase in speed in the ratio of 1 : 240 was obtained with a chain sprocket and belt pulley arrangement. The power requirement for operating a chaff cutter, winnowing fan, castor decorticator and water pump was 0.49 to 0.61 kW; 0.25 kW; 0.55 to 0.87 kW and 0.75 to 1.12 kW, respectively (Hallikery, 2002).

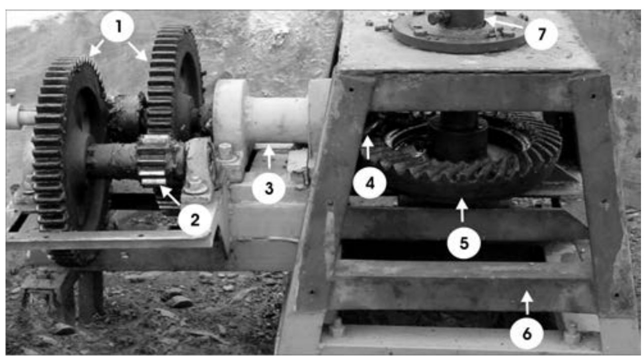
Use of draught animal power for generation of electricity and operating different agro- processing machines is an appropriate approach to increase their annual utilization and supplementing the rural energy needs. A number of power transmission units have been developed to harness animal power in rotary mode of operation. The efficiency of the developed systems was low and power losses were observed to be very high. However, a system acceptable to farmers is not yet available, which can be used for operations like chaff-cutting, flour grinding and threshing (Doshi and Tiwari, 2008). In order to mitigate the problem of power losses and improve the efficiency, an attempt was made to develop a power transmission system for operating various agro-processing machines (Anonymous, 2006 and 2009).

Materials and Methods

A power transmission system was developed and tested for its adaptability to operate small agro-processing machines (**Fig. 1**). The developed power transmission system consisted of a horizontal hitch beam, gear unit, universal couplings, shafts, ratchet, flywheel and pulleys. Different components of the gear unit were mounted on a M.S. angle frame. A horizontal hitch beam made of hollow MS square section was used to transmit the animal power to the vertical input shaft of the power transmission unit. A seat was provided at the outer end of the beam for the operator and a pneumatic wheel was used to support the beam. The vertical input shaft was mounted at the centre of the gear unit with the help of two thrust bearings encased in cast steel housings. The inner end of the hitch beam was clamped with the gear unit through a pin joint allowing the hitch beam to move vertically, thus, preventing damage to the system due to vertical component of forces acting on the beam. The gear unit was installed inside a circular pit at the centre of the circular test track. The gear unit was designed to step up the RPM and change the direction of motion. It consisted of a set of crown and pinion gears and two

Fig. 1 General view of animal powered rotary complex

Fig. 2 Gear unit of power transmission system



sets of spur and pinion gears (**Fig. 2**). A crown gear fixed with vertical input shaft meshed with the pinion mounted on a shaft enclosed in a housing with two ball bearings provided at both ends. A spur gear was fixed at the other end of the pinion shaft meshing with a spur pinion mounted on a counter shaft supported by two pedestal bearings. At the other end of the counter shaft a similar spur gear was mounted, which in turn meshed with another spur pinion. This set of crown and pinion gears and two sets of the spur and pinion gears stepped up the average rotational speed of 2-3 rpm of draught animals to the range of 250 to 375 rpm at the power output shaft.

The output shaft of the second stage spur pinion was connected with the help of two universal couplings, flanges and a mild steel shaft to an under ground shaft. The universal couplings easily transmitted power at an angle between the output shaft and underground shaft. To avoid the hindrance in the path of animals an underground shaft encased in a hollow pipe was laid under the test track at a depth of 300 mm. The extreme outer end of the under ground shaft and final out put shaft were connected through a pawl and ratchet (**Fig. 3**). It allowed power to be transmitted in one direction only preventing the backward flow of power avoiding hammering on the legs of animals when they stop or slow down. A flywheel was mounted on final output shaft to maintain inertia and conserve energy. Different sizes of pulleys were mounted on the power out put shaft to operate matching agro-processing machines.

Initially, a rope was used to hitch the animals with the horizontal hitch beam. Jerks were observed due to sagging and tightening of the rope. In order to avoid these jerks a hollow pipe pull beam/beams were used for hitching the animals. In the case of a camel, two beams similar to the hitching arrangement of a camel cart were used. Bushes made of hollow pipe were provided at the ends of the pull beams. A swingle tree made of hollow pipe was inserted in these bushes for providing movement in vertical plane. Further this swingle tree was attached with a horizontal hitch beam through a turntable arrangement to facilitate swinging movement of the pull beams in the horizontal plane (**Fig. 4**). A single hollow pipe pull beam was used for hitching a pair of bullocks. This beam was attached with turntable through a pin joint for allowing movement in vertical plane while movement in horizontal plane was maintained by the turntable as in case of camels. The movement in both the planes was provided to avoid the effect of unwanted forces acting on the vertical input shaft.

The developed system was tested for its performance at different loads. An animal loading car

Fig. 3 Output end of the power transmission system

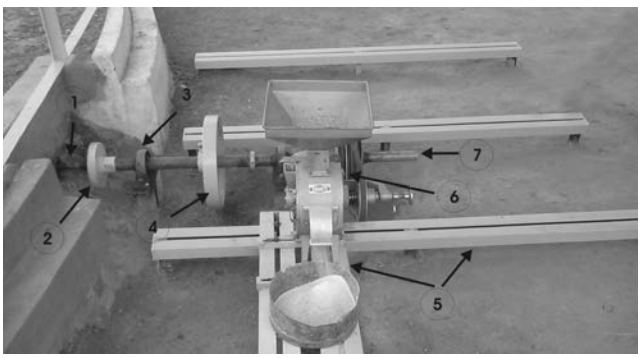


Fig. 4 Hitching arrangement and measurement of pull

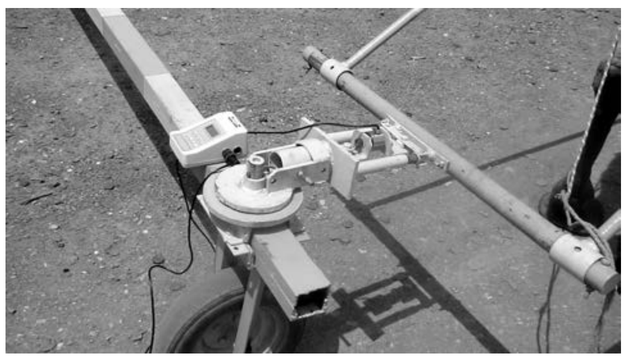


Fig. 5 Testing of power transmission unit by animal loading car

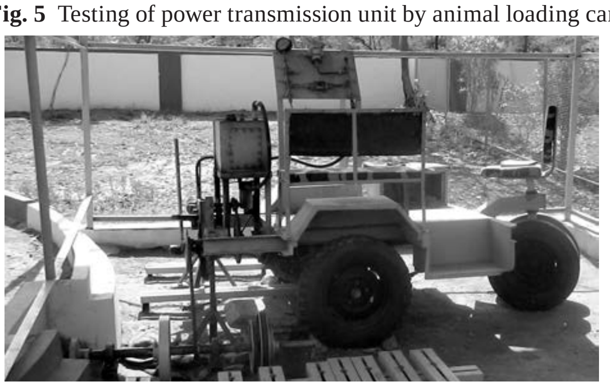


Fig. 6 Flour mill in operation

developed by Central Institute of Agricultural Engineering, Bhopal (India) was used to vary the load on the system. A loading car was attached with the help of chain and sprocket (**Fig. 5**) and load was varied by regulating the hydraulic valve of the loading car. A load cell was attached between horizontal pull beam and animal hitching system to measure the actual load on the power transmission system (**Fig. 4**).

Railings made of slotted channels were grouted for installation of agro-processing machines with perfect alignment. The railings provided the easy movement of agro-processing machines in both parallel and perpendicular directions to power the output shaft (**Fig. 3**).

On the basis of practical utility, four matching machines; i.e. flour mill, maize sheller, chaff cutter and seed cleaner cum grader were selected for exploring their suitability with the developed power transmission system. These machines were scaled down according to the power produced by a pair of bullock/single camel and their performance was evaluated (**Figs. 1, 6** and **7**). The performance of the machines was also compared with traditional practicesm which are performed manually.

Results and Discussion

The developed power transmission system was evaluated for its performance at various loads. During the test, bullocks/camel were hitched at a working radius of 3.5 m. the results of feasibility trials showed that agro processing machines requiring less than 1 hp could easily be operated by the power transmission unit. At a load of more than 125 kgf the camel/bullocks showed fatigue symptoms and were not able to work in sustained working conditions. The results are in confirmation with the findings of Doshi (2006).

The performance results of matching agro-processing machines are given in **Table 1**.

A minimum draught requirement of 35 kgf was observed with a seed cleaner cum grader (**Fig. 8**), whereas it was highest with the flour mill (55 kgf). The draught requirement of tested agro-processing machines indicated that camels and bullocks can work comfortably as their draught capacity is much higher than the power required for operating these machines.

The output of agro processing machines is work specific. It was observed that 500 to 550 kg of grain could be cleaned and graded in one hour (**Fig. 9**). The output of the flour mill and maize sheller was in the range of 8-10 and 120-130 kg, respectively. An average person can shell out around 15-21 kg of grains manually which indicated about 625-850 percent increase in output with the animal power operated maize sheller and at the same time

Fig. 7 Maize sheller in operation

Table 1 Performance of agro-processing machines

Agro processing machine	Draught, kgf	Operating RPM	Output, kg/h	
			Animal power	Human power
Seed cleaner cum grader	30-40	350-370	500-550	300-350
Maize sheller	35-39	130-150	128 -132	15-21
Chaff cutter	40-46	160-175	44-52	14-20
Flour mill	50-60	750-810	8-10	-

Fig. 8 Draught requirements of different agro processing machines

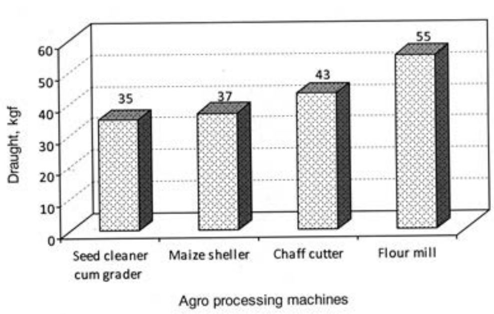
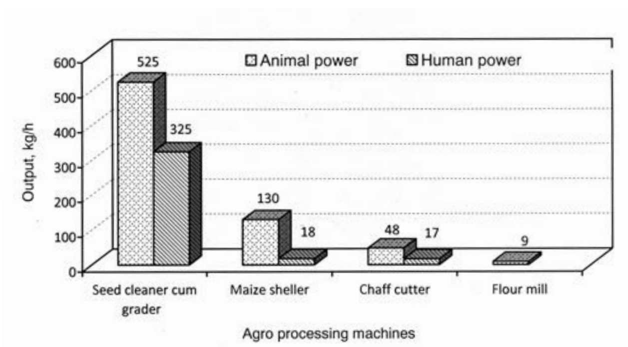


Fig. 9 Output of different agro processing machines



it reduced the drudgery and labour cost. The shelling efficiency of the maize sheller was 93 percent. The chaff cutter operated by the animal powered gear gave about 3-4 times more output as compared to hand operated chaff cutter. Further, there was an erratic supply of electrical power in rural areas, which supports the suitability of animal-based rotary mode complex.

Conclusions

The developed power transmission system was suitable to operate at a load of 125 kgf. The draught animals could work comfortably with the developed agro processing machines. The idle period of draught animals could be efficiently utilised and annual use could be increased by operating various agro processing machines using the developed power transmission system. Considerable amount of conventional energy can be saved with the use of the developed system. It will also help in generating self-employment to rural people and improving their socio economic status.

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Present Status and Future Strategies for Popularizing Greenhouses in Kashmir and Ladakh Region of J & K State (INDIA)

by

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Abstract

The temperate and cold region of the Jammu and Kashmir state are devoid of any vegetation greenery in winter because of low temperature (−5 ºC to −10 ºC) in Kashmir Valley and extremely low temperature (−30 ºC) in cold arid region of Ladakh. Hence, the use of a greenhouse has potential for production of quality horticultural crops during the severe cold climate. An extensive survey was conducted to know the present status and future prospects of greenhouses in Kashmir and Ladakh region. The survey revealed that both the regions have 10,558 different types of greenhouses covering 58.37 hectare out of which 3,327 were in the Kashmir valley and 7,231 in the Ladakh area covering 19.44 hectare and 38.92 hectare, respectively. It was observed that in the Kashmir valley the maximum temperature inside the greenhouse was 10 to 20 ºC higher than in the open field and 1.94 to 6.54 ºC difference in minimum temperature. However, the Ladakh region had a conventional design for polyhouse locally known as 'Ladakhi Polyhouse', which increased the temperature up to 20 ºC higher than the ambient outside temperature. Outcome of the study suggested that, during winter, a walk-in tunnel polyhouse could be best utilized for production of leafy vegetables in the Kashmir Valley and trench and Ladakhi polyhouse could be efficiently used in the Ladakh region.

Introduction

The state of Jammu & Kashmir occupies a central position in the continent of the Asia and is located in the Northern region of the Great Himalayan range in India, spreading over 33-37º N latitude and 72-80° E longitude (Dixit *et al.*, 2006). The state lays claim to a variety of climatic conditions within a comparatively narrow longitudinal expanse and geographical spread. The major climatic zones of the state have been classified as subtropical, valley temperate and cold arid zone. The temperate climatic zone, essentially,

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covers the valley of Kashmir. Its general resemblance to typical temperate climatic conditions is limited to pronounced and often severe winters with frosts, snow and rain, followed by fairly warm summers. The temperate valley comprises of six districts namely Kupwara, Baramulla, Srinagar, Pulwama, Badgam and Anantnag covering a total area of 15,948 sq. km and a population of 5.5 million. A single agriculture crop is predominant in the region. The cold arid zone which comprises of Kargil and Leh districts of Ladakh region are spread over a geographical area of 96,701 sq. km accounting for 43 % of the area of the state and 75 % of the cold arid region of India.

The temperate and cold regions of the Jammu & Kashmir state are devoid of any vegetational greenery in winter because of low temperature (−5 ºC to −10 ºC) in valley and extremely low temperature (−30 ºC) in cold arid parts of the Ladakh region. Most of the agricultural activities are confined to summer seasons only. Due to heavy snowfall in winter and closure of the national highway (linking Kashmir valley to rest of the country), people are forced to adopt pulses as a major part of their daily diet. In the cold arid zone of the Ladakh region, the crop season is even shorter and entire region remains cut off from the rest of the country for 7 to 8 months. In this region during winter season vegetables are transported by air to facilitate people. However, cost of such vegetables is beyond the reach of common man and sometimes shoots to 6-7 times the rate existing in summer months.

The present study was undertaken to collect the data regarding greenhouses such as the number, their covering area, temperature inside and outside the greenhouse and to record the existing trend and practices followed in Kashmir and Ladakh Region of J & K State for the production of vegetables.

Materials and Methods

To observe existing practices and status of greenhouses for cultivation of vegetables during off season, a district-wise extensive survey was conducted in Kashmir valley and Ladakh region during 2005-2006 under All India Coordinated Research Project on 'Application of plastics in Agriculture'. On the basis of the survey the present status of greenhouses installed by different development departments, NGO's, private firms, individuals in Kashmir Valley and the Ladakh region was recorded.

A walk-in tunnel (WT) polyhouse was constructed under AICRP on APA, in the division of Agricultural Engineering, SKUAST (K), SRINAGAR, J & K. The WT was 4 m wide, 17.5 m long and 2.2 m high (in the centre), providing a total planting area of about 70 sq m. The WT was covered with a single layer of 200 micron UV stabilized polyethylene sheet. To maintain inside temperature of the WT an exhaust fan and shade net were used. The shade net was used to cover the roof as temperature inside the tunnel exceeded 36 ºC. Daily maximum and minimum temperatures were recorded using two electronic sensors installed above one meter from the ground level outside and inside the WT during November 05 to February 06. Data regarding monthly maximum and minimum temperature in different types of greenhouses like glass house, ladakhi polyhouse, trench, WT polyhouse and poly-tunnel were collected from secondary sources.

Table 1 District wise database of number of greenhouse in Kashmir and Ladakh region

In Kashmir valley												
Year →	2000-01		2001-02		2002-03		2003-04		2004-05		Total	
District	No.	Area (ha.)	No.	Area (ha.)	No.	Area (ha.)	No.	Area (ha.)	No.	Area (ha.)	No.	Area (ha.)
Kupawara	770	3.08	94	0.76	0	0	0	0	287	1.6	1,151	5.44
Baramula	169	0.74	57	0.46	88	0.7	0	0	285	1.64	599	3.54
Srinagar	28	0.23	53	0.43	97	0.77	0	0	290	2.32	468	3.75
Badgam	0	0	30	0.24	14	0.11	0	0	290	1.56	334	1.91
Pulwama	0	0	22	0.18	0	0	0	0	290	1.72	312	1.90
Anantnag	20	0.16	78	0.62	0	0	0	0	365	2.12	463	2.90
Sub total (A)	987	4.21	334	2.69	199	1.58	0	0	1,807	10.96	3,327	19.44
In Ladakh Region												
Leh	892	4.81	588	3.18	701	3.74	450	2.43	210	1.04	2,841	15.2
Kargil	1,548	8.35	2,000	10.8	251	1.35	336	1.81	255	1.42	4,390	23.73
Sub total (B)	2,440	13.16	2,588	13.98	952	5.09	786	4.24	765	2.46	7,231	38.93
Total (A + B)	3,427	17.37	2,922	16.67	1,151	6.67	786	4.24	2,272	13.42	10,558	58.37

* Data from polyhouse coming under defense area were not included in the study

Results and Discussion

Status of Greenhouses in the Region

In comparison to other countries, India has very little area under greenhouses. The total greenhouse area in India at the end of the 8th plan period was estimated to be 500 ha, which may now be about 800 hectares (Sirohi *et al*., 2004). The major share has been in the Ladakh region of Jammu and Kashmir where commercial cultivation of vegetables is being promoted. A district wise database of number of greenhouse and covering area in Kashmir and Ladakh region installed by different development departments, NGO's, private firms and individuals in Kashmir Valley and the Ladakh region from 2001 to 2005 has been presented in **Table 1**. Survey data revealed that both the regions of J & K state have 10,558 different types of greenhouses covering 58.37 ha area out of which 3,327 are in Kashmir valley and 7,231 in the Ladakh region covering an area of 19.44 hectare and 38.93 hectare, respectively (**Fig. 1**). Both the Kashmir valley and Ladakh regions are under the frequent electricity cut and shortage of power supply and the regions have very few controlled greenhouse. The most common greenhouse is constructed by making the use of locally available material such as wood, M.S. iron, G. I. pipes, Aluminum, mud, bricks, sawdust and rammed earth. Due to subsidies provided by development departments, the growth of greenhouses has increased considerably for the last few years.

Mostly vegetables are suitable to be grown in all types of solar based greenhouses during winter months (Oct-April). Polyhouses and trenches in Ladakh were found to help in raising early nurseries of vegetables, production of early vegetable crops, extension of growing season and vegetable production during frozen winter (Singh, 2000). But yield of the vegetables is dependent upon the altitude, type of greenhouse and selection of the crop to be grown in greenhouse. Some suitable vegetables and their growing period in the Ladakh region are given in the **Table 2** (Singh and Ahmed, 2005).

Types of Greenhouses in the Region

On the basis of the survey carried out in Kashmir valley and Ladakh region, it was observed that the greenhouses are constructed as glass houses, gable type, gothic type, walk-in tunnel, trench, Ladakhi polyhouse, FRP greenhouse, double layer polycarbonate, triple layer polycarbonate and polyench greenhouses, which are being effectively used in the region. The brief discussion of each type is enumerated below:

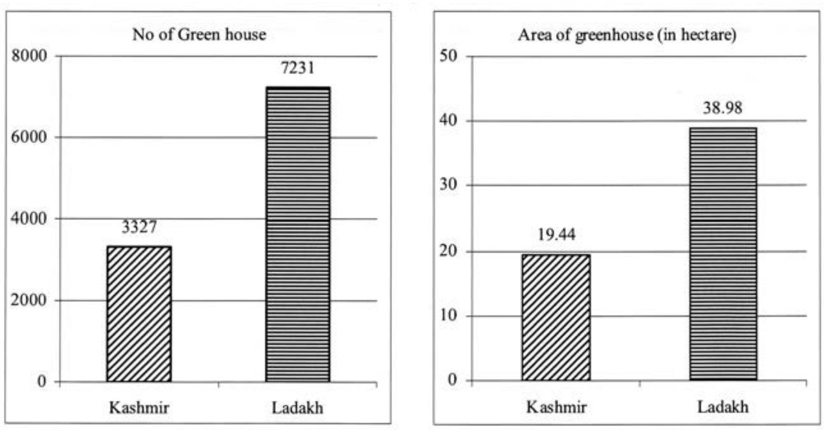
Glasshouse: Glass is used as a glazing material in the greenhouse. Glass houses are fitted with the help of wooden or metal frame. The glass houses are constructed in all shapes and sizes and are quite effective for winter cultivation but, due to increase in day temperature in summer, it becomes unfit for cultivation during summer. High initial cost, difficulty in construction and frequent damage of glass panels by strong winds has limited its use in both the regions. A number of glass houses have been erected in the Kashmir region but very few were observed in the Ladakh region. The variation in temperature between outside and inside conditions is 20 to 25 ºC.

Gable Type: A number of wooden structures, constructed gable type, uneven span type and even span type structures are used in Kashmir valley and are covered with 200 micron ultra violent stabilized polythene. Generally wooden structure fabricated gable type greenhouses are predominant in the valley with an average size of 40 sq. m (4 × 10 m).

Gothic Type: The large size polyhouse is generally made of gothic type in Kashmir valley because the use of heavy iron structure which can sustain heavy snow load. The slope of the top layer is 30 degree and its side walls and central height is 1 m and 3.7 m, respectively. Generally gothic type greenhouses are an average size of 120 sq. m. (6 m × 20 m).

Walk in Tunnel: It is the most popular type greenhouse, which is small semi spherical frame structure made of materials like wood or plastic, iron and G.I. pipes and is covered with polyethylene or fiber reinforced plastics. Maximum number of walk in tunnel type greenhouses has been installed in Kashmir valley and the Ladakh region. The Department of Horticulture is providing these types of greenhouses to the

Fig. 1 Number of greenhouse and covering area in Kashmir and Ladakh region



farmers on subsidized rates. The various sizes of tunnel type greenhouses that were being utilized by the farmers and installed by different development departments are 40 sq. m (4 m × 10 m), 80 sq. m (5 m × 16 m) and 54 sq. m (9 m × 6 m).

Ladakhi Polyhouse: The most common greenhouse in the Ladakh region is the Ladakhi polyhouse and is constructed by three side mud brick wall in place of polyethylene sheets, which not only cuts down the installation cost but also reduces the adverse effects of strong winds and increases temperature retention in the greenhouse. The polyhouse has three sides made of sun dried mud bricks. The back wall is 7 ft in height, while the front has no wall. The average length of the poly house is 32 ft. with a width of 16 ft. The polythene is supported on wooden poles and side walls.

Trench: This is a very simple, cheap and common greenhouse structure especially for the Ladakh region of the state and, thus, has unlimited potential in the region. The sizes of the trenches are (9 m × 3 m × 0.9 m) and (10 m × 4 × 1 m). In this pit type of structure, wooden poles are used to hold UV stabilized polyethylene film. The polyethylene is also covered by an additional polyethylene film or woolen or cotton sheet during the night to reduce heat loss in extreme winter.

FRP Greenhouse: The glazing material used in this greenhouse is fiber reinforced polyester. The normal dimensions of the greenhouse are (30 m × 9 m) with a centre height of 3.04 m and a side height of 1.82 m. The initial cost required for fabrication of the greenhouse is high but the comparative life of the greenhouse is much more than the others.

Double Layered Polycarbonate Greenhouse: The glazing material used in the green house is double layer polycarbonate. The normal dimensions of the greenhouse are 16.8 × 9.1 m with a center height of 3.3 m and a side height of 1.8 m. The variation in temperature between outside and inside conditions is 20 ºC.

Polyench Greenhouse: This type of greenhouse combines the trench and greenhouse technology for achieving more temperature inside greenhouse during peak winter. The glazing material utilized in the greenhouse is polyethylene, FRP, double layer and triple layer polycarbonate. The normal recommended dimensions of the greenhouse are (18 m × 4.5 m × 0.8 m).

Solar Greenhouse for the Trans-Himalayas

A solar greenhouse is a greenhouse heated entirely by sunlight, with no additional fuel-based heating. In the trans-Himalayas, the temperature inside these greenhouses can be kept high enough to grow vegetables throughout the year, even in winter, if the greenhouse is built efficiently.

One of the major factors affecting the amount of solar radiation entering a greenhouse is the position of the sun in the sky, length of the day, the amount of clouds, the elevation of the site, the angle of the site with respect to the sun, and the presence of objects that can cast shadow (Stauffer V., 2004). In the summer, when the intensity of the sun is high, most of the solar radiation enters the greenhouse, through the roof of the horizontal part, but in winter, when the intensity of sun is low, the

Table 2 Suitable vegetables to grow in greenhouse during winter in Ladakh

Vegetable	Growing Months						
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April
Amaranth	√	√	X	X	√	√	√
Cabbage	√	√	√	√	√	√	√
Cauliflower	√	√	X	X	X	X	X
Chenopodium	√	√	X	X	X	√	√
Chicory	√	√	√	√	√	√	√
Coriander	√	√	√	√	√	√	√
Fenugreek	√	√	√	√	√	√	√
Kale	√	√	√	√	√	√	√
Karam Sag	√	√	√	√	√	√	√
Knol Khol	√	√	√	√	√	√	√
Musturd	√	√	X	X	X	√	√
Onion	√	√	√	√	√	√	√
Orich	√	√	X	X	X	√	√
Pakchoy	√	√	X	X	√	√	√
Radish	√	√	X	X	X	√	√
Spinach	√	√	X	X	X	√	√
Swiss chard	√	√	√	√	√	√	√

√ can grow, X can not grow

maximum radiation enters from the south side, the sun warms the east face during the morning, the south face at midday and the west face in the afternoon and evening. Thus, an efficient greenhouse should be designed along an east-west axis.

In the Ladakh region, solar radiation is taken up through a transparent polythene sheet covering only the south face of the greenhouse. In the south face the angle of the lower section of the polythene is 50-degrees or more (measured from the horizontal)—the best angle to transmit solar radiation in the early morning or late afternoon when intensity is low. The angle of the upper section is 25 degrees or more (measured from the horizontal); the optimum angle to transmit the mid-day solar radiation. Moveable insulation (parachute, cloth) is used as a curtain below the polythene after sunset to reduce heat loss; it is removed after sunrise. Movable insulation can increase the ground and interior temperature at night by a maximum of to 5 ºC. During the night, a double polythene layer can be used to reduce heat loss; it can also increase the interior temperature by a maximum 4 ºC at night (**Fig. 2**).

For storage of radiation three side walls are composed of three layers: an outer load-bearing wall built with sun dried bricks, rammed earth, or stone; an inner wall used to store heat during the day and release it at night (also built with sun dried bricks, rammed earth, or stone); and an insulating layer of material like straw, sawdust, wood shavings, dry leaves, dry grass, or wild bush cuttings, is pressed between the two layers.

Relationship between Temperature Inside and Outside the Polyhouse

Average weekly maximum and minimum temperature both inside and outside polyhouse were analyzed during November 05 to February 06. The average minimum temperature inside the walk-in tunnel was 1.94 to 6.54 ºC higher than the outside temperature. However, 10 to 20 ºC difference in maximum temperature was observed dur-

Fig. 2 Solar Greenhouse for Ladakh region

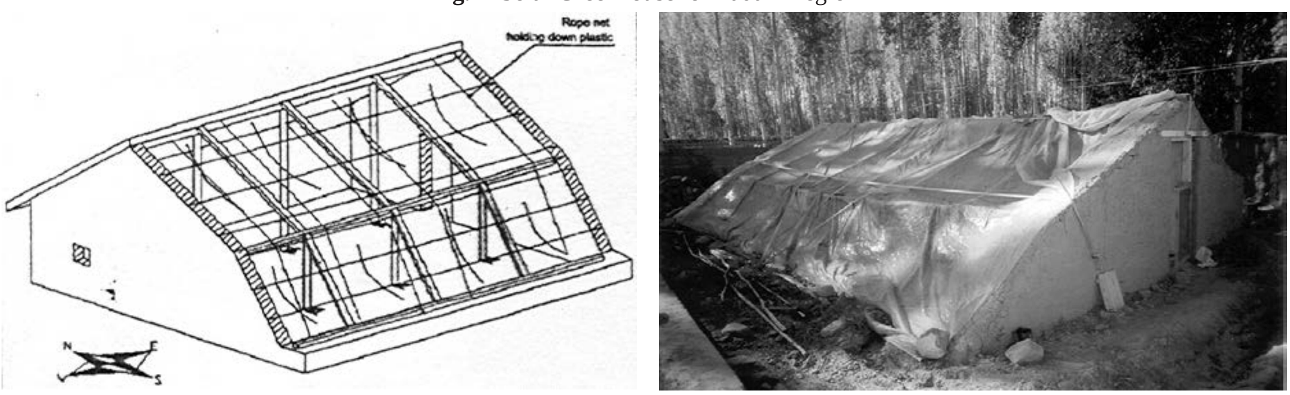
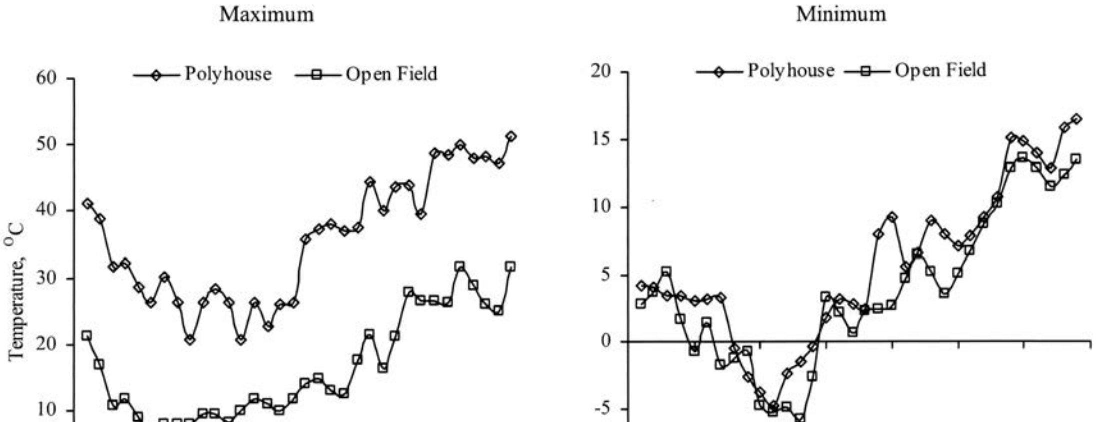


Fig. 3 Average maximum and minimum weekly temperature inside the Polyhouse and outside (field) during winter at Kashmir region



ing this period. These results are in accordance with the findings of several authors (Santos *et al*., 2002; Edlabadkar *et al*., 2004; Sethi and Sharma 2007).

The relationship between maximum inside (Tmaxin) and outside temperature (T^{max}_{o}) and minimum inside (T^{min}_{in}) and outside temperature (T^{min}_{o}) of the polyhouse were studied and it was found that a strong positive correlation existed between the outside and inside temperatures as shown by the equations given below.

$T^{max}_{in} = 1.0995\ T^{max}_{o} + 17.614$
($R^2 = 0.8493$)
$T^{min}_{in} = 0.9695\ T^{min}_{o} + 1.9127$
($R^2 = 0.8875$)

Comparison between Temperatures Inside and Outside a Greenhouse in the Ladakh Region

In the Ladakh region the maximum average monthly temperature in the winter season (from Oct. to April) ranged from 13.0-35.5, 9.0-33.0, 13.0-33.5, 16.0-36.5, 15.5-32.5 in the glasshouse, polyhouse, Ladakhi polyhouse, trench and tunnel, respectively. In the open field the maximum average temperature varied from 1.0 to 15.0 ºC (**Fig. 4A**). The minimum average monthly temperature ranged from −10.5 to 5.5, −11.0 to 6.0, −7.0 to 6.0, −5.7 to 7.0 and −7.9 to 6.0 ºC in the glasshouse, polyhouse, Ladakhi polyhouse, trench and tunnel, respectively, as compared to open field temperature that varied from −13.6 to 5.5 ºC (**Fig. 4B**). The average maximum monthly temperature was found higher in trench and lower in polyhouse, whereas, average minimum monthly temperature was higher in trench and lower in glasshouse during the winter season (**Fig. 5**).

Strategies for Popularizing Polyhouse in Kashmir and Ladakh Region

Viewed as an integral part of farming technique in cold regions with a focus on fruit production, quality planting material, nursery raising, increasing vegetable production must be the guiding principle of the promotion of greenhouse technology. The approach is to produce quality vegetables, fruits during severe winter in temperate and cold arid regions of the state. The concept should be streamlined in the national policy on development and management of the state. The

Fig.5 Average maximum and minimum temperature inside the greenhouse and open field during winter season in the Ladakh region.

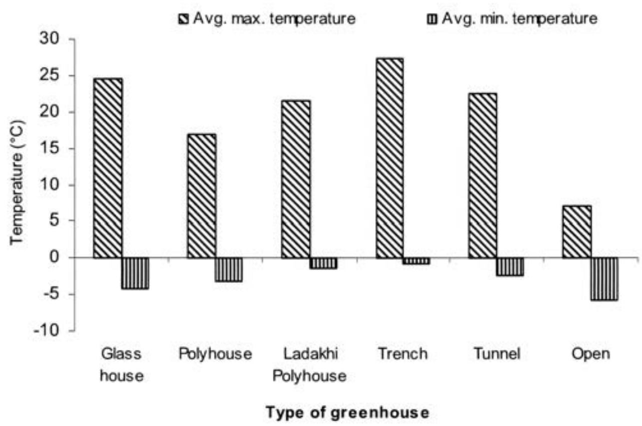
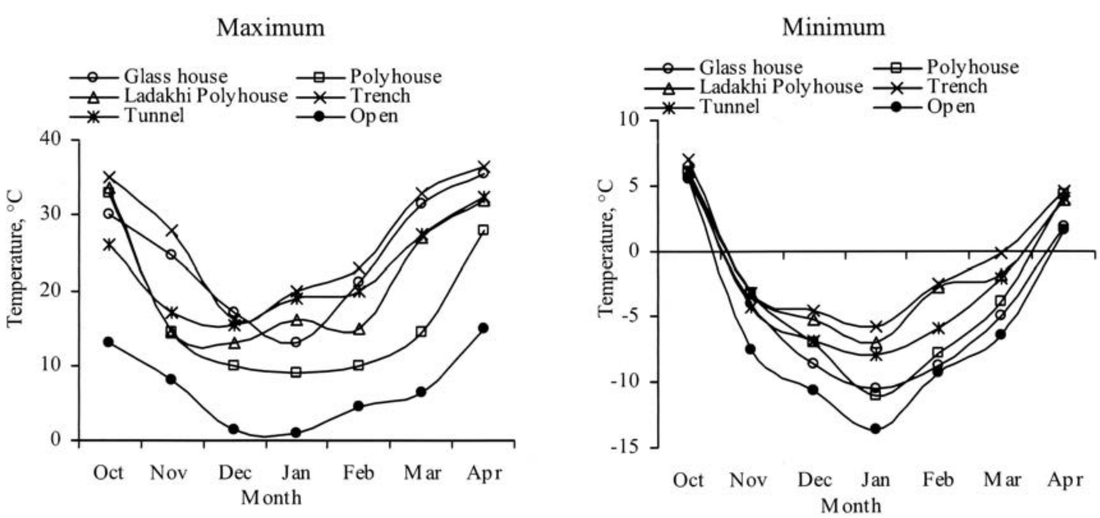


Fig. 4 Average maximum and minimum monthly Temperature (oC) in different types of greenhouse in the Ladakh region



investment and funding should consider greenhouse technology as an important infrastructural development and must increasingly occupy center stage towards food security, poverty alleviation and sustainability especially for the winter seasons. Some strategic considerations for adoption of greenhouse technology are:

- Appropriate mechanism and institutions for managing the financial support should be in place.
- For the large scale adoption of this technology, especially by small farmers, financial assistance could be required, initially, and, at least for two plan periods.
- The private sector should be a partner in the development and diffusion of greenhouse technology and should work in a tandem with the public sector and the NGO's.
- Cultivation of vegetables (in greenhouse technology) in cold arid regions of the Ladakh region during winter months at subzero temperatures should be popularized when it is not possible to grow in open fields.
- Greenhouse technology to be encouraged for export production in view of quality vegetable production and in turn enhancing income.
- Financial support should be given for raising vegetable nursery, advancing vegetable availability, raising quality planting material, etc.
- The technology must be popularized among the farmers of the state, especially the temperate and cold arid regions with small land holdings.
- Some package should be earmarked for growing vegetables under a greenhouse.
- Loan credit at the lowest possible interest rate should be given to farmers for growing vegetables and drying of apricots under polyhouse.

Conclusion

The present study showed that the greenhouse has a great potential for growing vegetables in cold regions in India provided it would be well supported by different government institutions for effective adoption and popularization. For promoting small farmers to adopt greenhouses for the production of vegetables, financial assistance must be provided by various agencies or banks and, also, private organizations must take part in the process. Application of greenhouse technology could be a lucrative resource for generating an extra income with more profitability by producing export quality vegetables during off season. During winter season, the walk-in tunnel polyhouse proved to be best for cultivation of leafy vegetables in Kashmir Valley and trench and Ladakhi polyhouse could be efficiently utilized in the Ladakh region. Temperature above ambient inside the polyhouse could be advantageous for growing early vegetable seedlings, off season vegetable production and propagation of fruit plant (especially, walnut for maximum graft success) It is also supposed to be favourable for cultivation of leafy vegetables during severe cold in the Ladakh region.

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Effect of Kinematic Parameter on some Performance Indces for the Self-Propelled Compost Turning Machine

by

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Abstract

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 can be 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 in the view in compost fields nowadays. Among these is the self-propelled compost turning machine.

The major concern 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 operation of standing and lodging rice gave a reel kinematic parameter of 1.2 and 1.5, respectively, and 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 rotary plow kinematic parameter of 2-2 minimized energy requirements and improved tillage efficiency. Morad (1995) stated that proper adjustment of the kinematic parameter for the 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 decreasing field efficiency, cutting efficiency, fuel consumption and energy requirements. A rotary mower kinematic parameter of 25 minimized the mowing cost.

Mohamed, *et al*. (1999) showed that higher values of the harvesting-machine kinematic parameter are more effective in lifting lentil plants and laying them back on to the cutter bar to avoid the shaking action of the mower cutter bar. Increasing the kinematic parameter values from 1.33 to 2 increased grain losses from 5.9 to 8 %. It was recommended that a reel kinematic parameter of 1.33 be used with the self-propelled harvesting machine to harvest the lentil crop using at. Abd El-Mottaleb (2006) showed that increasing forward speed of a self propelled turning machine from 200 to 600 m/h measured at rotor speeds of 80, 160 and 240 rpm increased fuel consumption 14.9 to 19.1 and 26 %; increased the power requirement by 14.9, 23.2 and 26.9 %; and increased the energy requirements by 12.40, 21.50 and 28.10 %, respectively.

Alfano *et al*. (2007) stated that a simplified low-cost turning machine was planned and realized. The total cost of the turning machine prototype was 3,600 Euro. The total cost of the turning operations was 285 Euro and the cost of the complete composting process in the first year was 4,200 Euro, making the cost of the cured compost 0.63 Euro kg^{-1}.

Fouda *et al*. (2008) showed that increasing compost turning machine forward speed from 1,200 to 1,500 m/h increased fuel consumption from 7.5 to 10.0 lit/h. 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 of four times per month and pile height of 100 cm. This worked well with 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 a company for compost, Sharkia Governorate, to optimize the kinematic parameter of the self-propelled compost turning machine.

The Raw Material

Crop residues (especially rice straw) were used as a raw material for producing compost. Poultry and livestock manure were also used to accelerate the composting process and 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 shown in **Table 1**.

Kinematics of Compost Turning Machine

The blades of the turning drum perform complex motions. They perform translatory motion with velocity (v) and rotary motion of angular velocity,, 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, Ao, is initially on the X axis. After an interval of time, t, the axis of the shaft is displaced to the position, O1, having covered the distance, Vt. During this interval, the blade turns through an angle, t. The point, Ao, 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.

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

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

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

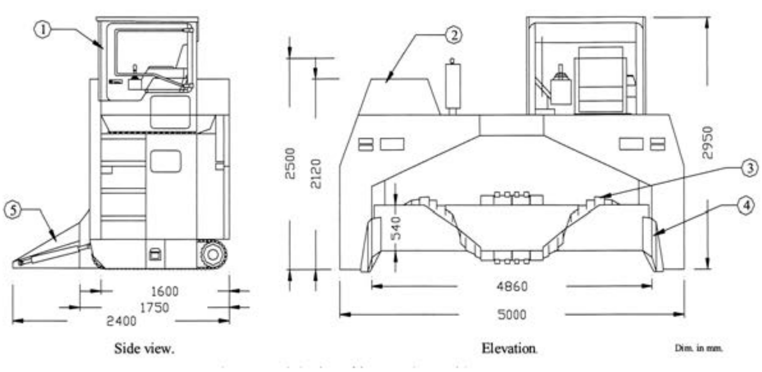
$\ddot{X}_A = v - \omega R \sin \omega t_1 = 0$

Or

$\sin \omega t_1 = (v / \omega R) = (1/ \lambda)$

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

Fig. 1 The self-propelled compost turning machine



1 Cabaine 2 D. engine 3 Turning knives 4 Turning drum 5 Heap opener

Fig. 2 Kinematics of compost turning machine

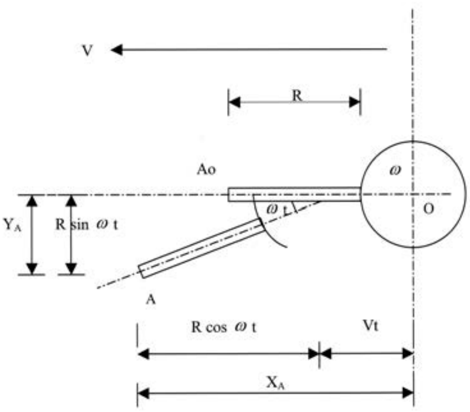


Table 1 The self-propelled compost turning machine specifications

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

peripheral speed should be equal to or higher than the machine forward speed.

$\lambda \geq \omega R / v$

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 is the time per revolution X forward speed.

Turning pitch = time per revolution and

$S_H = (2\pi / \omega) \times v$

$S_H = 2\pi R / \lambda$

Assuming that the number of blades per course, n,

$S_Z = 2\pi R / n\lambda$

where S_z is the turning pitch per blade.

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

$\lambda \geq 2\pi R / S_Z n$

The previous equation shows that the kinematic parameter as well as the turning pitch has a great effect on the compost turning machine performance. Thus, 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.

In the present investigation, a 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 these kinematic parameters was done taking into consideration machine capacity, fuel, power, energy and turning cost.

Measurements

Compost Density ρ:

Compost density was determined according to the following formula:

$\rho = m / v$

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

Machine Capacity (MC):

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

$MC = A \times V$

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

Fuel Consumption (FC):

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

Turning Power (TP):

The turning power was calculated by using the following formula (Barger *et al*., 1963).

$TP = Fc \times Cv \times \eta_{th} \times 427 \times (1 / 75) \times (1 / 1.36)\ kW$

where Fc = Fuel consumption, kg/s;

Cv = Calorific value of fuel, kcal/kg (Cv = 10,000 kcal/kg)

427 = Thermo mechanical equivaleut, kgm/kcal;

η_{th} =Thermal efficiency of the engine, % (η_{th} = 30 % for diesel engine)

Energy Requirements (ER):

Energy requirement can be calculated using the following equation:

$ER\ (Wh / n) = [TP\ (W) / MC\ (m^3 / h) \times \rho\ (ton / m^3)] \times$ *turning number to maturity*

Turning Cost (TC):

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

$c = p / h\ [(1 / e) + (i / 2) + t + r] + (0.9hp \times f \times s) + (w / 144)$

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

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

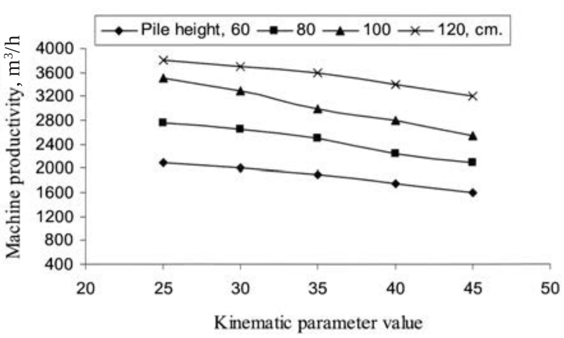
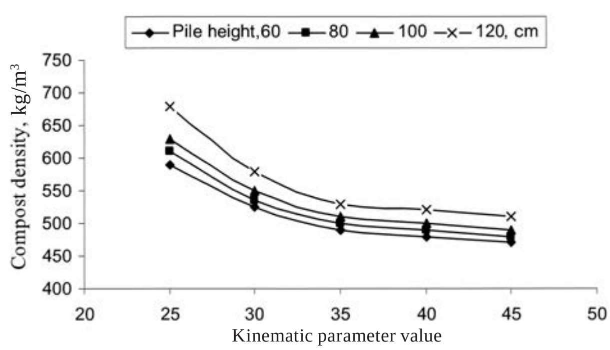


Fig. 4 Effect of kinematic parameter value on composting density at different pile heights



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:

Operation cost (L.E. / m^3) = *[*Machine cost (L.E. / h)*]* / *[*Machine capacity (m^3 / h)*]*

T.C (L.E. / ton) = Operational 1 cost / Composting density (ton/m^3) × turning number to moturity

Results and Discussion

Effect of Kinematic Parameter on Machine Productivity

The most critical factor in productivity of the turning machine was its kinematic parameter. **Fig. 3** shows the effect of the kinematic parameter on machine productivity. Results showed that increasing the 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 kinematic parameter was attributed to the increase in quantity of turning materials per unit time because the decease in kinematic parameter was accompanied by an increase in forward speed.

Effect of Kinematic Parameter on Compost Density

Compost density was inversely affected by the kinematic parameter. **Fig. 4** showed 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 by increasing kinematic parameter was attributed to more cutting and mixing by the rotor blades per unit volume of the disturbed compost due to 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 were greatly affected by the turning machine and its kinematic parameter (**Fig. 5**). Increasing the kinematic parameter from 25 to 45 with a pile height of 100 cm decreased fuel consumption from 36.6 to 26.6 lit/h. Increasing the kinematic parameter decreased energy requirements up to 35. Further kinematic parameter increase, up to 45, significantly increased energy requirements. When the kinematic parameter was 35, energy requirements values were 875 Wh/ton under the same previous condition.

The increase in energy requirements by increasing the kinematic parameter from 35 to 45 was attributed to the increase in rotor blades knocking the number per unit time on compost material. While 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 was the cost required for the turning operation. **Fig. 6** shows the effect of the turning machine as well as its kinematic parameter on both hourly and turning costs. Increasing the kinematic parameter from 25 to 35 at a pile height of 100 cm decreased turning cost from 15.3 to 12.7 L.E/ton. Any further increase in kinematic parameter from 35 up to 45 increased turning cost from 12.7 to 14.9 L.E/ton under the same previous condition.

Conclusions

The proper adjustment of the turning machine kinematic parameter value during the compost turning operation was of great importance in order to decrease both energy and

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

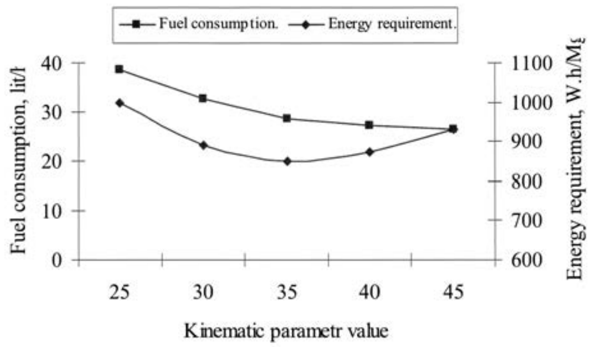
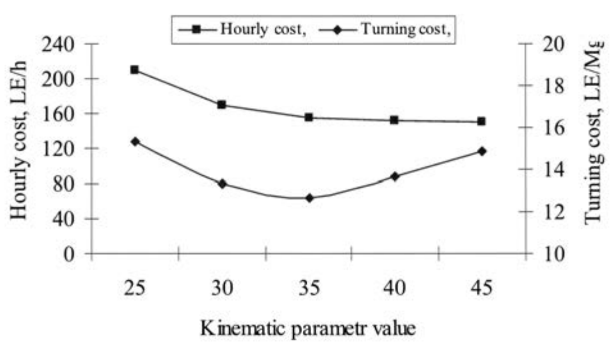


Fig. 6 Effect of kinematic parameter value on hourly and turning cost at different pile heights



cost.

A kinematic parameter value of between 30 to 35 and pile height of 100 cm was considered the optimum conditions for compost turning operation.

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NEWS

"Food Engineer of the Year Award 2010"

Dr. Said Elshahat Abdallah

Congratulations!!

The paper "Thermal Efficiency Enhancement of a Solar Drier for Hay Making from Sugar Beet Tops", written by Dr. Said Elshahat Abdallah, which was published on *AMA* vol.41 No.4, has won ***"Food Engineer of the Year Award 2010".*** The Institution of Mechanical Engineers of PM group in UK presents this prize every year. This prize has been specifically designed to help raise the profile of Food Engineering and promote excellence within the industry. A prestigious award of £1000 will be presented to the author of the best paper relating to the food industry.

Dr. Said Elshahat Abdallah is also known as a new co-editor of AMA in Egypt, as well as the author of the paper. We are all happy to hear the great news from him.

http://www.imeche.org/knowledge/industries/process-industries/news/FoodEngineerAward2

The Present State of Farm Machinery Industry

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Outlook of Agriculture

Trend of Agriculture

In 2007 agricultural total products was ¥4,443 billion, accounting for 0.9 % of GNP. The agricultural products imports was ¥5,004 billion in 2006, ¥5,530 billion in 2007, ¥5,982 billion in 2008. The agricultural products exports was ¥236 billion in 2006, ¥268 billion in 2007, 288 billion in 2008.

Japan depends on imports for large part of domestic consumption of feed cereals, soybean, wheat. Food self-sufficiency rate was 40 % by calorie base in 2007, 28 % for cereals, almost the same as preceding year.

Population mainly engaged in farming has been decreasing yet, 2.45 million in 2008, 3.8 % of total working population. The number of farm households decreased to 2.52 million in 2008. 69 % of them are commercial farms selling their products in market. Total arable land in Japan was 4.63 million ha in 2008.

Japanese have been getting to enjoy more a variety of food since 1970's. The production of rice, oranges, milk, eggs has exceeded domestic consumption. Under such circumstances, GATT New Round Agreement gave great impact to Japanese agriculture. In order to get world competitive power, saving of production cost became the urgent issue. Other big issues in Japanese agriculture are, to have enough people engaged in farm work to maintain stable agriculture, production of high quality and safe products to meet the needs of consumers, and preservation of natural environment in rural areas.

In July 1999, Japanese government enacted the New Agricultural Stable Law, which aims to assure constant food supply by raising domestic production, to encourage multi-functions of agriculture, to have sustainable development of agriculture and to promote the development of rural areas. In the "Basic Plan for Food, Agriculture and rural Areas" established in 2005, the government set the target for food self-sufficiency ratio to 45 % on calorie basis, 76 % on productive value basis by 2015. "Rice and Vegetable Farming Management Stabilization Program" started in 2007 to strengthen domestic agriculture and improve self-sufficiency ratio. In this program conventional measures to encourage production individual commodities such as wheat, barley, and soybean are replaced by new farm management stabilization programs targeted at principal farmers. In the lower house election held in 2009, the democratic party of Japan, which made “The Realization of Individual Income Support System for Agriculture ” as one of the “manifesto”, became the ruling party. For the full-scale actualization of the Individual Income Support, they are planning to work out the model measure targeting at rice farmers in 2010.

Trend of Farm Mechanization

Agricultural mechanization in Japan has remarkably progressed in the field of low land rice, chief crop, in a short period since 1955. Now rice production is almost mechanized from planting to harvesting. In 2005, average working hours on 10 a paddy field reduced to 30.0 hours from 117.8 hours in 1970. In recent years farm machines for rice crop is developed to be larger-sized, higher-efficiency and more commonly used. In addition, farm machinery for field crops and live stock farming is being developed and improved, which had been lagged behind so far.

Government has been working on Agricultural Mechanization Promotion with three pillars "Development and Practical Application of High Performance Farm Machinery", "Reduction of Production Material

Cost" and "Farm Safety", and seeking for more enhancements. As for high performance farm machinery, a guideline named "Basic Guidance for Research and Development, Practical Application and Introduction of High Performance Farm Machinery" was set up in May 2008. Based on this guideline, further powers saving of farm work, decrease of environmental burden, and efficient use of agricultural product material have been encouraged.

In addition, regarding the cut down of agricultural production material, in 1995 Ministry of Agriculture, Forestry and Fisheries made a committee which studied method to reduce cost of farm product materials like farm machines. Those farm product materials are major parts of farming cost. In 1996 concrete movement started in the field of production and distribution. Low cost machinery with limited functions has been increasing.

Following are the numbers of farm machines in farm household of Feb. 1, 2005: riding tractor reached 1,942,000 units; rice transplanter 1,244,000; head feed combine 991,000.

Shipments of major farm machinery in the domestic market in 2008 are as follows: riding tractor 48,911 units (under 20 PS were 11,480; 20-30 PS 21,582; 30-50 PS 9,351; over 50 PS 6,498); walking tractor 142,330; rice transplanter 37,868; combine head feed types 24,013; standard types were 825; grain dryer 26,160; huller 20,029.

Plans for Farm Mechanization

2009 government budget for farm mechanization was used for;

- Developing and promoting innovative machines using IT, robot technologies and other advanced technologies: Accelerating the development of high-end and power saving agricultural machineries at less cost using advanced technologies (4th Urgent Development Project of Agricultural Machinery). A team for a project would be assembled for each type of developing machines. Also, the cooperation between farmers and specific growing districts would be strengthened for the further research and development of cultivation technology.
- Reducing the amount of costs for agricultural machinery: Promoting efficient usage of machines. Introducing direct seeding technology and generalizing the dispersion of cropping seasons. Using various ways to introduce agricultural machineries such as rental method.
- Measures for safe farming: Informing about machineries equipped with safe and secure features.
- Measures for reduction of environmental burdens: Promoting environmentally-sound agriculture. Researching and developing power saving agricultural machineries, and promoting the usage of biodiesel fuels.

Government Budget for Agriculture, Forestry and Fisheries

2009 government budget for agriculture, forestry and fisheries was 2,561 billion yen in total. Major subject items are;

- Increasing production of crops and developing the self-sufficient rate of food by effective utilization of paddy fields
- Preparing delivery system to increase the usage of rice powder and rice for animal feed
- Measures for improving the self-sufficient rate of the feedstuff, betterment of the production of

Table 1 Major farm machinery on farm Unit: thousand

Year	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer	Binder	Combine	Rice dryer
1975	3,426	501	740	2,607	1,327	344	1,497
1980	2,752	1,471	1,746	2,139	1,619	884	1,524
1985	2,579	1,854	1,993	2,151	1,518	1,109	1,473
1990	2,185	2,142	1,983	1,871	1,298	1,215	1,282
1995	1,344	2,123	1,650	1,714	836	1,120	1,052
2000	1,048	2,028	1,433	1,269	583	1,042	861
2005	-	1,943	1,244	1,206	-	991	-
2010							

Source: "Statistical Yearbook of Ministry of Agriculture, Forestry and Fisheris" by the Ministry of Agriculture, Forestry and Fisheries.

Table 2 Shipment of major farm machinery Unit: number

Year	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer	Binder	Combine	Rice dryer
2001	145,557	65,933	47,285	154,516	8,019	35,685	29,585
2002	142,774	64,781	48,054	150,035	6,991	34,397	28,893
2003	157,470	66,287	47,303	149,949	5,680	34,137	27,609
2004	142,316	60,964	45,065	154,049	5,421	31,136	30,435
2005	149,112	62,227	43,916	150,470	5,620	33,527	27,285
2006	158,858	56,095	42,161	127,219	4,765	30,046	24,436
2007	138,683	50,996	36,360	134,748	3,528	24,843	20,955
2008	142,330	48,911	37,868	140,375	3,432	24,013	25,628

Source: "Survey of Shipment of Agricultural Machinery" by the Ministry of Agriculture, Forestry and Fisheries.

Table 3 Yearly production of farm machinery (Unit: number, million yen)

Year	Total		Walking type tractor		Riding type tractor		Rice transplanter		Power sprayer		Running type sprayer	
	Quantity	for domestic	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
2000	493,906		243,995	31,647	163,536	204,339	56,784	44,887	162,527	7,763	6,000	9,896
2001	428,921		191,941	25,372	135,353	170,063	50,918	41,887	139,487	6,037	6,465	9,854
2002	434,337		174,683	22,172	149,202	184,843	47,911	40,696	191,940	7,953	4,907	7,691
2003	450,156		164,536	21,431	175,065	204,569	51,457	44,643	173,047	12,774	4,716	6,715
2004	478,039		194,018	24,444	190,599	236,160	47,522	42,606	184,221	14,881	3,984	6,421
2005	499,343	340,337	200,874	25,978	199,581	248,287	49,631	45,121	162,511	11,715	3,611	6,145
2006	494,990	312,099	166,856	21,418	204,064	259,760	50,562	46,881	164,722	9,083	3,247	5,456
2007	459,223	275,117	196,000	24,208	192,311	241,599	43,050	43,188	161,513	9,172	2,803	5,053
2008	496,404	282,098	188,336	23,520	212,224	264,082	48,098	51,619	170,790	9,676	2,836	5,408
2009	429,116	291,321	181,776	22,560	140,095	202,607	43,033	44,992	149,333	8,638	2,505	4,918
Year	Grain reaper		Brush cutter		Grain combine		Rice husker		Dryer		Grain polisher	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
2000	11,291	3,104	1,011,889	23,132	41,137	100,671	26,089	9,784	35,780	29,227	39,235	7,667
2001	8,172	2,274	963,965	20,200	36,158	91,210	23,973	9,209	31,567	26,007	36,427	6,972
2002	6,779	1,853	952,898	19,715	35,658	94,608	21,630	8,347	32,160	25,697	25,006	3,842
2003	5,664	1,521	836,409	19,333	36,899	90,811	26,174	9,827	27,419	21,730	27,975	1,825
2004	5,116	1,451	901,688	20,195	31,251	85,375	23,305	8,288	28,761	22,229	29,106	1,857
2005	5,940	1,686	900,943	17,984	34,741	97,241	22,373	8,304	27,111	22,143	25,846	1,518
2006	5,097	1,392	973,807	19,153	33,049	89,779	21,372	7,561	25,282	20,990	25,188	1,394
2007	3,217	910	1,233,084	25,060	25,969	74,049	17,585	6,660	21,205	17,341	23,475	1,389
2008	3,100	910	1,270,111	26,310	26,033	77,913	18,216	7,144	21,006	18,507	17,613	1,029
2009	3,159	960	1,337,549	23,972	25,073	79,151	18,613	7,618	22,273	22,012	18,882	1,109

Source: 1996-2002; "Survey of Status of Machinery, Production" by the Ministry of Economy, Trade and Industry, 2003-2007; JFMMA (Japan Farm Manufacture's Association statistics.

Table 4 Farm equipment distributor and sales value

Unit: million yen

Year	No. of retail-ers (1)	Em-ployes	Annual sales value (2)	Inven-tory	Square meters of shop m2	Annual sales value (2)/(1)
1988.6	9,444	45,952	1,015,304	159,798	923,726	107.5
1991.6	9,480	45,705	1,158,924	170,104	984,700	122.2
1994.6	8,838	43,112	1,128,087	166,298	978,788	127.6
1997.6	8,820	45,090	1,265,902	170,350	901,851	143.5
2002.6	8,123	40,441	979,066	145,725	982,529	120.5
2007.6	7,429	35,275	853,938	111,598	888,507	114.9

Source: Ministry of Economy, Trade and Industry.

Table 5 Handling of Farm Equipment by Agricultural Cooperative Association (1988 Business Year)

Unit: Million yen

Business year	Total number of coops. surveyed	Value of current supplies procured	Of which purchased through affiliated coop channel	Value of current supplies handled
2003	947	238,849	166,741	272,393
2004	913	238,303	164,936	271,703
2005	886	230,165	159,434	260,933
2006	844	210,181	144,140	239,119
2007	818	199,934	138,510	227,754
2008	770	205,654	141,100	230,573

Source: "Stastics on Agricultural Cooperatives-2008 business year" by the Ministry of Agriculture, Forestry & Fishieries.

coarse feeds, improving the usage and the production of eco-feed

- Subsidies as an emergency countermeasure for regenerating and reusing lands abandonment of cultivation
- Farmland accumulation and preparing equipments as an infrastructure for the generalization of paddy fields
- Leasing machineries and equipments to the approved farmers for the backup of advanced farmland management
- Activation of the rural areas, promoting the cooperation between manufacturers and farmers
- Strengthening the measures against global warming, and propulsive movement for the usage of biomass fuels
- Practical use and the improve-

Table 5 Export of farm equipment 2009

Unit: FOB million yen

Year	Unit	Value	Ratio	Major destinations
2002		148,581		
2003		160,734		
2004		200,533		
2005		225,131		
2006		258,772		
2007		268,694		
2008		287,263		
2009		187,221	100.0	USA, Korea, France
Seeder, planter	14,693	9,098	4.9	Korea, China,
Walking tractor	44,375	3,172	1.7	Belgium, China
Wheel tractor	143,945	115,607	61.8	USA, Thailand
Power sprayer	38,004	1,199	0.6	Mexico, USA, Korea
Lawn mower	46,201	5,477	2.9	France, UK, Germany
Brush cutter	937,952	18,937	10.1	USA, France, Italy,
Mower	47,519	1,191	0.6	France, Korea,
Combine	2,878	5,565	3.0	Korea, Egypt, China
Grain separator	477	2,979	1.6	India, Thailand,
Chain sow	383,110	7,040	3.8	USA, France, Italy
Others		16,956	9.1	

Table 6 Import of farm equipment 2009

Unit: CIF million yen

Year	Unit	Value	Ratio	Major destinations
2002		33,988		
2003		36,828		
2004		40,719		
2005		44,742		
2006		47,216		
2007		42,618		
2008		41,294		
2009		36,723	100.0	China, Germany, USA
Wheel tractor	1,270	5,898	16.1	France, UK, Italy
Pest control machine	4,401,038	1,873	5.1	China, Taiwan
Lawn mower	234,005	3,778	10.3	China, USA, France
Mower	4,341	2,217	6.0	China, Italy
Hay making machine	759	654	1.9	France, Germany, NL
Bayler	656	1,595	4.3	France, Germany
Combine	119	1,330	3.6	Germany, China
Chain sow	96,509	1,090	3.0	China, Taiwan
Others		18,288	49.8	

Source: Ministry of Finance. Totaled by Japan Farm Machinery Manufactures' Assn.

ment of forest resources, regeneration of the mountain villages and timber industry

Movement of Farm Machinery Industry

Total shipment value of Japanese farm machinery has been declining since the peak of the year 1985 (754.9 billion yen) and it was 474.5 billion yen in 2009. In addition, domestic sales of 2009 were 324.0 billion yen, which was almost half of the past record in 1976. Those are, considerable decline in the number of farm households and farmers exceeding the farm land decreasing, aging of farmers, decline in the demand for rice and production adjustment by the government. Aging farmers with no successors and small scale farmers have more tendencies to leave their farm works to contractors. The demand for agricultural machines is shifting to larger size, though total demand is going down. Domestic demand for farm machinery has been sluggish because of skyrocketing cost of fertilizers, fuels, and materials for recent years. In 2008 the sales of tractors, transplanters, combines, and almost all the models have increased after five years.

Regarding external demand, though it has stalled in the US because of banking crisis, it has made an active movement in Asia and covered the decrease in the US market. Regarding the national budget of Japan in 2009, there were about 1 trillion yen as a budget for the economic measures of agriculture, forestry and fisheries. As a consequence, domestic consumption of the machineries grew up, mainly because of approved farmers receiving subsidies from the country buying large machineries. Despite the downturn of the general economy and decreasing of the consumption of small machineries for side-job farmers, the total earnings increased from the previous year as a result of “Less sales, more amount”. In contrast, external demand ended up in a big decline both in American and European market, dogged by a global economic slump. Also, regarding the Asian market, which used to maintain a high level of sales, started showing the trend of local production. This made an unprecedented reduction of the external demand in Japanese agricultural machinery market.

Trend of Farm Machinery Production

Farm machinery production in 2009 amounted to ¥429.1 billion (13.6 % decrease over the preceding year) by JFMMA (Japan Farm Machinery Manufacture's Association) statistics. The production for domestic market was 291.3 billion yen, 103.3 % of the preceding year. The production for export was 137.8 billion yen, 64.3 % of the preceding year.

Production of the major farm machinery is as follows: Riding type tractor 140,095 units decreased by 33.7 % over the preceding year. By horse power (wheel type), those under 20 PS amounted to 16,344 units, 20-30 PS 46,191 units, 30-50 PS 45,035 units, over 50 PS 32,525 units. About 68 % of the total production is for export. The production of walking tractor amounted to 181,776 units, which showed an decrease of 3.5 % over the preceding year.

The production of combine, which is next to the riding tractor in production amount, is 25,073 units (a decrease of 3.7 % than the preceding year). The most popular type is with harvesting width of one meter head feed.

Following are the production of other types of farm machinery; rice transplanter amounted to 43,033 units (a decrease of 10.5 % than the preceding year), grain dryer 22,273 units (a increase of 6.0 %), huller 18,613 units (a increase of 2.2 %), bush clutter 1,337,549 units (an decrease of 14.3 %), power pest-controller 199,754 units (a decrease of 14.0 %), fodder cutter 23,328 units (a decrease of 1.4 %), rice pearling machine 18,882 units (an increase of 7.2 %), rice sorter 16,304 units (an increase of 30.6 %), farm carrier 12,886 units (a decrease of 4.4 %).

Trend of Farm Machinery Market

In Japan distribution systems for farm machinery is roughly divided into two major channels; the farm machinery dealers and Agricultural Cooperatives Association. As of June 2006, there were about 7,400 retail shops and about 35,000 employees, and the annual sales amounted to ¥854 billion.

According to the governmental survey by Ministry of Agriculture, Forestry and Fisheries, the total sales of farm machinery by Agricultural Cooperative Association was ¥230.6 billion in 2008 (¥227.8 billion in 2007). The number of Agricultural Cooperative was 770 in 2008. Average sales amount per cooperative decreased to ¥299 million.

About half of private dealers are small firms which less than 5 employees. In a long time view, with less demand for agricultural machines expected in future, improvement of management structure will be needed.

Export and Import of Farm Machinery

Export

In 2009 the export of farm machinery amounted to ¥187.2 billion (including used farm machinery), which showed an decrease of 34.8 % over the preceding year.

By the export destination, ¥67.5 billion for North America (a decrease of 36.3 %), ¥38.0 billion for Europe (a decrease of 35.3 %), ¥66.3 billion for Asia (a decrease of 33.4

%).

By the types of machines, tractor (consists main part of export); 143,945 units were exported in 2009, it amounted to ¥115.6 billion. Seeing by horse power, those under 30 PS amounted to 72,709 units, those from 30 to 50 PS 45,371 units, those over 50 PS 25,865 units.

Major farm machinery, next to tractor, is bush cutter. The total exports were 937,952 units, ¥18.9 billion. The exports of other farm machinery are as follows; walking tractor 44,375 units; power sprayer 38,004 units; lawn mower 46,201, units; chain saw 383,110 unit, etc.

Import

In 2009 the imports of farm machinery amounted to ¥36.7 billion, which means a decrease of 11.1 % over the preceding year.

Major imported farm machines: tractor 1,270 units (those more than 70 PS were 1,078 units of all the tractor); chain saw 96,509 units, lawn mower 234,005 units, fertilizer distributor 4,519 units. Tractors 331 units were imported from Germany, and 281 units from U.K., 199 units from Italy, 153 units from Korea, 125 units from France.

Trend of Research and Experiment

The surroundings of Japanese agriculture are very hard, because of increased imported agricultural products, consumer's various favor, the decrease of the new farmers, being called for the contribution to solve the environmental problems. That's why the structural and technical reforms in Japanese agriculture are required urgently.

The government issued "Basic Research Plan for Agriculture, Forestry and Fisheries" in March, 2005 to set the objectives of the development in the future ten years. In the field of next generation farm mechanization technology development, it is encouraged to develop “high performance production control system with IT technology“, "labor and energy saving, safe production system utilizing automation technology" and etc.

Research results of farm mechanization by National Agriculture and Food Research Organization in 2008 were;

- Energy-saving way of driving tractors and head-feeding combines
- Multiple-direct seeding technology of soybeans and multiple cropping of vegetables using lister with tillage unit loaded
- Air-circulation type humidification device for soybeans
- High-quality seeding technology of sunflowers compliant with paddy land conversion
- Automatic grafting implement with self-sowing unit loaded for cucurbitaceous vegetables
- High-speed operating disc-type intertillage machine kneading less moist soil
- A boom sprayer capable of controlling the application amount with operating history recording system
- Technology to decrease dirty grains when using general purpose combine to harvest soybeans
- Machinery capable of making TMR into densely-shaped roll bales of various diameters
- Variant teat antisepsis machine, a promising new equipment for decreasing the pathogenesis of garget
- Implement measuring airflow resistance to value the aeration property of compost feedstock easily
- Work-identifying program inside agricultural field using GPS to monitor farm works
- Web application that can record and manage production history
- “FARMS”, a system capable of managing various types of farming data with GIS system loaded
- Applying CAN-bus system to walking human-shaped robots for farm works

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Japanese Agriculture and Agricultural Machinery—Current Status and Problems

by
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Foreword

According to FAO, 850 million-out of 6,800 million people of the world (which means one out of 7 or 8) people, suffer from malnutrition. This number has not changed since 1990 to 1992 (FAO, 2008).

Global growth of food production, especially grains, such as rice and wheat, was mainly because of growth of yield per unit area realized by the "green revolution". This revolution started around late 1960s', growing semi dwarf varieties by heavy manuring culture and irrigation. However, in the late 1980s', after most of the suitable areas were developed by the technology of "green revolution", the global production of grains edged down. The grain production per farmer gradually declined since the peak of 370 kg in the middle 1980s' (Ministry of Agriculture, Forest, and Fisheries, 2010a).

It has been estimated that the world population would be 9,100 million in 2050 and, from this estimation, the demand of grain would be about 3,000 million tons, which is 1.6 times more than that in 1999 through 2001 (Horie, 2008). In spite of this estimation, global food supply in the future still looks bleak.

Agricultural Matters of our Country

Basic Projects of Food, Agriculture, and Farming Villages

The Japanese government declared in the "Basic Projects of Food, Agriculture, and Farming Village" (settled in March, 2010, henceforth, "Project") to increase the food self-sufficiency to 50 % from the current 41 %, and to increase the feed self-sufficiency to 38 % from 26 %. To accomplish the self-sufficiency of 50 %, they have a goal to expand the crop acreage to 49.5 million ha from 42.6 million in spite of the cultivated acreage being held down to 46.1 million ha, which is almost no change from the current 46.3 million. Regarding the policy aspect, there were approaches such as the "Door-to-Door Income Indemnity Method for Farmers", sextic industrialization of agriculture, improving food life of the citizens, and increasing the use of rice powder and feeding rice. Regarding the technical aspect, there were approaches such as developing varieties with high yielding ability and quality, all purpose usage of paddy for crop rotation, developing power saving and low cost mechanization systems. **Table 1** presents numerical goals from Ministry of Agriculture, Forest, and Fisheries (2010 b).

Table 1 Numeral goals for "basic projects of food, agriculture, and farming villages"

	Year 2008	Year 2020
Food Self-sufficiency Based on Calories (%)	41	50
Feed Self-sufficiency (%)	26	38
Farming Area (ten thousand ha)	463	461
Total Crop Acreage (ten thousand ha)	426	495
Rate of Farmland Utilization (%)	92	108
Amount of Rice Production (ten thousand tons)	882	975
Amount of Wheat Production (ten thousand tons)	110	215
Amount of Soybean Production (ten thousand tons)	26	60

Future Subject

To realize the project shown above, we must increase the rate of farmland utilization by making good use of abandoned farmlands, as well as promoting double cropping. It is only an estimation, but it is said that there will be 0.6 million less farmers in 2020, which means 32 % less than that of 2009 (**Fig. 1**). The total production of rice, wheat, and soybeans in Japan in 2008 was 10.18 million tons, but the numeral goals of the project mean that we must increase it by 12.5 million tons by 2020. This is, in the next 10 years, which is a very limited length of time, we need to improve about 20 % of the land productivity and 80 % of the labor productivity. It is too obvious that this is a very high bar for us to approach. To achieve the goal, we must make full use of specialists from each area to improve varieties, cultures, and lands.

Newly Developing Technologies

Aims

To improve the self-sufficiency, as well as the land and labor productivity, it is important to respond to the need of the citizens and adjust the price of domestic crops. This means to make an effort to get it closer to the global price. The global wholesale price rice, for example, in May 2008 was $1,000 per ton, that is, ¥6,000/60 kg (estimating ¥100/$). On the other hand, cost of domestic rice production was ¥8,853/60 kg in farms larger than 15 ha (Ministry of Agriculture, Forest, and Fisheries, 2010c). To compete with the peak global price, you need to reduce more than 30 % of the price. The working time per 10 ha, which is used for the estimation of production cost, is 13.93 h/10 ha. If you can cut this number down to 3.75 h/10 ha like that of wheat, ¥2,374 of the labor cost out of ¥8,853/60 kg would lower down to ¥639. This means reducing 20 % of the production cost. Additionally, by halving the machinery costs, you can decrease 30 % of the production cost in total.

After 2008, the global costs once turned back, but by looking at it in a long term, they are in an uptrend. Regarding the growth of land productivity and the home-court advantage, there are chances for global competitions. Rice was used for an example but we can say the same with other crops.

Problems to Solve

To aim the goal, machinery plays a big role especially in the meaning of labor productivity. There are many problems to solve as shown below.

1. Developing high efficient machines and equipment for land for crops such as rice, wheat, and soybeans. This should be done by automation, informatization, and using new materials. Also, achieving high precision and expanding running time, as well as applying the technologies to mountainous and other disadvantaged areas, which is an important matter.
2. Developing machines and the generalization of them in areas not yet adequately mechanized such as gardening, fruits, and livestock.
3. Developing power-saving and energy self-contained greenhouses, drying facilities, and other energy-intensive equipment, to prevent lack of food production in the upcoming energy supply crisis.
4. Improving the working environment so that it is safer and healthier with improved comfort for farmers including elderly adults, for example.
5. Supplying low cost machines and equipment, that could be accommodated by both manufacturers and farmers.

Technologies needed to solve these problems would be noted afterward.

Envisioned Technology 1: IT

IT is used in various types of business nowadays, including agriculture, and has a chance to provide a great breakthrough. Practical farmers have the technology to produce crops with both high yield and quality, which is inimitable to non-experts. This great technology has

Fig. 1 Transition of numbers of farmers

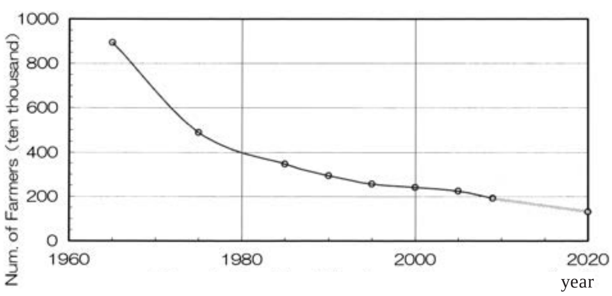
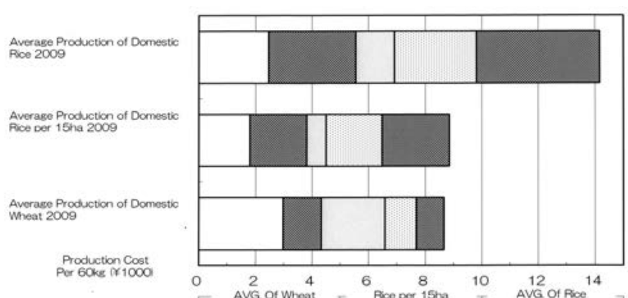


Fig. 2 Production cost of rice and wheat



	AVG. Of Wheat 1	Rice per 15ha 2	AVG. Of Rice 3
Labor Costs	0.97	2.37	4.37
Other Material Costs	1.11	1.97	2.89
Borrowing and Lending Costs	2.25	0.70	1.36
Machinery and Equipment Costs	1.36	2.01	3.10
Seeds, Fertilizers, Chemicals	2.98	1.79	2.46

been achieved from a great amount of experience and information. Forecasts can be made of such things as weather, nutrient elements in soil, disease by just looking at the little change of leaf color, or identifying the yield and quality of the farm field from the past. To spread this high-skilled technology, full use must be made of a leaf color sensor and nutrient sensor to forecast disease and nutrient conditions. Also, a database of yields, crop disease, and other information must be assembled. From this, the optimum application amount of fertilizers and agricultural chemicals can be determined for each or any part of farm land. This makes the work much more precise than before IT agriculture.

In fact, this type of approach has already being promoted for 20 years, which is called ”Precision Farming”. It is gradually being put to practical use to generalize and spread the technology to practical farmers. Precise agriculture saves the environment and cuts cost at the same time by not using too much fertilizer and agricultural chemicals. It also improves the yield as well as the quality of the crop itself (**Fig. 4**).

The key technologies regarding this are as below.

1. Precise sensor technology and machine operating technology to make it able to detect the conditions of soil and plants accurately and efficiently.
2. A database assembled from past farming information from which software or other information processing technology can be developed that determines efficient operation.
3. Developing machinery for sufficient operation such as a variable fertilizing machine regarding the result of 1 and 2.

Envisioned Technology 2: Automation and Robot

During field works such as tilling, implantation, and harvesting, farmers are simultaneously working on 3 types of operations. They are 1 observing the condition of operation and adjusting the operating machine, 2 driving the vehicle, and 3 planning the operating project of the whole farm. One of these 3 types of operation, adjusting the operating machine, has been gradually automated since the 1980s’. Today, there is also research to automate the other operations, such as driving the vehicle and planning the whole operating project. **Fig. 4** shows the tiller robot I’ve made. Automation and robotization of fieldwork vehicles play a big role on improving labor productivity greatly and would be able to generalize by solving the problems on safety and cost.

On the other hand, the problems on areas such as fruits and vegetables that are not mechanized enough definitely can not be solved by just using the existing technologies. Sufficient mechanization will be able to be realized by using new mechatronic or robot technology. **Fig. 5** shows the strawberry-harvesting robot developed mainly by BRAIN. It automatically harvests strawberries from late night and the farmers, additionally, harvest and prepare them for the shipment in the early morning. This operation system would enable the speedy shipment of fresh strawberries to the market. Robot technology has the power to change agriculture dramatically in years to come. The technologies listed below would be the key technologies.

1. The three main technologies are the sensor, the controller and its software, and the actuator and their technical balance
2. The reliability, stability, durability for agriculture, and cost-performance of the three main technologies
3. Controlling soft capable for various changes and conditions

Envisioned Technology 3: Farm Work Safety

It is not only Japan’s, but also Korea, U.S. and other countries’ problem that the percentage of labor accidents per worker is higher in agricultural area than other business areas. To make agriculture advance

Fig. 3 Basic Concept of Precise Agriculture

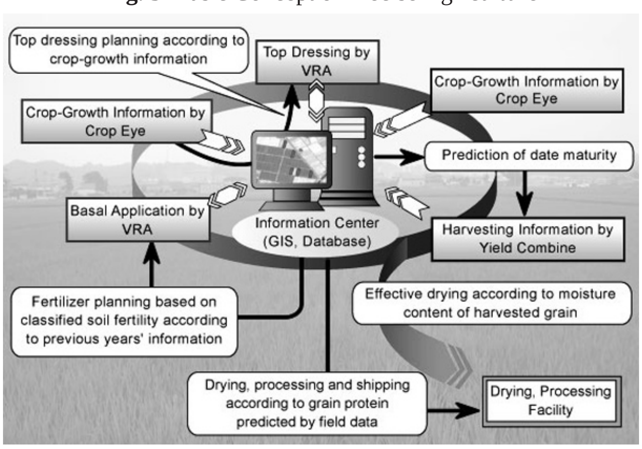
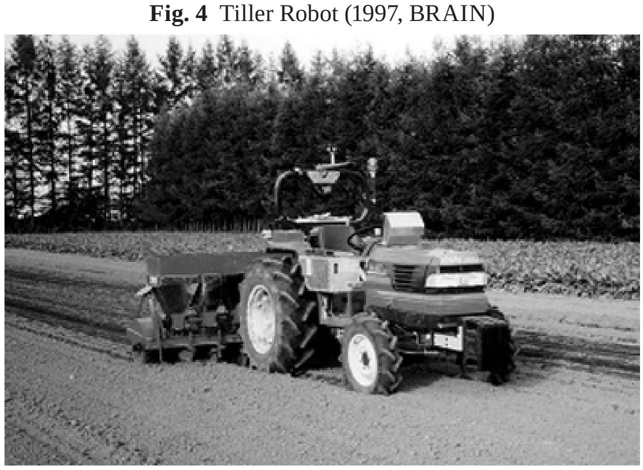


Fig. 4 Tiller Robot (1997, BRAIN)



to a growing industry, we must not forget to make agriculture cast off from high-risk jobs. The "Project" also clearly notes the needs for promoting safety measures of farm work. The background of the farm work accidents is the aging (60 % of the farmers are 65 or older) and the feminization of farmers.

To ensure farm work safety, requirements listed below are necessary.

1. Fail safe based dead-man clutch, or other safe start-up equipment that make it impossible to start-up the engine without stepping on the clutch. Developing any other features that prevent accidents such as security features for rotating parts.
2. Protective equipment such as safety frames to minimize the damage in case of an accident.
3. Controlling equipment and instruments in a universal design regarding elderly and women farmers to prevent malfunctions leading to an accident.
4. Features and equipment to prevent health problems, such as backache, Raynaud's disease or any other disease.
5. On-going education for the safety of farmers.

Envisioned Technology 4: Low-volume production of Various Varieties

Cabbage, with a growing area larger as compared to other vegetables, has only 30,000 ha of that in Japan. Even if you develop a machine capable of handling 20 ha a year, it is estimated that 10 years will be needed to introduce it to half of the total growing area. That is to say, its yearly demand is only 75 machines a year. This small demand makes the unit price more expensive. There are cases where people have difficulty introducing a brand new machine because of its high cost, though the performance of the machine itself is outstanding. It is very important to develop agricultural machines and equipment for both prosperous farmers and manufacturers. Technology to develop low priced machinery capable of low-volume production of various varieties is needed. The ideas noted below would be the clue.

1. Assembly system to be built by farmers using the agricultural off season.
2. Selling only parts and drawings to be built at the iron factory in each regions.

Afterword

It is not easy to accomplish the aims noted in the "Project", but I believe we can achieve the goal with the cooperation among academic, business, and governmental circles. Recently, not only in Southeast Asia, but also in countries like China and India, that is to say, in the vast areas that western agricultural machines (mainly suitable for upland crops) can not deal with, the agricultural machines made in Japan are active in the front lines. This means that the machines suitable for agriculture in East Asia are growing rapidly, such as tractors, rice planters, and combines for paddy field farming. We have spent decades developing and improving these machines.

Solving difficult technical problems does not just mean the approach for balanced domestic food supply in Japan, but it also means contributing to many countries suitable for paddy field farming. I hope that the result of this "Project" reduces the number of undernourished people in the world down to zero.

Fig. 5 Strawberry Harvesting Robot (BRAIN, S-I Seiko Co., etc)

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The Organization and Activities of JAICABE

by

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Agriculture and Agricultural Engineering

In proportion to the development of science, all the technologies used for agricultural production have appropriately branched out into specialties such as the science of agriculture, animal husbandry, agricultural chemistry, and agricultural engineering. None of the aforementioned can be lacking for the development of crop production necessary for human beings.

The origin of agriculture can be traced back to approximately 9,000 years ago. When the moving slash-and-burn type of agriculture changed to the settled type of cultivation, farmland was formed and irrigation was built. Sustained efforts have been made in pursuit of both stable and repeatable crop production until these days. Subsequently, cities were formed when the technology of stable food production was secured, which can be clear in light of the origin and development of the four major cradles of civilization in the world. In this regard, the roles of agricultural engineering and technology have been of great significance and will be increasingly important in the future.

In recent years, climate changes due to global warming have come to cause new types of disasters, which have had a bad influence on food production. Securing water, energy and food is beginning to be the major breakthrough on earth. Moreover, the population in the world has currently increased to 6.9 billion but expected to reach 9 billion in the year 2050. Of these at present, 1 billion are threatened with starvation. In expectation of an increase in starved population in the future, the researchers of the Academic Frontier are required to unify their specialized research and development so as to secure a stable food supply.

An increase in population has an important relationship with food supply problems. Accordingly, stable food production based on sustainable agricultural development is essential to deal with the increase of population. To overcome various problems of both agricultural and natural environments that have relationships to each other, comprehensive cooperative research is required in the fields of agricultural engineering. In other words, academic organizations in the countries and regions affiliated with CIGR are required to cooperate all together since their respective research is of great importance to the development of agricultural science.

Outline of JAICABE

Outline of Activities

With approval of six academic societies and one association in cooperation, the Japan Association of International Commission of Agriculture and Biosystems Engineering (hereinafter referred to as JAICABE) was founded in 1984 for the purpose of contributing to development in agricultural engineering and technology. Since then, three more societies joined and JAICABE currently has a ten member organizations to which 17,132 researchers and engineers belong. JAICABE holds annual conventions and symposiums as academic projects in addition to awarding ceremonies for fellow recognitions. Furthermore, JAICABE participates in the activities of CIGR (International Commission of Agricultural Engineering) as the representative society of Japan and, furthermore, dispatches its members as the officials to CIGR along with committee members to the respective sections from Section 1 to Section 7.

The CIGR branch society started as the Science Council of Japan and joined CIGR in 1994. As a result, activities in cooperation between JAICABE and CIGR came to be significant.

In 2007, JAICABE was approved by the Science Council of Japan as its collaborative research society. In cooperation with the CIGR branch society at the Science Council of Japan, JAICABE makes proposals to the Japanese government for agricultural engineering and, furthermore, holds both international academic symposiums and workshops in cooperation with the Science Council of Japan. JAICABE is a coalition society, consisting of academic societies, which covers the whole field of agricultural engineering in Japan. Since this particular organization has a variety of personal networks among the member organizations, there is an advantage of collaborative activities in which researchers from said organizations join widely. The member organizations in the agricultural section of the Science Council of Japan are appointed to only JASS (Japanese Agricultural Scientific Societies) and JAICABE in expectation of being able to deal with domain-crossing issues in science such as global warming and food problems.

JAICABE Annual Conference and Symposium

With the help of the 10 member organizations in cooperation, JAICABE holds an annual conference as part of the symposium. During these annual activities that have been held 26 times. Discussions on a variety of themes in the field of agricultural engineering have been held and opinions have been exchanged among the researchers and engineers. The symposiums held since 1996 are as follows:

- Education and Culture in Rural Districts and Agricultural Communities (1996)
- Education in Agricultural Engineering (1997)
- Large Scale Agriculture and Agricultural Engineering (1998)
- Environmental Harmony and Agricultural Engineering (1999)
- Highly Utilized Information in Agricultural Engineering (2000)
- Food Production and Agricultural Engineering in the 21st Century (2001)
- North-South Divide and Agricultural Engineering (2002)
- Improvement in Global Warming Issues and Agricultural Production Environment (2003)
- Recycling-Based Society and Promoting Local Industry (2004)
- Challenge to Environmentally Sustainable Biological Production (2005)
- New Development of Food Production Engineering (2006)
- Scenery of Transformed Agricultural and Mountain Villages (2007)
- Utilization of Geographical Space Information in the Field of Agricultural Engineering (2008)
- Innovative Technology in the Field of Food Production (2009)
- Initiative and Practice of Global Development in Human Resources in Agricultural Engineering (2010)
- Global Warming and Agriculture (2011)

Fellow Recognitions

The event of fellow recognitions at the annually-held general meeting is also a significant event. On condition of being recommended by their member organizations, JAICABE Fellow Recognitions can be awarded to researchers and engineers, who have been active for many years and achieved distinguished success in the development of agricultural science and engineering. From 1999 to 2008, JAICABE praised 194 people to the public as JAICABE Fellows for their achievements.

Education in Agricultural Engineering and JABEE

As a member of JABEE, Japan Accreditation Board for Engineering Education, JAICABE strives to improve the capacities of agricultural engineers at the universities. In pursuit of nurturing engineers who are equal in competence to or compatible with those in other countries, JAICABE assists JABEE in approving qualifications and holding training courses to improve education programs for engineers at the universities.

Assistance to CIGR

Having been established in 1930, CIGR is a nongovernmental and nonprofit international academic organization that unifies the fields of agricultural engineering in the world. The secretariat representing Asia was first established in Japan after being located in European countries. As a result, the domestic promotion of CIGR activities and the transmission of information on agricultural engineering in Japan to the world have come to be possible. The headquarters requested the secretariat be located in Japan and Professor Takaaki Maekawa of the University of Tsukuba, where the secretariat was placed, was selected as the secretary-general from January 2006 to 2010. In 2010, the secretariat moved to the University of Hokkaido and its Professor Toshinori Kimura became the secretary-general. JAICABE assists the secretariat in Japan in performing the CIGR activities smoothly.

International Symposium

Under the joint auspices of two organizations, Science Council of Japan and JAICABE, the 70th annual congress as the CIGR world congress was held at the University of Tsukuba in Japan in 2000. Many people participated in the first World Congress in Asia, which resulted in success. This particular congress resulted from the collaborative ability of all the JAICABE member organizations. Furthermore, JAICABE has a plan to hold another CIGR world congress in Japan. Due to the efforts of the people concerned, the CIGR world symposium will be held in Japan in 2011. Toward the symposium, the executive committee has been established in cooperation of all the members of JAICABE and the preparations are proceeding as scheduled. The 2011 CIGR International Symposium on "Sustainable Bioproduction - Water, Energy, and Food," September 19-23, 2011, Tower Hall Funabori, Edogawa, Tokyo, JAPAN will bring together researchers and professionals interested in new ideas, engineering, and technologies used in sustainable bioproduction systems. Attendees will be able to share ideas, theories, techniques, challenges, and concerns with peers and expand their professional networks worldwide. They will also have opportunities to attend many joint activities. The symposium is open to researchers and engineers from all over the world and to the general public interested in the global issues concerned with water, energy, and food. In this regard, all engineers, scientists and affiliates from the seven technical sections of CIGR will meet in Tokyo to discuss the updated controversial issues on water, energy and food along with the latest technological developments of which the world would be in pursuit. This International Symposium is sponsored by SCJ, JAICABE and CIGR. More information is available on the following web site: **www.cigr2011.org/**

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Table 1 Member organizations of *JAICABE*

		Members	Since
JSIDRE	The Japanese Society of Irrigation, Drainage and Rural Engineering	17,066	1984
JSAM	The Japanese Society of Agricultural Machinery	1,270	
SAMJ	The Society of Agricultural Meteorology of Japan	924	
JSFWR	Japanese Society of Farm Work Research	531	
SASJ	The Society of Agricultural Structures, Japan	522	
JAAE	Japanese Association of Agricultural Electrification	118 organizations	
ARP	The Association of Rural Planning	1,261	1990
SEE	The Society of Eco-Engineering	407	1994
JSAI	The society of Agricultural Infomatics	515	1997
JSABEES	Japanese Society of Agricultural, Biological and Environmental Engineering and Scientists	1,224	2007

JAICABE consists of ten organizations to which 17,250 members belong respectively. Of these, 17,132 are researchers and engineers and 118 are organizations registered at the Japan Association of Agricultural Electrification.

Table 2 The successive presidents of *JAICABE*

Name	Year
Prof. Kiyotsune Shirai (JSIDRE)	1984-1986
Prof. Seiji Sudo (JSIDRE)	1986-1988
Prof. Mutsumu Kadoya (JSIDRE)	1988-1990
Prof. Syoichiro Nakagawa (JSIDRE)	1990-1992
Prof. Fumihiko Sano (JSIDRE)	1992-1994
Prof. Toshio Tabuchi (JSIDRE)	1994-1997
Prof. Yasushi Hashimoto (SHITA & JSAI)	1997-2000
Prof. Osamu Kitani (JSAM)	2000-2003
Prof. Masashi Nakano (JSDRE)	2003-2006
Prof. Taichi Maki (SAMJ)	2006-2009
Prof. Takemi Machida (JSAI)	2009-2012

The officials of JAICABE (the directors and councilors) are from the member organizations but the president and vice president are co-opted.

Table 3 *JAICABE* Organization 2009-2012
The eleventh term of the JAICABE organization

Officer and Officials	
Honorary Advisors	Prof. Emeritus Dr. Fumihiko Sano, Prof. Emeritus Dr. Syoichiro Nakagawa, Prof. Emeritus Dr. Kiyotsune Shirai, Former Prof. of University Tokyo Dr. Toshio Tabuchi, Prof. Emeritus Dr. Yasushi Hashimoto
Council Members 2009-2012	
President	Prof. Takemi Machida, Japanese Society of Agricultural Informatics (JSAI)
Vice President (secretariat)	Prof. Haruhiko Murase, Japanese Society of Agricultural, Biological and Environmental Engineers and Scientists (JSABEES)
Vice President	Prof. Tatsuo Naka, Japanese Society of Irrigation, Drainage and Rural Engineering (JSIDRE)
Director	Prof. Taichi Maki The Society of Agricultural Meteorology of Japan (SAMJ), Prof. Sakae Shibusawa, Japanese Society of Agricultural Machinery (JSAM), Prof. Touru Shiga, Society of Agricultural Structures of Japan (SASJ), Prof. Kenji Ishida, Association of Rural Planning (ARP), Prof. Kenji Omasa, Association of Eco-Engineering (SEE), Prof. Noboru Noguchi (Recommended by the President), Mr. Yoshisuke Kishida (Recommended by the President)
Treasurer	Prof. Osamu Matsuoka, Japan Association of Agricultural Electrification (JAAE)
Treasurer:	Prof. Hisashi Horio, Society of Agricultural Meteorology of Japan (SAMJ)
JAICABE Secretariat:	Prof. Haruhiko Murase, Osaka Prefecture University Gakuen 1-1, Sakai, Osaka 599-8531, Japan Tel: 81+72-254-9429 FAX 81+72-254-9918

The secretariat of JAICABE is currently placed at Osaka Prefecture University and its professor Haruhiko Murase.

New Stage of Agricultural Mechanization Research in Japan

by

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Abstract

Three topics are mentioned in the paper; new responsibility of agriculture, a stage of technology package, and a process of decision making. The land use strategy should be changed under the serious food crisis; that is, production increase could not catch up with increase in demand during the last decade. All farm land, even house gardens, began to have responsibility to meet the demand of food supply. Even the city governments in Japan started to combat against the food crisis in 2009. Precision agriculture reaches a new stage of technology package, and this provides a new avenue to innovate farm management for any style of agriculture. A combination of the real-time soil spectrophotometer and a combine harvester with a yield monitor, for example, creates an environmental impact map of missing nitrogen. A model for the decision making process redefines by four learning phases and creates eleven process units of thinking from which a thinking process can be described for weed control practice as a case study.

Introduction

Shibusawa (2007) reported three new features in the policy of the Japanese government relating to precision agriculture: direct funding to growers for arranging a technology package, strategy and regulation on intellectual properties of agriculture, and pushing agriculture-retailing-industry collaborative roots-movement for branding-produce. The current decade achievements in precision agriculture in Japan taught that participating farmers (1) were familiar with internet communication, (2) had higher education levels, (3) grew high quality produce, (4) had a good sales and marketing experience, (5) were greatly outgoing and sociable, and (5) had ambition to become good practice farmers (Shibusawa, 2004, 2006).

In 2007 to 2008 the most serious event was the worldwide food crisis caused by population increase, shifts of lifestyle in the developing countries, and the emergence of the bio-fuel market. Japan, a low food self-sufficiency country, also quaked with the global food-energy crisis. Furthermore, natural disasters such as typhoons and cloud-bursts attacked agricultural areas, site by site, more frequently than previously experienced. This has required changes in the agricultural policy of Japan to rapidly increase food production and supply.

Current new projects were a modal shift of food chains for industrial uses of vegetables and fruits, skill transfer systems from professional farmers using agro-informatics, local sustainability movements of bio-fuel chains, and so on. Emerging is a city hall having its vision of agriculture enhancement against the low self-sufficiency of food in spite of its farm lands disappearing. People who know the concept of precision agriculture used to join these projects because of its potential of thinking process to the goal of solutions. A new potential of precision agriculture has become attractive for not only engineers and scientists but also politicians and business people. That is why the paper has the objectives to describe precision agriculture relating to issues in Japan: new responsibility of land policy, technology package in precision agriculture, and thinking process for farm management.

The main part of this article was

presented at the 3rd Asian Conference on Precision Agriculture in Beijing, China, 2009 (Shibusawa 2008, 2009).

Crisis Makes a New Target

Responsibility of agriculture has been to supply food to people continuously, accompanied by its multi-functional effects such as environmental conservation and landscape preservation. As shown in **Fig. 1**, the world food production could not catch up with the world consumption demand during the last decade, and this only increases in yield per area followed increase of consumption. Moreover, the area harvested per person has fallen to the critical unit area under a saturated net arable land. Consequently, the food crisis, rooted in this short of production compared with the demand, increased .

The facts have shown that (1) there is a responsibility to use all farm land for providing agricultural products even if it is a home garden, (2) all skills and knowledge must be used for encouraging a yield increase for higher productivity per area, and (3) food chains should be kept more effectively worldwide.

Productivity is variable across the countries in the world as shown in **Fig. 2**, for example. The yield per unit area followed an exponential decrease or logarithm decrease over the 193 countries and had 35 times difference between the top and the bottom countries. The yield of the top 20 countries was twice higher than the world average and 113 countries had yield lower than the world average. There were 124 countries with yield below 3 t/ha. Consequently, the top 20 countries must have responsibility to transfer their technological knowledge to the low yield countries. The data of

Fig. 1 Foods consumption worldwide requests increases in Yield

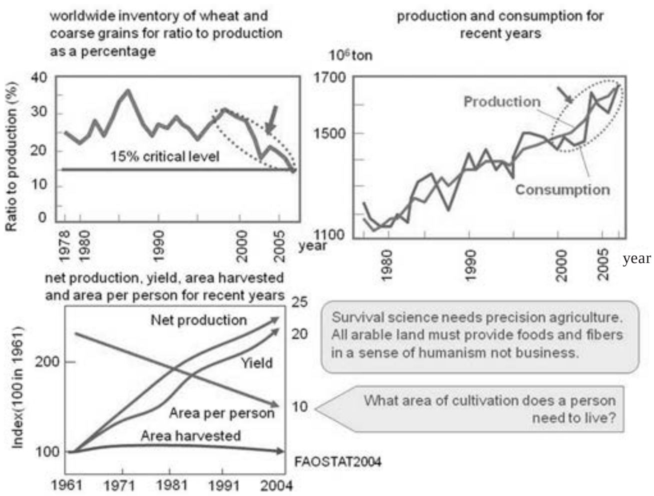


Fig. 2 Potential of cereals production (Calculated from FAOSTAT 2005 data)

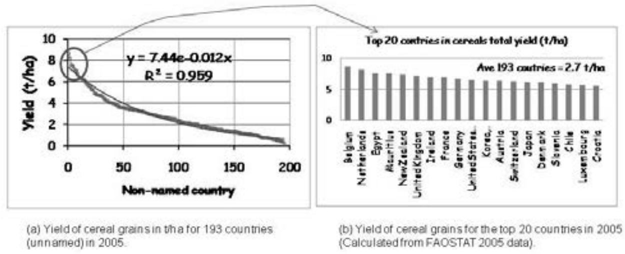


Fig. 3 Demonstration of technology package on precision paddy management (Research Report on Agriculture, Fishery and Forestry, No. 24, MAFF-Japan, 2008)

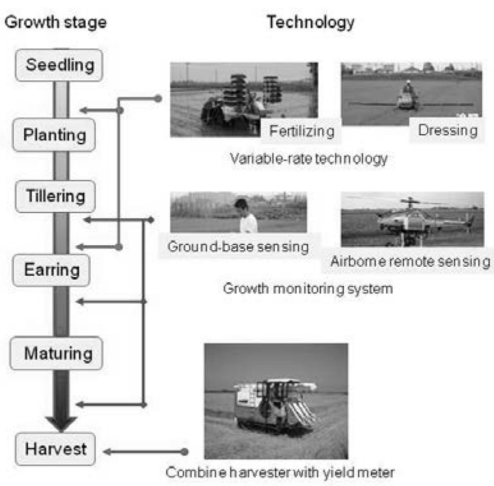
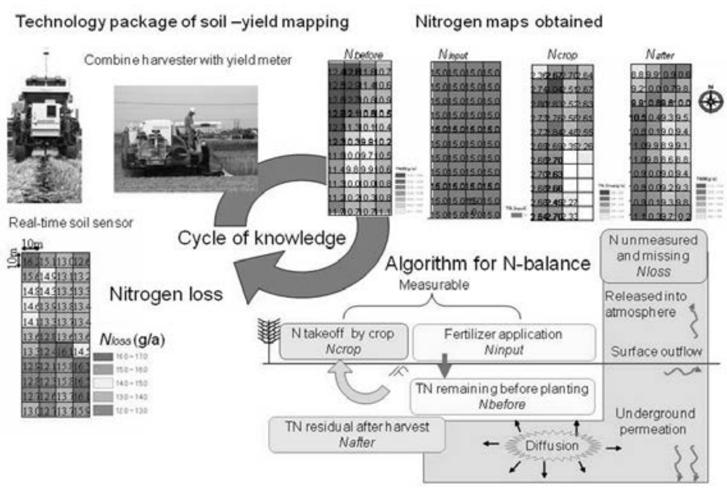


Fig. 4 Combination of real-time soil sensor and combine harvester with yield monitor. This creates the missing nitrogen map



FAOSTAT also indicated that each country has its own best crop management but no details of the management are described.

In this context agricultural informatics and mechanization, that is precision agriculture, will be a key issue in a global aspect as well as in an aspect of farmer motivation. Precision agriculture should be rediscovered as evidence-based farm management, which leads us to an avenue on "precision conservation" defined by Berry *et al.* (2005). This attitude will be attractive for global people in business and politics and for local people in industry and agriculture.

Stage of Technology Package

In 2006 the government agreed to create a three-year fund of 95 million yen per year for wise growers to introduce precision agriculture technologies and to change their farming style into environmentally friendly agriculture. This was based on the development of technology packages during the last 10 years as shown in **Fig. 3** (AFFRC 2008). Growers could see all technology available for their own farms and find a set of technologies with a target of 50 % reduction in environmental impact under keeping profitability. A stage of the technology package that is important is to have a demonstration of precision agriculture for all practitioners.

Shibusawa *et al.* (2008) demonstrated a package of soil sensor and yield monitor providing soil maps before planting and after harvest. This was followed by a nitrogen management strategy associated with a spatial variability of nitrogen loss, as shown in **Fig. 4**. An idea was as follows.

$$N_{lost} = (N_{before} + N_{input}) - (N_{crop} + N_{after}) \quad (1)$$

Where:

N_{before}: total nitrogen predicted before seeding (no fertilizer) in 2005,

N_{input}: fertilizer uniformly input on soil surface by 15 g/a,

N_{after}: total nitrogen predicted after harvesting in 2006,

N_{lost}: kinds of lost nitrogen from the field,

With the maps of yield, grain protein and nitrogen loss one could make a recommendation of soil management.

Process of Thinking

In 2009 the secretariat of the ministry of agriculture, forestry and fishery organized a consultation on application of informatics into agriculture, called by "AI agriculture consultation", to enhance the skill transfer of expert farmers using information science, such as cognitive science, robotics, and agricultural informatics. This policy helped to keep the level of knowledge and skill in productivity management because millions of aging farmers will retire in the coming decade in Japan and their skill and wisdom will go out with them.

McCown (2005) reported that a number of decision support systems developed were not used in farmer practice but used as a learning tool. He also emphasized the differences between objective knowledge embedded in a decision support system and the subjective knowledge which normally guides the actions of farmers in familiar situations of the local, personal, and social environment.

A concept of the thinking process was summarized in **Fig. 5**. First of all, four phases of learning were assumed; that is, data, information, knowledge and wisdom (Shibusawa, 2006; Shibusawa *et al.*, 2008). Data implies a set of facts such as digits, information implies definition of data, knowledge implies logic for judgment, and wisdom involves concept creation based on experience. The four phases are classified into two stages: an evidence collec-

Fig. 5 A plan of AI-network for decision process support

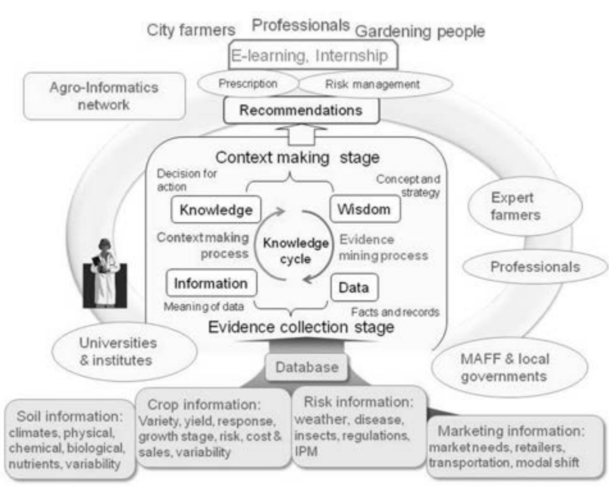
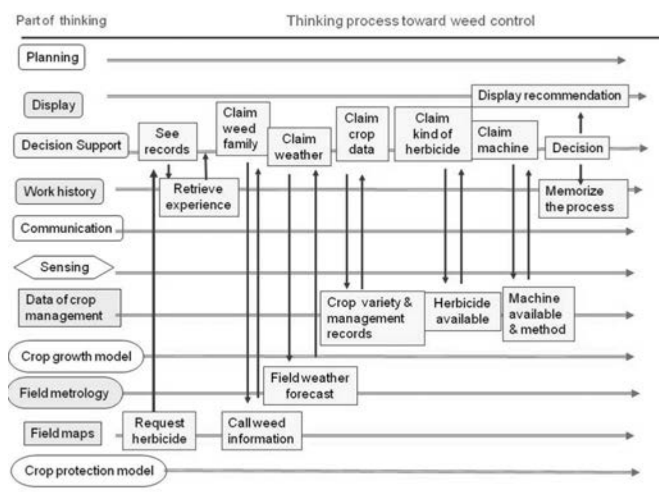


Fig. 6 Thinking process toward weed control



tion stage of data and information phases, and a context making stage of knowledge and wisdom phases. The evidence collection stage has been of keen interest for researchers and they used to try decision-making on the evidence stage, but it was sometimes impossible because an arrangement of facts did not motivate farmers with value of merit.

The database must be composed of four categories: soil information, crop information, risk information and marketing information. These categories are enriched by practices and exchange through a network, and they provide data and facts on the evidence collection stage.

The concept was broken into a work of weed control, as shown in **Fig. 6**. In the figure, eleven elements of the thinking process were assumed. The first action was applied from the element "field maps", which found a bunch of weeds and made a claim to kill them. The claim was sent to element "decision support", which referred to the record of herbicide in the element "work history" and made a claim to get information on the weeds against the element "field maps". Element "decision support" also made a claim to get the field weather forecast and the called the information on crop variety for the element "data of crop management", followed by the information on herbicide chemicals and machine for spray. Finally element "decision support" made a recommendation and memorized the process in the element "work history".

Hearing from farmers indicated that their thinking process was almost similar to that in Fig. 6, and that it will be convenient to use as a learning tool. They will make decision on their own paradigm or concept, and when a decision was changed is when the paradigm was changed.

Conclusions

Three topics were discussed in this paper: responsibility of high yield countries against the food crisis, a technology package in precision agriculture, and the thinking process of farmers. Technology transfer from high yield countries will become a serious task to combat against the undergoing food crisis, because the worldwide production increases has not kept up with the increased demand during the last decade. In standing on the science and technology, it was confirmed that precision agriculture has reached a new stage of technology that involved innovations in farm management. A combination of the real-time soil sensor and a combine harvester with a yield monitor, for example, created an environmental impact of missing nitrogen. Furthermore, a model of the decision making process was redefined by four learning phases and also provided eleven thinking units to understand the farmers' decisions. This approach provided useful tools to interpret a way of thinking of expert famers.

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Robot Farming System in Japan

by

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Abstract

The objective of the research is to develop a robot farming system using multiple robots. The research will discuss the application of multiple robots in Japan agriculture for rice, wheat and soybean. The robot farming system includes a rice planting robot, a seeding robot, a robot tractor, a combine robot harvester and various implements attached on the robot tractor. One of the key elements of the robot farming system is that it should be more economical to the farmers. The important parts of the farming system are the robot management system, low-cost system, robot farming safety, and real-time monitoring/documentation.

Introduction

With the ever-growing population comes the problem of food shortage. Researchers are finding ways to increase food production without compromising our planet's natural resources and ecosystem. One viable way to increase food production is to integrate the new technologies such as GPS (Global positioning system), spatial information, robotics technology, laser scanners, CCD (Charge coupled camera), gyroscopes, etc. to agriculture.

This research will discuss the application of robot tractors in agriculture by developing a robot farming system in Japan using new technologies. Research institutions around the globe are conducting researches about autonomous vehicle for agricultural use and usually they rely on RTK-GPS (real-time kinematic global positioning system), GIS (geographical information system), navigation sensors, image sensors, total stations, VRS (virtual reference station), etc. depending on the application.

Recently, there are many research institutions already developed robot tractors and robot vehicles for agricultural purposes. Khot *et al*., (2005) developed an autonomous tractor for intra-row mechanical weed control in row crops and a prototype robot vehicle for posture estimation of autonomous weeding robots navigation in nursery tree plantations greenhouse application. Nagasaki *et al.* (2004) developed automated rice transplanter. Barawid and Noguchi (2010) developed low-cost and small scale electronic robot vehicle for orchard application.

Also, many researches have desire to modernize agriculture (Linker and Blass, 2008). This desire led researches to numerous studies related to the development of agricultural robot and semi-robot vehicles (e.g. Debain *et al*., 2000; Han *et al*., 2004; Pilarski *et al*., 2002; Morimoto *et al*., 2005).

The problem with the recent researches is that it is only concentrated on a specific application such weed control, crop detection, etc. Robot farming system is necessary that can be applied from seeding/planting to harvesting. This can be done by the recent advances in science and technologies using spatial and temporal information.

In Japan, the number of farmers is decreasing and aside from the fact the problem in aging farmers. In the near future, Japan farmers will decrease rapidly that will result to shortage in food production. That is why researchers in Japan are doing a research about robot farming system which is one of the possible solutions to solve the food shortage production. The objective of the research is to develop a robot farming system using multiple robots for rice, wheat, and soybean. The research will discuss the recent ongoing projects and future projects on how to develop a robot farming system. It includes management system, low-cost navigation system, safety of robot farming, and real-time monitoring of the crops/plants.

Research and Materials

Robot Platforms

Our laboratory, Laboratory of Vehicle Robotics successfully developed one electronic robot vehicle and two robot tractors. The electronic robot vehicle could control basic functions such as movement (forward, backward, and neutral), steering, speed, and emergency stop (manual or remote control switch). This robot vehicle will be used for real-time autonomous data acquisition and crops monitoring in the robot farming system. **Fig. 1** shows the electronic robot vehicle.

The two robot tractors could both control functions such as transmission (forward, backward, and neutral), speed, steering, three-point hitch, PTO (power take-off), and emergency stop (manual or remote control switch). These robot tractors will be used as a platform for the implementation of the tractor implements such as rotary tillage, weeder, seed broadcaster, fertilizer, and seed planter in the robot farming system. **Fig. 2** shows the robot tractors.

Rice transplanter and combine harvester are also included in the robot farming system shown in **Fig. 3**. These robot vehicles are under development and hopefully, test runs will be conducted in early summer of 2011. Actual experiments will be conducted using the multiple-robots at the same time to make the farming as autonomous as possible. Monitoring system will be also included in the system and it will be discussed in the results and discussion section of the research.

Navigation Sensors

To perform an autonomous navigation of the robot tractors and vehicles, navigation sensors are necessary. In the laboratory's current system, a method called sensor fusion was used to determine predetermined paths. Predetermined path also called as navigation map can be made by obtaining two-points in UTM (universal transverse Mercator) coordinates. These two-points will be used as the reference points to create navigation map using the developed software in the laboratory (Kise *et al*., 2001). The sensors used were RTK-GPS (real-time kinematic global positioning system) and IMU (inertial measurement unit). The RTK-GPS was used to obtain the vehicle position with respect to UTM coordinates and IMU was used to obtain the vehicle posture (roll, pitch, and yaw angles). These navigation sensors were used to follow the predetermined points in the navigation map. **Fig. 4** shows the RTK-GPS and IMU. The RTK-GPS has an accuracy of ± 2 cm while the IMU has an accuracy of 0.5 deg/hr.

However, these sensors were expensive and it was not economically accepted to the farmers. That is why the laboratory tried to substitute the IMU with inexpensive sensor called Hemisphere GPS compass which is shown in **Fig. 5**.

This sensor gives absolute heading angle and position of the vehicle. The heading angle accuracy is 0.3 deg and position accuracy is 60 cm in DGPS (differential GPS). An autonomous run was conducted using the GPS compass and obtained a satisfactory result by following

Fig. 1 Electronic robot vehicle

Fig. 2a Wheel-type robot tractor

Fig. 2b Crawler-type robot tractor

Fig. 3 Rice transplanter and combine harvester

the navigation map with minimum errors both in lateral and heading deviations.

A new inexpensive sensor was also used as the navigation sensor called AGI-3 GPS compass shown in **Fig. 6**. The sensor includes a satellite receiver, antenna, inertial sensors and memory storage for complex path planning and control algorithms. This sensor substituted the RTK-GPS and IMU sensors and eliminated the difficult sensor fusion algorithm. Preliminary autonomous run tests were conducted using the AGI-3 GPS compass sensor. Using the AGI-3 GPS compass as the navigation sensor, results showed that it could follow the navigation map accurately. However, more experiments are needed in order to increase the accuracy of the navigation system.

Safety System

One of the important things needed to include in the robot farming system is the safety of the farmer or operator. During the operation of the robot tractor in the field in an autonomous mode, safety measure should be included in the system. A 2-dimesional laser scanner was used as the safety sensor attached at the front of the robot tractor shown in **Fig. 7**. This laser scanner could obtain distance and angle of the objects in front of it with respect to its set scanning range distance. The laser scanner scanning angle can be set into 100 deg and 180 deg modes. The scanning distance can be set into 8 m, 16 m, 32 m, and 80 m modes.

For obstacle detection sensor, an ultrasonic sensor (Bosch and Sensing Technology) was used to detect obstacle in front of the robot tractor. **Fig. 8** shows the ultrasonic sensor and its basic specifications. This obstacle detection system is still under development.

Research Methods

Robot Farming System

The idea behind this research was to develop a robot farming system for rice, wheat, and soybean fields. The robot framing system will fully automate the farming from planting to harvesting until to the end user of the products. The robot tractors will be used to plant and seed the crops using inexpensive sensors for its navigation. A full overview of the robot farming system is shown in **Fig. 9**. It includes robot management system, real-time monitoring system, low-cost navigation system, and safety system. In the robot farming system, the robot tractors receive command from the control center and send information data using wireless LAN and packet communication. The robot tractors can perform its designated tasks and can work simultaneously with each other. The operator at the control center

Fig. 4 RTK-GPS and IMU as navigation sensors

Fig. 5 Hemisphere GPS compass

Fig. 6 AGI-3 GPS compass

Fig.7 Two-dimensional laser scanner attached to the robot tractor

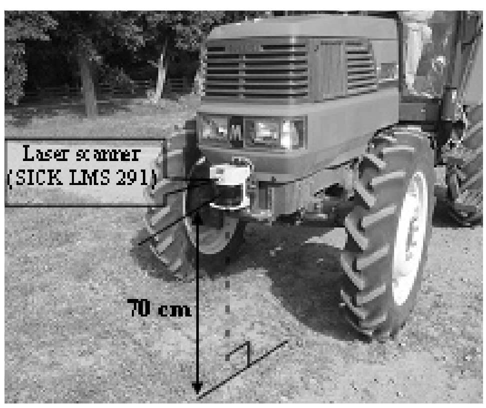
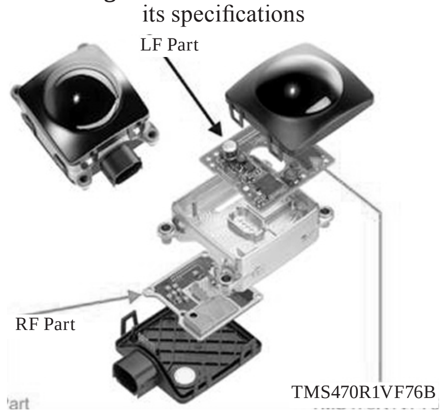


Fig. 8 Ultrasonic sensor and its specifications



Bosch LRR2 with dimensions of 73 × 70 × 60 mm (2.9 × 2.8 × 2.4 in) can be integrated almost anywhere on the front of the vehicle can analyze the data sent by the robot tractors in a real-time basis and can immediately send the necessary information to the farmers, retailers, producer's cooperation, etc. Also, the operator can see the real-time status of the robot tractors using a GeoMationFarm (Hitachi Soft) while their performing its task.

Low-Cost Navigation System

In order to be economically acceptable to the farmers the application of the robot farming system, low-cost navigation system is necessary to consider. The choice of navigation sensors will depend on the accuracy and its application. There are many companies commercializing navigation sensors but the problem is the algorithm on how to do sensor fusion and how to increase its accuracy. In our laboratory, we already successfully made a sensor fusion of RTK-GPS and IMU sensors to obtain the vehicle's absolute heading angle and position in UTM coordinates. However, these sensors were expensive. In this system, a low-cost navigation sensor based on multi-GNSS (global navigation satellite system) was used as navigation sensor called AGI-3 GPS compass made by TOPCON. This AGI-3 gives vehicle's absolute heading angle and position in UTM coordinates. The fusion of RTK-GPS and IMU sensors will be replaced by this AGI-3 sensor. Aside from the low-cost of the AGI-3, the company already did the sensor fusion of the GPS and inertial sensors.

Robot Management System

One of the important parts of the robot farming system is the robot management system. Robot management system is developed based on GeoMationFarm integrated with GIS map which is commercialized by the Hitachi Soft. Different information can be generated and can be seen by the operator which is located in the control center. The robot management system will send the information necessary to control the robot tractors during their operation such as navigation map. In the navigation map, details about working information of the vehicle are included such as number of path, three-point hitch position, vehicle speed, and PTO rotation. Robot management system can also obtain crop information data from the robot tractors using the sensors attached to them. This crop information includes crop status and soil quality. From this information, a variable rate fertilizing map can be generated and the control center can send it back to the robot tractors for fertilization of the crops. **Fig. 10** shows the mission plan map.

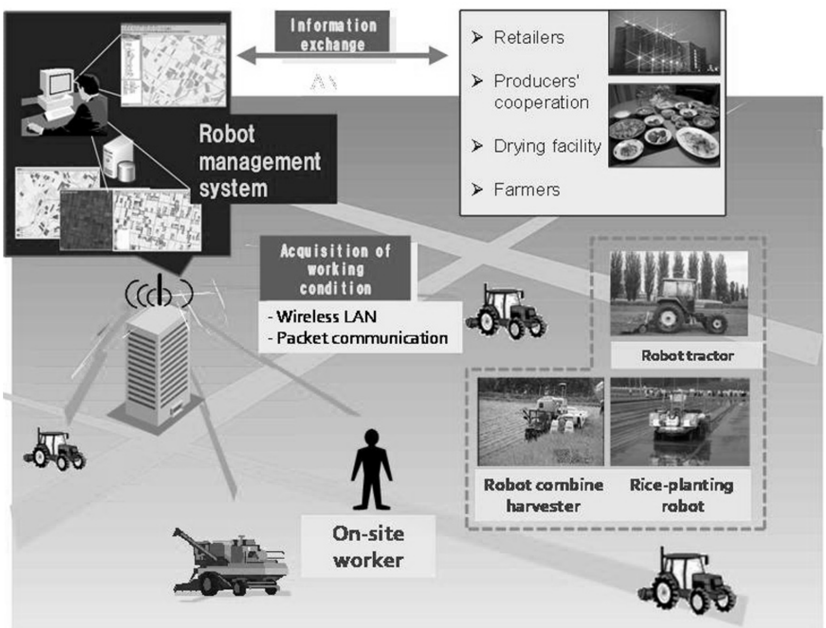
Another function of the robot management system is the real-time monitoring of the robot tractors while in working condition. Using this management system the current location and status of the robot tractors can be seen. Also, the current information of the working condition of the robot tractors can also be observed. **Fig. 11** shows the real-time monitoring system of the robot tractors. In the figure, each working robot tractor has its own Robot ID. By clicking the Robot ID to the computer screen, details about the robot tractor will be seen.

Safety System

Our laboratory successfully developed an obstacle detection algorithm system using 2-dimensional laser scanner. This system was used for safety purpose. The system was included in the robot tractor navigation program. If the laser scanner detects obstacles in front of it within the set scanning range, the navigation program will command the robot tractor to stop. Even though the laser scanner has high accuracy, it is expensive and it is not economically accepted for the farmers.

That is why the research is focusing on the inexpensive sensors. Ultrasonic sensor is one of the choices to substitute the laser scanner. The obstacle detection using this ultrasonic sensor is still under development.

Fig. 9 Overview of the robot farming system



Results and Discussion

Current Status of the Robot Farming System

Three-robot vehicles (electronic robot vehicle and two-robot tractors) were already developed for the robot farming system as platforms. The electronic robot vehicle will be used to obtain crop information by attaching sensors to it and two-robot tractors will be used to perform the various implement functions. On-going developments and modifications on the rice-transplanter robot vehicle and combine harvester robot platforms are in the making.

Low-cost navigation sensor selection is also one of the top priorities in the implementation of the research. The navigation sensor that will be used will come from different companies which have the lowest cost compared to the other companies.

The current status of the robot farming research is already started and good developments are going-on according to its research plan.

Future Plan and Evaluation of the Robot Farming System

The research is under a five-year plan and it was started April 2010. The first three years will focused more on hardware developments of robot platforms (rice transplanter robot, combine harvester robot and robot tractor) and also it will include the software developments such as robot management system, obstacle detection algorithms, and real-time monitoring system.

For the remaining two-year in the plan, a feasibility test and evaluation of economics of the robot farming system will be conducted.

Conclusions

The research discussed about the development of robot farming system for rice, wheat, and soybean fields in Japan. Multiple robots were used in order for possible development of a robot farming system. Robot platforms were already developed and other robot platforms are on its way of developments. Also, the research discussed the application of inexpensive navigation sensors to be able to economically acceptable with the community. The robot farming system development will be a great help in the near future in Japan agriculture because the farming will be fully automated. Also, increase in food production will be one of the great outputs of this research.

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Fig. 10 Mission plan map in robot management system

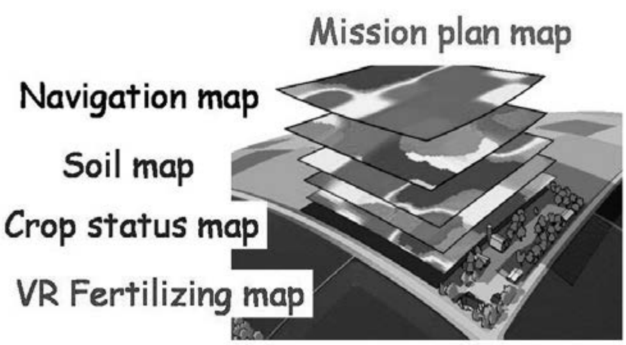
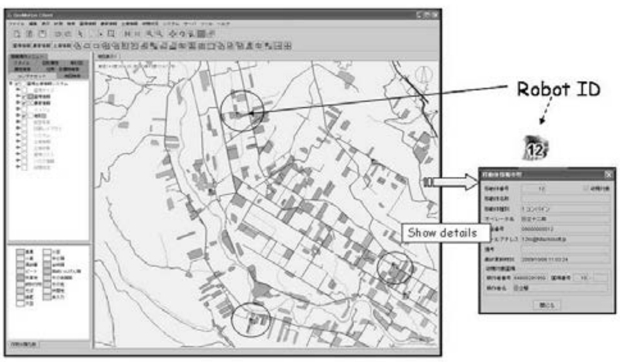


Fig. 11 Real-time monitoring system



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NEWS

The 4th Asian Conference on Precision Agriculture

July 4-7, 2011 Tokachi Plaza, Obihiro, Hokkaido, JAPAN
http://www.ec-pro.co.jp/acpa2011/

Welcome to ACPA2011 Obihiro

As an initiative on precision agriculture research and applications in Asia, the series of Asian Conferences on Precision Agriculture have been connecting representatives from all sectors involved in agriculture across counties and regions. The program includes industry updates, activities in organizations and communities, and social events city sponsored. All of the conference has a focus on information exchange and exploration of future needs community-based.

We would like to call all of you who combat the global crises of food and natural resources using PA technologies, and who contribute local community and industry development with agriculture, and who crate agro-information technology. We are looking forward to seeing all participants in Obihiro.

Sakae SHIBUSAWA
Chair of Management Committee of Asian Conference on Precision Agriculture
Dr. Prof., Tokyo University of Agriculture and Technology, Japan

Important Dates

Abstract submission deadline:	March 31, 2011
Full paper submission start:	April 27, 2011
Full paper submission deadline:	May 31, 2011
Early Registration deadline:	May 31, 2011
Registration deadline:	June 17, 2011
Icebreaker Party & Registration:	July 4, 2011
Conference:	July 5-6, 2011
Technical Tour:	July 7, 2011

Investigation of Nonlinear Vibration Characteristics of Agricultural Rubber Crawler Vehicles

by

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Abstract

In this study, the nonlinear interactive characteristics between a track roller and a rubber crawler were investigated. The dynamic spring constants and the viscous damping coefficients of the rubber crawler were measured by using the dynamic viscoelastic measuring system with a varying range of frequency and preload. The results indicated that the relationships between the vertical load forces acting on the track rollers and the vertical displacements of the rubber crawler were approximately linear near the lug (core bar), whereas the relationships were nonlinear at the middle portion between the two lugs. The nonlinearity indicated by the hardening spring property could be represented by cubic nonlinearity. The dynamic interactive relationships between the dynamic spring force of the track roller and the displacement of the rubber crawler showed hardening nonlinearity near the middle portion between two lugs, while around the lugs were linear with a tendency similar to static interaction. And also, the higher the exciting frequency, the larger was the dynamic spring constant, while the viscous damping coefficient decreased. Furthermore, the dynamic model for agricultural rubber crawler vehicles based the non-linear interaction between the track roller and rubber crawler was developed, and comparisons of measurements and analytical simulations were performed in order to validate the analysis. The results indicated that the simulation based on the non-linear interaction of the track roller and rubber crawler shows better agreement with experimental results than those of simulation, based on the conventional linear interaction.

Introduction

Rubber crawlers have been widely used as the driving system of agricultural and industrial machinery on account of their high mobility and traction on soft and uneven terrain and low damage to bituminous pavement surfaces as compared with iron crawlers. Therefore, a head-feeding combine harvester, which requires high traction in a paddy field, has been introduced with rubber crawler since the earliest stage of development in the 1960s. Moreover, in recent years, rubber crawlers are adopted as the driving system of some tractors that mainly used a wheel-driven system to improve its traction.

However, structure of the driving system of rubber crawler vehicles is complex, and the power requirements and mechanical vibrations are greater in comparison with those of wheel-driven vehicles. In particular, it is necessary to reduce the amount of vibration while driving on the pavement road. The vibration characteristics of rubber crawler vehicles are influenced by the mass of the vehicle, moment of inertia, location arrangement and diameter of track rollers, dynamic viscoelastic property (the dynamic spring constant and viscous damping coefficient), and configuration of the rubber crawler such as height, wide and pitch of lug. Among these factors, the location arrangement of track rollers is a particularly important design factor with regard to estimating and modifying the vibration characteristics without the influence of factors such as traction and development cost. Thus, obtaining an optimum arrangement at the design stage contributes to reducing not only the amount of vibration but also the development costs by shortening the period of testing process.

In previous researches, a dynamic model for an agricultural rubber crawler vehicle, which had fixed track rollers, driven on a rigid horizontal surface was proposed by Inoue *et al.* (1990a). In this model, the mechanical interaction between the track roller and the rubber crawler was defined by the Voigt model. In addition, the dynamic spring constant and viscous damping coefficient of the rubber crawler, which vary periodically between two lugs, could be expressed in the form of a Fourier series. Furthermore, the identification of the dynamic spring constant and the viscous damping coefficient for the rubber crawler was performed by using the measured dynamic loading forces acting on the track rollers in order to improve the accuracy of the analytical simulation (Inoue *et al*., 2004). However, there was a limitation with regard to accurately identifying the model parameter because the relationships between the vertical load forces acting on the track rollers and the displacement of the rubber crawler were assumed to be linear. In contrast, the actual relationships were observed to be approximately linear around the lug (core bar) and nonlinear at the middle portion between the two lugs. Hence, in order to conduct an accurate simulation of driving the rubber crawler vehicle, it was necessary to extend the present model from a linear to a nonlinear model.

In this study, the nonlinear interactive characteristics between a track roller and a rubber crawler were investigated to develop the nonlinear model of an agricultural rubber crawler vehicle

Fig. 1 The basic structure of the typical agricultural rubber crawler

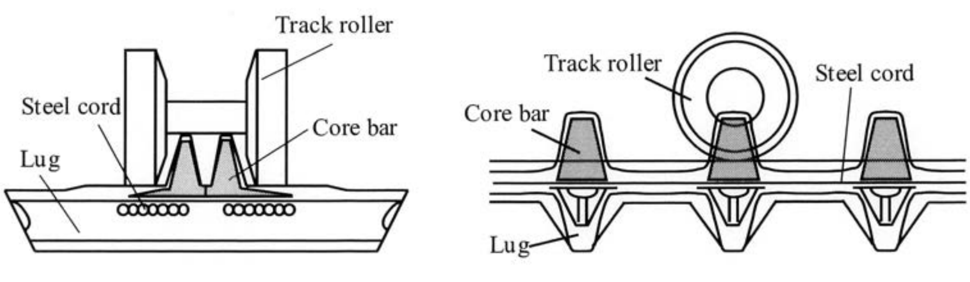


Fig. 2 The vertical load forces acting on a track roller and the vertical displacements of the rubber crawler

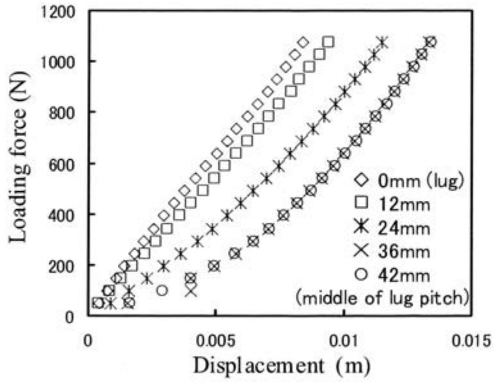
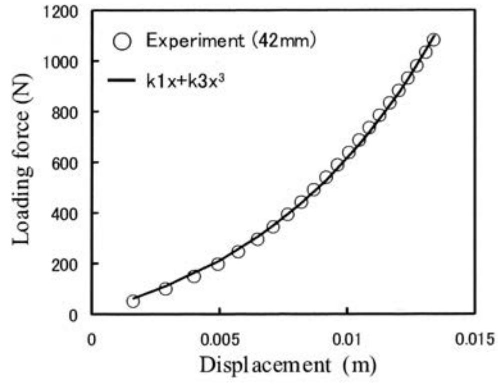


Fig. 3 Approximation of the interactive relationships between the rubber crawler and the loading force acting on the track roller



Nonliear Interactive Characteristics between Track Roller and Rubber Crawler

Static Interaction

Fig. 1 shows the basic structure of the typical agricultural rubber crawler. The rubber crawler is composed of lugs, core bar (embedded metal), steel cord, and vulcanized rubber. Due to the sectional form and the particular components of a rubber crawler, the compressive strength changes between the two lugs (core bars) when the track rollers come into contact with the surface of the rubber crawler. Static nonlinear interactions between a rubber crawler and a track roller were investigated by using the quasi-static compressive experimental data (Inoue *et al*., 1990a). The experimental results are shown in **Fig. 2**. The relationships between the vertical load forces acting on a track roller and the vertical displacements of the rubber crawler were approximately linear near the lug (0 mm), whereas the relationships were nonlinear at the middle portion between the two lugs (42 mm). In general, the restoring force of a hardening spring is usually described as an odd-power series of deformation. Thus, the interactive relationship between the loading force acting on the track roller and the vertical displacement of the rubber crawler was approximately by least squares. As a result, it found that the relationship could be represented by cubic nonlinearity as shown in **Fig. 3**.

Dynamic Interaction

Experimental Method

In this study, the phase angle method (Sekiguchi and Asami, 1981; Dean *et al*., 1984) was used to measure the dynamic spring constant and the viscous damping coefficient of the rubber crawler. The schematic of the experimental system is illustrated in **Fig. 4**. **Table 1** shows the specifications of the sample rubber crawler. The sample rubber crawler, which was fitted into a steel case, was fixed on the base. When sinusoidal vertical loading forces of a pair of two track rollers are exerted to the sample rubber crawler, the response is sinusoidal displacement with the same frequency and phase difference γ, which is referred to as the phase angle, as shown in **Fig. 4**. The loading forces and displacements were measured by the load cell and displacement meter, which were incorporated into the loading device and the phase angles were obtained from them. Here, the loading force vector, displacement, and velocity vector are represented as follows, respectively

$$F = F_0 e^{i(\omega t + \gamma)} \qquad (1)$$

$$x = x_0 e^{i\omega t} \qquad (2)$$

$$\dot{x} = i\omega x_0 e^{i\omega t} = i\omega \dot{x} \qquad (3)$$

where $\omega = 2\pi f$ and F_0 and χ_0 represent the amplitude of the loading force and displacement. Furthermore, the dynamic spring constant k and the viscous damping coefficient c of the rubber crawlers acting on a track roller can be expressed as follows:

$$k = [\,(F/2)/x\,] \cos\gamma \qquad (4)$$

$$c = [\,(F/2)/x\,]\,(1/\omega) \sin\gamma \qquad (5)$$

The dynamic properties of vulcanized rubber materials were influenced by the frequency and preload or displacement and the amplitude of dynamic load or displacement. Therefore, in this study, the dynamic spring constant and the viscous damping coefficient of the rubber crawler were measured under various conditions of influence of the preload and frequency.

Result and Discussion

Fig. 5 shows the dynamic spring constants of the rubber crawler. Near the lug, the dynamic spring constants of the rubber crawler approached the constant values when the preload of the track roller was greater than 400 N. Consequently, the dynamic interactive relationships between the dynamic spring force of the track roller and the displacement of the rubber crawler were nonlinear under the low-load of the track roller; however, they were approximately linear when the load was more than 400 N. On the other hand, near the middle portion between the two lugs, the dynamic constants of the rubber crawler increased with the preload of the track

Fig. 4 The specifications of the sample rubber crawler

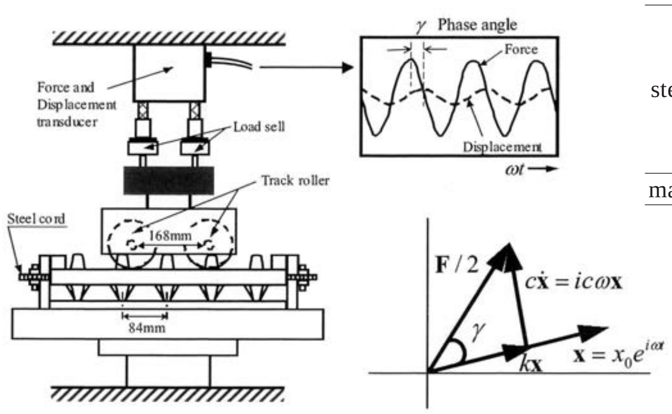


Table 1 The specifications of the sample rubber crawler

steel cord	number	44	rubber hardness degrees, °	lug side	60 + 5
	material	SWRH		track roller side	60 + 5
	tensile strength (N/cord)	1,530	lug pitch, mm		84
			width of crawler,mm		300
material of core bar		FCD600	height of lug, mm		33

roller. Hence, the dynamic interactive relationships between the track roller and the rubber crawler exhibited hardening nonlinearity. Further, the dynamic spring constants of the rubber crawler increased, as the frequencies were higher.

Simulation

Fig. 6 shows a dynamic model of an agricultural rubber crawler vehicle equipped with the movable track rollers based on the non-linear interaction between the track roller and rubber crawler. Here, z, ψ and $ø$ are the bounce, the roll angle and pitch angle of the vehicle, respectively, and φ_L, φ_R are the rotational angles of the left and right movable assemblies with respect to the vehicle frame. It is assumed that ψ, and $ø$, φ_L, φ_R are infinitesimal in this study. Thus, the equations of motion for the vehicle body based, which has the movable track rollers shown in **Fig. 6** are obtained as follows:

$$M\ddot{z} + F_{L1}(Z_{L1}) + F_{L2}(Z_{L2}) + F_{L34}(Z_{L3}) + F_{L34}(Z_{L4}) + F_{R1}(Z_{R1}) + F_{R2}(Z_{R2}) + F_{R3}(Z_{R3}) + F_{R4}(Z_{R4}) = Mg \quad (6)$$

$$I_y\ddot{ø} + l_1\{F_{L1}(Z_{L1}) + F_{R1}(Z_{R1})\} + l_e(F_{Le} + F_{Re}) + l_4\{F_{L4}(Z_{L4}) + F_{R4}(Z_{R4})\} = 0 \quad (7)$$

$$I_x\ddot{\psi} + L_L\{F_{L1}(Z_{L1}) + F_{Le} + F_{L4}(Z_{L1})\} - L_R\{F_{R1}(Z_{R1}) + F_{Re} + F_{R4}(Z_{R1})\} = 0 \quad (8)$$

The equations of motion for rotational motion of the left and right movable track rollers are obtained as follows:

$$le\ddot{\varphi}_L - mgaHe\varphi_L - F_{L2}(L - He\varphi_L) + F_{L3}(L + He\varphi_L) = 0 \quad (9)$$

$$le\ddot{\varphi}_R - mgaHe\varphi_R - F_{R2}(L - He\varphi_R) + F_{R3}(L + He\varphi_R) = 0 \quad (10)$$

Comparision of Numerical Analysis and the Experimental Results

Driving Experiment

Driving tests were performed using an agricultural rubber crawler vehicle equipped with movable track rollers. The experimental system comprised a two-row-type head-feeding combine harvester removed cutting and threshing sections. The driving section comprised eight track rollers with a diameter of 120 mm in diameter and a rubber crawler with a 300 mm in width; the lug pitch (i.e., the interval between two lugs) was 84 mm and a triangular lug pattern was used. The horizontal distance between the centers of the first and fourth track rollers was 630 mm. The first and fourth track rollers were fixed on the track frame. On the other hand, the second and third track rollers were movable; they were symmetric at the rotating support point. Twelve accelerometers were attached to a box based on the method for measuring the acceleration for six degrees of freedom. This box was attached at the end of the main body in order to measure

Fig. 6 Dynamic model of an agricultural rubber crawler vehicle equipped with movable track rollers driving on a rigid horizontal surface

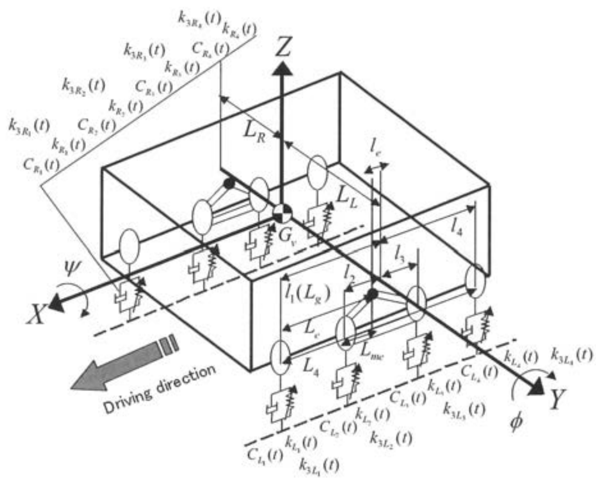
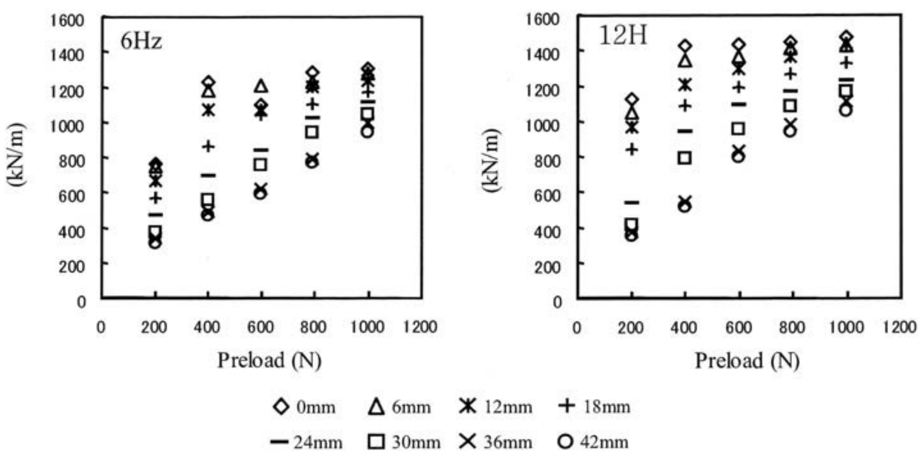


Fig. 5 The dynamic spring constants and viscous danping coeffficients of the rubber crawler



the translational and rotational accelerations of the machine.

Comparison

Fig. 7 shows the measured and simulated bounce and pitch acceleration time series of the vehicle based on nonlinear and conventional linear interaction. From the figures, results of simulation, based on the non-linear interaction of the track roller and rubber crawler, shows better agreement with experimental results than those of simulation, based on the conventional linear interaction. However, the simulated values are small compared with the measurements. This discrepancy can be attributed to the variation of the tension of a rubber crawler caused by passing an overlapping part of a rubber crawler, the stiffness of which is larger than the other parts, through a sprocket, an idler. In this analysis, the dynamic model is not taken into account the effect of the variation of the tension of a rubber crawler.

Conclusion

In this paper, the static and dynamic interactions between a track roller and a rubber crawler were investigated. The dynamic spring constants and the viscous damping coefficients of the rubber crawler were measured by using the dynamic viscoelastic measuring system with a varying range of frequency and preload. As a result, The relationships between the vertical load forces acting on the track rollers and the vertical displacements of the rubber crawler were approximately linear near the lug (core bar), whereas the relationships were nonlinear at the middle portion between the two lugs. The nonlinearity indicated by the hardening spring property could be represented by cubic nonlinearity. Furthermore, It was indicated that the simulation based on the nonlinear interaction of the track roller and rubber crawler shows better agreement with experimental results than those of simulation, based on the conventional linear interaction.

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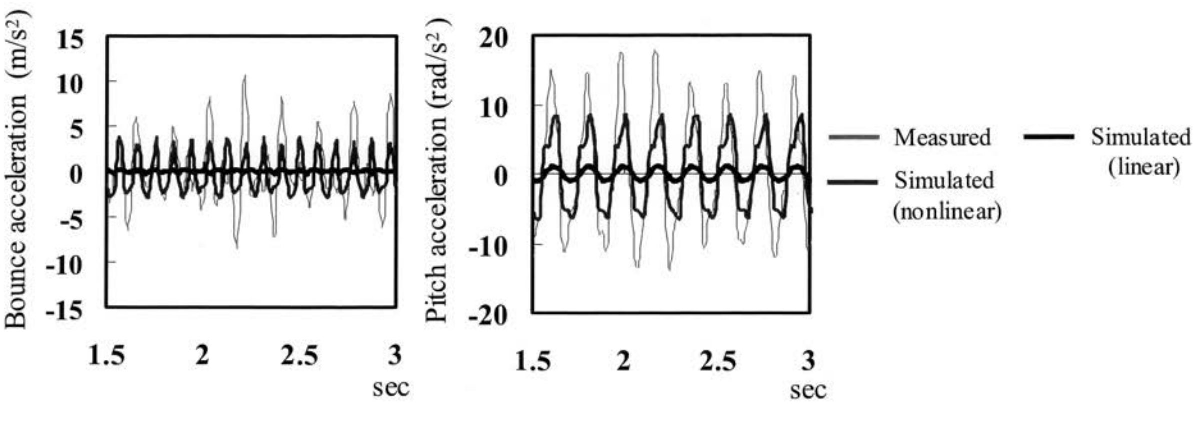
Fig. 7 Comparison between the experimental and the simulated bounce and pitch acceleration time series



Main Production of Agricultural Machinery Manufactures in Japan

by
Shin-Norinsha Co., Ltd.
2-7-22, Kanda Nishikicho, Chiyoda-ku, Tokyo, 101-0054 JAPAN

Introduced here are the main products of agri cultural machinery manufactures in Japan with a number of photographs. The products are developed and improved for both foreign and domestic makers. For further information please refer to the manufacturers listed in the directory.

ALPSKEIKI
Battery Tester ***"SP1250BT"***
Applying "Kinetic Inward Resistance System" (patent), which estimates the ohmic value by looking at the displacement of current and tension in the battery while charging and discharging. ■L145×W280×H70mm ●800g

CANYCOM
Bush Cutter ***"F1 Masao"***
Outstanding ability to turn in a small radius (minimum radius of 1.8m). 75 degrees of front wheel steering angle. ▲22hp □Running speed: 14km/h when moving, 8km/h when working. □Cutting height adjusting lever with 21 levels. □Working Width: 975mm

ISEKI
Sub-Compact Tractor ***"TXG237"***
Easy to jack up by applying full-open bonnet. A full flat floor with expanded floor space. HST with two pedals. Perfect lever alignment for efficient operation. ▲23 hp

ARIMITSU
Knapsack Power Duster **"SG-7030"**
Light-weight. But produces bigger air volume due to high performance turbofan. Driven by the powerful 59.2cc gasoline engine. ■L363×W520×H740mm ▲3.7ps/ 7,500rpm ●10.7kg □Chemical tank: 28L.

I-MEC
Multi Excavator Lorder ***"MEL30"***
■L2,540×W1,600×H2,550mm (when transporting) ▲27hp ●2,940kg □Running Speed: 7.5km/h (Max.) □Backhoe: Standard Bucket Content: 0.09m³ □Loader: Bucket Content: 0.4m³

ISEKI
Tractor ***"TJV95"***
High output and torque engine of 95 hp equipped. Common rail type electronic fuel injection system applied. This tractor computerizes the fuel injection, and the user is able to choose from two types of engine output patterns "Output Priority Mode" and "Fuel Consumption Priority Mode".

■: Dimensions ●: Weight ▲: Engine

ISEKI
*Rice Transplanter **"PZ60-HGRTE18"***
The transplanting part can automatically rise, and rotate with no brake. “Rotating Seedling Case” and “Big Deck” are equipped, and it can handle winding plants seen in many Chinese markets. ▲16hp □Row: 6

KAWABE
*Trencher for Multi-Crops **"NF-843"***
By forward movement you can plow to replace surface soil with subsoil. ■L2,150×W800×H1,090mm ●297kg □Water-cooled Diesel 8ps □Tire: 4.00×8AG □4 wheel driving vehicle with same Dia. tires. □Self propelled

KUBOTA
*Tractor **"L4708"***
L4708, is a high perforamnced L-series tractor which can be operated in both paddy and dry field with high horse power and column shuttle specification. ▲47ps

KAAZ
Backpack Brush Cutter
"VRS400(S)-TB43"
KAAZ has manufactured brush cutters over 40 years. Our concept is "Made in Japan". ■Shaft: 26mm, Length of main pipe section: 1,500mm ●10.6kg ▲2-stroke □Displacement: 42.7cc ■Fuel tank: 0.9L

KOSHIN
"Hidels Pumps SEV-80X"
PUMP □Connection: 80mm □Total Head: 25m □Delivery Volume: 1,050L/min □Max. Suction Head: 8m
ENGINE ▲3.1kW/3,600rpm, 179cc ●7.7kg

KUBOTA
*Tractor **"M9540"***
M9540 is a high performanced M-series tractor which can be operated in dry field including land preparation with high mobility and low fuel consumption. ▲95ps

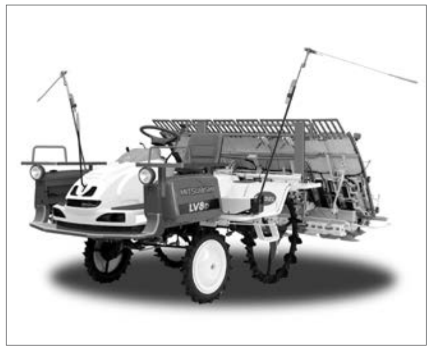
KARUI
*Chipper **"DraCom KDC-131B"***
Grind the branches in parks, bamboo woods, and fruit farms into useful woodchips and decrease the volume at the same time. ■L1,800×W770×H1,250 mm ●415kg □Power: 9.6kW □Max. branch: ø120mm □Processing Capacity: 800-1,300kg/h

KOWA
*Chipper **"Green Shredder P-550"***
Best for saving the environment. Spiral blade enables efficient cutting with less sound. ■L1,080×W695×H1,050mm ●98kg ▲4.9PS/2,000rpm □Max. branch: ø40mm □Processing Capacity: 4m^3/h

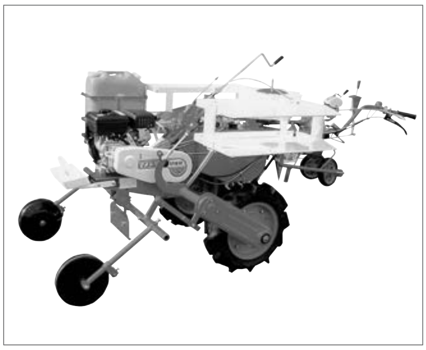
KUBOTA
*Combine **"DC-68G"***
Compact body & High-performance fulfills rigid professional demands. DC-68G Combine offers superb performance, outstanding durability, and ease of servicing.

KUCHOFUKU
"Air Conditioning Clothing"
Out-of-door work clothing with air conditioning fan inside. The two fans set on both sides of the waist gets fresh air into the clothing. By evaporating the sweat, vaporization heat would cool down the body and makes agricultural work a comfort one.

MARUYAMA
Boom Sprayer ***"BSA650LDE"***
For crop management in rice paddy and field cultivation. ■L3,940×W2,150×H2,400/800mm (effective ground height) ●1,145kg ▲15.4kW, 1,123cc □Discharge Rate: 100L/min □Working Width: 9.9-15.9m



MITSUBISHI
Rice Trans-Planter ***"LV8D"***
■L3,340×W2,220×H1,540mm □Ground height: 460mm ●855kg ▲Water cooled 4-cycle, 3-cylinder diesel. 22.6ps, 760cc □HST □Rotary type □Rows: 8 □Width of stub: 16/18/21cm



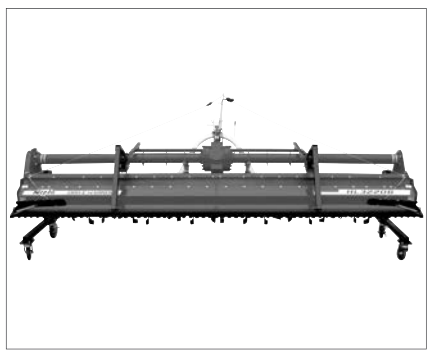
MAMETORA
Vegetable Transplanter ***"TP-4"***
This machine is available both pot and soil block in seeding transplanting. ■L217×W122×H106-130cm ●170kg ▲4.4ps/2,000rpm, 126cc □Speed: 0.2-0.4m/s □Efficiency: 10a/1.5-2.0h □Rows: 1

MITSUBISHI
Combine ***"TVR106A"***
■L4,830×W2,198×H2,480mm ●3,980kg ▲105ps/2,600rpm, 3,769cc □6 rows □Crawler: W500×Ground L1,715mm □Shift Transmission System: HST □Shifting Levels: 3 □Working Width: 1,980-2,030mm

NEWDELTA
Blower ***"NDBL 6500V"***
High-power engine blower. The original blow-integrated fan case is supported by various users. ■ L355×W457×H457mm ●10.8kg ▲64.7cc □Fuel Tank: 2L □Rotating Speed: 6,500rpm □Air Volume: 15.0m^3/min

MARUNAKA
Brush Cutter ***"F-5VD/TH43"***
■L1,610×W620×H330mm ●3.9kg ▲2 stroke 2.7ps, 43.2cc □Drive Shaft Housing: ø28×1,453 mm □Drive shaft: ø8×1,493mm □Handle: ø19mm wide handle □Fuel Tank: 1L

MITSUBISHI
Tractor ***"MT28"***
Cover all aspects of Ground and Lawn care ■W1,400×L3,190×H2,385mm ●1,170kg ▲Water-cooled 4-cycle, diesel 28ps/2,600 rpm, 1,318cc □Transmission □Speed change: 8F-8R □Rear PTO rpm: 540/1,000 □Tires: F7-16 R11.2-24 □Wheelbase: 1,716mm □Ground clearance: 330mm

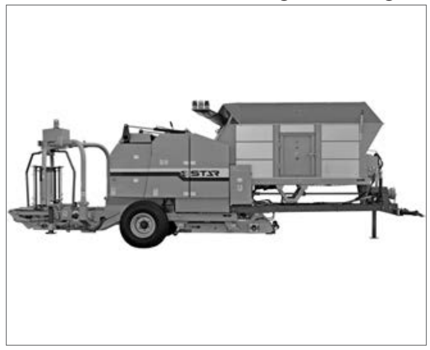


NIPLO
Disk Harrow ***"HL4020B"***
High durability guaranteed by the double frame structure. Large spring-brake ploughs in the straws and residual stems beautifully. ■ L850×W4,150×H1,395mm ●575kg ▲70-100ps □Working Width: 391cm □Side drive

■: Dimensions ●:Weight ▲: Engine

OCHIAI
Riding Type Tea Picking Mashine
"OHC-6A"
Full working width cutter bar. Stepless speed control. ▲Water-cooled Diesel engine 28.4ps.

SHIBAURA
*Riding-type Slope Mower **"SG280A"***
One of the best-in-class output engine loaded (meets emission control standards) ■L2,495×W1,590×H1,200 /140mm (Min. Ground) ●770kg ▲20.6kW/2,500rpm, 1,496cc □HST □Working Width: 1,524×H34-110mm



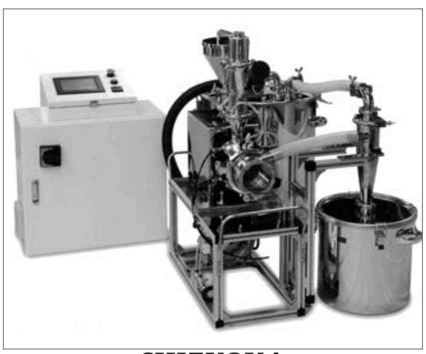
STAR
Storability of Round Baler/Wrapper
"TSW2020"
Combined machine of chopping role baler and bale wrapper, co-developed by BRAIN and Star. ■L870×W235×H270mm ●3,920kg □Hopper: 4.5m^3 □Wrapping Size: 100×100cm □Suitable Tractors: 37-73.5kW

OREC
Dehedral Levee Bush Cutter
"Wing Mower WM624A"
■L1,785×W830×H940mm ●61kg ▲4.3 hp □Handle load: 9kg □Speed change: F2, R1 □Driving wheels: F □Working Width: 600×H10-70mm (left roter adjustable in 4 levels) □4 bar knives

SHIBAURA
*Reel Mower **"SR525A-S"***
Lightweight Quintupulex. One of the best-in-class lightweight and full fledged, compact and underslung machine. ■L2,700×W2,900×H2,040mm ●1,320kg ▲27.9kW/2,850rpm, 1,662cc □HST □Working Width: 2,500mm

SUKIGARA
*ABLE Potato Planter **"TAP-110M"***
Planting, ridging, ground cover laying in one operation.

SATAKE
*Mill **"SRG30A"***
Rice Powder Food Responded Flouring Machine. Able to flour from small amount. ■W1,950×D1,000×H2,896mm □Processing Ability: 30 kg/h □Required power: 3-phase 200V 8.55 kW



SHIZUOKA
*Mill **"SM150"***
Rice Powder Responded Flouring Machine. Finishes up in a fine powder form by swirling airflow crush system. ■L1,010×W830×H700mm ●140kg □Processing Ability: 1-15 kg □Crushing Grain Size: 10-100μm

SUKIGARA
Three-Tine Light Cultivator
■Length: 51cm ●8.5kg □Cultivator width: 18-30cm

■: Dimensions ●:Weight ▲: Engine

SUZUTEC
Seeder for Box Nursery ***"THK2008"***
Full automatic seeding. You can just dial and control the seeding amount by the gram weights. Aluminium rails used to attain lighter bodies.

TOHNICHI
Torque Wrench ***"QL"***
The first click-type torque wrench made in Japan, 1956. A global standard structure of tightening a bolt. An alarm tells you the finish of tightening when it reaches the torque you've configured.

YAMAMOTO
Vertical Rice Milling Machine
The rice milled by of the vertical rice milling machine evolves further.
XP-4000 ■W1,315×L2,282×H2,282mm ●2,000kg □Required power: 58.2kW □Max capacity: 4.0t/h

DIRECTORY

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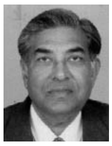
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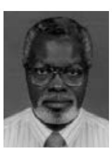
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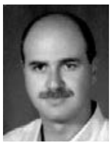
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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

(Vol.40, No.2, Spring, 2009-)

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