International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.47, No.1, WINTER 2016

A M A - AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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FARM MACHINERY INDUSTRIAL RESEARCH CORP.

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Edited by

YOSHISUKE KISHIDA

Published quarterly by

Farm Machinery Industrial Research Corp.

in cooperation with

The Shin-Norinsha Co., Ltd.

and

The International Farm Mechanization Research Service

TOKYO

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This is the 166th issue since its maiden issue in the Spring of 1971

EDITORIAL

To all readers, Best Wishes for New Year 2016.

Time flies. It has already passed 16 years since we entered in 21st century.

The world population exceeded 7.2 billion and keeps increasing more. It would not be far ahead when it reaches 9 billion. Some people predict that it will reach 9.6 to 10 billion in 2050. However food production for us human beings must be done in a very limited farm space. That means we have to enhance agricultural land productivity. For that there are important elements like breeding, farming methods and irrigation, but the most important element is working properly in proper timing. And the spread of agricultural mechanization is only the way to make it possible. It is not exaggeration if you say that promotion of agricultural mechanization is the most important subject for intensifying food production for feeding increased population.

However at present in many countries, especially in advanced countries, the keyword "agriculture" or "agricultural machinery" is getting difficult to find. This phenomenon is obvious in universities. In Japan, students who major in agricultural machinery are decreasing and teachers who teach agricultural machinery are beginning to dwindle.

I think we have to start a campaign for informing the importance of agricultural machinery widely to the world and strengthening the social recognition about research, development, education and cultivation of human resources in the field of agricultural machinery.

Development of agricultural machinery industry for agricultural mechanization is very important and it is really good news that agricultural mechanization has steadily been promoted in the countries which have large population like China and India. Agricultural machinery industry of these two countries has a very important role in Asian region which has a high percentage of the world's population.

Research, development and spread of agricultural robots such as Artificial intelligence (AI) and drone will be promoted toward the future. It means new technologies will be producing new agricultural systems.

Let's keep cooperating together with everybody for the development of agricultural mechanization in the world.

Yoshisuke Kishida
Chief Editor

February, 2016

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol.47, No.1, Winter 2016

Design and Development of Reciprocating Type Cumin Cleaner Cum Grader

by

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Abstract

India is famous for its pet name in the world of agriculture as the 'Home of Spices'. India grows 47 out of 70 varieties of spices that are grown in different parts of the world. The major marketing cities for cumin seeds are Unjha, Palanpur, Mahesana and Visnagar in Gujarat and Jaipur, Kisangarh and Kokri in Rajasthan. Cumin seeds as it comes from the field contain foreign matter like weed seeds, stems, leaves, broken seeds, stones, dirt, etc. These foreign matters must be removed to increase quality of seed in the market, storage period of seed, cost of selling and net income to the farmers as well as sellers and to perform different kinds of post-harvest operations.

Cleaning and grading of cumin in the marketing yard is time consuming and laborious operation because large quantity is to be handled. Some of the big traders used mechanical cleaners and graders, but the initial investment required in the purchasing of such machinery is quite high. Efforts were made to develop a low cost machine that can clean and grade the seed of cumin and can be utilized for the above operation at low investment for small farmers. Effects of different machine operating parameters on its performance i.e. feed rate, speed and screen slope were evaluated for cleaning efficiency and power consumption. For getting best cleaning efficiency and low power consumption, the machine should be operated at 50 kg/h feed rate, 150 rpm and 7-degree slope.

Key words: Spices, Cumin, Cleaner cum Grader, Processing, cleaning efficiency

Introduction

India is one of the major spices producing and exporting countries of the world. Cumin is mainly grown in India in the states of Rajasthan and Gujarat. In India, during the year 1998-99, the area under cumin cultivation was about 263,900 ha and producing 67,300 M.T. cumin seeds. In Gujarat, the production of cumin about 61,300 M.T. over an area of 145,100 ha with an average yields of 423 kg/ha during the year 2001-2002. An estimate shows that the cumin seeds received at the marketing yard from the field contain average 20-25 % impurities. These impurities must be removed to increase quality of seed in the market, storage period of grain, cost of selling and net income to the farmers as well as sellers and to perform different kinds of post- harvest operations.

Cleaning and grading of cumin in the marketing yard is very intensive operation. It is also very laborious and time consuming because large quantity is to be handled. Presently, in the marketing yard a single blower followed by screening through an inclined sieve is the system prevailing for the cleaning of cumin seed, which is quite inefficient and labor intensive. Some of the big traders also use mechanical cleaners and graders. The capacity of such machinery is quite high and the initial investment required in the purchasing of such machinery is also more. Thus, a low cost machine that clean and grade the seed of cumin and can be utilized for the above operation at low investment. It is expected that the outcome of the research work would be directly useful to the farmers and small traders. By introducing cleaner at farmer's level the margin of profit to the farmer's will be more as it would avoid further grading at disposal point.

Some research on cleaner cum grader of different seeds has been done. Saurabh (1990) developed a cleaner-cum-grader suitable for spices like cumin seeds, funnel seeds, etc. having vibratory screen. Kachru *et al.* (1990) tested a medium capacity pedal-cum-power-operated grain cleaner for various seeds. Hall (1991) measured the cleaner response for different parameters. Vishvanathan *et al.* (1994) developed a rotary sieve type cleaner-cum-grader suitable for small size impurities. Srivastava, (1996) developed a mechanical rotary double screen cleaner-cum-grader suitable for cumin seed to reduce the drudgery of manual cleaning.

Materials & Methods

Design Components of Cleaner Cum Grader

Feed Hopper

A prismoidal shape hopper to hold the cumin seeds up to 15-kg was designed. It was expected that the operator would periodically feed cumin seed to the hopper. The capacity of the developed cleaner cum grader was decided about 100 kg/h. As the average bulk density of the cumin seeds at 7.00 % moisture content is about 450 kg/m^3, the volume of the hopper would be 0.00333 m^3. A sliding type feeding arrangement was provided at the bottom the hopper.

Sieve Box

The schematic diagram of the developed cumin cleaner cum grader is shown in **Fig. 1**. The design of the sieve box was based on the time taken by the cumin seeds to move from hopper to discharge end. Volume of cumin seeds remain present on the screen in 1 minutes is 0.0037 m^3. The surface area required for sieve is calculated by the equation:

F_s = *(Amount of material required to the sieve box per unit time) / (Specific load of the sieve) =* q' / q_s

Where,

q' = amount of material required to the sieve box per unit time (kg/s), 100 kg/h = 0.027 kg/s

q_s = Specific load of the sieve (kg/s per m^2 of surface) = Amount of material required to the sieve box / Total area of the sieve box

Blower

Blower was designed on the basis of the aerodynamic properties of the cumin seed. The terminal velocity of the chaff was taken as 4 to 5 m/s. The specific speed and pressure coefficient of the blower are calculated by the equation:

Specific speed, $N_s = (N \times Q^{1/2}) / p_s^{0.75}$

Where,

N: rpm of the motor,

Q: air flow rate,

p_s: taking static pressure

Pressure coefficient, $\Psi = (2.35 \times 10^8 \times p_s) / N^2 \times D^2$

Where,

D: diameter of the impeller, inch

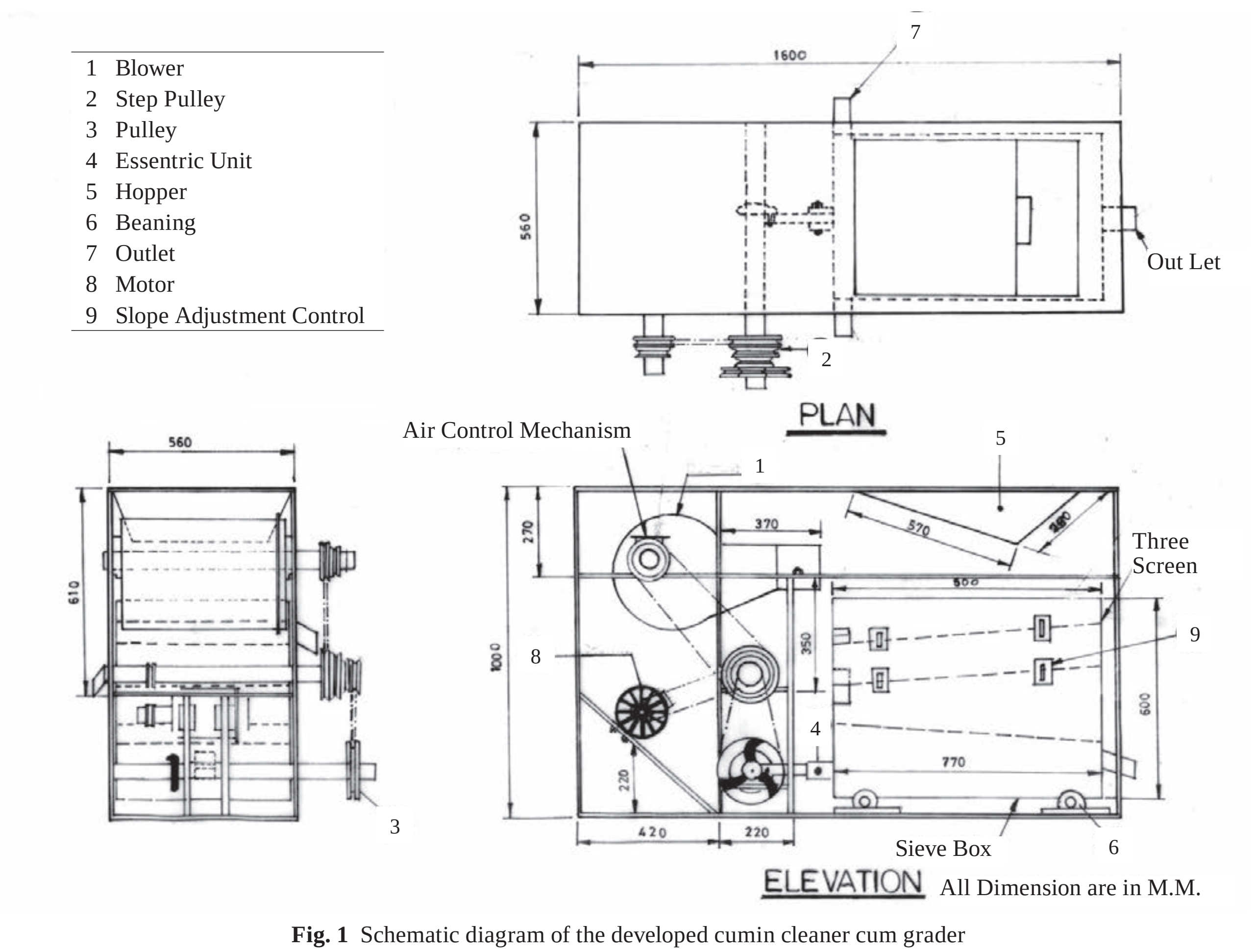

Fig. 1 Schematic diagram of the developed cumin cleaner cum grader

Power Transmission and Drive

A 1 hp, 1440 rpm single phase electrical motor was used as prime mover for the cleaner. The size of the motor was decided after preliminary functional requirements of the operations at rated capacity. For power transmission, a speed reduction ratio of 14 : 1 was considered from motor to sieve box through V-belt pulley drive arrangement. The required minimum and maximum speed for the sieve box would be 100 to 200 rpm. To evaluate the effects of the speed of the sieve box on the performance of the machine, pulleys of different sizes were used.

Construction and Operation

The machine consists of feed hopper, sieve box, blower and power transmission and drive (**Fig. 2**). A prismoidal shape hopper with 700 × 450 × 220 mm was fabricated. A sliding gate was provided at the bottom of the feed hopper.

A rectangular shaped sieve box of 800 mm length, 600 mm width and 450 mm height was fabricated. Three Galvanized iron screens having mesh openings of 25 mm round hole, 15 mm round hole and 0.49 mm wire mesh were selected for getting 3 grades of cumin. A slope adjustment screw in the sieve box is provided to adjust the slope of all the screens. The diameter of blower casing was 250 mm. The diameter of the impeller was 230 mm. The four blades were welded together at 90-degree to each other on 20 mm diameter shaft.

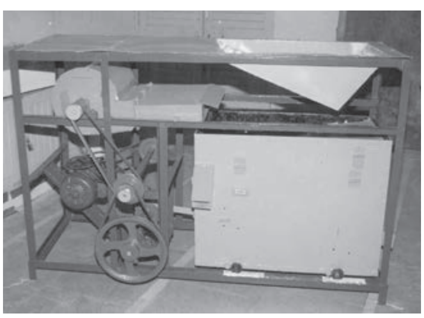

Fig. 2 Developed cumin cleaner cum grader

For power transmission, a speed reduction ratio of 14 : 1 was considered from motor to sieve box through V-belt pulley drive arrangement. Step pulleys of different sizes were mounted on 25 mm diameter shaft to transmit power from motor to the blower and eccentric unit with the help of V-belts pulleys arrangement.

A Gujarat Cumin (GC)$^{-1}$ variety of cumin seeds were used for the experiment. The cleaning efficiency of the machine was evaluated at 7.0 % moisture content (d.b.), feed rates (25, 50, 75 and 100 kg/h), screen speed (100, 150 and 200 rpm) and screen slope (0, 4 and 7 degree). The cleaning efficiency of the machine was determined by the using the following equation:

$$E = (mf - mu)\,(mo - mf)\,mo\,(1 - mu) / (mo - mu)^2\,(1 - mf)\,mf$$

Where,

E: effectiveness of the screen

mf: mass fraction of material in feed

mo: mass fraction of material in

Table 1 Effect of feed rates and speed on cleaning efficiency
Variety: GC-1, Moisture content (d. b.): 7.05 %

Speed, rpm	Cleaning efficiency at various feed rate, kg/h				
	25	50	75	100	Mean
100	66.82	70.60	67.73	64.59	67.43
150	71.94	75.40	72.92	68.87	72.28
200	70.31	72.84	71.18	68.48	70.70
Mean	69.69	72.94	70.61	67.31	70.13

SOURCE	S.E.M.	C.D. AT 5 %
Feed rate	0.3312	0.9349
Speed	0.2868	0.8096
Feed rate and speed	0.5736	NS

Table 2 Effect of feed rates and screen slope on cleaning efficiency
Variety: GC-1, Moisture content (d. b.): 7.05 %

Screen slope, degree	Cleaning efficiency at various feed rate, kg/h				
	25	50	75	100	Mean
0	64.01	67.55	64.40	59.57	63.88
4	69.95	73.07	71.00	67.85	70.46
7	75.12	78.23	76.43	74.53	76.07
Mean	69.69	72.95	70.61	67.31	70.14

SOURCE	S.E.M.	C.D. AT 5 %
Feed rate	0.3312	0.9349
Screen slope	0.2868	0.8096
Feed rate and screen slope	0.5736	1.619

Table 3 Effect of speed and screen slope on cleaning efficiency
Variety: GC-1, Moisture content (d. b.): 7.05 %

Screen slope, degree	Cleaning efficiency at various feed rate, kg/h			
	100	150	200	Mean
0	61.30	64.34	66.01	63.88
4	68.03	72.22	71.15	70.46
7	72.98	80.28	74.96	76.07
Mean	67.43	72.28	70.70	70.13

SOURCE	S.E.M.	C.D. AT 5 %
Speed	0.2868	0.8096
Screen slope	0.2868	0.8096
Speed and screen slope	0.4968	1.4049

overflow

mu: mass fraction of material in underflow

The specific power consumed by the machine was computed using the following equation:

Specific power consumed = $\{(f - i) \times 3600\} / (t \times F \times E)$

Where,

P: the power consumption, Kwh/kg

f: final energy meter reading, kw

i: initial energy meter reading, kw

t: time for cleaning the sample, sec

F: feed rate, kg/h

E: cleaning efficiency

Results and Discussion

Performance Evaluation of Cumin Cleaner Cum Grader

The developed cumin cleaner cum grader was tested for its performance at 4 feed rates, 3 slopes and 1 moisture content. The cumin cleaner cum grader was operated at different speeds of 100, 150 and 200 rpm. The test data were analyzed by using Analysis of variance techniques to determine cleaning efficiency or screen effectiveness at various operating parameters and their interactions. These are presented in **Tables 1** to **3**.

Effect of Feed Rates and Speeds on Cleaning Efficiency

The cleaning efficiency of cumin cleaner cum grader may be affected by moisture content, feed rate, speed, slope bed density, particle size & shape. The results of cleaning efficiency of cumin cleaner cum grader at various feed rates and speeds are given in **Table 1** and shown graphically in **Figs. 3** and **4**, feed rates and speeds had significant effect on cleaning efficiency. However, their interaction between feed rates and speeds had non-significant effect on cleaning efficiency (**Table 1**).

The mean values of cleaning efficiency for the sample at different feed rates are presented in **Table 1** and shown graphically in **Fig. 3**. The mean values of cleaning efficiency at 25, 50, 75 and 100 kg/h feed rates are 69.69 %, 72.94 %, 70.61 % and 67.31 % respectively. From the Figure, it is clear that as the feed rate increases from 25 to 50 kg/h the cleaning efficiency also increases and decreases with further increase in feed rates. The maximum cleaning efficiency was found at 50 kg/h feed rate i.e. 75.40 %, whereas the minimum cleaning efficiency was found at 100 kg/h i. e. 64.59 %.

The mean values of cleaning efficiency for the sample at different speeds are presented in **Table 1** and shown graphically in **Fig. 4**. The maximum cleaning efficiency 75.40 % was found at 150 rpm whereas the minimum cleaning efficiency 64.59 % at 100 rpm.

The lower cleaning efficiency at higher speed may be due to the reason that all the cumin seeds are not getting sufficient time on the screen and also cumin seeds may be overflowing over the screens and not passing through the holes of the screen. The individual effect of feed rate and speed found to be significant at 5 % level of significant but their interaction found to be non-significant at 5 % level of significant. The following multiple regression equations of the second order were developed by taking cleaning efficiency as a function of feed rates and speeds.

Cleaning efficiency of cumin cleaner cum grader = f [feed rates, FR and speed, S]

$$Y = 67.60 - 3.78 \times 10^{-2} (FR) + 3.27 \times 10^{-2} (S) \quad (1)$$

R^2 = 0.027 and Non-significant,

Where,

R = Coefficient of correlation

Effect of Feed Rates and Screen Slope on Cleaning Efficiency

The results of the cleaning efficiency at various feed rates and slopes are given in **Table 2** and shown graphically in **Figs. 5** and **6**. For the feed rates the similar results

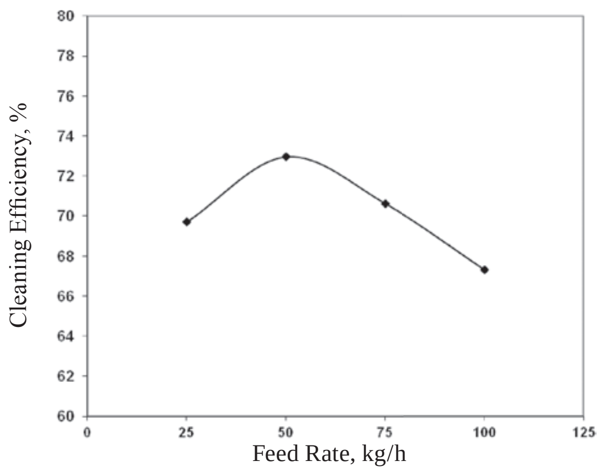

Fig. 3 Effect of Feed Rate on Cleaning Efficiency

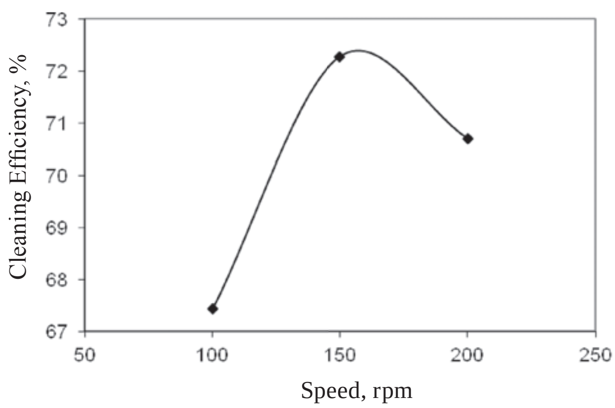

Fig. 4 Effect of Speed on Cleaning Efficiency

has been obtained (**Fig. 5**).

The mean values of cleaning efficiency at 0, 4 and 7-degree slopes were 63.88 %, 70.46 % and 76.07 % respectively (**Table 2**). It is clear from the **Fig. 6** that, as the slope increases the cleaning efficiency increases. The maximum cleaning efficiency 78.23 % was found at 7-degree screen slope and the minimum cleaning efficiency 59.57 % at 0-degree screen slope. The cleaning efficiency at higher slope may be due to the reason that, at higher slope, cumin seeds slides easily over the screen and passes through the holes which ultimately results in better cleaning efficiency.

The individual effect of feed rate and slope was found to be significant and their interaction was also found to be significant at 5 % level of significant. The slope is observed as most effective parameter, which influence the cleaning efficiency. The following multiple regression equation of the second order was developed by taking cleaning efficiency as a function of feed rates (FR) and slopes (SS).

Cleaning efficiency of cumin cleaner cum grader = f (feed rates, FR and slopes, SS)

$Y = 66.14 - 3.78 \times 10^{-2} (FR) + 1.74 (SS)$ ....(2)

R^2 = 0.720 and Significant at 5% level,

Where,

R = Coefficient of correlation

Effect of Speed and Screen Slope on Cleaning Efficiency

Table 3 gives the cleaning efficiency of cumin cleaner cum grader at various speeds and slopes. For the speeds and slopes, the similar results have been obtained as described earlier and shown graphically in **Figs. 7** and **8**.

The individual effect of speed and slope was found to be significant and their interaction was also found to be significant at 5 % level of significant. The speed and slope is observed as most effective parameter, which influence the cleaning efficiency.

The following multiple regression equations of the second order were developed by taking cleaning efficiency as a function of speeds and slopes.

Cleaning efficiency of cumin cleaner cum grader = f (speeds, S and slopes, SS)

$Y = 58.87 + 3.27 \times 10^{-2} (S) + 1.74 (SS)$ ....(3)

$R^2 = 1$ and Significant at 5 % level,

Where,

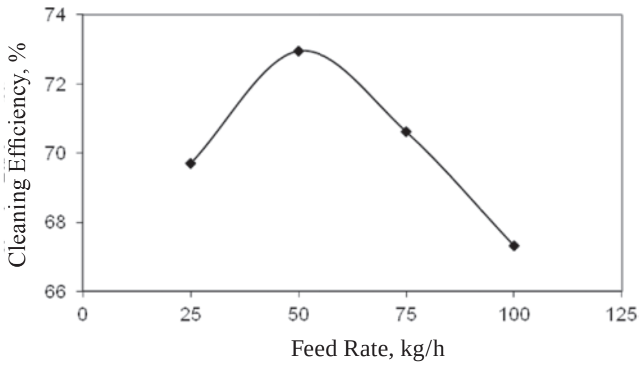

Fig. 5 Effect of Feed Rate on Cleaning Efficiency

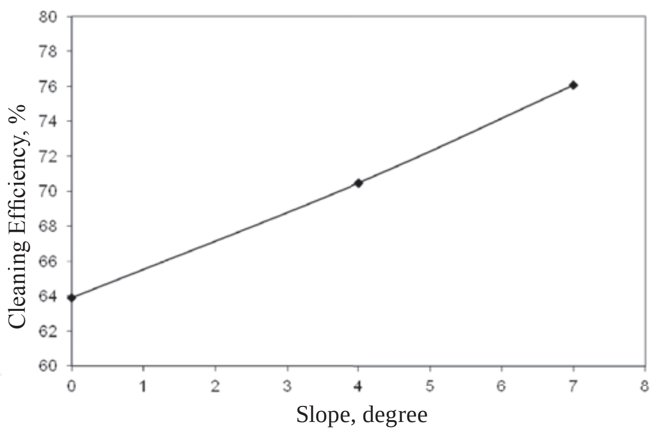

Fig. 6 Effect of Slope on Cleaning Efficiency

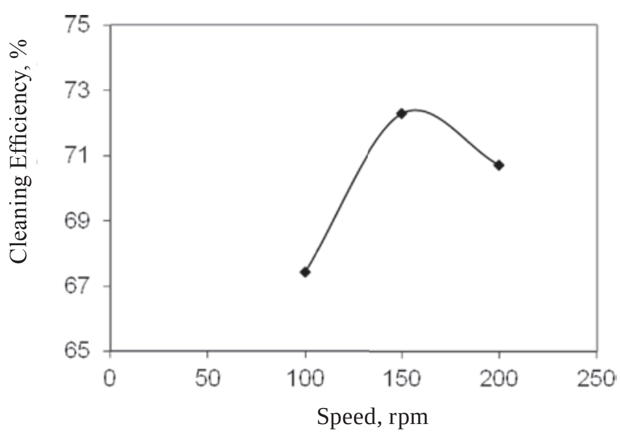

Fig. 7 Effect of Speed on Cleaning Efficiency

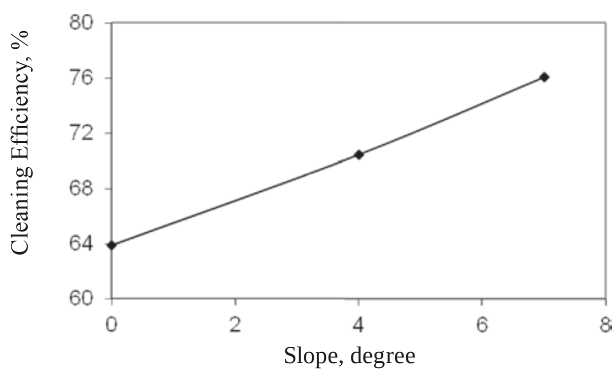

Fig. 8 Effect of Slope on Cleaning Efficiency

Table 4 Computation of Cost of Cleaning

Particulars	Cost (Rp/hr)
Depreciation cost per hour	2.34
Interest @ 13 % on initial cost of machine	1.86
Cost of housing per hour	0.26
A. Fixed Cost	4.46
Cost of repair and maintenance of machine	0.78
Operator's wages per hour	7.50
Electric charges per hour	2.63
B. Variable cost	10.91
C. Total cost (A + B)	15.37
Cost of cleaning	0.31

R = Coefficient of correlation

Cost of Operation of Cumin Seed

The cost of operation of the developed cumin cleaner cum grader was calculated by considering the full utilization of the machine for custom hire basis for entire season, no running capital investment has been proposed. Including the cost of machine as capital investment, the fixed cost per hour for the operation of the cleaner cum grader is the sum of depreciation, interest, etc. become Rp. 4.46, while the total variable cost including repair and maintenance, labor charges, electricity, etc was Rp. 10.91. The total cost for operating the machine for one hour was Rp. 15.37. Cost of cleaning of developed cumin cleaner cum grader per kg came to about Rp. 0.31 (**Table 4**). The cost of the developed cumin cleaner cum grader is Rp. 13,000/-.

Conclusions

The medium capacity cumin cleaner cum grader was designed and developed as described earlier was found to be suitable for cleaning and grading of cumin seeds at farm level. The developed machine classified the seeds into two grades namely, cleaned seeds and partially cleaned seeds. For obtaining the higher efficiency, the developed cumin cleaner cum grader should be operated at lower feed rate, higher slope and medium speed. Based on the results of cleaning efficiency of the developed cumin cleaner cum grader and the powder consumption, it may be recommended that a 50 kg/h feed rate, 150 rpm and 7-degree slope is the optimum condition for cleaning in the developed cumin cleaner cum grader. The cost of the cleaning is Rp 0.31/- per kg.

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Effect of Three Honeycomb Interplant Distances on Growth and Flowering of Two Cultivars of Bean

by
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Abstract

A factorial experiment (2 × 3) in randomized complete block design (RCBD) with three replications was conducted to examine the effect of honeycomb selection method using three interplant distances on the vegetative growth, flowering, and fruit set of two cultivars of bean, Bronco and Strike. Interplant distances used were 75 × 65 cm, 90 × 78 cm, and 105 × 91 cm (row x plant) represent short (high plant density), intermediate (intermediate plant density), and wide (low plant density) distance, respectively. Parameters used for selection were number of days from planting to the initiation of first flower, number of nodes formed prior to the onset of first flower, and number of main branches. Results showed significant superiority of the Strike cultivar in term of growth rate per plant represented in a significant increase in dry matter accumulated. At wide interplant distance, Bronco showed a significant increase in both plant height and number of branches per plant. Intermediately spaced plants showed to reduce flowering time and contribute towards early yielding which took only 47 days to flower and further 6 days for fruit set.

Key words: Competition, Interplant distances, Genotype, growth rate, Phaseolus vulgaris L

Introduction

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

Materials and Methods

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

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

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

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

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

The experiment consisted of 18 experimental units each contained approximately 50 plants grown in a 6 m length rows counted as 6, 8, and 10 rows in D_1, D_2, and D_3, respectively. Moving circle selection with 20 % selection pressure (10 plants from each experimental unit) was applied. The criteria used for selection were number of days from planting to the initiation of first flower, number of nodes formed prior to the onset of first flower, and number of main branches. From each sample, parameters of plant height (cm), number of branches, flowering time, number of nodes prior to the onset of first flower, time of fruit set, shoot dry weight (g/plant), and growth rate (g/plant/10days) were recorded. An additional experimental unit for each bean cultivar was used as control where beans are planted in its conventional way spaced 15 cm between plants and 75 cm between rows. A sample of 20 plants from each control unit was selected and all the physiological and biochemical analyses were also applied. Data were analyzed using the Duncan multiple range test at 95 % level of significance (Elsahookie and Wahib, 1990).

Results and Discussion

Results in **Table 1** exhibit significant differences between both cultivars under investigation in terms of plant height, number of branches, shoots dry weight, and number of nodes formed prior to first flower. These differences can be due to the act of genotype in the absence of competition. High values of the coefficient of variation (% CV) in Strike genotype indicate decreased uniformity within population and therefore, selection is necessary.

Vegetative Growth Characteristics

Growth is the final outcome of many physiological processes including absorption, photosynthesis, and carbon and nitrogen assimilation which plant height, branches count, and shoot dry matter are the most important indicators of growth status (Elsahookie, 2006). Data in **Table 2** show significant increase in shoot dry weight and growth rate of Strike cultivar compared to Bronco although plant height and number of branches per plant were not significantly different between the two tested cultivars. This may be due to the increase in number of leaves and leaf area or number of nodes per plant which can affect the rate of growth as shown in Strike which reached 4.10 g per plant in 10 days. Interplant distances used showed to have a significant effect on the genotypes under investigation in terms of plant height and number of branches per plant. As presented in **Table 2**, Bronco showed a significant increase in plant height and number of branches per plant when using D_3 which gave 36.33 cm and 5.73, respectively. Plant dry mass is the final result of the growth rate and the duration of growth cycle which depend on the interaction between genotype and environment during the growing season (Hamdalla, 2006). Usually, the rate of growth is slow in the early stages due to the relative small leaf area which decrease the amount of light absorbed followed by a rapid increase in growth rate when more leaves are formed and harvest sun light. The clear and significant increase in Strike's growth rate was probably the result of increased leaf area of this particular genotype which makes it more capable of harvesting sunlight and boost-up photosynthesis (Tollenaar and Aguilera, 1992).

Flowering and Fruits set Characteristics

Results in **Table 3** show no significant differences between the two cultivars in term of number of nodes on stem prior to the onset of first flower and flowering date although Bronco was the earliest in fruit set compare to Strike. Interplant distances alone had no significant effect on the number of nodes on stem prior to the onset of first flower; however, D_2 had the most positive

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

Trait / Cultivar		Plant height (cm)	No. of branches /plant	Dry weigh (gm/plant)	No. of nodes prior the onset of first flower
Bronco	$\bar{X}$	31.40	4.20	19.95	2.20
	% CV	7.54	18.78	34.55	19.16
Strike	$\bar{X}$	26.00	3.80	15.27	2.40
	% CV	16.81	24.18	34.49	21.52
Tcal. Value		**9.78	**2.96	**4.85	*2.70

effect on the earliness of flowering and fruit set which took 47 days for the plant to flower and further 6 days for fruit set. The interaction between interplant distances and genotypes used yielded a significant effect on the number of nodes on stem prior to the onset of first flower and fruit set although no significant effect was observed in term of flowering date. Nevertheless, flowering date was reduced when using intermediately spaced (D_2) Bronco cultivar due to the reduction of the number of nodes on stem prior to the onset of first flower which recorded an average of 1.8 nodes per plant compared to 2.8 nodes per plant in Strike. The number of nodes on stem prior to the onset of first flower is a valuable genetic trait that can be used as a genetic marker to distinguish between different varieties and also has an effect on the flowering time and the period to maturation. The response of both genotypes to D_2 and D_3 led to significant reduction in the number of nodes compared to the high density planting (D_1) treatment. This can be due to the lack of competition between plants which makes them more act-independent and overcome the negative effect of heterogeneity as suggested by Fasoulas (1981).

Table 2 Effect of cultivar (V_1, V_2), interplant distances (D_1, D_2, D_3), and their interaction on the traits of vegetative growth of two cultivars of beans in autumn, 2009.
Means within the same column that share the same letter are not significantly different.

Trait / Cultivar	Plant high (cm)	No. of branches/ plant	Shoot dry weight (g/plant)	Growth rate (g/plant/10days)
Bronco (V_1)	34.11a	5.24a	20.11b	1.28b
Strike (V_2)	32.49a	5.07a	26.25a	4.10a
Interplant distances				
D_1	32.93a	5.10a	20.98a	2.80a
D_2	33.73a	5.27a	24.64a	2.91a
D_3	33.23a	5.10a	23.93a	2.38a
Interaction				
V_1 D_1	32.93ab	4.80bc	17.88c	1.67b
V_1 D_2	33.07ab	5.20 ab	22.06abc	1.09b
V_1 D_3	36.33a	5.73a	20.39bc	1.10b
V_2 D_1	32.93ab	5.40ab	24.08a	3.94a
V_2 D_2	34.4a	5.33ab	27.22a	4.73a
V_2 D_3	30.13b	4.47c	27.46a	3.65a

Table 3 Effect of cultivar (V_1, V_2), interplant distances (D_1, D_2, D_3), and their interaction on flowering time and fruit set two cultivars of beans in autumn, 2009.
Means within the same column that share the same letter are not significantly different.

Trait / Cultivar	No. of nodes prior to the onset of first flower	Flowering time (day)	Fruits set time (day)
Bronco (V_1)	2.24a	48.22a	54.00b
Strike (V_2)	2.40a	48.56a	54.56a
Interplant distances			
D_1	2.37a	49.67a	55.57a
D_2	2.30a	47.00b	53.17c
D_3	2.30a	48.50ab	54.00b
Interaction			
V_1 D_1	2.40ab	49.67a	55.67a
V_1 D_2	1.80c	47.00a	53.33b
V_1 D_3	2.53ab	48.00a	53.00b
V_2 D_1	2.33b	49.67a	55.67a
V_2 D_2	2.80a	47.00a	53.00b
V_2 D_3	2.07bc	49.00a	55.00a

Conclusions

Wide and intermediate interplant distances showed to improve vegetative growth traits represented in increasing plant dry weight and reducing the flowering time and fruit set for both genotypes which significantly contributed to the early yield. Therefore, a mass selection program of beans is recommended using the honeycomb selection method with low plant density especially to improve local bean varieties that encountered a prolonged genetic depression.

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ABSTRACTS

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

1558

Computer Simulation and Kinetic Analysis of Auto-dump in Post-harvest Bulk Handling Machinery System for Onions: **Jongmin PARK,** Department of Bioindustrial Machinery Engineering, Pusan National University, KOREA; **Soonhong KWON,** same; **Sungwon CHUNG,** same; **Soongoo KWON,** same; **Wonsik CHOI,** same; **Jongsoon KIM,** same, jongsoonkim@pusan.ac.kr

Postharvest handling of onions (harvesting, cleaning, grading, cooling, storing, and transport) should be performed continuously for reducing costs and improving quality. The objective of this study was to conduct kinetic analysis and computer simulation of an auto-dump which plays an important role in the postharvest bulk handling machinery system of onions. The optimum working condition for the auto-dump was determined from the kinetic analysis. In addition, the interaction between the velocity of a hydraulic cylinder and the angular velocity of the auto-dump was analyzed in order to control the bulk handling machinery system. The acting forces and optimum operating conditions of the hydraulic cylinder were determined by analyzing forces related to the mass of inertia of the auto-dump assembly during a rotation.

■■

Test and Analyses of the Reciprocal Friction Properties between the Rapeseeds Threshing Mixture and Non-smooth Bionic Surface

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Abstract

The cleaning sieve blockage problem of rape combine harvester due to greatly increase of cleaning losses. Four non-smooth bionic surface of the cleaning sieve were designed to reduce cleaning losses. Using a UMT-2 tribometer and a ship-shaped collet, studies were conducted for the reciprocal frictional properties between a smooth sieve surface, two kinds of bionic convex dome surface, two kinds of bionic concave surface and the rape stalk, the rape pod shell. Analyses were conducted for the effects of four types of reciprocal frequencies on the frictional properties. It was found that the drag reduction ratio of the non-smooth bionic convex dome surface over the rape stalk reaches 74 % and that the drag reduction capability becomes more powerful with an increase in the reciprocal frequencies. A comparison test between the non-smooth bionic sieve surface and a conventional smooth sieve surface verified that the non-smooth bionic sieve surface can effectively solve the issues of rapeseeds threshing mixture adhesion and blockage on the sieve holes. Finally, the reasons for the drag reduction caused by the non-smooth bionic surface are discussed since these provide a basis for the design of a new type of rapeseeds cleaning sieve.

Keywords: Rapeseeds; threshing mixture; cleaning sieve; frictional force; engineering bionics.

Introduction

China has an annual planting area of 720 million hectares of rapes with average annual yields of 12 million tons of rapeseeds, which is the highest in the world. In 2009, the degree of mechanization of rapes in China accounted for only 8.2 %, which is far lower than the proportion of wheat (84 %) and rice (46 %) in China (Zong, 2009). It has been found from field experiments that the wet threshing materials often block the sieve holes (**Fig. 1**), resulting in a rapid increase of cleaning losses. After 3-4 hours of continuous operation of the combine harvester, the average thickness of the rapeseeds adhesive materials forming on the cleaning sieve surface reaches 1 cm, with portions having a thickness of over 2 cm, as shown in **Fig. 2**. Moreover, the rapeseeds adhesive materials stick firmly to the sieve surface and are difficult to clean, which creates a bottlenecking issue in mechanization of rapeseeds harvesting. It seriously restricts

Fig. 1 Blockage of the cleaning sieve holes for the rapeseeds

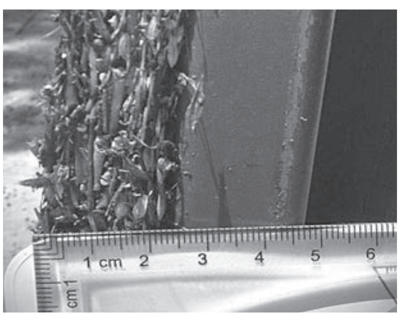

Fig. 2 The thickness of the obstructive layer on the sieve surface

the increase of rapeseeds combine harvesters and the improvement of mechanized harvesting.

The reciprocal vibration sieve has generally been used for conventional rapeseeds combine harvesters. During the cleaning processes, reciprocal friction occurs between the rapeseeds threshing mixture and the sieve surface. The frictional properties are directly related to the amount of time that the rapeseeds mixture resides on the sieves and the degree of difficulty through the sieve holes. The problem of blockage in the sieve holes is due to the issue of adhesive friction between the wet agricultural materials and the moving metal parts.

The drag reduction techniques employed by the non-smooth surface, which are derived from bionic surface theory, have been widely used for surface drag reduction in bulldozing machinery, agricultural tillage machinery, mining machinery, sieve cleaning machinery and high-speed military spiral bodies (McKyes, 1989; Ren, 2001; Tong, 1994; Tong, 2009; Zhang, 2008; Tian, 2007; Ren, 2007). Moreover, the slippery frictional frequencies and velocities can greatly influence the frictional properties (Bai, 2000). It is estimated that 40 % of the threshing mixtures of the rapeseeds are the residuals, where the short stalk and the rape pod shell of the residuals account for over 90 % of the mixture (Lu Lin, 2005). In this paper, studies were conducted to examine the reciprocal frictional properties between various cleaning sieves and the rape materials, providing basic theories for the consequential theoretical modeling and numerical simulation as well as approaches regarding the drag reduction mechanism of the non-smooth bionic sieve surface.

Materials and Methods

Test Equipment and Collet

The test apparatus was a UMT-2 micro tribometer from USA CETR Company, as shown in **Fig. 3**, which is a high-speed reciprocal testing module with continuously adjustable reciprocal frequencies ranging from 0 to 50 Hz and a maximum single stroke of 30 mm. The high-precision pressure sensor has a measuring range of 0-500 g and a resolution of 0.1 g. The samples were dynamically loaded through the mechanical servo system, which effectively reduced the errors that were due to the loading in the high-speed reciprocal condition.

The ship-shaped collet were designed to help reduce the difficulty that arises when attempting to make rape materials, such as the rape stalk and pod shell, into standard samples (**Fig. 4**). The bottom surface of the collet is arc shaped to reduce the contact area between the metal sieve and the rape stalk or pod shell. The reduced contact area minimizes the effects of the frictional area variation on the test results.

Testing Materials and Schemes

The upper frictional work piece that was installed at the bottom of the ship-shaped collet was replaced by the rape stalk or pod shell. The rape species that has been selected for this study is the Shilifeng rape, which is considered an excellent variety and is planted widely in the Jiangsu Province, China.

Fig. 3 UMT-2 tribometer
1. Upper frictional part
2. Bottom frictional part

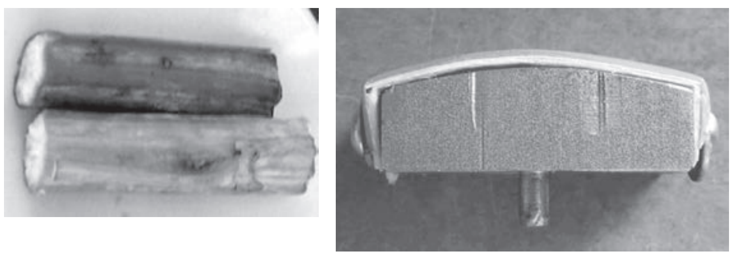

Fig. 5 Rape stalk and the testing part

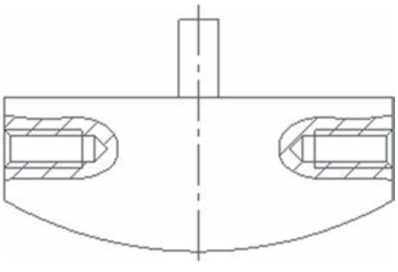

Fig. 4 Schematic of ship-shaped collet of the upper frictional part

Fig. 6 The rape pod shell and the testing part

Table 1 Parameters of the bottom frictional piece

Name	Surface morphology
Smooth surface	Smooth surface
Non-smooth large convex dome surface	Convex with a diameter of 0.2 mm
Non-smooth large concave surface	Concave with a diameter of 0.2 mm
Non-smooth small convex dome surface	Convex with a diameter of 0.1 mm
Non-smooth small concave surface	Concave with a diameter of 0.1 mm

When making the test samples for the rape stalk, the stalk slice with a length of 50 mm and a width of 10 mm were cut first, and after the removal of the internal fibers, a V-type notch was cut using upward bending. The stalk slices were installed firmly onto the collet with the nut, as shown in **Fig. 5**. When testing the rape pod shell surface, the surface was simply trimmed properly and installed on the arc surface of the collet bottom using the nuts, as shown in **Fig. 6**.

According to the research of Ren Lu-quan (Ren, 2001; Tong, 1994; Ren, 2007) at Jilin University, the geometric non-smooth morphology of the dung beetle can reduce adhesion and resistance. The four non-smooth sieve surfaces were designed according to the findings, using the bionic concave and convex domes, where the convex and concave domes were staggered with an angle of 60°, as shown in **Fig. 7**, **Fig. 8** and **Fig. 9**, respectively. The size of the bottom frictional piece is 75 mm × 60 mm, and the specific parameters are listed in **Table 1**.

The cleaning sieve of rape combine has a back-and-forth amplitude at 20-40 mm, with a reciprocal frequency of 4-6 Hz (Lu Lin, 2005). For the test, reciprocal frequencies of 1.67, 5.0, 8.33 and 11.67 Hz were selected with amplitude of 25 mm, and the main shaft rotary velocities were 100, 300, 500 and 700 rpm in the corresponding UMT-2 testing machine, respectively. The frictional time was 10 s, the normal pressure was 200 g, and the upper frictional pieces were rape stalk or pod shell samples. Each group test was replicated three times.

Results and Discussion

The Effects of the Surface Morphology on the Frictional Properties

The frictional characteristic curves of the rape stalk, the surface of the rape pod shell and the five kinds of surfaces are plotted as

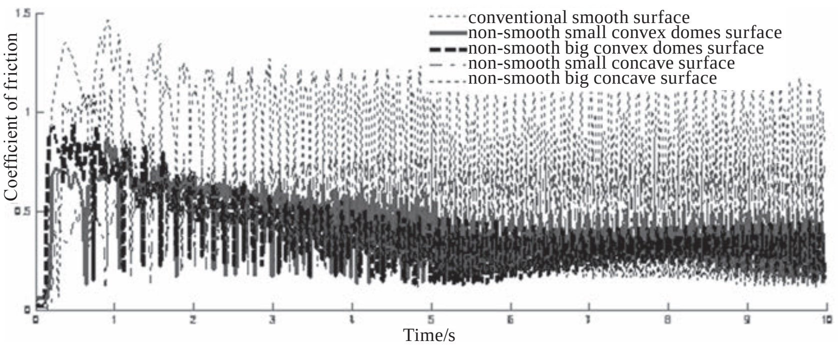

Fig. 10 Frictional characteristic curves between the rape stalk and various surface morphologies

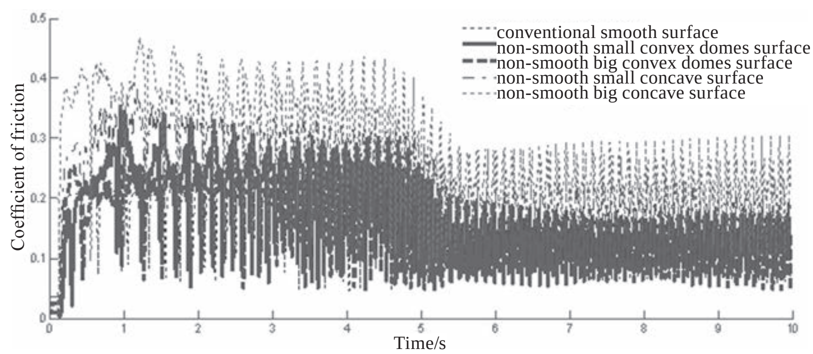

Fig. 11 Frictional characteristic curves between the rape pod shell and various surface morphologies

Fig. 7 Common smooth surface

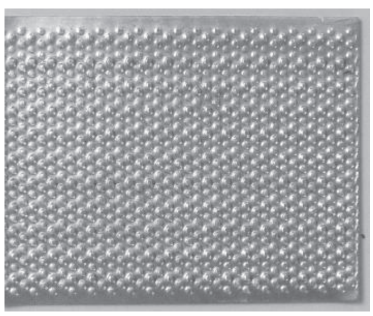

Fig. 8 Non-smooth convex dome surface

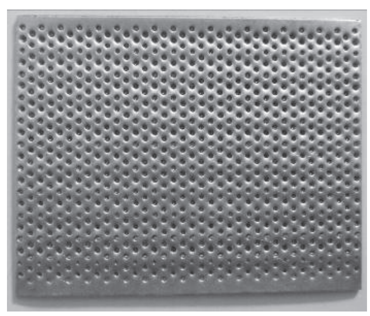

Fig. 9 Non-smooth concave surface

shown in **Fig. 10** and **Fig. 11**.

As shown in **Figs. 10** and **11**, during the reciprocal friction, the condition of the interfacial friction repeatedly changed from the static mode to the acceleration-dynamic friction and then from the reduced slipping friction to the static mode. Therefore, it is anticipated that the testing friction coefficients periodically changed from the maximum frictional coefficient to the instantaneous slippery coefficient and then back to the maximum frictional coefficient. A certain amount of time was needed for the reciprocal module of the tribometer to accelerate from startup to the given reciprocal frequencies; accordingly, as shown in the Figures, at 8.33 Hz, the reciprocal friction lasted approximately 5 seconds and then entered the stationary status.

As shown in **Fig. 10**, during the stationary status, the friction coefficient between the rape stalk and the smooth surface is the maximum coefficient, with a maximum instantaneous static frictional coefficient of approximately 1.2 and an average frictional coefficient of 0.835. The friction coefficient between the rape stalk and the bionic surface was generally lower, which accounts for the remarkable drag reduction caused by the bionic surface. In such conditions, better drag reduction occurred for the large convex domes, the large concave cavities and the small convex domes, and the average values of the corresponding coefficients are 0.309, 0.219 and 0.359, respectively. The maximum drag reduction ratio was 74 % while the drag reduction of the small concave dome was relatively low, with an average frictional coefficient of 0.591, and a drag reduction ratio of up to 29 %.

As shown in **Fig. 11**, during the stationary status, the friction coefficients between the outer surface of the rape pod shell and the five smooth surfaces are much lower. The coefficient with the smooth sur-

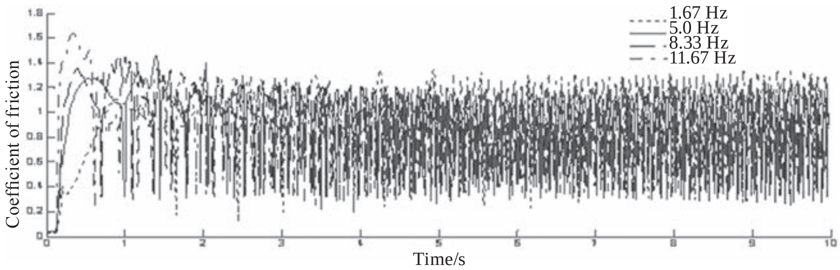

Fig. 12 Frictional characteristic curves between the rape stalk and the smooth surface at the various reciprocal frequencies

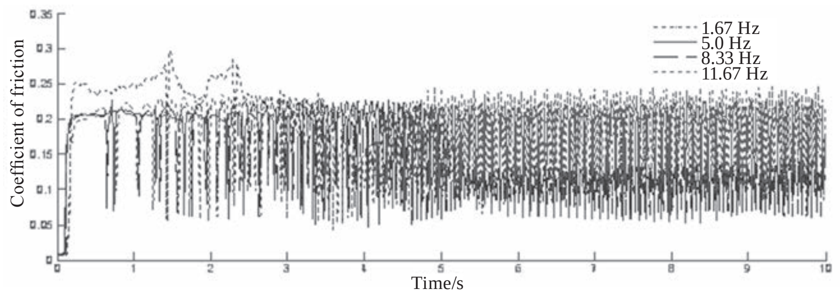

Fig. 13 Frictional characteristic curves between the rape pod shell surface and the smooth surface at the various reciprocal frequencies

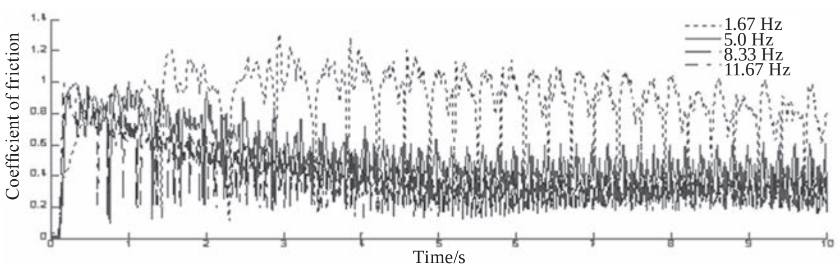

Fig. 14 Frictional characteristic curves between the rape stalk and the bionic large convex dome surface at the various reciprocal frequencies

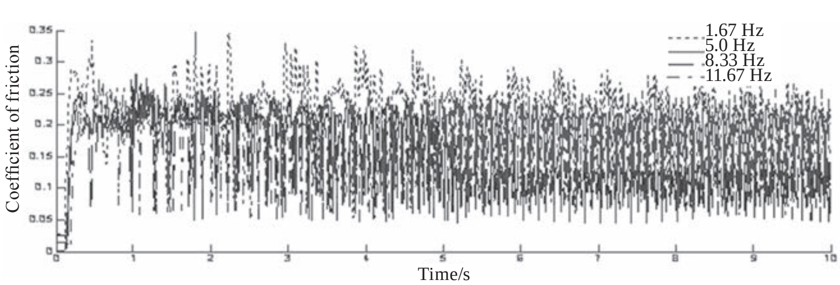

Fig. 15 Frictional characteristic curves between the rape pod shell surface and the bionic large convex dome surface at the various reciprocal frequencies

face is a minimum at 1, the average coefficient is 0.11, and the maximum coefficient is approximately 0.13 after the stationary conditions. As for the non-smooth bionic surface, the frictional coefficients between the large convex dome surface and the outer surface of the rape pod shell are highly overlapped with the frictional coefficient of the smooth surface, without the action of the drag reduction and without an increase in frictional force. The average coefficients between the outer surfaces of the rape pod shell and the small convex domes, the small concave domes and the large concave domes were 0.138, 0.160 and 0.220, respectively. Their frictional forces were even greater than those with the smooth surfaces.

The Effects of the Reciprocal Frequencies on the Frictional Coefficients

The frictional characteristic curves for the rape stalk, the surface of the rape pod shell, the smooth surface, and the bionic surface with diameters of 0.2 mm were tested by the tribometer for the four reciprocal frequencies, as shown in **Figs. 12-15**.

As shown in **Figs. 12** and **13**, the average frictional coefficients between the rape stalk and the smooth surface decreased gradually from 1.012 to 0.870, but the maximum frictional coefficient remained approximately 1.2, and there was no change corresponding to an increase in the reciprocal frequencies. Similarly, the average frictional coefficients between the surface of the rape pod shell and the smooth surface were from 1.95 to 0.175, and there was no change corresponding to an increase in the reciprocal frequencies.

As shown in **Fig. 14**, at a reciprocal frequency of 1.67 Hz, the maximum frictional coefficient between the rape stalk and the bionic convex dome surface is 1.2, with the average frictional coefficient of 0.869, which is close to that of the aforementioned condition, without remarkable drag reduction. With an increase in the reciprocal frequencies to 5.0, 8.33 and 11.67 Hz, the average frictional coefficients after the stationary conditions were 0.431, 0.308 and 0.292, respectively, and the corresponding drag reductions were 50 %, 65 % and 66 %, respectively. Obviously, the frictional forces between the rape stalk and the bionic convex domes decreased with an increase in the reciprocal frequencies. The drag reduction of the bionic convex domes becomes increasingly remarkable with an increase in the reciprocal frequency.

As shown in **Fig. 15**, when the reciprocal frequencies increased from 1.67 Hz to 11.67 Hz, the average frictional coefficients between the surface of the rape pod shell and the bionic convex domes were 0.227, 0.194, 0.109 and 0.170, respectively. The coefficients are equivalent to those with the smooth surfaces. Therefore, the frictional forces between the bionic convex domes and the surface of the rape pod shell are not closely related to the variation in the reciprocal frequencies without remarkable drag reduction.

The Field Comparison Tests

According to the results of the reciprocal tests, the prototype of the non-smooth bionic sieve has been made. In Wujiang city on May 30th of 2000, a prototype of the bionic cleaning sieve and a sieve with a common smooth surface (with the same size, installation and parameters) were installed on two rapeseeds combine harvesters that are made by Huzhou Xingguang Agricultural Machinery Manufacturing Ltd, Co. to conduct the field comparison testing. The surfaces of the cleaning sieves after harvesting rapeseeds in an area of 0.33 hectares are shown in **Figs. 16** and **17**.

As shown in **Fig. 16**, after harvesting the rapeseeds in an area of 0.33 hectares, the mixture of the rapeseeds adhered significantly to the smooth sieve surface, blocking most of the holes of the sieves and

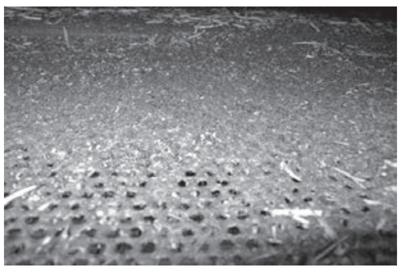

Fig. 16 The adhesion of the rapeseeds cleaning sieve with the smooth surface

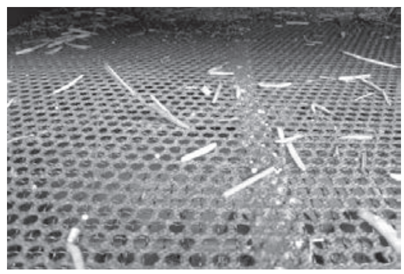

Fig. 17 The adhesion of the rapeseeds cleaning sieve with the non-smooth bionic surface

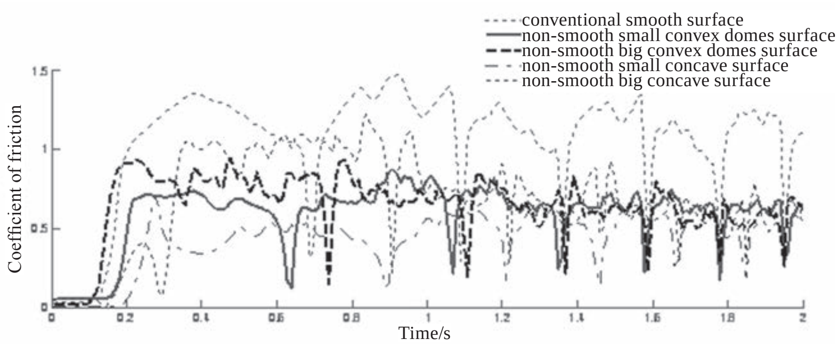

Fig. 18 The frictional characteristic curves between the rape stalk and various surficial morphology at the frequency of 8.33 Hz within 2 second

forming a thick layer that caused serious losses, resulting in abnormal conditions in the combine harvester, and wiped out the sieve surface, requiring the harvester to be stopped. On the contrary, the entire bionic sieve surface was clean, as shown in **Fig. 17**, without the remarkable phenomenon of the sieve surface adhesion. It is verified from the field tests that the non-smooth bionic sieve surface caused a remarkable reduction in adhesion, thus reducing the cleaning losses in the rapeseeds and improving the efficiency of the harvester.

The Analyses of Adhesion and Causes of Resistance Reduction

The acting force of the elastic materials is proportional to the elastic deformation, while the acting force of the viscous materials is proportional to the deformation velocity. The acting force of viscoelastic materials is in between. Studies by several scholars show that the damped characteristics of viscoelastic materials are strongly influenced by the effects of temperatures and frequencies (Zhang, 2005). At the low frequency and high temperature conditions, viscoelastic material exhibits characteristics similar to rubber with a little damping, while at the high frequency and low temperature condition, it exhibits characteristics similar to glass, with no damping. Only in the medium frequency or temperature conditions are damping characteristics at a maximum. The specific materials in the critical frequency and temperature conditions must be discussed.

It can be determined from the above tests that at the various frequencies, the frictional coefficients between the stalk and the smooth plate vary slightly, but the frictional coefficients with the non-smooth bionic surface, especially with the bionic large convex domes, greatly decreased with an increase in the frequency. At some reciprocal frequencies after the stationary status, it can be seen from the comparison curves of several periodic frictional characteristics of the rape stalk, smooth surface and the non-smooth bionic surface shown in **Fig. 18**. At the single cycle, the frictional curve fluctuations between the rape stalk and the bionic surface were remarkably greater than that between the rape stalk and the smooth surface. At one reciprocal cycle between the rape stalk and the bionic surface, more small cycles were found in the frictional curve between the rape stalk and the bionic surface, which caused the actual frictional frequencies between the rape stalk and the bionic surface to be several times higher than the test-setting reciprocal frequencies. Therefore, the actual frictional frequencies between the rape stalk and the bionic surface were much higher than those between the rape stalk and the smooth surface. The rape stalks with moisture contents of approximately 60-80 % during harvesting are the typical viscoelastic material that exhibits the rubber characteristics with an increase in the frictional frequencies, no damping and reduced frictional coefficients. The non-smooth status of the bionic surface resulted in the discontinuity of the frictional surface and causes more small cycles to be found in the friction between the rape stalk and the bionic surface. Therefore, compared with the smooth surface, the non-smooth bionic surface creates a damping action on the rape stalk.

However, such actions do not occur on the surface of the rape pod shell, because the moisture in the ripened rape pod shell decreases by less than 30 % during the harvesting and a thin rape pod shell did not clearly exhibit the properties of the viscoelastic material. Therefore, the frictional coefficients between the rape stalk and various surfaces had fewer total changes, and the non-smooth bionic surface had no obvious effect of the drag reduction on the rape pod shell.

Conclusions

1. The non-smooth bionic surface created a damping action on the rape stalk, where the maximum drag reduction ratio of the bionic convex dome on the rape stalk was as high as 74 %, and the capability of the drag reduction became increasingly obvious with an increase in the reciprocal frequencies.
2. The effect of the non-smooth bionic surface on the rape pod shell was not obvious, and the variation of the frictional coefficients with increased reciprocal frequencies was not remarkable.
3. It has been shown from the field tests that the non-smooth bionic surface can effectively resolve the adhesion and blocking of the sieve holes by the mixture of rapeseeds and the sieve surface, which decreased the cleaning losses and improved the efficiency of the harvester.
4. The non-smooth bionic surface created a damped action on the rape stalk, which originated in the viscoelastic properties and frequency action of the high-moisture rape stalk.

Acknowledgements

This project was supported by the National Natural Science Foundation of China (Grant no. 50805068), the National Key Technologies R&D Program (Grant no. 2009BAD-B5B05, 2010BAD01B06), the Foundation of Jiangsu University (Grant no. 10JDG088), the high-tech key laboratory of agricultural equipment & intelligentization of Jiangsu province (No. BM2009703) and a project funded by the Priority Academic Program Development of Jiangsu Higher Education Institutions (PAPD). The authors would like to thank the reviewers for their helpful suggestions on the manuscript.

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■■

Preparation of Value Added Products from Waste Collected from Cotton Ginneries




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Abstract

Ginning of seed cotton occupies a very important place in the passage of cotton from the field to the factory. The ginning machine is to be accurately adjusted and the seed cotton (kapas) is to be presented in a proper condition in order to get satisfactory results, otherwise the quality of lint or seeds is likely to suffer in the ginning process.

In modern ginning factories, cotton is subjected to pre-cleaning and post cleaning operations to get clean trash free cotton. During these operations along with the trash about 2-4 % of good quality cotton fibres are lost. Due to this loss of fibres and thus revenue, many ginners are not keen to adopt modernization. In the present study, an attempt has been made to prepare value added products like absorbent cotton, pulp and paper from this ginnery waste. It was observed that good quality absorbent cotton can be made from the pre-cleaning waste and high grade pulp and good quality paper can be prepared from the post cleaning waste collected from ginning factories.

Introduction

Ginning is the process of separating the cotton fibres from the seed-cotton. The ginning factory or the ginnery is a primary processing industry where seed-cotton (kapas) produced in the farms is ginned to separate the lint which is then made into bales for use by the textile industry. Thus ginning is the first mechanical process undergone by cotton fibres prior to the spinning and weaving operations. This process needs to be carried out with least damage to the fibres in order to maintain the grade and quality of cotton.

In USA, saw gins are mainly used (Sundaram, 1979) while most of the cotton in India is ginned on roller gins. Saw gins are only found in the northern parts of the country. In a saw gin, the seed-cotton before being ginned is opened and cleaned by means of pre-cleaning machine to remove foreign matter such as leaf bits, burrs, stems, hull, sand, dust and other impurities but such a provision does not exist in a roller gin.

Till the beginning of 21st century, most of the gins in India were conventional, poorly maintained, pre or post cleaners were not used and the entire material handling was carried out manually. As a result, Indian cottons were of poor quality due to high trash content in spite of the initial low trash content of hand picked seed- cotton. On the other hand, countries like USA, Australia and Uzbekistan were able to produce bales with a low trash content of 1-2 % from the machine picked cotton having a trash content of -25 % by using advanced ginning machines and practices.

The globalization of markets and demand for quality textiles has recently led to the adoption of new technologies in ginning and pressing machinery, and process automation by the Indian ginneries also. Many modernized composite ginning and pressing factories were newly established or upgraded during the past decade with financial support from the Technology Mission on Cotton launched by Govt. of India in the year 2000. Establishment of pre and post cleaners, automated material handling system, improved storage infrastructure and trained manpower are the essential features of a modern ginning and pressing unit. As a result, there has been a substantial reduction in levels of trash and contaminants in Indian cottons and these have become acceptable to local and overseas textile industry. It is evident from the increase in cotton exports and fall in imports (Iyer, 2010).

The shortage of labour for agriculture related operations in India is increasing day by day. It may become necessary in near future to adopt mechanical picking of cotton. It is known that machine picked cotton contains around 20-25 % trash, the nature of which varies compared to those found in handpicked cotton. The machine picked cotton contains a large quantity of sticks, burrs and green leaves. Appropriate pre-cleaning and post cleaning machines would then be necessary to process mechanically picked cotton.

Though pre-cleaning and post cleaning operations are needed in a ginnery to get clean trash free cotton but it is observed that about 2 to 4 % of good quality cotton fibres are also lost (up to 2 % in pre-cleaning and up to 1.5 % in post-cleaning) along with the trash during these operations (Arude, 2010, Patil, 1999). This results in a loss of revenue to the ginners hence they are reluctant to invest in modernization.

Disposal of ginning waste is also a problem. Traditionally it has been burned but this is no longer permitted for environmental reasons. Ginning waste consists mainly of leaf particles, twigs and remains of boll walls. It can be used as soil conditioner by merely spreading it on the soil. Some research has been conducted on utilization of ginning waste to produce bio-gas. Technology for making compost from ginnery waste is also developed. A large ginnery, generating about 4-5 tonnes of trash daily can produce good quality compost (Anonymous, 2007).

The present study was taken up with an objective to recover good quality fibres from the ginning waste and to standardize processing parameters to utilize them for the preparation of value-added products. Waste samples pertaining to pre-cleaning and post-cleaning operations were collected from modernized ginning factories located at Nagpur and Surat.

Samples from pre cleaners having longer fibres (around 18-20 mm) were explored for use as absorbent cotton, while samples from post cleaners having shorter fibres (about 6-12 mm) were utilized for the preparation of high grade pulp and good quality paper.

Materials and Methods

Samples pertaining to wastes from pre-cleaning and post-cleaning operations for three varieties of cotton viz. H-6, LRA-5166 and JK-34 were collected from ginneries located in Nagpur and Surat. These samples were mechanically cleaned on Shirley Trash Analyser to remove trash and cleaned fibres thus collected were used for further processing

Chemicals used in the experiment viz. sodium hydroxide, hydrogen peroxide and sodium silicate were of analytical grade whereas commercial grade sodium hypochlorite of approximately 40 gpl available chlorine was employed in the treatment.

Scouring/Cooking of Fibres

Mechanically cleaned fibre samples were treated with 4.0 % om weight of material (owm) sodium hydroxide in a rotary digester at 160 ºC for 90 min keeping material to liquor ratio 1 : 8 for removing non cellulosic impurities. The cleaned/cooked fibres were washed thoroughly with water.

Preparation of Absorbent Cotton

Above cleaned fibres pertaining to pre-cleaner wastes were then bleached by employing two step bleaching process for preparing absorbent cotton. In the first step, hypochlorite solution having 3 % available chlorine was used at 70 ºC for 120 min with material to liquor ratio of 1 : 20 followed by a thorough washing with water. The second step of bleaching was carried out using hydrogen peroxide (0.2 % w/v), along with sodium hydroxide (0.1 % w/v) and sodium silicate (0.15 % w/v) as stabilizer at 90-95 ºC for 60 minute with material to liquor ratio 1 : 20. Bleached samples were washed thoroughly with water and air dried.

The absorbent cotton thus prepared was opened by using Shirley Opener machine and then tested for various properties like moisture, ash, acidity, alkalinity, solubility in 75 % H_2SO_4 and solubility in 4 % NaOH as per Pharmacopoeia of India, 1985. Absorbency was evaluated as per Bureau of Indian Standard-2369, 1967 (Reaffirmed in 2000).

Preparation of Pulp and Paper

Cooked fibres pertaining to post cleaner wastes were beaten in a valley beater to get the pulp of desired freeness i.e. 250 CSF (Canadian Standard Freeness) and then bleached employing the same bleaching conditions used for absorbent cotton. Bleached pulp was air dried and tested by standard methods for % yield, moisture, ash, CSF, brightness and degree of polymerization (Sundaram, 1979). It was then converted into paper sheets of 60 ± 1 g/m^2 on a standard laboratory model paper making machine as per TAPPI (Technical Association of the Pulp and Paper Industry) standard T-205 om-81 (1981). The paper sheets were dried in air and tested for various properties using TAPPI standard test methods T-220 m-60 (1960) under standard conditions.

Photograph of absorbent cotton (**Fig. 1**) and paper (**Fig. 2**) shown below.

Results and Discussion

Results of fibre yield obtained upon passing the pre and post cleaner waste samples of the three cotton varieties through Shirley analyser to separate fibres from trashy materials are presented in **Table 1**. It is seen that both pre and post cleaner wastes were almost similar in composition and there was very little difference between the varieties. Fibre yield was more than 60 % for these wastes and trash content was -20%.Value for percent loss which reflects the amount of very small sized fibres and trash particles was little lower for pre-cleaner waste as it consisted of longer fibres.

Some of the important properties of absorbent cotton prepared from pre-cleaner waste of three varieties are presented in **Table 2**. Standard specifications for these properties as per Indian Pharmacopoeia are also provided at the bottom. Moisture content was less than 8 % for all the varieties. Also ash content was less than 0.5 %. These values conform to the standard requirements for absorbent cotton. Tests for acidity and alkalinity showed that samples were neutral.

Absorbency test is one of the most important tests for absorbent cotton. For H-6 and LRA-5166 samples, the absorbency was 2.9 and 2.6 sec respectively. It was 5.3 sec for J-34 which is though slightly higher is well within the specifications. These differences in absorbency may be due to the differences in varietal response to the processing conditions. Nachane *et al*. (2004) also made similar observations while preparing absorbent cotton from two varieties of cotton- Y1 and RH-arb-02-1 (w). It was observed that Y1 uncleaned and cleaned cotton required more time [5.2 and 6.5 second] than RH-arb-02-1 (w) [1.9 second] for absorbency.

Solubility tests showed that all three samples were soluble in 75 % H_2SO_4 and insoluble in 4 % NaOH as required for absorbent cotton. Thus the product obtained after purification of pre cleaner ginning waste is suitable for use as absorbent cotton as it meets or exceeds the criteria for absorbent cotton and there is not much difference between the varieties.

Properties of pulp prepared from post cleaner ginning waste of three varieties after cooking, beating and bleaching are listed in **Table 3**. It can be seen from the **Table 3** that the pulp yield from the fibres obtained from H-6 and LRA-5166 varieties was 68 and 69 % respectively where as it was slightly higher for J-34 variety that is 71 %. Moisture content in all the samples was roughly the same. Ash content was low for all the samples as it ranged from 0.12 to 0.19 %.

Pulp being purified cellulose, its Degree of polymerization (D.P.) is important as higher value is desirable for good tensile properties. The values of D.P. obtained for the experimental varieties range from a lowest of 422 for LRA-5166 variety to a highest of 549 for the H-6 variety. These values are high enough to impart good strength properties to the paper. Varietal variations may have been caused by the inherent differences in the D.P. values of fibres of these varieties or by their differential response to the cooking and bleaching treatments which though essential to pulp making for removal of non cellulosic impuri-

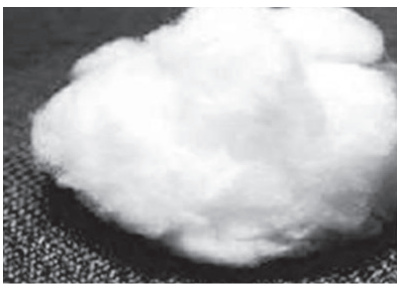

Fig. 1 Absorbent Cotton

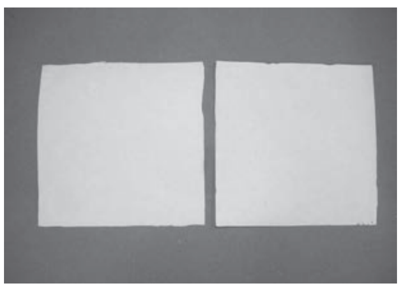

Fig. 2 Paper

Table 1 Composition of Pre-Cleaner and Post Cleaner Waste

Sample	Pre-cleaner waste			Avg.	Post-cleaner waste			Avg.
Parameter	H-6	LRA-5166	J-34		H-6	LRA-5166	J-34	
Fibre Yield (%)	59	63	62	61.3	60	60	62	60.7
Trash (%)	23	20	20	21.0	21	21	19	20.3
Loss (%)	18	17	18	17.7	19	19	19	19.0

Table 2 Properties of Absorbent Cotton Prepared from Pre-Cleaner Waste

Sample	Moisture (%)	Ash (%)	Acidity	Alkalinity	Absorbency (Sec.)	Solubility (in 75 % H_2SO_4)	Solubility (in 4 % NaOH)
H-6	6.5	0.15	Nil	Nil	2.9	Soluble	Insoluble
LRA-5166	6.3	0.11	Nil	Nil	2.6	Soluble	Insoluble
J-34	6.3	0.15	Nil	Nil	5.3	Soluble	Insoluble
*Standard	< 8	< 0.5	Nil	Nil	< 10	Soluble	Insoluble

*Standard values required for absorbent cotton as per Indian Pharmacopoeia ties and coloured substances also cause some damage to the cellulose thereby reducing its D. P. value. The brightness values of the prepared pulps ranged from 80 % to 82 % which can be considered to be high and useful in preparing good quality paper. Thus the pulp prepared in the experiments can be said to be of high quality which has the potential for usage in making good quality paper.

Table 4 contains the various properties of the paper prepared from the above pulps. Quality requirements for computer paper, which is a high end paper, are also listed at the bottom of the **Table 4** for comparison. A perusal of the Table shows that papers prepared from all three varieties either meet or exceed the specifications for this type of paper. It is observed that LRA-5166 variety has performed best in respect of bursting factor and number of double folds. It was noted that pulp of this variety had the lowest DP value of 422. This DP value therefore appears to be more suitable for these parameters. H-6 variety which had highest DP was found to have lowest value for tear factor but highest value for breaking length. Tear factor and breaking length values obtained for experimental paper samples in general are very high about 2.5 and 1.7 times of the required standard values respectively. Therefore pulp prepared from ginning waste of any cotton variety can be used for blending with inferior quality of pulp to reduce costs.

Table 3 Properties of Bleached Pulp Prepared from Post-Cleaner Waste

Sample	Pulp Yield (%)	Moisture (%)	Ash (%)	CSF	D. P.	Brightness (%)
H-6	68	6.2	0.12	250	549	80
LRA-5166	69	6.3	0.13	250	422	82
J-34	71	6.2	0.19	250	483	81

CSF (Canadian standard freeness)

Table 4 Properties of Paper Prepared from Post-Cleaned Waste

Sample	GSM (g/m^2)	Bursting Factor (kg/cm^2)	Tear Factor ($mN.m^2/g$)	Breaking length (m)	No. of Double Folds (No.)
H-6	60 ± 1	17	119	3010	15
LRA-5166	60 ± 1	18	125	2950	18
J-34	60 ± 1	15	129	2900	15
*Standard	60 ± 1	> = 12	> = 50	> = 1700	> = 15

*Standard value required for computer paper as per IS 12766:1997

Conclusions

On the basis of the data it is concluded that good quality fibres can be recovered from the wastes obtained from pre-cleaner and post-cleaner in a modern ginnery. The processing parameters for preparation of value-added products were standardized. Fibres from the pre-cleaner wastes were successfully utilized to prepare good quality absorbent cotton. As there was not much difference in the properties of absorbent cotton prepared from different cotton varieties, this waste in general, irrespective of the variety appears to be suitable for this end use. High grade pulp and very good quality paper could be prepared from the fibres obtained from post cleaner waste. Pulp yield, its degree of polymerization and brightness as also the quality parameters of paper prepared from the pulp also indicate that there is not much variation among different varieties. Though these materials are termed as wastes in the ginning process because fibres present there cannot be used for textile purposes, the results indicate that such fibres can find application in preparation of value added products like absorbent cotton and high grade pulp and paper.

Utilization of the ginning waste along with better remuneration for clean cotton would improve the earnings of Indian ginners and change their outlook towards modernization in a positive way that would also make available good quality cotton to textile industries.

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Quantification of Agricultural Mechanization for Soybean -Wheat Cropping Pattern in Bhopal Region of India

by
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Abstract

Agricultural mechanization is the process of using agricultural machinery to reduce input cost and to increase farm output. The one of the purpose of this study was to quantify the agricultural mechanization of Bhopal region of India with the help of degree of mechanization, level of mechanization, power availability and mechanization index. The study was carried out in Bhopal and Sehore districts of Madhya Pradesh in India. The primary data required to quantifying agricultural mechanization were collected using developed questionnaire. The average power availability of Bhopal region was found to be 2.07 kW/ha. The average mechanization index of a farmer for Bhopal region was found to be 0.89 with 95 % confidence interval and it was also observed that the Bhopal district is more mechanized in comparison to Sehore district. The existing level of mechanization due to tractor was found to be 1.21 kW/ha.

Introduction

Mechanized agriculture is the process of using agricultural machinery to increase farm output. In modern era, agricultural mechanization draws a major controversy that it is considered as the application of mechanical power technology, particularly tractors. However, three main levels of mechanization technologies need consideration: human power, animal power and mechanical power technologies, with varying degrees of sophistication within each level (Rijk, 1989), on the basis of capacity to do work, costs, and precision and effectiveness (Morris, 1985). Agricultural mechanization technology further varies from location to location and crop to crop. Thus the quality of inputs of mechanization, and consequently land and labour productivity may differ considerably (Gifford & Rijk, 1980). So, mechanization planning requires the quantification of level of mechanization for each crop production.

Several authors developed different methods to quantify the level of mechanization based on power or energy availability, and its impact in agricultural and labour productivity.

Singh and De (1999) reviewed the methodologies adopted by several investigators to express a mechanization indicator. For macro-level planning, a mechanization indicator MI based on the ratio of electrical and mechanical power over total farm power was introduced as a measure of qualitative assessment of modernization of agriculture

$$MI = P_M / (P_H + P_A + P_M) \quad (1)$$

where, MI is the mechanization indicator; P_M is the total electrical and mechanical power; P_H is the human power, and P_A is the draught animal power.

A higher mechanization indicator based on electrical power and stationary engines as per **Eq. 1** might only reveal mechanization of stationary operations. From a qualitative drudgery reduction point of view, a mechanization index MI based on mechanical tractive power P_{Mt} could be a better measure

$$MI = P_{Mt} / (P_H + P_A + P_M) \quad (2)$$

A major limitation in quantifying

a mechanization indicator based on the ratio of mechanical tractive farm power to total farm power is that it does not bring to light the actual use scenario. While unit farm power could be considered as indicative of potential power availability, it may not necessarily be fully utilized on the farms. This may depend upon availability of diesel and electricity, and adequate workload. The majority of the farmers in developing countries use tractors for transport of agricultural and non-agricultural commodities. Mechanisation index MI expressed by the percentage of machine work E_M to the sum of manual E_H, animal E_A and machine work E_M expressed in energy units, as suggested by Nowacki (1978), has been accepted for model forecasting using

$$MI = E_{Mt} / (E_H + E_A + E_M) \quad (3)$$

Zangeneh *et al.* (2010) defined Mechanization Index (*MI*) and Level of Mechanization (*LOM*), to characterize farming system of potato in the Hamadan province of Iran. These indicators are defined mathematically as **Eqs. 4** and **5** respectively. The *MI* elaborated here is an expression of the deviation of the actual amount of motorized farm work from the normal values at the regional level.

$$MI = \frac{1}{n} \sum_{i=1}^{n} \frac{M_{e(i)}}{M_{av}} \times \frac{L_i}{TL_i} \quad (4)$$

where,

MI = Mechanization Index for the production unit ‘a’, $M_{e(i)}$ = Overall input energy due to machinery in the production unit ‘a’,

M_{av} = Regional-average energy due to machinery,

L_i = Land area cultivated in the production unit ‘a’,

TL_i = Total farm land ownership of production unit ‘a’,

n = Number of farms.

The *MI*, proposed by Andrade and Jenkins (2003) is an indication of the amount of machinery a given farmer uses for farm work compared with the average in the region. The second term in **Eq. 4** includes a ratio between the land area cultivated with soybean crop and the total land ownership. This term was introduced because it reflected the importance of land demand for cultivation. The *LOM* index is based on the premise that a mechanized farmer is the one that finds a way to utilize amounts of mechanical energy that are higher than the typical values using locally available technology.

$$LOM = \sum_{i=1}^{n} \frac{P_i \times \eta}{L_i} \quad (5)$$

where,

LOM = level of mechanization,

P_i = power of tractors,

η = correction factor for utilized power (0.75),

L_i = Land area cultivated using *i*th tractor.

Field capacity was multiplied by rated power so the quantification of energy expenditure was made in work units (kWh). The regional normal will be obtained after compiling a full dataset of all respondents and then it would be defined the mode for the number of passes for each operation as well as the mode in tractor size and field capacity.

The mechanization index can also be calculated by the following formula (Almasi *et al*., 2000)

Mechanization Index (hp / ha) = Total power / cultivated Area ....(6)

The Total power of existing tractors (hp) = Average nominal power of one tractor × Number of working tractors

Total real power of tractors = Total power of existing tractors × Conversion coefficient (0.75)

Animal energy (kW/h) = Total existing animal power × Annual functional hours.

Annual functional hours = Number of functional days × Mean functional hours during a day.

Total existing animal power (kW) = Produced power of animal × Number of animals

Human energy (kW/h) can also be calculated in the same manner.

Mechanical energy: To calculate the mechanical energy, the number of days machinery is used during a year should be noted according to the calendar, as well as the limitations of using machinery on some days. And the mean daily functional hours of machines are separately calculated according to existing resources and field studies. Besides calculating the energy of machines, all existing machines should be considered, whether stationary or mobile, which are producing powers for cropping work.

Mechanization index (*MI*), represents the percentage of work of the tractors in the total of human work and that of the machinery. It was calculated using **Eq. 7** (Nowacki, 1974);

$$MI = \frac{LM}{LT} \times 100\,\% \quad (7)$$

where,

MI = Mechanization index, %;

LM = Average sum of all mechanical operation work of the machine, kWh/ha;

LT = Sum of all average work outlays by human and tractor powered machines, kWh/ha

$LT = LM + LH,$

where LH is average work outlays by human.

Parameters for *LM* and *LH* were determined based on the exact response of the average farmers in the surveyed areas on the estimated resting period in minute per hour of work on each manual operation.

Andrade and Jenkins (2003) proposed an index for quantifying mechanization.

$$MI = \sum_{i=1}^{n} \frac{M_{e(a,i)}}{M_{av}} \times \frac{L_{(a,i)}}{TL_a} \quad (8)$$

where,

MI = Mechanization Index for the production unit ‘a’

$Me_{(a,i)}$ = Overall input energy due to machinery for crop ‘i’ in the production unit ‘a’

M_{av} = Regional-average energy due to machinery

$L_{(a,i)}$ = Land area cultivated with crop ‘i’ in the production unit ‘a’

$TL_{(a)}$ = Total farm land ownership of the production unit ‘a’

This index is an indication of the amount of machinery a given farmer uses for farm work compared with the average in the region. The second term includes a ratio between the land area cultivated with different crops and the total land ownership. This term was introduced because it reflects the importance of land demand for cultivation.

Many of the equations which are used to formulate mechanization indices, lack some information at farm level for Indian condition. Especially mechanization of agricultural production was mainly carried out by mainly three sources viz: machine, human and animal technologies. This also varies from crop to crop and location to location. **Eqs. 1 to 3** measure the mechanization status by considering either stationary or non-stationary power, but excluded the importance of individual production unit. **Eq. 7**, animal power has not been considered. While **Eqs. 4** and **8** overcame that omission but neglected human and animal power which exist in Indian condition. So, all these indicators should have further modifications to assess the mechanization status of a farming system of production of various agro-products in a region.

A new approach to construct Mechanization index has been discussed here in this study to assess the mechanization status of a farming system that is suitable at farm level in Indian condition.

Materials and Methods

To study the mechanization status of soybean-wheat cropping pattern, many variables were selected based on requirements to estimate degree of mechanization, level of mechanization (power availability) and mechanization index. The following variables were selected:

Degree of mechanization(MD): Area under bullocks, cultivator, power tiller, disc plough, M B plough, deshi hal (local plough), seed cum fertilizer drill, diesel engine, electric pump, sprinkler, dripper, sprayer (manually operated), sprayer (tractor operated), manual harvesting, thresher and combine harvester.

Level of mechanization (power availability): Villages wise number of tractor, combine harvester, bullocks, agricultural workers, power tiller, diesel engines and electric pump

Mechanization index: Farmers wise human power, animal power and machinery power availability like tractor, thresher, combine.

After selection of variables, a questionnaire was prepared to collect primary data from Bhopal and Sehore districts of Madhya Pradesh in India. A Stratified Multistage Sampling Design was applied considering districts and blocks as strata. Then from each blocks, villages and then from each villages, 10 farmers were selected using random sampling. Primary data were collected from 200 farmers from 20 villages. The villages were selected from each block of Bhopal and three blocks of Sehore districts using random sampling.

As mechanization is a multi-dimensional concept, thus the following indices were evaluated to study the mechanization status in target region:

Degree of Mechanization (*MD*)

It is one of the quantitative measure of mechanization, by which the degree of mechanization of different operations in a cropping system like land preparation, sowing, weeding, irrigation, spraying, harvesting, threshing, transportation of agricultural produce and etc. can be assessed. It is the ratio of mechanization area accomplished to the area to be mechanised (Almasi *et al.*, 2000). The degree of mechanization of a particular implements used in a particular agricultural operation can be given as

$$\text{Degree of Mechanization} = \text{Mechanized area} / \text{Area to be Mechanized} \quad \text{.....(9)}$$

In other words, the degree of mechanization can be used to evaluate the extent of different agricultural operations performed using machinery or improved implements to the operations performed by humans, animals or traditional implements.

Mechanization Index (*MI*)

In this study, a new approach to evaluate Mechanization Index had been proposed to overcome the demerits in the above mentioned methodology to evaluate Mechanization Index and is given below:

$$MI_i = \left(\sum_{j=1}^{r}\sum_{k=1}^{s} M^p_{jk} \times M^t_{jk}\right) / \left[\sum_{j=1}^{r}\sum_{k=1}^{s}\left(M^p_{jk} \times M^t_{jk} + H^p_{jk} \times M^t_{jk} + A^p_{jk} \times A^t_{jk}\right]\right. \quad \text{.....(10)}$$

Where,

MI_i = Mechanization Index of *i*th farm

M^p_{jk} = Power of machine used in *k*th operation in *j*th crop (including stationary and movable)

M^t_{jk} = Time taken by machine to perform kth operation in jth crop

H^p_{jk} = Power of human used in kth operation in jth crop (including stationary and movable)

H^t_{jk} = Time taken by human to perform kth operation in jth crop

A^p_{jk} = Power of animal used in kth operation in jth crop (including stationary and movable)

A^t_{jk} = Time taken by animal to perform kth operation in jth crop

i = 1 to n, where n is number of farm

j = 1 to r, where r is number of crop cultivated in a calendar year

k = 1 to s, where *s* is no of farm practices in *j*th crop

Farm operation wise mechanization index is one of the quantitative measures of mechanization and it can be defined as per capita power in terms of hp per hectare for a particular region. Evaluation of operation wise mechanization index first requires determining the number of all kinds of active machine in the region which are used as the source of power. Therefore, it was necessary to have complete information of machineries to calculate total power of machine with respect to their individual power with the help of collected information through questionnaire. The mechanization index can be evaluated machine wise like tractors, power tiller, thresher, combines and etc. The operation wise mechanization index was calculated by the **Eq. 6** (Almasi *et al*., 2000).

Power Availability

Farm power is an essential input in agricultural production system to operate different types of equipment for timely field completion of agricultural works to increase productivity and maintain sustainability of farm. The mobile power is used for different field jobs like land preparation, sowing, weeding, spraying, and harvesting etc., whereas stationary power is used for lifting water, operating irrigation equipment, threshing, cleaning and grading of agricultural produce. The main sources of mobile power are human, draught animal, tractors, power tiller and self-propelled machines (combines, dozers, reapers, sprayers and etc.) whereas the source of stationary power is oil engines and electric motors.

In this study, power availability was also evaluated for Bhopal region. The main sources of mobile power were human, draught animal, tractors and combines whereas the sources of stationary power were oil engines, electric motors and threshers in the Bhopal region. The power availability was evaluated using formula given by **Eq. 11**.

Power availability (hp/ha) = Total Power / Net Cultivated Area .. (11)

Where,

Total power = Total mobile power + Total stationary power

Net Cultivated Area = Net Cultivated Area of Target Region

Also, comparisons between two districts namely Bhopal and Sehore based on energy utilized through different power sources like Animal, Human, Tractor, etc. were also performed using TTEST procedure of SAS-9.3 (SAS Institute India Private Limited) software available at CIAE, Bhopal.

Result and Discussion

The degree of mechanization was evaluated for each village and for Bhopal region also using **Eq. 9**. The Degree of mechanization (in % area) for Bhopal region of some agricultural operation is given in **Table 1**.

Very few farmers were having bullocks in the study region. Some farmers were using bullocks only for transportation of agricultural produce, so the area under bullocks for tillage operation is only 5 %. The area under sprinkler irrigation was only 12 %, whereas area under drip irrigation was 0 %, in the study area for soybean-wheat cropping pattern. The drip irrigation system is practiced mostly in commercial/horticultural crops. Even, most of the farmers were not having tractor operated sprayer and combines, but they were using it on custom hiring basis. In harvesting season, combines were brought to this region by some entrepreneur of Punjab and Haryana states.

Mechanization Index was also evaluated for all 200 farmers using their data in Bhopal region with the help of **Eq. 10**. The mechanization index varied from farmers to farmers. The minimum mechanization index was 0.12, where the farmer used only human and animal power source in his cultivation practices, also, there was no availability of irrigation sources whereas, the maximum was around 0.98 where the farmer was doing most of his agricultural operations using tractor and harvesting using combine harvester. The average of Mechanization index for this study region was 0.89 with 95 % confidence interval (lower limit: 0.86, upper limit: 0.92).

Table 1 Degree of mechanization in Bhopal region

Area under Bullock (in %)		Area under Human (in %)		Area under Machine (in %)	
Tillage	05	Spraying	63	Tillage	95
Sowing	04	Harvesting	53	Sowing	96
				Oil engine	31
				Electric pump	52
				Sprinkler	12
				Dripper	00
				Spraying	34
				Combines	45
				Thresher	53

The Mechanization Index of all 200 farmers was utilized as output variable in fitting ANN model with their respective input variables.

Mechanization index of different power sources like tractors, draught animals (Bullocks), agricultural workers, oil engines and electric pumps were also calculated for the study region using **Eq. 6**. The current Mechanization of different power sources is given in **Table 2**. Also, the number of tractors or other power sources required to achieve a certain mechanization can be calculated using inverse procedure for calculating the mechanization level.

Power availability in Bhopal region was also evaluated using data on tractors, agricultural workers,

Table 2 Level of mechanization of different power sources

Power sources	Existing MI (kW/ha)
Tractor	1.21
Bullock	0.04
Agricultural workers	0.03
Oil engines	0.34
Electric pump	0.71

bullocks, oil engines and electric pumps. In calculation of power availability, **Eq. 11** was used. The average power availability in Bhopal region was 2.07 kW/ha with 95 % confidence interval (lower limit: 1.55, upper limit: 2.59).

Comparison between Bhopal and Sehore districts based on evaluated Mechanization Index and energy utilization through different power sources was also performed. The mean comparison with their p value (level of significance) is given in **Table 3**. The mechanization index of Bhopal and Sehore districts was significantly different and thus we can conclude that mechanization in Bhopal district is more in comparison to Sehore district. This is also supported by the results of tractor energy and human energy which are also significantly different in these districts. The tractor energy is higher in Bhopal, whereas human energy is higher in Sehore. There was no significant difference ($P > 0.05$) in animal energy and energy of irrigation sources like oil engine and electric pump in Bhopal and Sehore districts.

Conclusions

The average mechanization index of a farmer for Bhopal region was 0.89 with 95 % confidence interval (0.87, 0.92) and it was also observed that the Bhopal district is more mechanized in comparison to Sehore district. The average power availability of Bhopal region was 2.07 kW/ha with 95 % confidence interval (1.55, 2.59). Also, the level of mechanization of tractor, bullock, agricultural worker, oil engine and electric pump were found to be 1.21, 0.04, 0.03, 0.34 and 0.71 kW/ha, respectively.

Table 3 Comparison of districts (energy in hp*h/ha)

Districts	Mean		p value
	Bhopal	Sehore	
Mechanization index	0.92	0.85	0.02*
Tractor energy	474	349.2	0.0001*
Animal energy	16.27	34.52	0.08
Human energy	44.32	52.04	0.02*
Oil engines energy	89.84	58.89	0.06
Electric pump energy	245.5	212.2	0.33

*Significant at 5 % level of significance

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Development and Performance Evaluation of a Power Operated Onion Seed Extractor

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Abstract

A power operated seed extraction machine for extracting onion seeds from sun dried onion umbel was developed for increased capacity and timely operation in comparison to manual seed extraction process. The onion seed extractor consisted of seed extraction unit for extraction of seeds from capsules of dry onion umbel and onion seed cleaning unit for separation of seeds and husk. Trials were conducted at three different drum types and three peripheral drum speeds. The machine performance parameters viz., extraction efficiency, extraction capacity, specific energy consumption, seed damage, seed germination, vigor index, cleaning efficiency and cleaning capacity were determined. The test results of the machine showed that a maximum seed extraction efficiency of 99.7 %, extraction capacity of 28.9 kg/h, specific energy consumption of 0.051 kWh/kg, seed damage of 3 %, germination of 96 % and vigor index of 7,736.13 were attained at 420 rpm drum speed with horizontal rasp bar drum. The cleaning unit had a cleaning efficiency of 99.5 % and cleaning capacity of 40 kg/h. The seed extraction capacity was about 10 times higher than manual seed extraction.

Introduction

Onion (*Allium cepa L.*) is one of the important commercially cultivated vegetable crops throughout India. It is widely grown in different parts of the country mainly by all categories of farmers in an area of 1.0 million hectare in India with the production of 15.1 million tonnes and productivity of 14.2 tonnes/hectare (*Bijay Kumar, 2011*). India's onion production is about 13 % of total world's production and ranked second after China. It is also consumed world wide.

The onion seed from dried onion umbels are extracted and used for propagations. Seed extraction from dried umbels is carried out mostly by manual methods. Manual seed extraction techniques include rubbing the onion umbels on one another, rubbing on bricks, stone and wire mesh by using iron cylinder. After extraction, the seeds are cleaned using different (2-3) sieves. As the onion seeds are small and specific gravity is very less, manual seed extraction and cleaning are very tedious and time consuming thus leads to lower extraction capacity. Manual seed extraction is also highly labour consuming and often leads to physical injuries to the hands. Non-availability of trained and experienced labour for manual seed extraction during peak harvesting season is another serious constraint which delays the timely production of seeds. More over the quality of seed plays an important role, as the crop yield is directly dependent on seedling emergence and establishment. The quality of seed is influenced by time of harvest, seed extraction methods and seed moisture especially in vegetable crops like onion (Steiner and Akintobi, 1986). Several types of extractors for other crops have been introduced and evaluated throughout the country. However no onion seed extractor has been adopted by farmers so far. Hence a power operated onion seed extractor was developed and the performance of the machine was evaluated.

Materials and Methods

The onion seed extractor consisted of two major units namely i) seed extraction unit and ii) seed cleaning unit. The onion seed extraction unit consisted of feed tray to feed the onion umbels, seed extraction drum to extract the onion seeds from capsules by rubbing against perforated stationary concave, onion seed extraction drum casing, rotary drum sieve to separate unextracted flower and chaffy material and outlet chutes. The onion seed cleaning unit consisted of screens for the separation of seeds and husk, blower to blow out lighter particles and collection chutes for the collection of material. The machine was operated with 2 hp three phase geared motor with necessary pulley and belt power transmission system. All these units were supported on a wheeled main frame as shown in **Fig. 1**.

The detailed dimensions of major components and its material of constructions are given in **Table 1**.

Performance Evaluation of Onion Seed Extractor

Fully matured, good quality onion umbels of variety Arka Kirthima were procured from a local farm near Bangalore for conducting the laboratory experiments. The onion umbels were sun dried to a moisture content of 10.5 % (d.b.) suitable for extraction of onion seeds. (Raghuraj singh *et al*., 2010)

The developed extractor was evaluated as per standard procedures. Seed extraction were carried out for three drum types namely horizontal rasp bar, inclined rasp bar and rubber button type seed extraction drum at three drum speeds of 210, 350 and 420 rpm respectively with three replication each. Five hundred grams of onion umbels were fed through the feed tray for each treatment. The extracted onion seeds and husks were collected at the corresponding outlets. The extracted seeds collected in the seed outlet were taken and fed through the seed cleaning unit. The cleaning unit separated the extracted seeds as four grades viz., i) clean seeds, ii) over size material, iii) under size material and iv) husk. The materials from each outlet were collected and weighed. For calculation of various parameters the following formulae were used (Anon., 1983, 1985 & 2008).

Extraction Efficiency

The extraction efficiency was determined by using the following formula

Extraction Efficiency (%) = (A − H) / A × 100

Where,

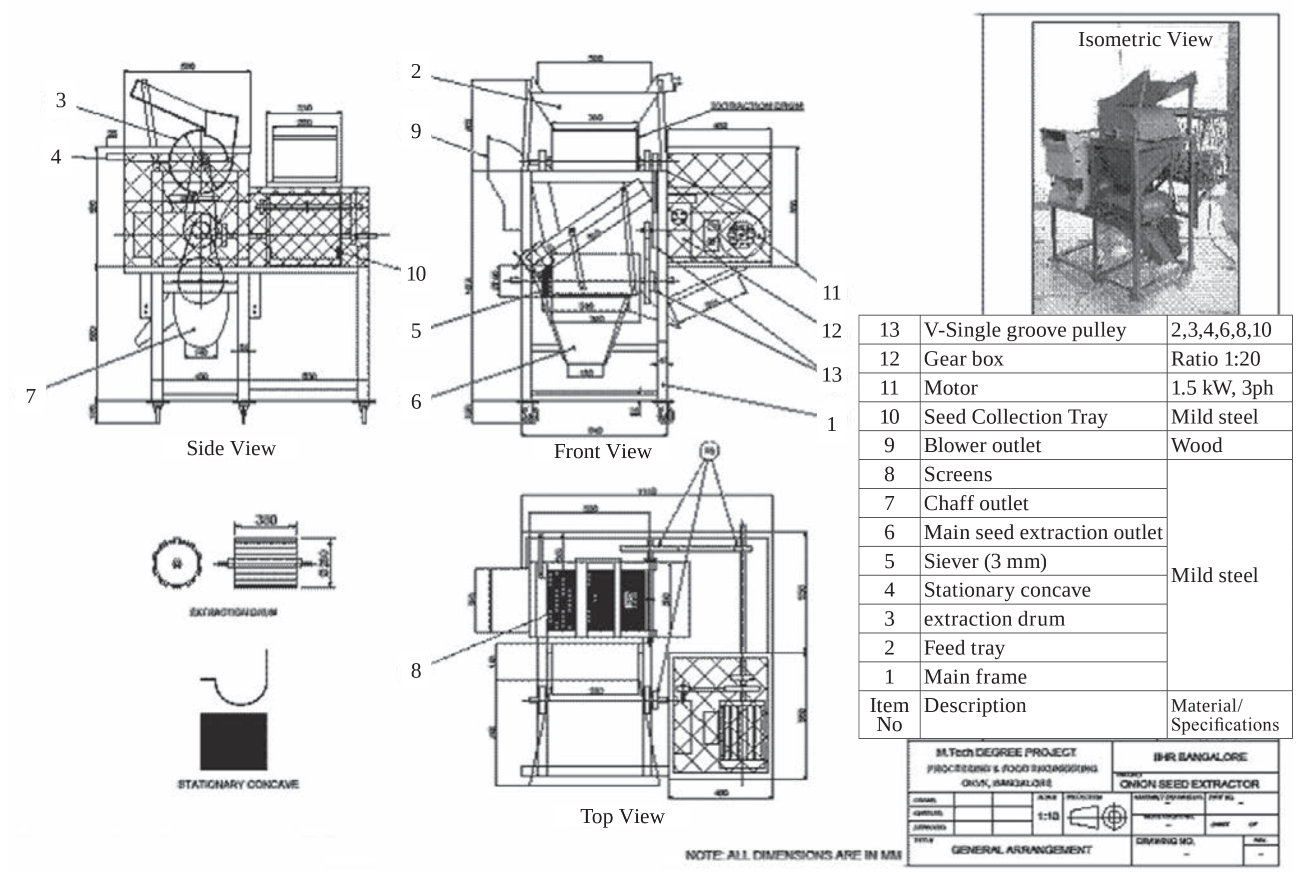
H = Weight of unextracted flower per unit time at all outlets, kg

A = Total feed input per unit time by weight, kg.

Extraction Capacity

The extraction capacity was estimated by weighing the total seeds (whole and damaged) received per unit time at main seed outlet of the extractor.

Extraction capacity (kg/h) = Weight of seeds extracted (kg) / Time



Item No	Description	Material/ Specifications
13	V-Single groove pulley	2,3,4,6,8,10
12	Gear box	Ratio 1:20
11	Motor	1.5 kW, 3ph
10	Seed Collection Tray	Mild steel
9	Blower outlet	Wood
8	Screens	Mild steel
7	Chaff outlet	
6	Main seed extraction outlet	
5	Siever (3 mm)	
4	Stationary concave	
3	extraction drum	
2	Feed tray	
1	Main frame	

Fig. 1 Onion seed extractor machine

taken (h)

Specific Energy Consumption

The specific energy consumption of onion seed extractor and cleaning unit were calculated by using the following formula.

Specific energy consumption = Power of electric motor (kW) / Output capacity of machine per hour (h)

Damaged Seed

The numbers of damaged seeds at the outlets were estimated from the samples by using physical purity board. The percentage of damaged seeds was calculated by using the following formula.

Percentage of damaged seeds (%) = (E / A) × 100

Where,

E = Quantity of damaged seeds collected at all outlets per unit time, kg

A = Total seed output per unit time by weight, kg

Seed Germination

The percentage of seed germination was determined by standard procedures. Fifty seeds were randomly taken from each treatment and placed on moist towel paper. The paper towel was rolled and placed in the BOD incubator maintaining 20 ± 1 ºC temperature and 90 % relative humidity. The viability of the seeds were counted on sixth and twelfth day and expressed in percentage.

Vigor Index

Vigor index was determined by measuring the root and shoot length of 10 randomly selected seedlings. The vigor index was calculated using the following formula.

Vigor index (VI) = Seedling length (mm) × Germination (%)

Cleaning Efficiency

The percentage of cleaning efficiency was calculated by using the following formula (Anon., 1983).

Cleaning efficiency (%) = [Weight of whole seeds/unit time (kg) / Weight of whole material/unit time (kg)] × 100

Cleaning Capacity

The cleaning capacity was estimated by weighing the total seed (whole and damaged) received per hour at main seed output of the cleaner.

Table 1 The detailed dimensions of major components and its material of constructions

Part	Dimension in mm	Material / Section
Onion seed extraction unit		
Feed tray- Trapezoidal shape	L-430; B1-500; B2-300; H -75	MS sheet of 1 mm thickness.
Seed extraction drum	OD -254; L- 380	MS pipe of 5 mm wall thickness.
Rubber bars		Rubber sheet of 5 mm thickness.
• Horizontal rasp bar	L-380; B- 40	
• Inclined rasp bar	L-380; B- 40	
Rectangular rubber button- Fixed in zig-zag manner over the circumferential area of drum	L-50; B-40	
• 10 No's fixed at equal distance over the circumferential area of drum		
Stationary perforated concave	L-380; B- 600	SS perforated sheet with 3 mm hole size of 1mm thickness.
Rotary Drum Siever	Dia-140; L-380	MS Perforated sheet with 3 mm hole size.
Main Frame	L-630; B-420; H-1016	MS angle of size 40 × 40 × 6 mm.
Onion seed cleaning unit		
Screens		MS perforated sheet with 3 and 1.25 mm hole size of 1 mm thickness.
Top screen	L-380; B-280	
Bottom screen	L380; B-280	

Note: L-Length. B-Bredth, H-Thickness

Table 2 Effect of extraction drum type and drum speed on seed damage, germination and vigor index of onion seeds

Parameter	Extraction drum type (D)	Drum speed(S)			Mean	S. Em ± (CD at 5 %)		
		210	350	420		D	S	D × S
Extraction efficiency (%)	Horizontal rasp bar	98.6	99.8	99.7	99.4	0.169	0169	0.615
	Inclined rasp bar	98.9	99.9	99.7	99.5	(NS)	(0.355)	(NS)
	Rubber button	98.5	99.3	99.6	99.1			
	Mean	98.7	99.7	99.6				
Extraction capacity (Kg/h)	Horizontal rasp bar	23.8	27.9	28.9	26.8	0.605	0.605	1.04
	Inclined rasp bar	25.4	30.2	29.6	28.4	(NS)	(1.27)	(NS)
	Rubber button	24.5	25.1	30.9	26.8			
	Mean	24.6	27.7	29.8				
Specific energy consumption (kWh/kg)	Horizontal rasp bar	0.062	0.053	0.051	0.055	0.001	0.001	0.002
	Inclined rasp bar	0.058	0.049	0.050	0.052	(NS)	(0.002)	(NS)
	Rubber button	0.060	0.059	0.048	0.055			
	Mean	0.060	0.054	0.050				

Note: Figs. in the parenthesis indicate CD results

Cleaning capacity (kg/h) = Weight of seeds cleaned (kg) / Time taken (h)

Results and Discussion

The developed onion seed extractor was evaluated for three drum types at three drum speeds. The performance of the onion seed extractor with reference to the different parameter is presented in **Tables 2** and **3**. The results were analyzed statistically.

Extraction Efficiency

The extraction efficiency increased when the drum speed increased for all the three types of extraction drums (**Table 2**). The data indicated that the umbel extraction efficiency found to be significant at different drum speeds similar findings were reported by Sudajan *et al*., (2002).

Extraction Capacity

Extraction capacity increased as the drum speed increased (**Table 2**). The data showed that extraction capacity in onion seed extractor varied significantly at different drum speeds (210, 350 and 420 rpm) used for evaluation. The higher output (30.9 kg /h) was observed at the drum speed of 420 rpm with rubber button extracting drum. It was deduced that the higher speed conveyed the material faster to increase the extraction capacity.

Specific Energy Consumption

The specific energy consumption was found to be significant with drum speeds (**Table 2**). It decreased with increase in drum speed for all types of drums. As the drum speed increased the extraction capacity also increased. This led to decrease in specific energy consumption with increase in drum speed.

Seed Damage

The percentage of damaged seeds increased when the drum speed was increased (**Table 3**). The data indicated that the damage caused to the seed was found to be non-significant at all drum speeds and extracting drums.

Seed Germination

The data given in **Table 3** indicate that the viability of the seeds tested was found to be significant with different types of drums. The horizontal rasp bar provided higher germination percentage compared to inclined rasp bar and rubber buttons. Though the inclined rasp bar drum had the highest extraction efficiency, it had the lower germination percentage of 94 % when compared to horizontal rasp bar drum. This would have been due to the reason that the orientation of inclined rasp bar might have created internal damage to the seeds. The higher percentage of germination indicated that the less damage was caused to the seeds during extraction.

Vigor Index

The horizontal rasp bar showed more vigor of the seeds (**Table 3**). The data indicated that vigor index was found to be significant with different extraction drums. The higher vigor index showed more vigor of the seedlings. Though the inclined rasp bar drum had the highest extraction efficiency of 99.9 % (**Table 2**), it had the lowest vigor index 7,096.3 (**Table 3**). The inclined position of rasp bar might have made internal injury to the seeds.

Selection of Drum Type and Drum Speed

The extraction capacity and extraction efficiency were non-significant of drum type, but significant of drum speeds. Further the germination percentage and vigor index were found to be significant of drum type and non-significant of drum speed.

The germination percentage, vigor index are the very important parameters to be considered for any seed quality (Steiner and Akintobi, 1986). Hence, the horizontal rasp bar which gave higher germination percentage and vigor index was se-

Table 3 Effect of extraction drum type and drum speed on seed damage, germination and vigor index of onion seeds

Parameter	Extraction drum type (D)	Drum speed(S)			Mean	S. Em ± (CD at 5 %)		
		210	350	420		D	S	D × S
Seed damage (%)	Horizontal rasp bar	1.3	1.3	3.0	1.8	0.50	0.50	0.87
	Inclined rasp bar	2.6	2.6	4.0	3.1	(NS)	(NS)	(NS)
	Rubber button	1.3	1.6	1.6	1.5			
	Mean	1.7	1.8	2.8				
Germination (%)	Horizontal rasp bar	97.3	97.6	96.0	97	0.989	0.989	1.714
	Inclined rasp bar	96.0	94.0	89.3	93.1	(2.07)	(NS)	(NS)
	Rubber button	90.6	94.0	93.3	92.6			
	Mean	94.6	95.2	92.8				
Specific energy consumption (kWh/kg)	Horizontal rasp bar	7,252.8	7,874.4	7,736.1	7,621.1	135.0	135.0	233.9
	Inclined rasp bar	7,568.2	7,096.3	6,832.1	7,165.5	(491.4)	(0.002)	(NS)
	Rubber button	6,592.4	6,869.5	7,369.4	6,943.7			
	Mean	7,137.8	7,280.1	7,312.5				

Note: Figs. in the parenthesis indicate CD results.

lected. The highest drum speed of 420 rpm was selected to get higher extraction capacity.

Conclusions

A power operated onion seed extractor was developed. The seed extractor was evaluated for its performance for three types of seed extraction drum, viz., horizontal rasp bar, inclined rasp bar, rubber buttons and for three drum speeds, viz., 210, 350 and 420 rpm. The horizontal rasp bar drum at 420 rpm drum speed provided the best performance in terms of extraction efficiency (99.7 %), extraction capacity (28.9 kg/h), specific energy consumption (0.051 kWh/kg), seed damage (3 %), germination (97.6 %), and vigor index (7,736.1). The cleaning unit had a capacity of (40 kg/h) with a cleaning efficiency of (99.5 %).

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Development of an Evaporative Cooling Transportation System for Perishable Commodities

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Abstract

An evaporative cooling (EC) system suitable for vehicles used for transportation of perishable agricultural produce was designed and developed at the Indian Institute of Horticultural Research (IIHR), section of Agricultural Engineering. The performance evaluation was carried out during summer season using different vegetables viz., French beans, carrot, okra, tomato and amaranth. The vegetables which are kept inside the cooling chamber maintained the freshness, keeping quality and also increased the shelf life of the vegetables considerably compared to ambient condition by lowering the temperature and increase in the relative humidity. Thus, it reduces the respiration and transpiration rate of the stored vegetables. The developed EC system was fitted at the space available at the bottom of the pushcart. The pushcart which was developed has a steering mechanism, top surface cover and a space to fit the EC system. The EC system which was fitted increased the shelf life of more than 2-4 folds as compared to ambient conditions.

Key words: transportation vehicle, evaporative cooling system and shelf life

Introduction

India is the largest producer of fruits and second largest producer of vegetables in the world. The varied agro-climatic conditions provide an enormous scope for the cultivation of a wide range of horticultural produces. During 2010-2011, from about 14.8 million hectare of area, about 231.4 million tonnes of fruits and vegetables were produced (Bijay Kumar, 2011), which is about 18 % of gross agricultural output. But unfortunately, a sizeable portion of above produce is lost in food cycle before reaching the consumer. It has been estimated that the post-harvest losses of horticultural produce in India are as high as 30 % and the monetary value is about Rs. 44,000 crores/annum (Anon, 2009). One of the reasons for post-harvest losses is lack of proper storage facilities.

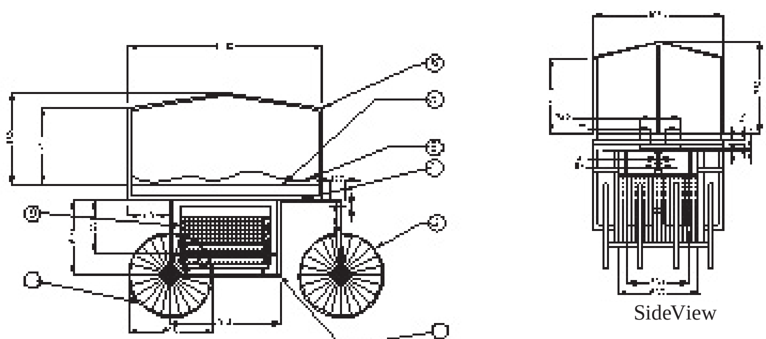
Evaporative cooled storage is one of the alternative low cost storage systems which is capable of maintaining lower temperature coupled with high humidity. It provides enough promise for short term storage of fresh produce to increase the market value and high demands (Maini and Anand, 1992; Khurdiya, 1995).

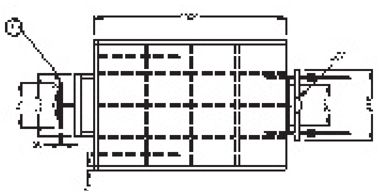
Fruits and vegetables are the living entities and all the vital activities of the tissues such as transpiration, respiration and ripening continue even after harvest leading to decay and senescence (Khurdiya, 1995). Temperature and water activity are the two most important physical parameters which control the rate of decay of food commodities in storage. Higher the temperature more is the rate of respiration. For each increment of 10 °C above optimum temperature, the rate of spoilage increases by 2-3 fold (Jimenez, 1983).

The lower temperature of storage, less likely is the development of abnormalities with loss of quality. Similarly, the high moisture content of the horticulture commodities accelerates transpiration and respiration making them highly perishable. Very low humidity in the storage space causes physical deterioration, which occurs as the evaporative loss and affects the texture of vegetables, resulting in shriveling and wilting. The psychological changes may have a direct influence on acceptability in terms of color, texture, appearance and over all acceptability (Dennis, 1984a). The principle aims of storage in fresh form is to control wilting and shrinkage and prevent undesirable physiological changes and disease infections (Das and Kumar, 1989). This could be achieved primarily by controlling the post-harvest environment such as maintenance of low temperature and high humidity (Khurdiya, 1995), as done in refrigerated/cold storage of fruits and vegetables. However, in places where cold storage facilities are not available, the evaporative cooling could be a cheap alternative and this technique has been suggested as an effective means to provide cool air temperature and high RH for cooling produce (Ash, 1959; Rama, *et al*., 1990; Maini and Anand, 1992).

Street vending as a profession that has been in existence in India since time immemorial. However, their number has increased manifold in recent years. Women constitute a large number of street vendors in almost every city. Some studies estimate that street vendors constitute approximately 2 % of the population of a metropolis. The number of street vendors in the country is estimated at around 1crore (10 million) (Harlen Dimas, 2008). Urban vending is not only a source of employment but provide affordable services to the majority of urban population.

The pushcarts are commonly used for vegetable vending. The pushcarts are made up of metal frame with wooden top and four wheels are mounted for transport. These loaded push carts are hard to push and often lifted to make a turn in the road/street corners. It does not have enough storage space for keeping vegetables fresh. Hence, the vegetables are to be sold within a day otherwise, they lose their freshness, market value and may not be suitable for next day vending.





All dimensions are in mm.

Part Number	Name	Material Used
1	Top Frame	M S Angle
2	Bottom Frame	G I Sheet
3	Swivel Front Whees	Cycle Wheel
4	Rear Wheel	Cycle Wheel
5	Plat Form	G I Sheet
6	Top Frame	M S Angle
7	Steering Handle	M S Pipe
8	Top Covering	Polythene Sheet
9	Standardized Ec System	Mild Steel & Charcoal Packing

Fig. 1 Developed pushcart with EC system (Coirpith cooler)

Materials and Methods

Developed Pushcart

The total weight of the frame was around 160 kg at fully loaded condition, suitable frame was required to withstand heavy weight, the frame was made up of mild steel angle of 40 × 40 × 6 mm, the main frame was fabricated by restricting the overall length, width and height of the frame to 150 × 105 × 105 cm, based on the width of the frame the handle was fabricated for easy transport of the vegetables for vending (**Fig. 1**).

Bottom Frame

Bottom frame was attached to the main frame. The overall dimension of the frame was of 90 × 66 × 75 cm was fabricated using MS angle of size 40 × 40 × 6 mm. This was utilized to house the standardized EC chamber at the bottom of the cart.

Steering Mechanism

Steering system was provided for front wheels to maneuver the cart in the turns easily and for this a separate steering frame was fabricated; the wheels used were of heavy duty. Wheel supporting arms were fitted to the sides of the frame for easy steering, two 6 mm thick flat of 40 mm width were fitted to the arms and joined at the rear end of the main frame, handle was provided for to and fro motion which enable the wheels for easy turning. The cart had turning radius of 1m for easy turning operation.

Plat Form

The Galvanized iron (GI) sheet of 1mm thickness was fitted to the main frame which acted as a platform such that vegetables could be kept on the platform during vending. One more GI sheet was taken and fitted to the bottom frame to house the coirpith cooler.

Top Surface Cover

To the top of the cart a suitable frame was fabricated and fitted to cover the top frame. A polythene sheet was used to cover the top surface to protect vegetables from dust, rain and high temperature and sunlight. A Velcro was used for attaching and detaching the side covers.

Operation Procedure

The coirpith cooler was kept at the bottom of the main frame. Fresh and mature vegetables were kept in trays and were placed inside the chamber. Two water troughs were designed one upper trough and one lower trough, the upper trough was placed on the top of the EC chamber. Four gunny cloths were used to cover the EC chamber, the gunny cloths were suspended from upper water holding trough to the lower trough. After few minutes the water flowed down by capillary action, within 30 min the gunny becomes completely wet and water got collected at the lower trough. When the upper trough becomes empty the water which was collected at the lower trough was taken out and it was recycled manually. The stepwise operation of modified pushcart and testing of standardized EC system was given in **Plate 1**.

The different vegetables were kept on the platform and also inside the EC chamber. If the vegetables kept on the platform was sold out, then the fresh vegetables were taken out from the EC chamber and filled the platform. Otherwise, if the vegetables were not completely sold during day time the left over vegetables were kept inside the EC chamber to maintain its shelf life and the consumer acceptability.


Storage space at the bottom


Side view of cart


Front view of cart

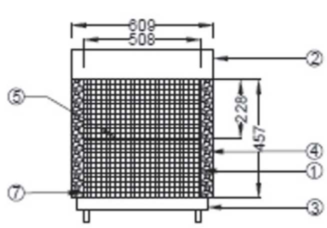

Keeping standardized system


Filling water to upper trough

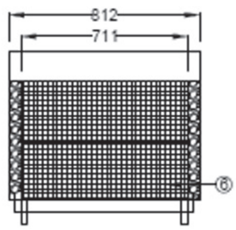

Standardized system in cart


Final system

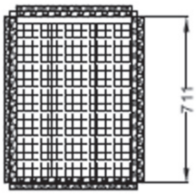
Plate 1 Stepwise operation of modified pushcart



Front View



SideView



Top View

All dimensions are in mm.

Part Number	Name	Material Used
1	Frame	M S Angle
2	Upper Water Trough	G I Sheet
3	Lower Water Trough	G I Sheet
4	Packing Material	Charcoal
5	Vegetable Storage Trays	G I Sheet
6	Mesh	M S Mesh
7	Hinged Door	M S Mesh

Fig. 2 Evaporative cooling system (Coirpith cooler)

Design of EC system (Coirpith Cooler)

The EC system was designed according to the space available at the bottom of the pushcart, and it was shown in **Fig. 2**.

Results and Discussion

French Beans

Temperature and Relative humidity

The mean daily temperature and relative humidity (March-June) both inside the system and ambient were measured and record. It was observed that the mean maximum temperature and relative humidity under ambient was 36-38 ºC and 50-59.56 % humidity, respectively. Similarly, the maximum temperature and humidity inside the EC system was 28-30 ºC and 85-90 %, respectively. The minimum temperature and humidity under ambient was 28-30 ºC and 35-40 %, respectively. Similarly, the minimum temperature and humidity inside the EC system was 21-23 ºC and 88-90

%, respectively. Hence, around 5-70 ºC decrease in temperature and 35-45 % increase in RH were observed in the system in comparison to ambient. Similarly the temperature and RH values of other vegetables are given in **Table 1**.

Physiological Loss in Weight (PLW %)

The physiological loss in weight was kept as standard as 10 %. If the % weight loss of the vegetables goes beyond this value, then it was considered as the end of the shelf life of the vegetables. It was observed from **Table 1** that the percent PLW for French beans, after 2 days of storage period under ambient condition was 9.7 %. The percent PLW of beans stored inside the EC system was 9.8 % after 9 days. Hence, it was found that French beans kept inside the system could be stored safely for about 8-9 days compared to only 2-3 days under ambient condition. Thus, the shelf life of beans could be increased by about 5-6 days in summer season, if it was kept inside EC system.

Sensory Evaluation

The sensory evaluation was carried out based on visual quality for beans through 9 point hedonic scale. It was observed from **Table 1**. That the beans stored under ambient condition lost their keeping quality after 2 days of storage. Similarly the beans kept under EC system lost their keeping quality after 9 days

Table 1 Performance evaluation of EC system (Coirpith cooler)

Storage period, days	1		2		3		4		5		6	
	C	S	C	S	C	S	C	S	C	S	C	S
Temperature (ºC)	29.4	21.4	29.4	22.2	29.6	21.8	29.2	21.5	29.1	21.2	28.7	21.3
Relative humidity (%)	41.8	89.6	37.7	90.2	38.3	90.3	36.8	90.5	46.1	89.8	49.1	88.7
French beans												
PLW (%)	3.5	0	9.7	0	ND	0	ND	1.5	ND	3.1	ND	4.3
Sensory evaluation (10)	7.6	9	4.2	8.7	ND	8.4	ND	8.0	ND	7.6	ND	6.5
Carrot												
PLW (%)	2.1	0	5.2	0	9.3	0	ND	0	ND	1.2	ND	2.3
Sensory evaluation (10)	8.2	9	6.6	8.8	3.8	8.5	ND	8.2	ND	8.0	ND	7.3
Okra												
PLW (%)	4.1	0	9.3	0	ND	0	ND	1.4	ND	2.9	ND	5.2
Sensory evaluation (10)	7.1	9	3.9	8.6	ND	8.1	ND	7.5	ND	6.7	ND	6.1
Tomato												
PLW (%)	0.6	0	3.5	0	6.2	0	10.1	0	ND	0.9	ND	2.2
Sensory evaluation (10)	8.3	9	7.4	8.7	5.8	8.6	4.6	8.2	ND	7.9	ND	7.5
Amaranthus												
PLW (%)	6.6	0	9.6	2.8	ND	6.3	ND	9.2	ND	10.8	ND	ND
Sensory evaluation (10)	5.9	8.8	2.4	7.6	ND	6.1	ND	4.4	ND	3.2	ND	ND

Storage period, days	7		8		9		10		11		12	
	C	S	C	S	C	S	C	S	C	S	C	S
Temperature (ºC)	28.3	22.3	29.3	23.1	29.6	23.6	29.3	23.8	29.2	22.4	29.4	23.7
Relative humidity (%)	45.2	91.2	44.8	90.2	50.9	89.4	45.3	89.6	44.7	89.5	43.6	90.1
French beans												
PLW (%)	ND	6.4	ND	8.2	ND	9.8	ND	ND	ND	ND	ND	ND
Sensory evaluation (10)	ND	5.8	ND	5	ND	4.1	ND	ND	ND	ND	ND	ND
Carrot												
PLW (%)	ND	4.2	ND	5.8	ND	7.6	ND	9.5	ND	10.9	ND	ND
Sensory evaluation (10)	ND	6.8	ND	6.1	ND	5.5	ND	5.0	ND	4.2	ND	ND
Okra												
PLW (%)	ND	6.9	ND	9.8	ND	ND	ND	ND	ND	ND	ND	ND
Sensory evaluation (10)	ND	5.5	ND	4.6	ND	ND	ND	ND	ND	ND	ND	ND
Tomato												
PLW (%)	ND	3.2	ND	4.1	ND	5.4	ND	6.7	ND	8.5	ND	9.8
Sensory evaluation (10)	ND	7.1	ND	6.5	ND	6.0	ND	5.4	ND	4.9	ND	4.1
Amaranthus												
PLW (%)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sensory evaluation (10)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

C: Control, S: System, ND: Not determined, RH: Relative humidity of storage. The sensory evaluation was carried out regularly at the end of storage period the hedonic scale reading was found to be 4.2 for ambient condition and 4.1 for EC system. Hence, if the hedonic scale reading goes beyond 4 then it is considered as the end of the shelf life of vegetables.

Carrot

The physiological loss in weight was kept as standard as 10 %. If the % weight loss of the vegetables goes beyond this value, then it was considered as the end of the shelf life of the vegetables. It was observed from **Table 1** that the percent PLW for carrot, after 3 days of storage period under ambient condition was 9.6 %. The percent PLW of carrot stored inside the EC system was 10.9 % after 11 days. Hence, it was found that carrot kept inside the system could be stored safely for about 8-9 days compared to only 2-3 days under ambient condition. Thus, the shelf life of beans could be increased by about 6-8 days in summer season, if it was kept inside EC system.

Sensory Evaluation

The sensory evaluation was carried out based on visual quality for beans through 9 point hedonic scale. It was observed from Table 1 that the carrot stored under ambient condition lost their keeping quality after 3 days of storage. Similarly the carrot kept under EC system lost their keeping quality after 11 days of storage. The sensory evaluation was carried out regularly, at the end of storage period the hedonic scale reading was found to be 3.8 for ambient condition and 4.2 for EC system. Hence, if the hedonic scale reading goes beyond 4 then it is considered as the end of the shelf life of vegetables.

Okra

The physiological loss in weight was kept as standard as 10 %. If the % weight loss of the vegetables goes beyond this value, then it was considered as the end of the shelf life of the vegetables. It was observed from Table 1 that the percent PLW for okra, after two days of storage period under ambient condition was 9.3%. The percent PLW of okra stored inside the EC system was 9.8% after 8 days. Hence, it was found that okra kept inside the system could be stored safely for about 5-6 days compared to only 2-3 days under ambient condition. Thus, the shelf life of beans could be increased by about 5-6 days in summer season, if it was kept inside EC system.

Sensory Evaluation

The sensory evaluation was carried out based on visual quality for beans through 9 point hedonic scale. It was observed from Table 1 that the okra stored under ambient condition lost their keeping quality after 2 days of storage. Similarly the okra kept under EC system lost their keeping quality after 9 days of storage. The sensory evaluation was carried out regularly at the end of storage period the hedonic scale reading was found to be 4.2 for ambient condition and 4.1 for EC system. Hence, if the hedonic scale reading goes beyond 4 then it is considered as the end of the shelf life of vegetables.

Tomato

The physiological loss in weight was kept as standard as 10 %. If the % weight loss of the vegetables goes beyond this value, then it was considered as the end of the shelf life of the vegetables. It was observed from **Table 1** that the percent PLW for tomato, after 5 days of storage period under ambient condition was 10.8 %. The percent PLW of tomato stored inside the EC system was 9.8 % after12 days. Hence, it was found that tomato kept inside the system could be stored safely for about 7-9 days compared to only 2-3 days under ambient condition. Thus, the shelf life of beans could be increased by about 7-9 days in summer season, if it was kept inside EC system.

Sensory Evaluation

The sensory evaluation was carried out based on visual quality for beans through 9 point hedonic scale. It was observed from **Table 1** that the tomato stored under ambient condition lost their keeping quality after 5 days of storage. Similarly the beans kept under EC system lost their keeping quality after 12 days of storage. The sensory evaluation was carried out regularly at the end of storage period the hedonic scale reading was found to be 3.2 for ambient condition and 4.1 for EC system. Hence, if the hedonic scale reading goes beyond 4 then it is considered as the end of the shelf life of vegetables.

Amaranthus

The physiological loss in weight was kept as standard as 10 %. If the % weight loss of the vegetables goes beyond this value, then it was considered as the end of the shelf life of the vegetables. It was observed from **Table 1** that the percent PLW for amaranth, after 1-2 days of storage period under ambient condition was 9.6 %. The percent PLW of amaranth stored inside the EC system was 9.1 % after 4-5 days. Hence, it was found that amaranth kept inside the system could be stored safely for about 2-3 days compared to only 1 day under ambient condition. Thus, the shelf life of beans could be increased by about 2-3 days in summer season, if it was kept inside EC system.

Sensory Evaluation

The sensory evaluation was carried out based on visual quality for beans through 9 point hedonic scale. It was observed from **Table 1** that the amaranth stored under ambient condition lost their keeping quality after 1-2 days of storage. Similarly the amaranth kept under EC system lost their keeping quality after 4-5 days of storage. The sensory evaluation was carried out regularly, at the end of storage period the hedonic scale reading was found to be 2.4 for ambient condition and 4.4 for EC system. Hence, if the hedonic scale reading goes beyond 4 then it is considered as the end of the shelf life of vegetables.

Microbial Growth

Microbial growth was not observed through physical appearance during the storage period in any of the selected vegetables (French beans, carrot, okra, tomato and amaranth).

Conclusions

Low Cost Cooling System could be used effectively for short-duration storage of fruits and vegetables even in hilly areas. The shelf life of French beans, carrot, okra and tomato could be increased to 5-8 days where as the shelf life of amaranth could be increased by 1-2 days, respectively if it is kept under mud pot in pot system. Similarly, the shelf life of French beans, carrot, okra and tomato could be increased to 4-7 days; whereas, the shelf life of amaranth could be increased by 1-2 days, respectively if it is kept under mud pot with ventilation holes.

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News

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Effect of Chemical Fertilizers on Soil Compaction and Degradation

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Abstract

Soil compaction adversely affects nearly all physical, chemical and biological properties of the soil. In this research, effects of fertilizers that resulted in soil degradation and compaction were studied. Soil penetration resistance was measured by electronic penetrologger in 12 wheat fields at depth 0-30 cm (each farm is a treatment with 3 replications), and the randomized complete block design was applied. Having applied a variance analysis, the mean values of data were compared using Duncan's multiple range tests. Results indicated that bulk density changed from 1.34 to 1.80 $Mg.m^{-3}$, as well as, penetration resistance from 0.89 to 3.54 MPa in noncompacted and highly compacted soils, respectively. According to the results, soil compaction decreased permeability by 81.4 %, available water by 34 % and yields by 40 %. Therefore, usage of fertilizers more than the recommended amounts causes formation, accumulation and concentration of mineral salts of fertilizers which leads to compaction layer and soil degradation in the long-term. High compaction decreases porosity and aeration while increasing bulk density and soil penetration resistance. Furthermore, root development and plant growth will be limited by reducing water and nutrient uptake which decreases yields.

Key words: bulk density; compaction; degradation; penetration resistance; permeability.

Introduction

Soil compaction is an important component of land degradation syndrome and is a significant challenge facing advanced agriculture that adversely affects nearly all soil properties: physical, chemical and biological (Weisskopf, *et al*., 2010). When soil is compacted, its structure alters by crushing aggregate units, reducing the size of pore spaces between the soil particles, reduction in soil volume and total porosity that leads to increase in soil bulk density and penetration resistance. Soil compaction refers to the formation of dense layers of well filled that occurs on cultivated layer, even more, the compressive forces are applied to compressible soil from wheels (Hamza and Anderson, 2005). Compaction is caused by the use of heavy machinery, reduction in use of organic fertilizer, frequent use of chemical fertilizers and plowing at the same depth for many years (Mari *et al*., 2008). One of the principal causes of compaction is over use of fertilizers (usage of fertilizers more than the recommended amount) for long periods and intensive cropping. Soil compaction causes problems including excessive soil strength, limiting root growth, poor aeration, poor drainage, runoff, erosion and soil degradations (Batey, 2009). These changes lead to reduction in permeability, hydraulic conductivity and groundwater recharge (Blanco, *et al*., 2002). Excessive soil compaction impedes root growth and this can decrease the plants uptake ability of nutrients and water. If the bulk density increases from 1.3 to 1.4 $Mg.m^{-3}$ in some sort of soil with loamy texture, infiltration rate and aeration will reduce (Osunbitan *et al*., 2005). Compaction reduces root growth, as well as, the yield by more than 80 % (Rannik, 2009). When the soil bulk density increases, nitrification decreases by 50 % and plant absorbs less nitrogen, phosphorus and zinc from soil (Barzegar *et al*., 2006). Reduction of biological activity due to compaction is a great concern (Beylich *et al*., 2010). Organic matter is the most important factor in soil structure stability. Soil that has high organic matter contents and thrives with soil organisms is more resistant to compactions and can recuperate much better from slight compaction damage (Dexter, 2008; Celik *et al*., 2010). This research aims to study the effects of over use of fertilizers more than the recommended amounts that cause compaction and soil degradation in long term.

Materials and Methods

The soil studied in this research had been planted with wheat for over 50 years. This research was carried out on 12 wheat farms (each plot is a treatment) in Pakdasht regions, station (35º37′ N, 35º37′ E; 1005 m above sea level) located 35 km southeast of Tehran. Average annual precipitation at this site is 210 mm. The research procedure was as follows:

Farms with different levels of soil compaction were randomly selected. After taking soil samples from each farm (2 m × 1 m × 0.3 m), the necessary analysis was performed in soil laboratory using routine methods. The experiment was a randomized complete block design with 3 replications. N-P-K fertilizers were applied in the seedbed at average rates of 405 kg N ha^{-1} (urea), 203 kg P_2O_5 ha^{-1} (triple phosphate) and 120 kg K_2O (Potassium sulfate) sulfate ha^{-1}. The average amounts of recommended fertilizers were 178 kg N ha^{-1}, 85 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1} (Azadegan and Amiri, 2010). Bulk density was determined from undisturbed soil samples and was measured by the core method. Soil moisture content and penetration resistance were measured at the same time. In order to determine the soil moisture content, undisturbed soil samples were taken from each plot using a steel cylinder of 100 cm^{-3} volume at depths of 0-15 and 15-30 cm. Soil gravimetric moisture content was calculated from the weight difference between wet and oven-dried samples (24 h at 105 ºC). The volumetric moisture content was calculated by dividing the gravimetric moisture content by the soil volume of 100 cm^3. Soil optimum moisture was determined via standard proctor test (ASTM). Soil water permeability was measured using double rings and aggregate stability was determined by measuring the mean weight diameter (M.W.D) of soil aggregates in a sieve under running water. Soil bulk density (ρ_b) was determined via volumetric cylinder method and particle density was measured using a Pycnometer. In order to calculate soil porosity, the relationship between bulk density and particle density was used. Available water equals the difference between the water content at field capacity (FC) and permanent wilting point (PWP) which was measured by the use of a pressure membrane apparatus. Wheat net water requirement was determined using regional meteorological data and Crop-wat software.

Soil penetration resistance was determined by a hand-pushed electronic cone penetrometer (Eijkelkamp penetrologger, 06.15.SA) following ASAE standard procedures, using a cone with 2 cm^2 base area, 60º included angle, speed of 3 $cm.s^{-1}$, 80 cm driving shaft; readings were recorded at 10 mm intervals. The measurements were performed at 10 points in each plot. In order to minimize the effect of compaction caused by agricultural machinery traffic in each plot, the soil from the middle cultivation rows (between the tractor tracks) was used for sampling and testing. The penetration resistance of 10 different points in each plot was randomly measured at depths of zero to 30 cm (at distance is 5-10 m each of point). The average penetration resistance of those 10 points represented the compaction status of the soil in each plot. Values of the average penetration resistance of 12 treatments (each plot was considered as one treatment) were compared. In order to compare the average values of penetration resistance, the normality of the data was tested. Grain yield of each plot was measured after harvest. Variance analysis of data was done based on the randomized complete block design and mean comparison was done using Duncan's multiple range test ($P \leq 0.05$). The soil compaction status was studied and conclusions were made based on the results.

Results and Discussion

The experiment showed that the studied soil contained 36 % clay, 33 % silt and 31 % sand at the depth zero-30 cm. Soil texture was loam-silt loam with 1-2 % slope. The soil had a pH of 7.48-7.70, ECe of 1.15-2.20 ds.m-1 and particle density 2.60-2.62 $Mg.m^{-3}$. Soil bulk density and penetration resistance were used to characterize the compaction and soil degradations.

The result of soil analysis of physical properties (**Table 1**) shows bulk density of 1.34-1.80 Mg m^3- and the mean aggregate diameter (M.W.D) changes from 1.43 to 0.28 mm. The aggregates diameter in non-compacted soil (plot, P_2) is 5 times greater than the highly compacted soil (plot, P_4). The macro-aggregates are disintegrated into micro-aggregates that decrease the size and proportion. The total pore volume and porosity is decreased 17.4 % which slows down water and air movement in the soil. Previous studies revealed that the number of small pores decreases, and so does the amount of plant-available oxygen. As a result, as soil density increases, total porosity decreases up to 17 % in the severe compaction. The soil with aggregates about 5mm in diameter, has relatively low volume of inaccessible water for the highest crop yield (Jung, *et al*., 2008; Kaufmann *et al*., 2005; Stawinski *et al*., 2010) and reduction in nutrient uptake (Kuht and Reintam, 2004). These adverse effects may be due to restriction in root depth, where roots in compact soil are confined to macro pores and the rate at which they can extract water and nutrients from the soil between the macro pores may be considerably slowed.

To achieve higher yield of crops, it is essential to provide the optimum level of nutrients requirement. In Pakdasht regions, farmers applied usually N, P and K fertilizers in the seedbed at rates of 405 kg N ha^{-1}, 203 kg P_2O_5 ha^{-1} and 120 kg K_2O ha^{-1} for wheat in each year. But fertilizers were applied at average rates of 227 kg N ha^{-1}, 118 kg P_2O_5 ha^{-1} and 70 kg K_2O ha^{-1} more than the recommended amounts. However, there were no significant increases in yields. Results showed that calcium carbonate content increased from 12.24 % in non-compacted soil to 24.8 % in highly compacted soil (increased by 100 %). The calcium carbonate concentrated and accumulated into sub soils with little solubility, which created a compressed layer that slows down the water movement in the soil (Jung, *et al.*, 2008). Phosphorus and excessive calcium in soil form insoluble calcium phosphate which reduces phosphorus absorption. Compaction affects phosphorus uptake strongly because the phosphorus is very immobile in soil and the rate of residual phosphorus fertilizers in soils is 75-80 % (Tisdale, *et al.*, 1993). Compaction also reduces penetration and growth of the roots because phosphorus uptake is inhibited in compacted soil. Therefore, extensive root systems are necessary to enable phosphorus uptake (Oussible, *et al.*, 1992). Potassium uptake is affected the same way as phosphorus. The rate of residual potassium fertilizer is 30-40 % in the soils and gradually forms carbonate Potassium (Kaufmann, *et al.*, 2010). Also, nitrification capacity decreases by 50 % while the rate of residual nitrogen fertilizers is 30-35 % in the soils. The results show a reduction in absorption efficiency of fertilizers, as well as, annual increase in fixation and concentration of insoluble forms of nitrogen, phosphorus and potassium in soils. This effect leads to reduced uptake of nutrients in return (Mari, *et al.*, 2008). Overuse of fertilizers in each year for monoculture crop causes formation and concentration of mineral salts of fertilizers leading to compaction layer and soil degradation in the long-term. These results in increase of physical properties of the soil, such as, bulk density, penetration resistance and soil compaction which in return decreases plants-absorbable nutrients, crop yield and increases the production cost. In some soils dissolution of salts due to irrigation causes dispersion of soil particles. Once aggregates are dispersed, fine clay particles leach into soil pores and block them. These fine and structure-less substances cover the soil surface which hinders water penetration and forms a hard and impermeable layer (Stawinski, *et al.*, 2011).

In this study, 20-40 ton.ha-1 of cow manure was used in non-compacted soil, and nothing in compacted soil. Organic carbon was 0.58-1.17 %, C/N decreased from 19.5 in non-compacted soil to 8.28 in highly compacted soil (42.5 % reduction). Insufficient use of animal manure causes organic matter deficiency in soil that contributes to its compaction decelerates the organic carbon mineralization. This consequently disrupts the biotic activities of the soil which decreases the absorbable nutrients, stunts plant growth and limits the yield. With this loss of organic fertilizer, soil aggregate stability reduces. Total number of bacteria and enzymatic activity in soil under soybean decreased in

Table 1 Results of the soil physical analysis in Pakdasht County (0-35cm depth)

Plot	Clay (%)	ρ_b ($Mg.m^{-3}$)	M.W.D (mm)	Porosity (%)	Permeability ($mm.h^{-1}$)	Available Water (%)
P_1	33	1.62	0.53	37.6	37	19
P_2	32	1.34	1.43	48.2	71	24
P_3	33	1.40	1.37	46.5	64	23
P_4	35	1.79	0.30	30.8	12	16
P_5	35	1.78	0.29	31.5	25	17
P_6	30	1.46	1.32	43.9	59	22
P_7	36	1.55	1.25	41.3	48	21
P_8	30	1.56	1.20	40.4	42	21
P_9	35	1.68	0.32	35.5	33	18
P_{10}	36	1.75	0.28	31.7	19	16
P_{11}	34	1.80	0.28	31.0	15	16
P_{12}	33	1.51	1.25	42.6	53	22

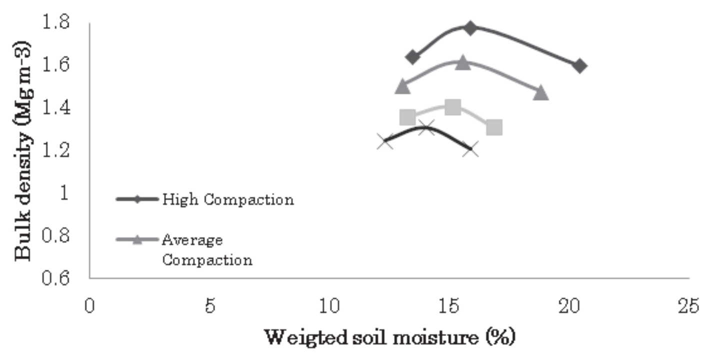

Fig. 1 Soil moisture versus soil bulk density

strongly compacted soil (Beylich, *et al*., 2010; Siczek and Frac, 2012). To optimize organic matter input in the soil for maximum productivity, one should reduce losses of organic matter by preventing the soil erosion (Bandyopadhyay, *et al*., 2011). Structural stability of topsoil with greater organic matter content was considered as enhanced resistance to compaction. Organic matter decomposition is slower in compacted soils, and less biological activity occurs because the size and number of macro pores in the soil, aeration and microbial activity are reduced. Soil with high organic matter content that thrives with soil organisms is resistant to compaction and can better recuperate from degradation.

Fig. 1 shows soil moisture content versus soil bulk density. Soil optimum moisture was 13.2 %. Farmers were usually tilling soil at moisture content above the optimum level (15-16 %) which contributes to soil compaction. The compacted soil often has higher soil moisture because soil water is unable to drain away freely and air movement in the soil is restricted. Compaction of soil pushes the soil particles closer together, reduces the pore space and so bulk density increases. That process reduces porosity, permeability and crop yield. A tractor of 75 HP cannot easily till the farm due to its highly compacted soil. Therefore, heavy-duty tractor with more than 75 HP is needed, which results in increasing the cost of production. High penetration resistance and soil compaction are functions of soil moisture content. Each soil type with a certain amount of moisture (optimum moisture content) has optimum penetration resistance, bulk density, compression and compaction. When the soil rewets and expands, the extra soil present in the subsoil will induce compaction (Kaufmann, *et al*., 2010; Jung, *et al*., 2010). If tillage is done under improper moisture conditions, big clods are formed. The wetting of clogged soil pores gradually after irrigation reduces soil porosity and permeability (Weisskopf, *et al*., 2010). The effect of the plowing and machineries traffic on yield can be predicted by measuring of penetration resistance and soil compaction. If soil is dry and firm throughout the profile, there may be no significant effect. If the surface layers are moist and soft lying over dry soil, the upper layers may be strongly compressed. But if the surface layers are dry and firm with moist soil below, the compression may be transmitted downwards to compress the moisture in the more vulnerable soil. Obviously, suitable moisture content, during the cultivation, prevents soil compaction.

Fig. 2 compares the mean values of penetration resistance and soil depth in non-compacted, low compacted, moderate compacted and highly compacted soils. Values of soil bulk density were strongly correlated to soil penetration resistance. Penetration resistance in non- compacted soil at first increased slightly with depth but later changes were insignificant because soil compaction was within the normal range due to stable aggregates and proper soil structure. Penetration resistance changes dramatically from the soil surface to greater depths in highly compacted soil as a result of compaction caused by the disintegration of soil macro-aggregates and formation of micro-aggregates, reduction in the aggregates diameter, total volume of soil pores, porosity percentage, the size and proportion of the voids in it. An increase in soil bulk density and penetration resistance reduces soil permeability, air diffusivity, rate of root development and plant growth (Zhang, *et al*., 2006). As noted, a moderate increase in soil bulk density leads to an increase in the cohesion among particles and better adhesion between particles and root surfaces by facilitating water and nutrient absorption.

Table 2 shows the variance analysis of soil compaction in order to

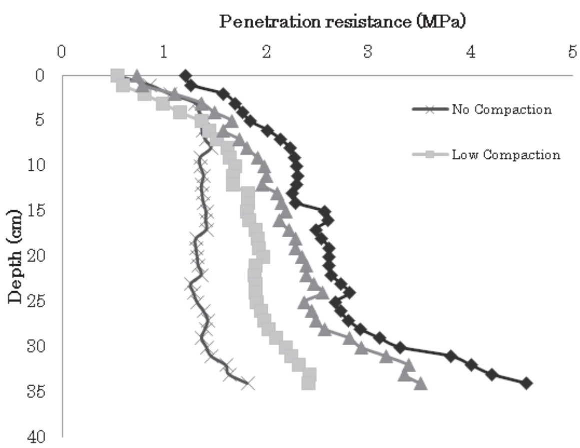

Fig. 2 Comparison the mean of penetration resistance and soil depth

Table 2 Variance analysis of soil compaction to compare 12 farms

Variation Source	df	Ms
Block	58	0.4189**
Treatment	12	6.1008**
Error	509	0.0499
C.V = 7.79 %		

Table 3 Comparison of the mean values of soil compaction in 12 farms using Duncan's multiple tests ($P \leq 0.05$)

Plot	P4	P10	P11	P5	P9	P1
average	3.54a	2.73b	2.72b	2.69b	2.00c	1.67d
Plot	P8	P7	P12	P6	P3	P2
average	1.66de	1.60de	1.48ef	1.41fg	1.34g	0.89h

compare the 12 farms on the basis of randomized complete block design. The results have been significant at ($P \leq 0.01$). **Table 3** shows the comparison of mean soil compaction amounts of 12 farms using Duncan's multiple range test ($P \leq 0.05$). **Table 1** shows that plot P_4 has the penetration resistance 3.54 MPa (highly compacted), while plot P_2 has 0.89 MPa (non-compacted). Soil penetration resistance in highly compacted soil is 14 times greater than non-compacted soil. Penetration resistance is a better indicator of the effects of soil compaction on root growth because results can be interpreted independent of soil texture. In **Table 1**, the average bulk density increases from 1.34 $Mg.m^{-3}$ in non-compacted soil to 1.80 $Mg.m^{-3}$ in highly compacted soil. It can be observed that penetration resistance increases as the bulk density increases; this leads to an increase in soil compaction which adversely affects the indices of porosity and available water. Highly compacted soil constrains root penetration and development, impedes plant growth and reduces the yield. The biggest differences between bulk soil and the rhizosphere occurred in heavily compacted soil, where soil penetration resistance limited root growth (Nosalewicz, 2011). When soil penetration resistance is over 2 MPa (the critical level), root growth in many plants will be restricted and may stop due to soil compaction (Henderson, 2005). Penetration resistance index may individually account for 50 % of the variations in wheat growth and yields (Passioura, 2002; Rannik, 2009). Soil compaction destroys soil structure and leads to a more massive soil structure with fewer natural voids. When penetration resistance changes from 0.4 to 4.2 MPa due to compaction, the lengths of the primary root and lateral roots are reduced by 71 and 31 %, respectively. Consequently, the yield reduces by 20-40 % (Kuht and Reintam, 2004; Jung, *et al*., 2008). Compaction alters soil structure by increasing soil bulk density, breaking down the soil aggregates, decreasing soil porosity, aeration and infiltration (Weisskopf, *et al*., 2010).

Fig. 3 shows the relation between soil bulk density and porosity. Porosity was 48.2 % in non-compacted soil and changed to 30.8 % in highly compacted soil (reduced by 17.4 %); the bulk density also increased from 1.34 $Mg.m^{-3}$ normal to 1.80 $Mg.m^{-3}$ in highly compacted soil. Soil high compaction reduces the pores diameter by disintegrating the soil particles; therefore, increases soil strength and decreases porosity. High bulk density and low porosity reduced the pore-spaces due to which roots were incapable to extract soil nutrients. Therefore, reduced nutrient uptake by plant and also inadequate water may impede and even stunt plant growth, resulting in decreased yields. Compaction reduced air-filled porosity considerably and caused more frequent and pronounced conditions of low O_2 concentration in soil air (Bassett, *et al*., 2005). Soil compaction causes other problems such as poor aeration, limited root growth, excessive runoff, erosion and a degradation of soil structure. This degradation is enforced when tillage is used to break up compacted soils.

Fig. 4 shows the relation between permeability and available water. Permeability reduced from 71 mm/h in non-compacted soil to 12 mm/h in highly compacted soil (81.4 % reduction). The permeability in highly compacted soil is 6 times less than that in non-compacted soil. Consequently, available water is also reduced from 23.5 % in non-compacted soil to 15.5 % in highly compacted soil (34 % reduction). Plant suffers from nutrients deficiency, physiological dryness and water stress. The occurred water stress hinders plant growth and reduces yield. Permeability and available water decreased by 21 and 49 % in moderately and highly compacted soils, respectively. In this study, average wheat yield was 3,500 to 5,800 $kg.ha^{-1}$

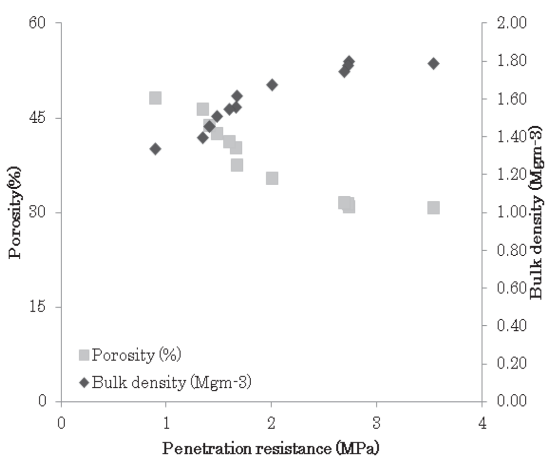

Fig. 3 Relation between the bulk density and soil porosity

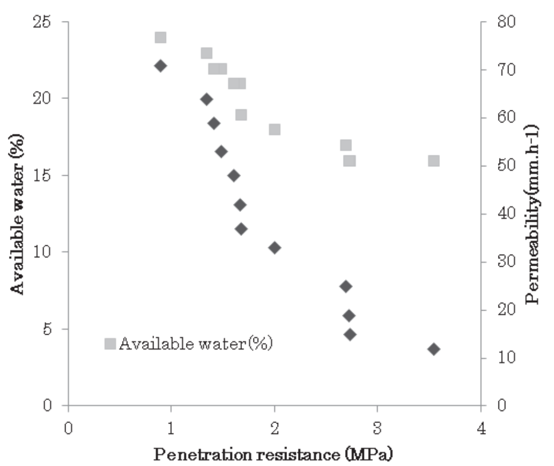

Fig. 4 Relation between permeability and available water

in highly compacted soil and non-compacted soils, respectively. The yield decreases 2,300 kg.ha^{-1} (40 % reduction) due to high compaction (Azadegan and Amiri, 2010). This yield reduction not only reduces the farmer income but also increases the production cost. Reduction of yield components was due to compaction and less supply of necessary nutrients from soil because roots were less proliferated, and were unable to supply the required material, thus the yield decreased. Insufficient water and nutrients absorption, as well as, increasing water stress in plants reduced the yield (Kaufmann, *et al*., 2010). With slow permeability through the clay pan, soils saturate quickly creating a high probability of runoff (about 30 %), clay pan soil reduced yields by 20-47 % (Blanco, *et al*., 2002; Jung, *et al*., 2010)

High soil compaction substantially damages the physical, chemical and biological properties of soil and reduces the yield. In this research, some operations like performing tillage at optimum moisture condition, employing appropriate methods of irrigation, and observing the technical tips of soil and water management have been undertaken in farms P_4, P_3, P_6 and P_{12} under the supervision of an expert, soil compaction had been within the normal range. But in farms P_2, P_5, P_{10} and P_{11} soil is highly compacted because of the farmers' excessive use of fertilizers and not using organic matter. Also, there was mismanagement of the soil and water and not observing crop rotation traditionally. Soil compaction in farms P_1, P_7, P_8 and P_9 had been moderate. High soil compaction decreased absorbability of water and nutrients, increased resistance against root penetration and development, stunted plant growth, decreased available water, reduced soil quality, yields and finally, increased production costs. Soil compaction affects significantly the soil structure, and nutrient uptake in wheat plants (Mari *et al*., 2008).

Soil structure can be improved by adding enough organic matter to soil, reducing usage of chemical fertilizers, observing crop rotation, proper cultivation operation, using modern irrigation methods and applying sub-soiler to shatter the deep compact layers (Azadegan and Amiri, 2010).

Conclusions

Over-use of fertilizers more than the recommended amounts for continuous monoculture cropping caused formation, accumulation of mineral salts of fertilizers that lead to compaction layer, compaction and soil degradation in long-term. Soil degradation affects significantly the soil structure and nutrient uptake.

Results showed that the size and number of macro pores in the soil reduced which lead to increase in soil bulk density and penetration resistance that degraded soil physical properties. Soil bulk density values were strongly correlated with soil penetration resistance.

The plowing is performed moisture content higher than the optimum level. Consequently soil structure is damaged and caused compaction because soil water is unable to drain away freely and air movement in the soil is restricted.

Not using organic fertilizers reduced C/N, organic carbon mineralization, aggregate stability and porosity which consequently disrupted the biotic activities of soil, decreasing the absorbable nutrients.

High soil compaction decreased permeability, drainage, aeration, water availability, absorption of nutrient, plant growth and yield. It can be concluded that the major contributory factors to high soil compaction are caused by the over-use of fertilizers.

Acknowledgement

This project was funded by the research deputy of College of Abouraihan, University of Tehran which is really appreciated.

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Field Evaluation of Deep Soil Volume Loosener-cum-Fertilizer Applicator for Management of Sugarcane Ratoon Crop

by

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Abstract

Sugarcane ratoon crops is common in India but with low productivity. To overcome this, various cultural operations such as cutting of old roots (off-barring), stubbles shaving, inter-cultivation between rows for weed control, gap filling, placement of fertilizers, etc. have been recommended. The traditional cultural practices, tilling and mixing of broadcast fertilizer in ratoon crop are insufficient for proper soil management and nutrient utilization. An innovative machine named as 'Deep Soil Volume Loosener-cum-Fertilizer Applicator' has been developed for performing recommended cultural practices in ratoon crops such as deep tilling of soil up to a depth of 300 mm within the rows, cutting of old roots, deep placement of fertilizer at 200 ± 50 mm depths in the moist root zone, breaking of clods and consolidation of tilled soil for moisture conservation with improved traction of power unit. The developed machine is pulled by 40-45 kW tractor and leaves the tilled surface completely levelled after operation, thus making it an efficient machine for soil cultivation in laser levelled fields. The field performance evaluation of this machine in comparison to conventional practice of ratoon management with row crop rigid tines cultivator have shown significant increase in crop growth parameters, yield attributes, juice analysis and cane yield increase of over 30.7 % and has created great demand amongst sugarcane growers.

Introduction

Scientific ratoon management for enhancing its productivity is of paramount importance. Sugarcane roots spread side ways to about 2 m from the centre of stool, penetrate up to 6 m deep and decay in about 60 days after harvesting (Smith *et al*., 2005). Cutting of old roots (off-barring), inter-cultivation between rows for weed control, placement of fertilizers into soil while off-barring, gap filling etc. have been recommended for increasing productivity of ratoon crop (Yadav, 1990; Thakur *et al*., 2010). Traditionally in sugarcane ratoon, fertilizer is broadcast and mixed either by row crop rigid tines cultivator or by manual spade. Sometimes farmers also use disc harrow for mixing of fertilizers with very poor nutrient utilization efficiency. A ratoon Management Device' was developed to work for management of sugarcane ratoon crops but cannot be used for normal soil cultivation operations (Srivastava *et al*., 2006). About 20 % saving of fertilizers has been found with the use of a commercialized machine named as Pant-ICAR subsoiler-cum-differential rate fertilizer applicator (Mandal and Thakur, 2010 a & b). A Deep Soil Volume Loosener-cum-Fertilizer Applicator for soil cultivation immediately behind the rear wheels of a tractor without disturbing the level of a field by overcoming re-compaction of tilled soil with improved traction was designed to perform off-barring operation i.e. cutting of old roots and deep placement of fertilizers in bands along both sides of rows and a well pulverized soil with level field surface thereby not only allowing a better managed ratoon crop but also companion cropping of wheat, pulses etc. (Manoj Kumar, 2010; Manoj

Kumar and Thakur, 2013). The results of field performance evaluation of developed machine alongside the conventional methods of sugarcane ratoon management have been presented in this article.

Materials and Methods

The experiment was conducted in Farmer's participatory research mode in the year 2008-2009 in silty clay loam soil which lies in a narrow belt of Tarai region of Uttarakhand (India) in the foothills of Shivalik ranges of the Himalayas. Three ratoon crop management equipment, i.e. 1) a tractor drawn rigid tines row crop cultivator with a group of three tines adjusted in two rows, 2) a controlled field traffic inverted-T openers type zero-till ferti- seed drill with a pair of tines adjusted to apply fertilizers along both sides of a row and 3) Deep Soil Volume Loosener-cum-Fertilizer Applicator with V-shaped tines for soil loosening and simultaneous placement of fertilizers at varying depths in two rows, were selected for comparative performance evaluation and are shown in **Fig. 1**. It had three main units i.e. a deep soil volume loosening unit, fertilizer application unit and clod crusher unit. The deep soil volume loosening unit consisted of a rectangular frame, two V-shaped tines and a hitching system. The fertilizer application unit consisted of two fertilizer boxes with four positive feed grooved roller type metering system, a pair of inverted-T openers positioned at the rear of V-shaped tines for placement of fertilizers in a narrow band, a ground drive wheel for power transmission and its accessories. The clod crusher unit consisted of two floating type spiked roller clod crushers and their accessories for soil pulverization and consolidation for moisture conservation. This machine is used for tilling of soil up to 300 mm depth and simultaneous application of fertilizers and micro-nutrient directly into the root zone of crops at the depths of 200 ± 50 mm. It pulverizes the clods, consolidates the soil and leaves a completely levelled field surface after operation, thereby making it the most appropriate machine for soil cultivation in laser levelled fields (Manoj Kumar and Thakur, 2013).

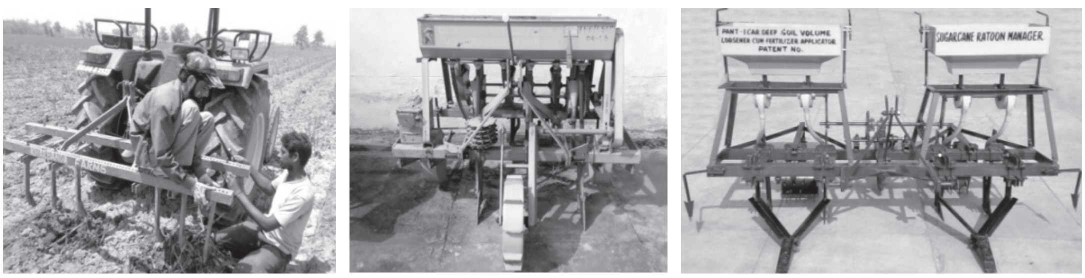
The experiment was laid in Randomized Block Design with four treatments and five replications after harvesting of sugarcane plant crop (Var : CoS 8436) planted at 900 × 300 mm paired row spacing. The gross area of experimental field was 5,160 m^2 with 24 m × 10 m size of each plot. The following four treatments were selected:

T_1: Broadcasting of fertilizer + mixing with a rigid tines row crop cultivator (Control)

T_2: Off-barring and fertilizer application at 120 mm depth along both sides of a row with inverted-T openers' zero-till ferti-seed drill (ZT drill)

T_3: Deep Soil Volume Loosener-cum-Fertilizer Applicator (soil loosening up to 300 mm depth and fertilizer placement at 120 mm depth)

T_4: Deep Soil Volume Loosener-cum-Fertilizer Applicator (soil loosening up to 300 mm depth and fertilizer placement at 200 mm depth)



a) Rigid tines two row cultivator b) Inverted-T openers ZT-drill (c) Deep Soil Volume Loosener-cum-Fertilizer Applicator

Fig. 1 Differnet equipment used in the experiment

a) Rigid tines cultivator b) ZT-drill c) Deep Soil Volume Loosener-cum-Fertilizer Applicator

Fig. 2 Field operations of different equipment in the experimental field

The field operations of selected equipment are shown in **Fig. 2**. The data in respect of crop growth parameters, yield attributes, yield of sugarcane and juice analysis were collected and analyzed using standard measurement techniques.

Results and Discussion

The results of crop performance in terms of growth, cane yield attributes, cane yield and juice analysis of sugarcane ratoon crop are described below:

Crop Growth Parameters

The shoot population and shoot height were measured at 120, 150, 180 and 210 days after harvesting (DAH) of the plant crop and the results are presented in **Table 1**. The data on shoot population revealed maximum number of shoots at 120 DAH which successively declined at various stages of growth up to 210 DAH. It is also evident from the table that at any stage of growth, there was a significant ($P \leq 0.05$) increase in shoot population from treatment T_1 (control) to T_4.

The shoot height from 120 to 210 DAH shows that the difference in shoot height in various treatments was significant at 120 and 180 DAH. At all the growth stages, successive increase in shoot height was observed from treatment T_1 (Control) to T_4. Treatment T_4 exhibited the maximum shoot height of 0.98, 1.29, 1.51 and 1.79 m; whereas the treatment T1 produced the minimum shoot height of 0.74, 1.07, 1.34 and 1.63 m after 120, 150, 180 and 210 DAH, respectively.

Cane Yield Attributes and Yield

The effect of different treatments on Cane length showed significant difference ($P \leq 0.05$) under different treatment. It was found to be 5.7, 11.1 and 12.5 % higher in treatments T_2, T_3 and T_4 in comparison to T_1, respectively (**Table 2**). The cane girth was found to be 2.0, 5.6 and 7.7 % higher in treatments T_2, T_3 and T_4 in comparison to T_1, respectively. Similarly, the cane weight was found to be 3.5, 6.9 and 12.8 % higher in treatments T_2, T_3 and T_4 in comparison to T_1, respectively. This may be due to deeper soil loosening and deeper placement of fertilizer in root zone of sugarcane ratoon crop.

The number of millable canes was found higher in the order of 4.3, 11.2 and 15.9 % in treatments T_2, T_3 and T_4 vis-à-vis T_1, respectively. The cane yield due to different treatments was found significant ($P \leq 0.05$). Similarly, the cane yield was found to be 7.7, 18.8 and 30.7 % higher in treatments T_2, T_3 and T_4 in comparison to T_1, respectively.

Cane Juice Analysis

The results of juice analysis at the time of harvesting are presented in **Table 3**. The effects of different treatments on juice extraction and brix percentage showed non-significant difference. However, the juice extraction and brix percentage was found maximum in treatment T_4 and minimum in T_1.

The effects of different treatments on sucrose content, available sugar and commercial cane sugar (CCS) showed significant difference. The treatment T_4 (18.21 %) was found at par with treatment T_3 but exhibited significantly ($P \leq 0.05$) higher sucrose content than treatments T_2 and T_1. The treatment T_4 produced maximum value of available sugar (12.54 %) which was at par with treatment T_3 but significantly higher than treatments T_2 and T_1. Similarly, the commercial cane sugar yield was found significantly maximum in treatment T_4 and it was found to be 9.5, 25.1 and 41.2 % higher in treatments T_2, T_3 and T_4 in comparison to treatment T_1, respectively.

Table 1 Shoot population and shoot height at various stages of growth in different treatments

Treatments	Shoot population, 000 ha^{-1}				Shoot height, m			
	120 days	150 days	180 days	210 days	120 days	150 days	180 days	210 days
T_1	206.7	157.5	127.5	120.0	0.74	1.07	1.34	1.63
T_2	228.8	177.5	131.3	123.8	0.80	1.10	1.35	1.66
T_3	232.1	183.3	142.1	130.8	0.86	1.23	1.41	1.74
T_4	245.4	195.0	148.8	136.3	0.98	1.29	1.51	1.79
S. Em ±	6.02	4.39	2.22	1.92	0.045	0.063	0.032	0.061
CD at 5 %	18.55	13.52	6.83	5.91	0.139	NS	0.099	NS

Table 2 Cane yield attributes, yield and cane juice analysis of different treatments

Treatments	ane yield attributes and yield					Cane juice analysis				
	Cane length, m	Cane girth, mm	Cane wt., g	NMC, 000/ha	Yield, t/ha	Juice extraction, %	Brix, %	Sucrose content, %	Available sugar, %	CCS, t ha^{-1}
T_1	1.77	78.2	614	115.8	71.1	57.90	20.14	17.11	11.61	8.25
T_2	1.87	79.8	635	120.8	76.6	58.18	20.26	17.34	11.81	9.03
T_3	1.96	82.6	656	128.8	84.5	60.34	20.66	17.84	12.20	10.32
T_4	1.99	84.2	692	134.2	92.9	60.48	20.80	18.21	12.54	11.65
SEm	0.039	2.54	23.87	2.05	3.02	1.39	0.27	0.17	0.14	0.37
CD (5 %)	0.12	NS	NS	6.31	9.30	NS	NS	0.51	0.43	1.13

The maximum cane yield of 92.9 t/ha was obtained in treatment T_4 which was approximately 30.7 % higher over treatment T_1. This may be due to the soil loosening and off-barring operations were carried out deeply (300 mm) by the developed equipment, higher amount of root biomass could be expected to decay soon after its operation (The sugarcane has a very extensive root system contributing to about 3.5-4 t ha^{-1} of root biomass). Moreover, the band placement of fertilizers was carried out deeply at 200 mm depth which ensured regular availability of nutrients because of higher soil moisture content at deeper depths. The combined effect of new root emergence, fertilizer placement in moist zone and soil loosening is reflected in terms of higher crop growth parameters and yield of ratoon crop.

The yields obtained in treatment T_2 in comparison to T_1 revealed a yield advantage of about 7.7 % which is non-significant. This may be because of the reason that the row-crop cultivator performed soil tilling between the rows and off-barring operation at shallower depth of 120 mm, therefore, broadcasting and mixing of fertilizers could have induced a lot of inefficiencies in its utilization by the crop. The inverted-T opener drill, however performed an effective off-barring operation and enhanced nutrient utilization due to band placement of fertilizers at around 120 mm depth, thus, giving a little higher yield.

The treatment T_3 gave about 10.3 % higher yield over T_2 which shows the effect of deep loosening of soil (300 mm depth) by the developed machine, as the fertilizer was placed at the same depth of 120 mm in both the treatments. Deep soil loosening between the rows gives easy proliferation of new roots and also prolonged storage of moisture. However, the increase in yield of T_3 over T_1 was significant and substantial (18.8 %). There was only a marginal increase (9.9 %) in cane yield in T4 over T_3 in which case the fertilizer was placed at 200 mm depth, thus showing a non-significant effect of depth of placement of fertilizers with the developed machine for the depth.

In addition to this, the difference may also be due to placement of nutrients in the root zone with lower bulk density and higher moisture content obtained by the use of deep soil volume loosener-cum-fertilizer applicator as evident from **Table 3**. It could, therefore, be inferred that the deep soil volume loosening and band placement of fertilizers in sugarcane ratoon crop as performed by the developed machine is an effective technique requiring further extension of this technology.

Table 3 Effect of inter-row cultivation and fertilizer placement methods on soil dry bulk density and moisture content at harvest

Treatments	Dry bulk density, Mg m^{-3}			
	0-100 mm	100-200 mm	200-300 mm	300-400 mm
T_1	1.36	1.51	1.57	1.54
T_2	1.35	1.59	1.56	1.51
T_3	1.34	1.50	1.50	1.52
T_4	1.32	1.48	1.49	1.49
S. Em.±	0.01	0.02	0.02	0.01
C.D. at 5 %	NS	NS	0.06	NS
Treatments	Moisture content (d.b.), %			
	0-100 mm	100-200 mm	200-300 mm	300-400 mm
T_1	17.2	17.6	17.6	18.4
T_2	15.9	18.8	19.7	19.5
T_3	17.3	18.3	20.1	19.8
T_4	17.8	19.4	20.4	20.2
S. Em.±	0.42	0.33	0.46	0.38
C.D. at 5 %	NS	1.13	1.60	NS

Conclusions

The following conclusions were drawn from this experiment:

1. In general, there was significant effect of different treatments on shoot population and shoot height at all the growth stages.
2. The increase in ratoon yield was found 7.7 % increase with inverted-T opener ZT-drill (fertilizer application at 120 mm depth along both sides of row), 18.8 % increase with developed machine with fertilizer application at 120 mm depth and, 30.7 % increase with developed equipment when fertilizer was applied at 200 mm depth in comparison to control.
3. The increase in ratoon CCS yield was found 9.5 % increase with ZT-drill (fertilizer application at 120 mm depth), 25.1 % increase with developed equipment (fertilizer application at 120 mm depth) and 41.2 % increase with developed equipment (fertilizer application at 200 mm depth) in comparison to control.

The deep soil volume loosening, cutting of old roots (off-barring) of sugarcane plant crop and simultaneous deep placement of fertilizers in the moist root zone of crops is found to be an effective technique for increasing the productivity of sugarcane ratoon crop in comparison to the conventional method of broadcasting of fertilizers followed by inter-row tilling and mixing with rigid tines row crop cultivator and it is recommended for ratoon management.

Acknowledgements

The financial assistance provided through the ICAR National Professor Scheme on 'Technologies Development for Subsoil Structure Modification, Deep Placement of Fertilizers (P & K) and Micronutrients, and Controlled Field Traffic for Different Cropping Systems of Indo-Gangetic Plains' for the development of subsoil health management technologies is thankfully acknowledged.

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Comparative Grinding Behavior and Powder Characteristics of Basmati Rice Brokens

by

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Abstract

Dry grinding behavior and powder characteristics of raw and parboiled Pusa 1121 basmati rice brokens were assessed. Grinding duration was found to be having the role in deciding the ultimate size of ground particles with the particle size distribution and confirmed its direct influence on the characteristics of pretreated parboiled rice. Grinding laws namely Kick's, Rittinger's and Bond's law were applied. The grinding constants (K_K, K_R, W_I) for different laws reflected the dependency on grinding duration. Dry grinding of raw rice brokens produced higher fractionations on smaller sieve size in comparison with parboiled rice brokens in the identical grinder and grinding process. Dry grinding of raw and parboiled broken rice resulted in significant difference in powder characteristics. Consequently, the grinding time and powder characteristics of raw rice brokens are more viable in producing fine particulates than parboiled one.

Introduction

Rice (Oryza sativa) is an important starchy cereal crop around the globe and used as staple food. In order to improve acceptability and palatability hull and bran layers are removed from rough rice through the process of hulling and polishing. The degree of milling during polishing finds the crux role and limits the extent of head rice recovery. The extent of damage is associated with the dimensional characteristics. For extra long rice kernels as in case of Basmati variant, the degree of milling decreased head rice yield significantly (Singh and Prasad, 2012). Pusa 1121, a promising Indian basmati variety (Bhatia *et al*., 2009) known for its extra long slender grains of length up to 8.3 mm. High yielding characteristics and more linear elongation on cooking associated with this variety, not only replaced traditional rice varieties but also gaining popularity among Indian farmers (Prasad *et al*., 2012).

Grinding is one of the important size reduction technique applied often to produce small particulate matter following compression, impact, attrition or cutting forces. Grinding time controls the particle size and the processing techniques provided to rice or paddy controls the particle size distribution, which may be considered as the key factors for the powder characteristics and its suitability for various rice flour based preparations. The rice flour is an important ingredient in both traditional and novel foods prepared across the world (Villareal *et al*., 1993). Some of the traditional rice flour based products in India are puttu, made by steaming rice flour and grated coconut, and appam, a cake formed by mixing rice flour and fermented coconut milk, Idlis and dosas are delicacies also made from rice flour batter (Prasad *et al*., 2012).

Considering grinding as a reproducible size reduction process adopted for most of the rice based product formulations in developing countries, the objectives of comparing effect of dry grinding raw and parboiled broken rice (*Pusa 1121*) for particle size, its distribution and applicability of grinding laws on powder characteristics were adjudged.

Theory

Milling is the trade term used relative to the reduction of grain into flour by mechanical means in such a way to maintain the chemical characteristics unaltered. The performance, thus characterized by the milling capacity, power required per unit of milled material, the size and shape of raw and milled material and particle size distribution of the resultant product (Henderson and Perry, 1976). The particles undergo milling may be from macroscopic to microscopic range. The particle size classification system in form of fineness modulus (FM) as devised by D. A. Abrams (1918), the sum of the percent weight fraction retained above the selected sieves was determined to calculate the average particle size using the modified formula as:

$D, mm = 0.0587 \times 1.632^{FM}$........(1)

The fundamentals of product size, shape and of energy requirements are however common to most machines employing size reduction principles. It is feasible to understand the grinding characteristics with the help of different theories such as Kick's, Rittinger's and Bond laws (Austin, 1973). Size reduction of broken rice was enumerated by the comparison made between the new surface areas generated to the energy consumed for generating that area. Three empirical relationships (Kick, Rittinger and Bond) have been suggested for determining energy. Each model assumes that the energy input per unit mass ∂E required to change the size of material by a fractional amount ∂d is proportional to the particle size and can be expressed as:

$\partial E / \partial d = Kd^n$............................(2)

Where, ∂E is energy required, ∂d is the change in typical dimension, K and n are constants (Earle, 1996; Smith, 2010).

Kick assumed as $n = -1$ to estimate energy required for size reduction, that is proportional to the new surface created. Hence by putting value of n in **Eq. 2**

$\partial E / \partial d = Kd^{-1}$...........................(3)

$\int_0^E \partial E = K_K \int_{d2}^{d1} n^{-1}\, \partial d$.................(4)

$E = K_K \ln d_1 / d_2$........................(5)

Where, K_K is Kick's constant which has units of $J.kg^{-1}$. In Kick's law the energy input is proportional to the size reduction ratio.

Rittinger assumed that $n = -2$, Hence energy input for size reduction by putting value of n in **Eq. 2** is

$\partial E / \partial d = Kd^{-2}$...........................(6)

$\int_0^E \partial E = K_R \int_{d1}^{d2} n^{-2}\, \partial d$................(7)

$E = K_R (1/d_2 - 1/d_1)$..................(8)

Where, K_R is Rittinger's constant which has units of $J.m.kg^{-1}$. Rittinger's equation tends to apply for particles which do not deform before breakage, in other words for brittle materials and for fine grinding. It suggests that the energy required is proportional to the increase in surface area per unit mass. In using either of the models due to Kick and Rittinger the relevant constant must be obtained by experiment using both the same equipment and the same material.

The Bond's law, who proposed that the work input is proportional to the square root of the surface-volume ratio of the product, by putting n = −3/2 in **Eq. 2** and thus

$\partial E / \partial d = Kd^{-3/2}$.........................(9)

$\int_0^E \partial E = K\int_{d1}^{d2} n^{-3/2}\, \partial d$.............(10)

$E = 2K\, [d^{-3/2}]_{d1}^{d2}$......................(11)

$E = 2K\, [(1/\sqrt{d_2}) - (1/\sqrt{d_1})]$.......(12)

$E = (2K/\sqrt{d_2})\, [1 - (1/\sqrt{q})]$.......(13)

Where $q = d_1/d_2$. Bond put the constant equal to $5W_I$, where W_I is known as the work index and is defined as the energy required reducing unit mass of material from an infinite size to a size where 80 % of the material is below 100 μm (Smith, 2010). Hence,

$E = W_I\, (100/d_2)^{1/2}\, [1 - (1/\sqrt{q})]$. (14)

Materials and Methods

Materials

Pusa 1121 paddy variety (Crop year 2012) was obtained from Chaudhary Charan Singh Haryana Agricultural University, Hisar (India) as the raw material for the present study. Paddy was parboiled using the standard procedure followed by Sharma *et al*., (2008). Raw and parboiled head and broken rice were obtained during shelling and polishing (Singh and Prasad, 2013). The moisture content of 10.72 ± 0.41 % (dry weight basis) was found for equilibrated broken rice stored under refrigerated condition for 15 days.

Hundred grams of broken rice kernels were subjected to grinding process in a dry grinder (Make: Sujata, India; Model: Dynamix, 810 W). Ammeter was used to measure the current drawn for the evaluation of energy consumption during grinding operation. The obtained samples subjected to grinding for 0-15-30-60-120-180-240 Sec were subjected for particle size analysis with selected set of seven sieves 12-20-30-48-72-120-200 BSS using a vibratory sieve shaker (Make: Nihal Engineering Corporation, New Delhi, India). Weight fractions were obtained as the ratio of individual fractions to total sum fractions and used to determine the time dependent particles size, fineness modulus and grinding law constants.

Powder Characteristics

The weights of the samples were recorded using electronic balance (Ishida Co. Ltd., Japan) to an accuracy of 0.001 g. The bulk density (BD) of the rice flour samples were evaluated following the procedure (Singh and Prasad, 2013) and the true density (TD) and porosity (POR) values by compressing the flour to form the compressed palette considering the negligible porosity for the formed palette in a hydraulic press.

The angle of repose (AOR) was determined using the relationship:

$AOR = \arctan\, (2H / D)$...........(15)

Where, H and D are the height and diameter of the heap in mm.

The static coefficient of friction (μ) was determined for four frictional materials namely glass (CFG), galvanized iron sheet (CFGI), plywood surfaces with horizontal movement (CFPH) and vertical movement (CFPV) as per methods adopted by Singh and Prasad (2013).

Results and Discussion

Grinding Characteristics

The effect of grinding time on particle size distribution of raw and parboiled rice broken represented in **Fig. 1** shows that the dependency of grinding time on type of sample and particle size. With the increase in grinding time, the particles on grinding became finer (**Table 1**). Moreover, the reduction in particle size is easier with raw rice as compared to parboiled justifies the properties of parboiled rice. The shear and cutting forces are involved to achieve the particle size reduction and energy consumption for grinding increased with time or the fineness of the grinding particles. The relationship between the fineness modulus and average particle size was calculated using the **Eq. 1**, which is graphically represented in **Fig. 2**.

The energy consumed by the grinder for size reduction were used to calculate the constants for Kick's, Rittinger and Bond's law both considering the fractional time interval for raw and parboiled rice represented in **Fig. 3**. The trend of constant reflects that the grinding process is energy intensive and requirement of energy increases till increase in the compression and impact forces. Further, the grinding energy helps in the reduction of uneven particle size to uniform particle size distribution to follow trend of normal distribution (**Fig. 3**). Excessive grinding of rice brokens for longer time further lead to damage the native structure of the biomaterial and thus affect the characteristics of the product to be prepared out of it (Unpublished data).

Table 1 Process dependent fineness modulus and average particle size kinetics of ground rice fractions

Grinding time (Sec)	Fineness Modulus		Average Particle Size, mm	
	Raw	Parboiled	Raw	Parboiled
0	5.29	5.35	0.783	0.805
15	4.34	4.39	0.491	0.504
30	3.80	3.90	0.377	0.398
60	3.25	3.63	0.288	0.348
120	2.94	3.42	0.248	0.314
180	2.66	3.29	0.216	0.294
240	2.49	3.17	0.198	0.277

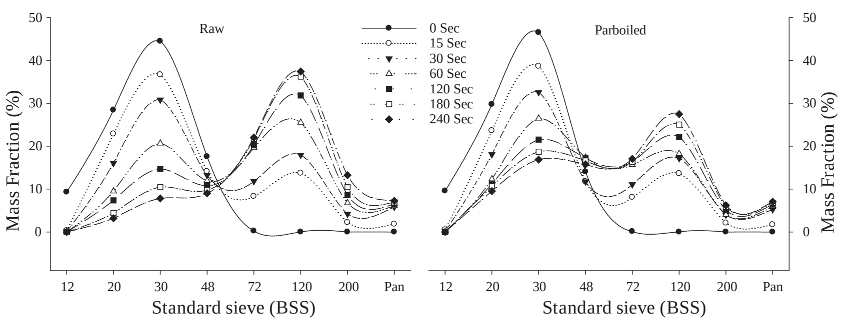

Fig. 1 Process dependent particle size distribution kinetics of ground rice fractions

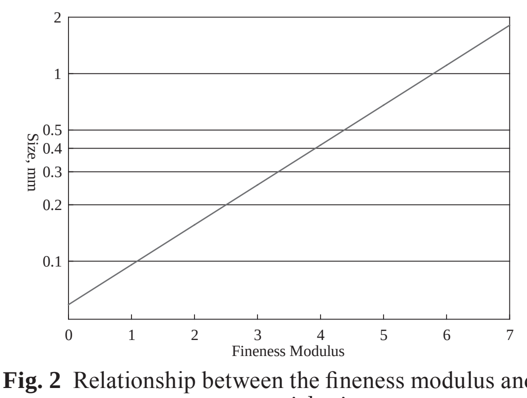

Fig. 2 Relationship between the fineness modulus and average particle size

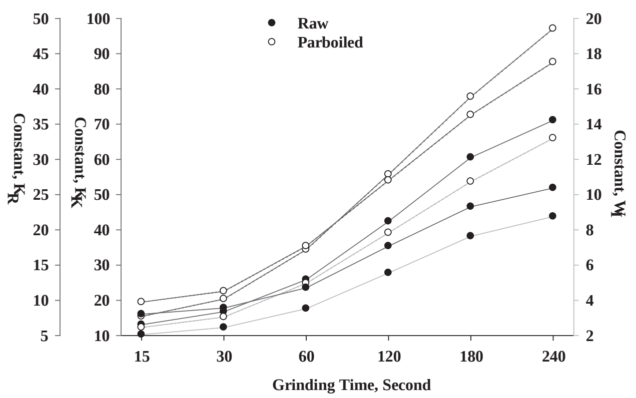

Fig. 3 Time and process dependent grinding law constants

Powder Characteristics

The gravimetric and frictional characteristics (**Fig. 4**) of Pusa 1121 raw and parboiled rice flour were assessed. The bulk density (BD) of rice flour (raw and parboiled) was observed decreasing trend with increase in grinding time and ranged in 781.89 to 979.45 kg/m^3 and 782.94 to 995.83 kg/m^3 for raw and parboiled rice fractions, respectively. It may be attributed to grinding increases the volume with higher rate than that of mass. The trend of true density (TD) was first decrease then increase with highest as 1356.72 kg/m^3 and 1309.62 kg/m^3 for raw and parboiled rice fractions, respectively. The variations in porosity (POR) were found dependent on bulk as well as on true densities.

The experimental values of angle of repose (AOR) show the increasing trend with increase in grinding time and varied from 35.40° to 52.18° and 33.64° to 49.12° for raw and parboiled rice fractions, respectively (**Fig. 4**). The static coefficient of friction for raw and parboiled rice fractions was determined with respect to four different surfaces and for glass (CFG) ranged from 0.239 to 0.627, for galvanized iron sheet (CFGI) ranged from 0.293 to 0.450, for plywood surface with horizontal movement (CFPH) ranged from 0.329 to 0.676 and plywood surface with vertical movement (CFPV) ranged from 0.457 to 0.754. This variation in the frictional properties thus may very well be used for the development of storage and handling equipments.

Conclusions

The study showed that the parboiling process affects the dry grinding behavior of rice. The dry grinding of raw broken rice resulted smaller particle size than its counterpart. Duration of grinding time had an inverse effect on the particle size and has direct relation with the energy consumption. The grinding constants (K_K, K_R, W_I) for different laws show dependency on the grinding durations. The parboiling process of rice significantly affects the powder characteristics of rice flour.

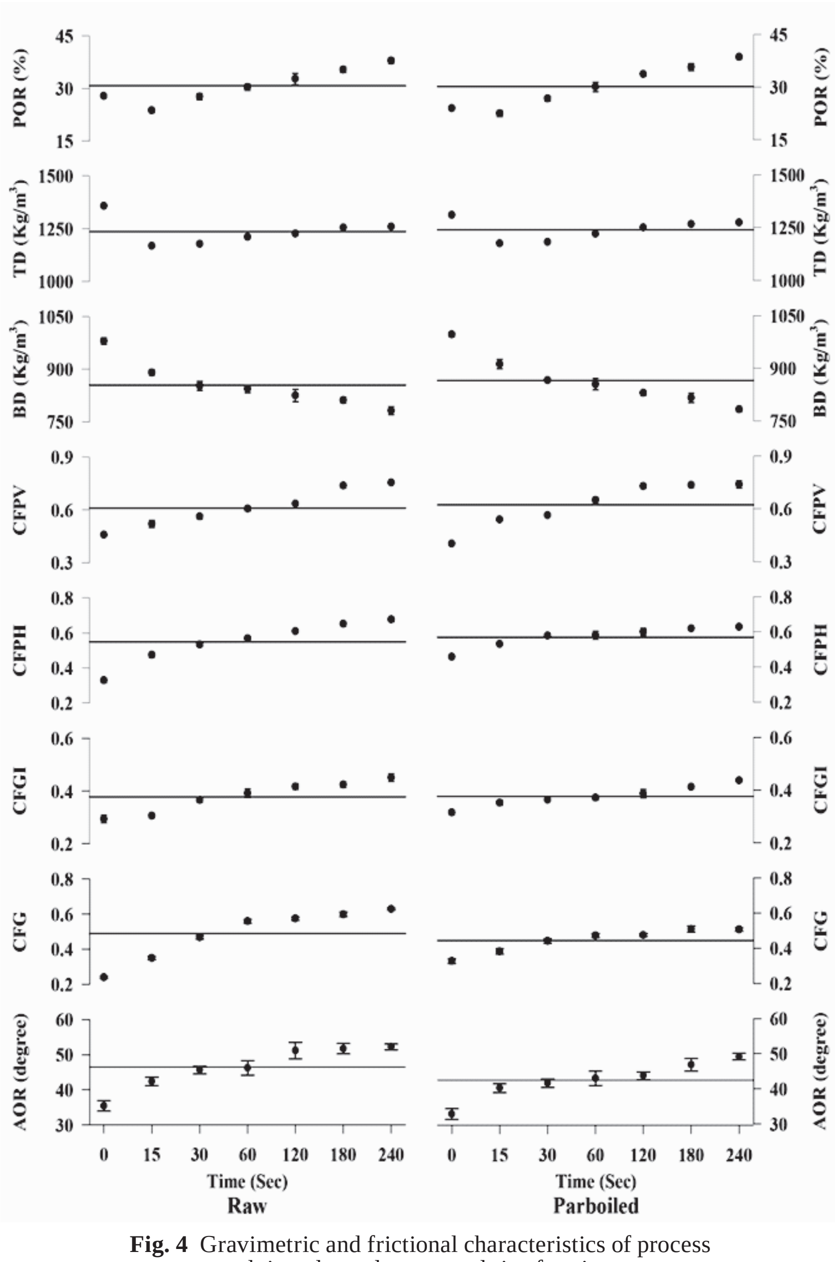

Fig. 4 Gravimetric and frictional characteristics of process and time dependent ground rice fractions

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Design and Installation of Pot-Based Indigenous Hybrid Hydroponics Technology with Water and Nutrient Recirculation System for Commercial Greenhouse Vegetable Production: *Part 1*

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Abstract

In this study, an indigenous pot based Hybrid Hydroponics Technology (HHT) (soilless) is designed and installed inside a micro-climatically controlled greenhouse for better plant growth, higher yield, higher water and nutrient savings along with significant cost reduction to make it affordable technology for farming community particularly in the developing countries. The HHT combines the features of two available hydroponics technologies viz; Substrate Hydroponics Technology (SHT) (for deep root system crops using soilless media) and Shallow Water Pond Hydroponics Technology (SWPHT) (for shallow root system immersed in water) and converting the HHT into a more effective single hybrid technology. The hybridization of HHT induces two main features; firstly, innovatively designed perforated plate and its insertion inside a square pot at about 6-8 cm height from the base to create air pressure equivalence above and at the bottom of the pot for better oxygen supply to the roots. Secondly, the optimal design of the water retention and siphoning system to create a shallow water pond of 1.6 to 2 liter capacity at the base of the pot to facilitate the lower roots immersed in water to have direct access to the nutrient rich solution. By this innovation, solid and liquid layers are separated inside a single pot for their respective benefits. Water siphoning system was designed in such a way that the excess nutrient rich solution unused by the plants was filtered through the plate itself, drained and collected in the recovery tank under gravity head for reuse thereby eliminating the need of filters towards the recovery side. An automatic nutrient dossier system was also designed and developed for online preparation of optimal nutrient solution consisting of all macro, micro and bloom components required by the crop. The developed closed loop HHT was installed and tested inside a 100 m2 greenhouse (saw-tooth fully ventilated design) having 125 pots (250 plants) of 32 cm (L) × 32 cm (W) × 38 cm (H) size each. These were arranged in five rows of 25 pots each in zig-zag manner and planted with selective crops of two plants per pot. Experimental testing of the developed technology is presented in part II.

Introduction

Due to ever increasing global population, demand of vegetables and ornamental plants is increasing day by day. Nowadays, due to financial subsidies given by various government agencies, more farmers and entrepreneurs are adopting polyhouse/greenhouse cultivation as part of their living and as an additional source of income. In modern semi-automatic/automatic greenhouses, drip irrigation systems along with evaporative cooling systems such as fan-pad or fan-fogger systems along with night heating provisions and shade net/aluminet (thermal screens) are pre-installed which significantly increases the total cost of the whole project. To eliminate the soil based problems, a soilless mechanized agriculture for growing vegetables and ornamental plants popularly known as substrate hydroponics has been developed commercially in western countries to further enhance the crop yield in lesser time and space under controlled environment conditions. This process also lowers the operating cost of pesticides and nutrient significantly apart from limiting the use of precious water. Overall, the main advantages of hydroponics over soil culture are: more efficient nutrition regulation; availability in regions having arid land; efficient use of water and fertilizers; ease and low cost of sterilization of the medium; and higher density planting leading to increased yield per plant.

Seawright *et al.* (1998) studied nutrient dynamics in integrated aquaculture -hydroponics systems. it was observed that nutrient concentrations and mutual ratios of nutrients quickly departed from initial conditions because the relative proportion of dissolved nutrients excreted by fish and subsequently absorbed by plants differed. Bota *et al.* (2001) observed the effects of withdrawing nitrogen (N) from the nutrient solution of adult tomato plants growing in rock wool media in a greenhouse reduced total plant growth after a lag period of about 2 weeks. The commercial fruit yield after 6 weeks of N deprivation was 7.7 kg/m^2 compared to 9.3 kg/m^2 in control plants.

Schwarz *et al.* (2005) observed that the effect of water quality in hydroponics culture and recommended that water from the natural lake and the peat ditch to be used with care because of the high nutrient concentration. Gorbe *et al.* (2010) while studying the optimization of nutrition in soil-less systems observed that the high yield and product quality of crops grown in soilless systems are only possible if nutrition is optimized. This implies accurate management of all factors involved in crop nutrition: nutrient solution composition, water supply, nutrient solution temperature, dissolved oxygen concentration, electrical conductivity and pH of the nutrient solution. If any of these factors is under non-optimal conditions, plants may suffer from stress leading to a decline of yields and product qualities.

Wallach (2008) studied the physical properties of soil-less media such as bulk density, particle size distribution, porosity, and pore distribution apart from water content and water potential. Water potential quantifies the tendency of water to move from one area to another due to osmosis, gravity, mechanical pressure, or matrix effects such as surface tension. It was concluded that the movement and fate of solutes in soil are affected by a large number of physical, chemical, and micro-biological processes, and the understanding of gas transport in growing media is important for the evaluation of soil aeration or movement of oxygen from the atmosphere to the medium.

Ashraf *et al.* (2009) studied the growth behavior and P utilization efficiency of seven wheat cultivars grown in hydroponics using rock phosphate as P source. The wheat cultivars grown for 30 days were significantly different in biomass accumulation, P uptake and P utilization efficiency. The dry matter production of all the cultivars was significantly correlated with P uptake, which in turn correlated to the drop in the root medium pH.

Carusoa *et al.* (2011) studied the effects of cultural cycles and nutrient solutions on plant growth, yield and fruit quality of alpine strawberry (*Fragariavesca L.*) grown in hydroponics with the Nutrient Film Technique (NFT) in order to evaluate the effects of four buffer concentrations (1.3, 1.6, 1.9, 2.2 mS/cm^{-1}) and two cultural cycles (summer-spring versus autumn-spring) in terms of growth, yield and fruit quality (dry and optical residues, sugars, acids, antioxidants, mineral composition). It was observed that fruit quality improved when the nutrient solution concentration increased.

Sethi *et al.* (2013) developed a wick type self regulating system (zero energy requirement) for hydroponically grown tomatoes to supply water and nutrients to the potted plants having porous root media of coco peat, perlite and vermiculite in ratio of 3 : 1 : 1 respectively placed above 2 litre capacity empty soft drink bottles used as water containers. Capillary action through the double cotton wick wetted the porous media inside the pot providing optimum water and nutrients to the plants without consuming any energy. Water use efficiency was high in hydroponic system as very little water was used using wick system as compared to conventionally grown soil based plants.

Crop physiological response to nutrient solution electrical conductivity (EC) and pH in a re-circulating ebb-and-flow hydroponic system was discussed by Wortman (2015) to assess the growth, yield, quality, and potential gross returns of four crops with nutrient solution EC and pH levels commonly observed in hydroponic (high EC-low pH) and small-scale aquaponic (low EC-high pH) systems.

Apart from high energy costs in mechanized protected cultivation in agriculture, water consumption is one of the most cost-intensive resources used in greenhouse production due to the large quantities of water required for irrigation and a worldwide water shortage, especially in arid regions (Ozkan *et al.*, 2007; Rout *et al.*, 2008). Based on the lack of freshwater resources in some parts of the world, a large proportion of the world's population (40 %) is currently experiencing water stress, which means that appropriate plant production is not viable as discussed by Vörösmarty *et al.* (2000). Under such circumstances, and considering that 70 % of global water consumption is needed in the agricultural sector for food production alone, responsible water management is absolutely essential (Pimentel *et al*., 2004). Several approaches have been undertaken to reduce the water consumption of crops, e.g., external greenhouse mobile shading, genetically modified plants, different salinity levels of the nutrient solution and controlled drip irrigation (Karaba *et al*., 2007; Lorenzo *et al*., 2003; Payero *et al*., 2008; Reina-Sanchez *et al*., 2005; Zhai *et al*., 2010).

In India, not much work has been done in the area of hydroponics as it being a relatively new technology and has not yet been introduced at the commercial level. Only a few progressive farmers/greenhouse growers are growing vegetables by importing this costly technology from USA, Netherlands or Israel. However, in western countries and Japan, this technology has already been standardized and is being practiced commercially inside micro-climatically controlled greenhouses for producing higher yields of vegetables and ornamental plants. In addition to that concept of urban agriculture on the rooftop is also catching up fast due to availability of all the required parts of this technology from manufacturing industry. Grewal and Grewal (2012) suggested that the city of Cleveland, Ohio could theoretically achieve up to 100 % self-reliance in fruits and vegetables through maximizing the use of rooftop hydroponic farming methods.

Re-circulating type hydroponics is also one such technology that has been devised in western countries is also becoming attractive amongst the farming community due to huge water saving. Currently, there are two separate hydroponics technologies being practiced for raising vegetables in greenhouse conditions in western countries. The first technology is a substrate hydroponics which requires a soilless inert root media fully filled inside a specially designed pot with a side groove for draining excess water (called Bato Bucket pot design) for raising two plants in one pot. However, by filling the pot with solid porous media from top to bottom causes a basic problem of choking of water drain system caused by substrate material clogging at water outlet system installed for recovery of excess nutrient rich water solution from the pot. Once the choking occurs, the older solution in the pot does not get replaced and there are lesser pore spaces available for oxygen supply to the plants leading to slower growth. The second drawback of this technology is that, with the excess water coming out through the pot, solid media particles keep on entering the drain pipe and block the filtering system over a period of time which needs regular cleaning for smooth operation of the water recirculation system.

The second hydroponic technology is the water based pure hydroponics in which shallow water pond is created in a tray or tub and leafy vegetables are grown at a faster rate as compared to soil based agriculture by direct immersion of lower roots in the nutrient rich water solution. Although the existing system of shallow water pond hydroponics can supply dissolved oxygen and direct absorption of nutrients to the immersed roots in water, yet the major problem is that the only leafy vegetables can be grown which have a shorter growth time and smaller root system. Those plants which bear bigger fruits and need support system to their root system cannot be grown under this technology. To overcome the problems of two existing hydroponic technologies and to improve the effectiveness, in this study, indigenous hybridized hydroponics technology (HHT) is designed, developed and tested by eliminating the problems related to choking, better oxygen supply and timely water filtration along with reduction in technological cost and operating costs with better growth and yields.

Design Details of Hybrid Hydroponics Technology (HHT)

A new innovation has been used to indigenously develop low cost soilless Hybrid Hydroponics Technology (HHT) by combining the features of two separately existing hydroponics technologies such as Substrate Hydroponics Technology (SHT) and Shallow Water Pond Hydroponics Technology (SWPHT) thereby converting it into a single more effective pot based hybrid hydroponics technology for off-season commercial greenhouse vegetable raising as (**Fig. 1**). The main feature of this innovation is the creation of two separate layers in one pot of length L × B as 32cm each, and height H as 38 cm separated by innovatively designed square perforated plate (having 3 mm holes) introduced between the two layers at 6 to 8 cm height from the bottom of each pot. The upper layer was created for porous root media up to 28 to 30 cm depth of the pot from the top (75 to 80 % of pot depth) consisting of substrate porous media (cocopeat, vermiculite and perlite mixed in 3 : 1 : 1 respectively) for holding the root system and its growth along with supply of abundance oxygen. The use of cocopeat as the major component of porous media was due to its much lower cost as compared to perlite and vermiculite. The perforations in the plate allow only the excessive nutrient rich water solution to rinse through the media to reach at the shallow water pond at the bottom of the pot. No solid media particles pass through the perforations, thereby stopping any choking in the drain pipes or filters.

The second main advantage of adding the perforated plate is that the plate helps in the creation of atmospheric pressure both above and below the root media (inside the pot) as there is always a 2 cm air gap between the base of the plate and the water level which increases the flow of oxygen through the pores of the soilless media for better absorption by the root system (**Fig. 1**). The lower layer was created as a shallow water pond at the bottom (about 6 to 8 cm from the base of the pot) for abundance availability and direct suction of water and nutrients by the immersed roots. A water siphoning system was also designed at the bottom end just below the perforated plate which allows the drainage of excessive nutrient rich water solution without any solid particles, thereby eliminating the need of any filtering system towards the recovery side.

The other advantage of creating the shallow water pond at the bottom of the pot is that even if due to some reason (non availability of water for many hours or even days, interruptions in electrical supply due to power failures etc. are common problems in developing countries like India) the water and nutrients are not supplied to the plants through the motored operated laterals, 1.6 to 2 liters of nutrient rich solution is always made available to the plants for their survival for a few days. During uninterrupted operation, the solution is regularly replaced by the fresh solution about 4 to 5 times in a day by automatic operation of motor.

The design details of pot, water siphoning system and perforated plate using locally available materials are shown in **Fig. 2**. A plastic net cloth is wrapped along four sides of the perforated plate to properly seal it along the edges and corners of the pot. If the plate is uniformly cut in square then the wrapping of the cloth can be avoided.

The return nutrient rich water solution (unused by plants) is collected through 50 mm diameter PVC pipes arranged just below each pot row in a shal-

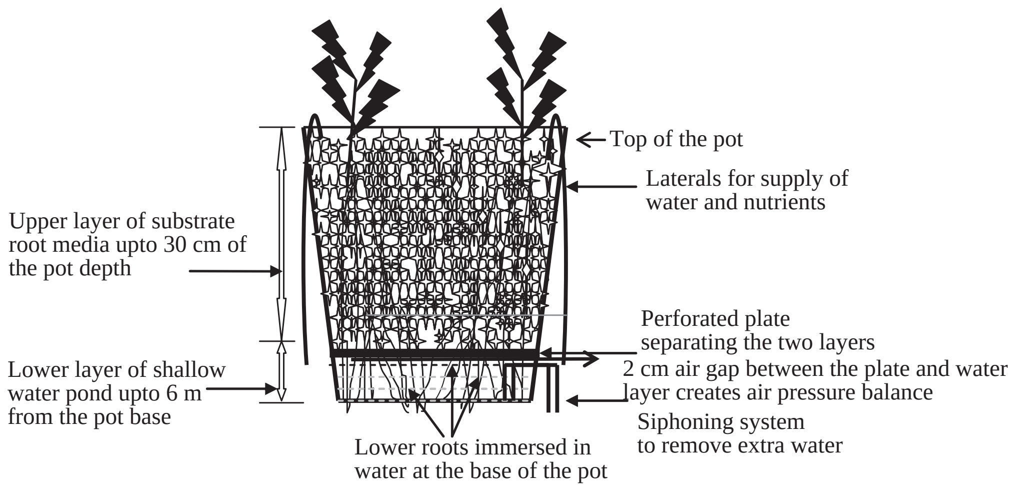

Fig. 1 Sectional view of the pot design of Hybrid Hydroponic Technology (HHT) having two layers; the upper layer of solid porous media and the lower layer of shallow water pond as separated by the perforated plate, and connected with water siphoning system.

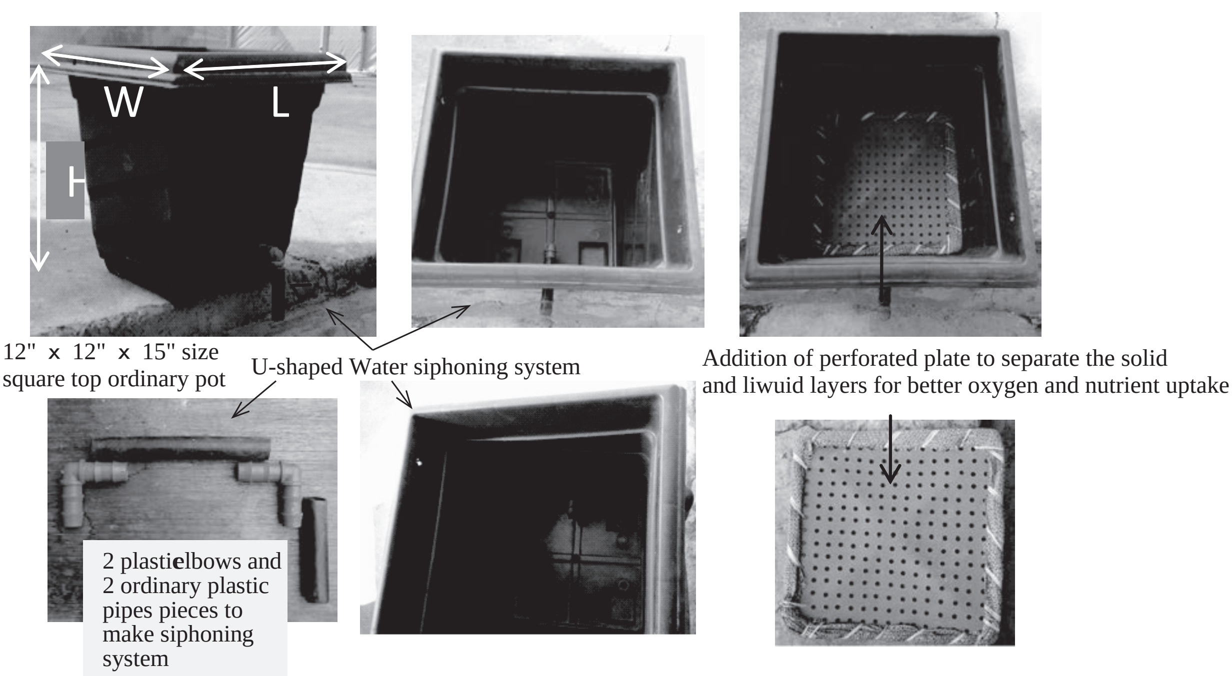

Fig. 2 Design details of pot, indigenously developed water siphoning system and perforated plate

low trench dug with a gradual slope (gravity head) towards the recovery tank of 1000 litre capacity (**Figs. 3a** and **3b**). Supply of optimum quantities of water and nutrients, duration and interval is controlled by a timer operated electrical motor of 560 W power. The nutrient rich water solution is reused and supplied as per needs of the plant after making necessary adjustments in pH, EC and TDS values required for optimum plant growth. In this way not even a small amount of water and nutrients is wasted.

The developed HHT has many innovative features as compared to the existing hydroponic technologies such as:

1) Atmospheric pressure created on the upper and lower sides of the porous root media through the addition of perforated plate supplies better oxygen to the roots through the pores to equalize the partial pressure of the air which is not available in the existing substrate hydroponic technology.
2) Rinsing of the excess water through the perforated plate does not allow any solid media particles to pass through to avoid the choking of the inlet of siphoning system, thereby eliminating the need of any filters towards the recovery system side. In the current practice, a super saturated mixture of water and solid root media (slurry) is formed at the bottom of the Bato Bucket design (Netherland design of bottom grooved pot prevalent in USA and European countries) which tends to choke the inlet of the siphoning elbow and the filters have to be regularly cleaned.
3) Appropriate design of the siphoning system allows desired amount of nutrient rich water solution to stand at the bottom of the pot in the form of a shallow water pond which helps the lower roots to remain immersed for continuous water and nutrient uptake.
4) The nutrient rich water solution is replaced at least 4 to 5 times in a day facilitating fresh supply throughout the pot thus keeping the Electrical Conductivity (EC), pH and total dissolved salts (TDS) along with dissolved oxygen in the optimum range as required by the plants. The availability of shallow water layer in the pot keeps the plant alive even if the water is not supplied thorough the pumping system as the lower roots once cross the boundary of the perforated plate remain immersed in water and directly absorb the water and nutrients which makes this technology more reliable in the case of power failure or non availability of water for a few hours or even days.
5) Cost of this indigenously developed pot based Hybrid Hydroponics Technology (HHT) is much lower and effectiveness is much

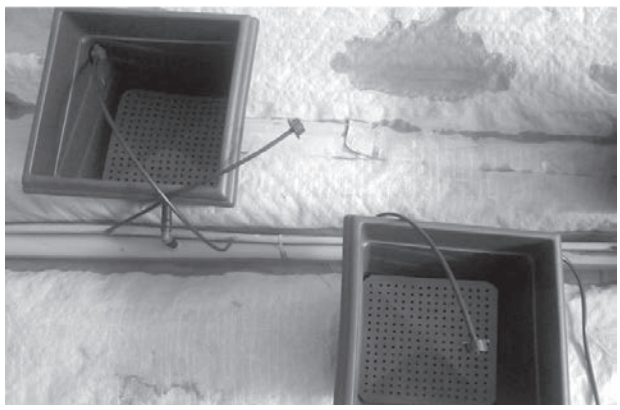

Fig. 3b Zig-zag arrangement of the pots connected to the water supply system through two lateral pipes and a drainage pipe connected to the siphoning system to recovery tank.

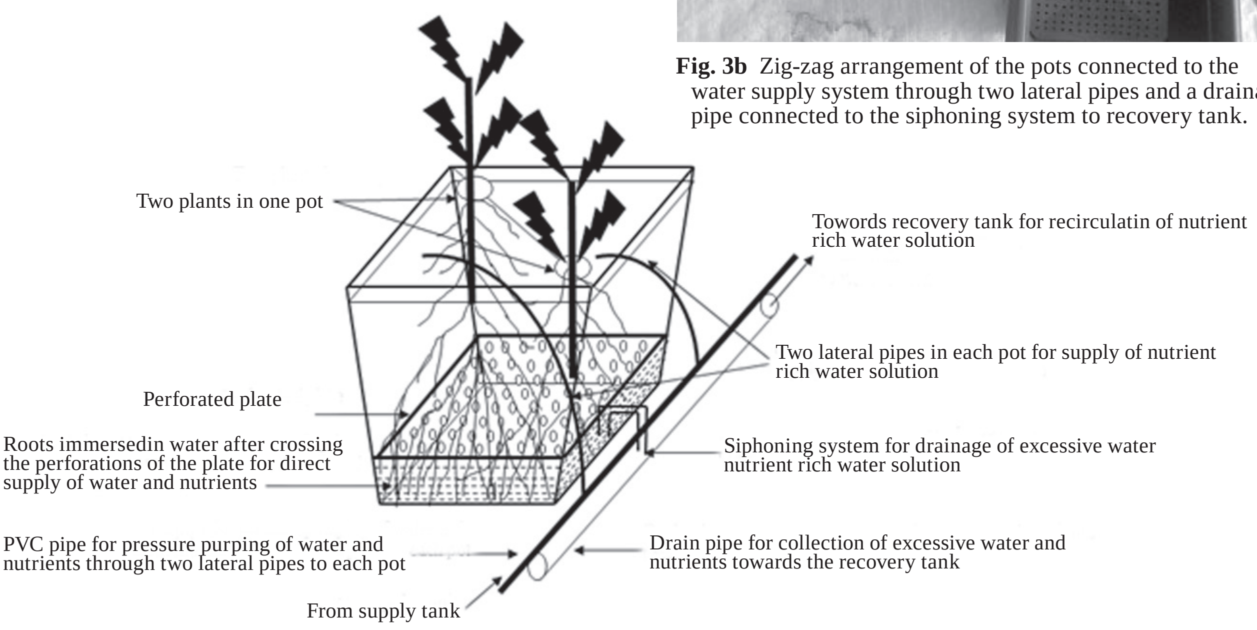

Fig. 3a Connection of the nutrient rich water supply system through the lateral pipes and siphoning system for drainage of the excessive water to the drain pipe connected to recovery tank.

higher along with the easy availability of all the spare parts needed for its assembling as compared to expensive imported system and non-availability of system parts. The developed technology has a higher efficacy with enhanced quality and yield in addition to significant reduction in the constructional, operational and maintenance costs of this technology.

Installation of Hybrid Hydroponics Technology (HHT)

The developed HHT was installed inside an east-west orientation 100 m^2 area greenhouse (saw-tooth fully ventilated design) equipped with fan-fogger evaporative cooling system for summer, convective heating system for winter and 50 % light control aluminet to provide optimum micro-climatic conditions to the crop. Pots were arranged in five rows of 25 pots each in zig-zag manner and connected to the drain pipes of 50 mm diameter running along the base of the pot through a siphoning system to collect the excessive water to the recovery tank for recirculation of excessive nutrient rich solution (not used by the plants) as shown in **Fig. 4**.

Automatic Nutrient Dossier System

Three Electronic metering pumps (E dose NEO, Faridabad India, Model No ED 114) with a digital display using a solenoid, controlled by an internal circuit to drive a reciprocating diaphragm were used to lift the required quantity of nutrients ranging from 1.4 to 10 L/h at 4 kg cm^{-2} into the main water line.

In order to maintain proper supply of nutrients in the range of 600-650 ppm of total dissolved salts (TDS) during early stages of plant growth, the pump settings of the nutrient dossier system was made in such a way that 1 litre of nutrient solution of grow, micro and bloom component each was automatically lifted from the nutrient storage tanks and mixed in the 1,000 liter water storage tank through the main water line during the particular time interval of pump operation (**Fig. 5**). Later on the pump operation speed was increased to have output of 1.6 liter of each nutrient solution to obtain higher concentrations of TDS in the range of 900-1,200 in 1,000 liters of water storage tank. The measured parameters were TDS (in the range of 600-1,200 ppm), EC (Electrical Conductivity in the range of 1.4-1.7 μs/cm and pH between 6-6.5 during different stages of crop growth (**Fig. 5**). It was observed that the time taken for emptying the nutrient supply tank gradually decreased from 15 days from the beginning of the crop cycle to just 6 days up to the fruiting stage. It was observed that the low cost design of automatic nutrient dossier system was able to optimally mix the macro (grow), micro and bloom components in the fresh water supply line in order to prepare the desired ratio of nutrient rich water solution as per plant requirement during different stages of crop growth.

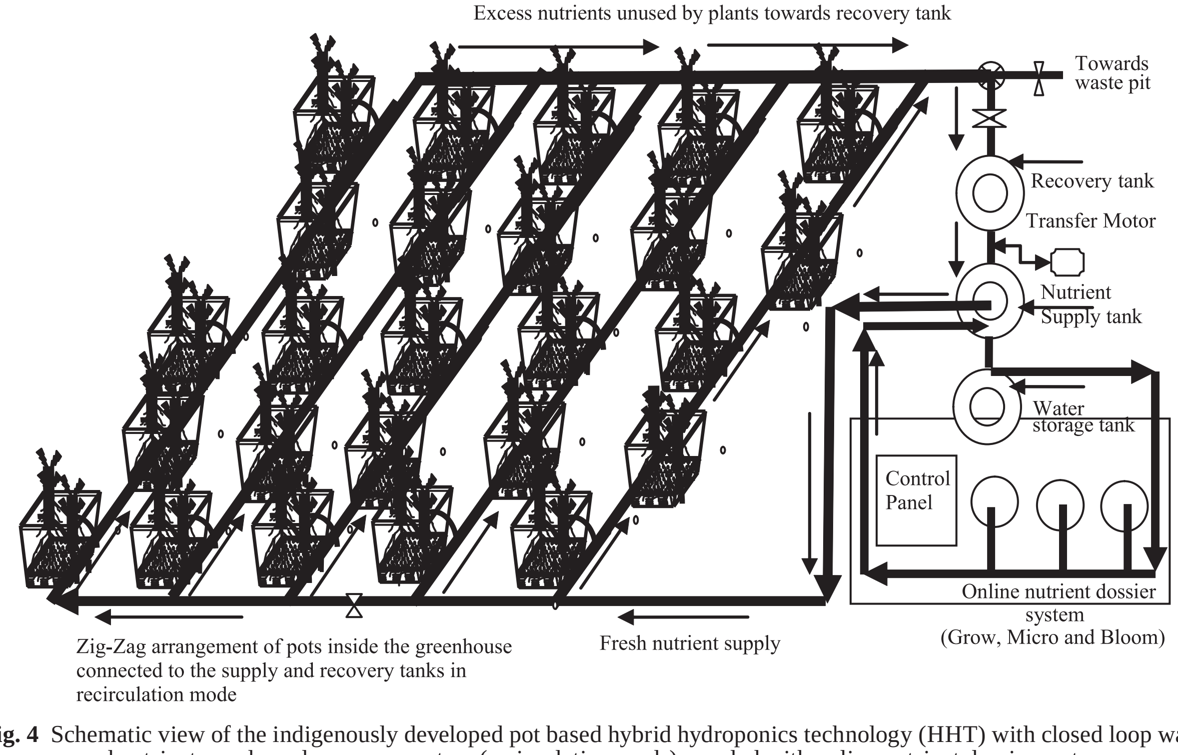

Fig. 4 Schematic view of the indigenously developed pot based hybrid hydroponics technology (HHT) with closed loop water and nutrient supply and recovery system (recirculation mode) coupled with online nutrient dossier system.

Supply and Recirculation System for Water and Nutrients

Nutrient rich water supply to each pot (fitted with two laterals) was given five to six times a day by the timer controlled motor operation after every 2 hrs starting from 8 am to 6 pm each day. Every time the motor was operated for about 1 minute during early stage and for 2 minutes during the fruiting stage so that 1.6 liter of nutrient rich water solution was supplied which also replaced the previous solution left at the bottom of the pot in the form of shallow water pond. The excess solution at the bottom was then drained through the siphoning system and connected to the return pipes arranged in parallel and leading to a single pipe towards the recovery tank under the gravity head. The transfer motor was also operated automatically to shift the nutrient solution from the recovery tank to the supply tank when about 100 liters of solution was left in the supply tank (**Fig. 6**). In this way, supply and recovery of the nutrients was continued in the recirculation mode till the whole nutrient solution was consumed by the plants. It was observed that the nutrient balance of the excess solution was not much disturbed and the same could be supplied again and again for many days without wasting even the single drop of water and nutrients thus making this technology as highly precise. The only slight adjustment that had to be done was the pH adjustment after every 3 to 4 days operation and a few drops of phosphoric acid were used to maintain the pH level at around 6 to 6.5.

An east-west orientation saw-tooth design greenhouse (asymmetric overlap roof) of 100 m^2 floor area (12.2 m length, 8.3 m width and 6 m central height) having manual opening and closing mechanism of side and top polyethylene sheet rollup system over the screen net (mesh 40 × 40) was designed and constructed (**Fig. 7a**) at the research field of the department of Mechanical Engineering, Punjab Agricultural University, Ludhiana at 31º N latitude, India. The semi-automatic greenhouse was fitted with cyclic timer based temperature and relative humidity control system. Two slow speed axial fans of 36 inch diameter and high pressure foggers operating at 28 psi and generating droplet size of 25-35 micron were fitted in five rows (8 foggers in each row) at 4 m height of the greenhouse just below the UV stabilized 50 % aluminet screen (thermal net). The aluminet sheet can be spread (unfolding) or wrapped up (folding) by manual operation of rope and pulley arrangement to control the excessive sun light during summer months and to conserve heat during winter nights (**Fig 7b**).

Two seedlings of capsicum (green, yellow and red), two seedlings of tomato and one seedling of cucumber crop were transplanted in each pot on 17th October, 2014. In this way, 150 plants of capsicum, 50 plants of tomato and 25 plants of cucumber were planted to test the effect of newly developed hybrid hydroponics technology. Pictorial view of tomato plants full of ripened fruits are shown in **Fig. 7c**. The experimental evaluation of HHT is discussed in Part II.

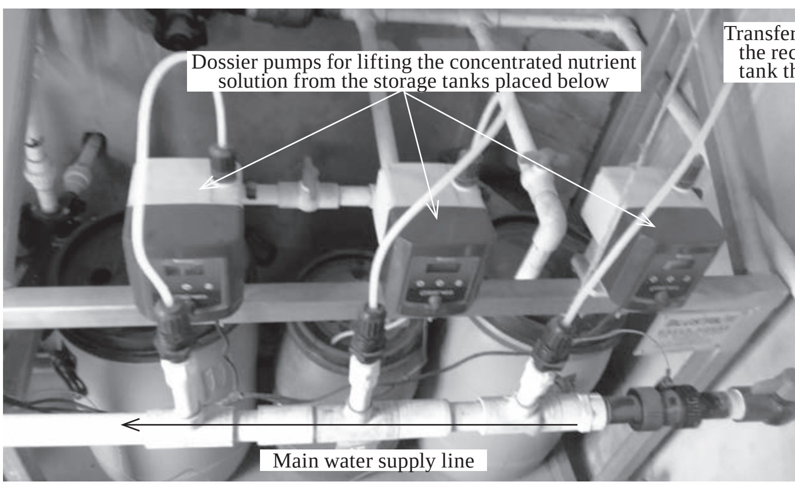

Fig. 5 Indigenously developed nutrient dossier system for automatic mixing of nutrients to the main water line entering to the supply tank using three dossier pumps for Grow, Micro and Bloom part of nutrient components.

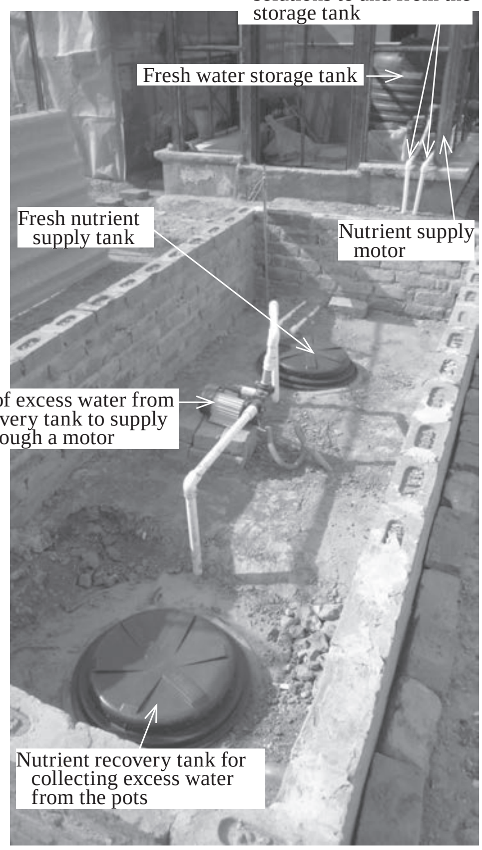

Fig. 6 Underground supply of fresh water nutrients and recovery tanks of 1000 liter capacity in closed loop along with transfer motor.

Conclusions

The HHT effectively combines the features of substrate hydroponics technology and shallow water pond hydroponics technology by inducing the perforated plate and water retention and siphoning system.

Effect of innovative design of the HHT can be clearly seen from the better plant growth and yield with huge savings in water and nutrients as discussed in part 2.

Acknowledgements

The Authors are thankful to the Government of India for providing financial assistance under the Rastriya Krishi Vikas Yojna (RKVY) through the Director of Research, Punjab Agricultural University, Ludhiana and the necessary facilities given by the PAU authorities for completing this project. The Authors are also thankful to the authorities of PAU for safeguarding the innovative part of this new technology by filing the Indian patent on behalf of PAU entitled "Improved water and nutrient perforation and recirculation system for pot based substrate hydroponics" Patent No. 1567/DEL/2015. The authors also acknowledge the efforts of Dr Praveen K Saxena, Director, Gosling Research Institute of Plant Preservation (GRIPP), Ontario College of Agriculture, University of Guelph for inviting Dr. V. P. Sethi, Professor and Head, Department of Mechanical Engineering, PAU Ludhiana as 'Guest Faculty' to deliver a seminar on this innovative Hybrid Hydroponics Technology (HHT) and for evaluating its innovative features through the relevant faculty of GRIPP and greenhouse industry of Ontario state in Canada for possible improvements in existing hydroponic technology around the world.

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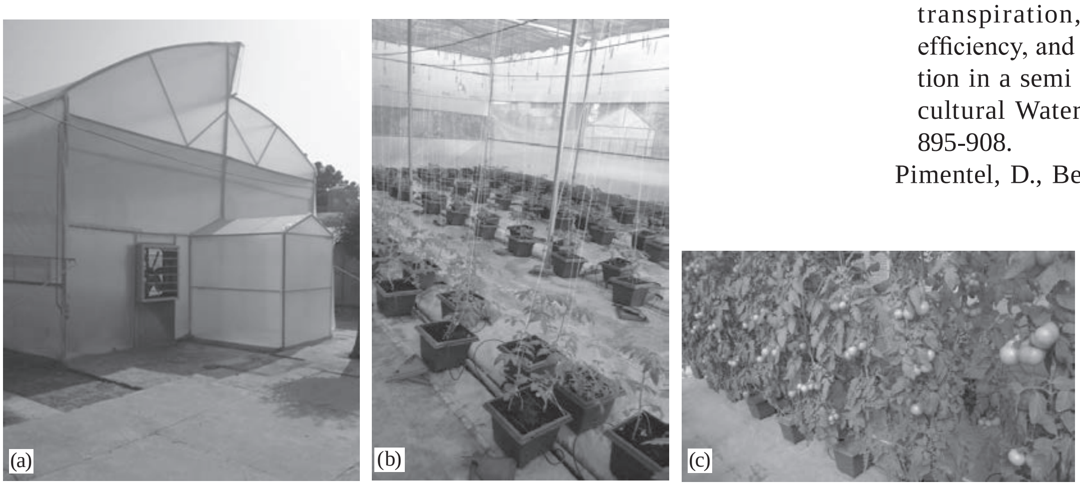

Fig. 7 Pictorial view of (a) asymmetric overlap roof greenhouse, (b) two transplanted tomato plants in each pot and (c) plants with full of fruits under HHT.

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Experimental and Economic Evaluation of Pot-Based Indigenous Hybrid Hydroponics Technology with Water and Nutrient Recirculation System for Commercial Greenhouse Vegetable Production: *Part II*

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Abstract

In this study, already developed pot based Hybrid Hydroponics Technology (HHT) (soilless) is experimentally tested by installing the same inside a micro-climatically controlled greenhouse to determine its effect on plant growth, yield, water & nutrient savings and cost reductions. It was observed that the effect of hybridization was much higher on the growth and yield of cucumber and tomato plants as the plants attained the fruiting stage 7 to 10 days earlier, the average yield of cucumber and tomato crops was 6.7 kg and 5.5 kg per plant which was significantly higher as compared to the existing hydroponics technology for the selected crop varieties. Water and nutrient savings under the HHT are about 90 % and 60 % as compared to non recirculation type hydroponics technology. Based on the estimated yields, the developed HHT has a break-even point of 4 to 5 years only thus making it economically feasible and affordable technology for off-season greenhouse vegetable production particularly at non-arable lands and at rooftops as urban rooftop farming technology in developing countries where growth of population pressure is higher and income of agricultural community is low.

Introduction

In India, majority of the farmers use conventional irrigation practices in open field for raising these plants. It was only about two decades ago, growing of vegetables and ornamental plants inside the greenhouse was initiated by a few progressive farmers and entrepreneurs. Although, yield and income from greenhouse cultivation is higher as compared to the open field cultivation, but overall, it has been observed that soil based mechanized greenhouse cultivation is a costly affair and energy intensive due to higher construction and operating costs along with excessive use of water and nutrients. Despite of all these arrangements, greenhouse cultivation has been facing many other existing problems. One of the major problems is the emergence of soil borne pathogens called nematodes with every crop cycle due to growing of roots on same piece of land inside the greenhouse, which ultimately affects the crop growth and plant fails to deliver its potential yield. Hence, to counter such maladies, huge quantities of pesticides and nutrients are required in the soil, which are not safe to the human health and environment and also add to the much higher cost of production as well.

In this method, plants are grown in pots or grow bags filled with porous root media (inert material) and placed in rows by connecting them in series with supply and drain pipes. Water and nutrients are premixed and supplied to each plant as per its requirements in a controlled manner thereby enhancing the crop yield many times in even lesser space as compared to conventional soil based polyhouse/greenhouse cultivation.

In a study conducted by Adams *et al.* (2001) it was concluded that the primary benefit of controlled environment agriculture is increased crop growth rate and reduced time to maturity. This can further be reduced by using soilless techniques such as Hydroponics, Nutrient Film

Technique (NFT) and Aeroponics etc. Effects of cultural cycles and nutrient solutions on plant growth, yield and fruit quality of alpine strawberry grown in hydroponics was studied by Carusoa *et al.* (2011). A series of experiments were conducted with greenhouse cucumber and pepper plants to determine the effects of oxygen enrichment of the irrigation water on yield and fruit shelf-life by Ehreta *et al.* (2010). Effect of slow-release oxygen supply by fertigation on horticultural crops under soilless culture was studies by Urrestarazu and Mazuela (2005). It was observed that oxygen supply has an immediate effect on both water and nutrient uptake and the yield is affected.

Chow *et al.* (1992) evaluated nutritional requirement for growth and yield of strawberry in deep flow hydroponic systems and observed that nitrate-nitrogen, magnesium, calcium and manganese increased with time, and plant components showed specific requirements during fruiting with flowering stage. Adema and Henzen (1989) while comparing the plant toxicities of some chemicals in soil and soilless culture observed that in soilless culture the EC50 values obtained were much lower than those in soil culture.

Rouphael *et al.* (2006) compared sub-irrigation and drip-irrigation systems for greenhouse zucchini squash production using saline and non-saline nutrient solutions and concluded that these studies can be useful for developing optimal management strategies in semiarid regions which are characterized by the shortage of good quality water. At the end of the trial, it was observed that the plants grown with sub-irrigation system resulted in a higher electrical conductivity in the upper and lower parts of the substrate in comparison to the drip-irrigation system.

Maher *et al.* (2008) worked on components of organic soil-less media used in soilless production such as; coco peat, perlite, coir, bark, wood products and compost. It was concluded that coco peat and perlite has long been used as a component of potting mixes and has become the most widely used growing mediums for pots and grow bags as complete growing medium by themselves individually or in an optimum mixture.

Grewal *et al.* (2011) evaluated water and nutrient use efficiency of a low-cost hydroponic greenhouse for cucumber crop in Australia. Results indicated that a total of 4.15 ML/ha of irrigation water was applied during the 13 weeks crop growing period of which 2.56 ML/ha was drained off and 1.59 ML/ha was used to meet the crop evapo-transpiration demand. The study showed that the recycling of the drainage water resulted in a 33 % reduction in potable water used for irrigation in cucumber production.

As discussed by Jackson (1980) biological demand for oxygen through root and micro-organism respiration is increased at higher temperatures which may further reduce oxygen concentration of solution in the root zone. Morard and Silvester, (1996) studied the effect of water logging of the pore space in a substrate which leads to the slowing down or even a rupture in gas exchange between the atmosphere and the rhizosphere. It was observed that depleted oxygen content of nutrient solution may lead to sub-optimal plant growth especially in the summer when inside temperatures are high and the oxygen-holding capacity of water is reduced. Urrestarazu and Mazuela (2005) studied the effect of diffused oxygen into the solution to determine its effect on cucumber and pepper yield along with fruit shelf-life.

It can thus be concluded that hydroponics is the technique for cultivation of plants in a soil free environment by providing perfectly balanced nutrient rich medium to fulfill the purpose of soil. Nutrients are fed directly to the roots which make the plants grow faster. Since the technique eliminate the use of soil, hydroponically grown plants do not come in contact with soil borne pests and diseases, thus saves costs of soil preparation, insecticides, fungicides, etc.

Materials and Methods

Experimental Evaluation of Hybrid Hydroponics Technology (HHT)

Testing of the Hybrid Hydroponics Technology (HHT) was conducted inside a 100 m^2 east-west orientation saw-tooth design greenhouse (asymmetric overlap roof) of 100 m^2 floor area (12.2 m length, 8.3 m width and 6 m central height) having manual opening and closing mechanism of side and top polyethylene sheet rollup system over the screen net (mesh 40 × 40) was designed and constructed at the research field of the department of Mechanical Engineering, Punjab Agricultural University, Ludhiana at 31 ºN latitude, India. The semi-automatic greenhouse was fitted with cyclic timer based temperature and relative humidity control system. Two slow speed axial fans of 36 inch diameter and high pressure foggers operating at 28 psi and generating droplet size of 25-35 micron were fitted in five rows (8 foggers in each row) at 4 m height of the greenhouse just below the UV stabilized 50 % aluminet screen (thermal net). The aluminet sheet can be spread (unfolding) or wrapped up (folding) by manual operation of rope and pulley arrangement to control the excessive sun light during summer months and to conserve heat during winter nights.

Two seedlings of capsicum (green, yellow and red), two seedlings of tomato and one seedling of cucumber crop were transplanted in each pot on 17th October, 2014. In this way, 150 plants of capsicum, 50 plants of tomato and 25 plants of cucumber were planted to test the effect of newly developed hybrid hydroponics technology. Pictorial view of the transplanted plants grown under HHT is shown in **Fig. 1**.

Results and Discussion

Growth and Yield of Plants under HHT

Average initial height of the seedlings was about 11 cm on the date of transplanting (17th October, 2014) and the growth was monitored on weekly basis. The growth pattern of cucumber plants under hydroponics conditions after transplanting (**Fig. 2**). On an average, these plants attained 64.33cm plant height at the time of start flowering after 20days. It reached to 90.66, 218.8, 340.73, 420.53, 556.8 and 625.6 cm after first, second, third, fourth fifth and sixth month of planting, respectively. The fruits were ready to harvest within 38-40 days (less than 6weeks time) of transplanting for both the crops which was about 7 to 10 earlier as compared to existing substrate hydroponics technology without the use of perforated plate.

It was observed that the plants attained the height of more than 5 meters vertically upward direction using trellising system within 100 days of transplanting. The maximum height of the cucumber plant was more than 7 meter and tomato plant was more than 6 meters at the end of the crop cycle. This faster growth and early maturity can be attributed to the multiple irrigations (3 to 4 times in a day) enriched with the desired nutrients as per crop requirements at various stages along with abundance of oxygen supply created inside the pots through the bottom perforated plate. The extrusion of secondary roots through the perforated plate and reaching up to the bottom solution also helped in optimal nutrient absorption by the plants.

During the whole cropping cycle 29 fruit pickings of cucumber were done and an average yield of about 6.7 kg per plant was obtained. Whereas, 19 fruit pickings of tomato were done and an average yield of 6 kg per plant was obtained. Fruit picking number and weight of fruits obtained during each picking are shown in **Figs. 3** and **4**.

Water Consumption in Open and Recirculation Mode of Hydroponics

Water consumption for recirculation type and open system (in which nutrient solution is not recovered for reuse) has been compared for the full crop cycle after transplanting of the crops. It was observed that during the early stages of crop 800 liters of nutrient rich water solution was consumed by total 225 plants in about 15-18 days time in recirculation mode. This consumption was gradually increased and the at the time of fruiting and further harvestings, the consumption of 800 liters was just reduced to 8 or even 6 days time depending upon the outside climatic conditions.

The calculation is based on the fact that about 1.6 liter of nutrient rich solution was supplied at one time through two laterals by operating the timer controlled motor for just 2 minutes. In total the motor

Fig. 1 Pictorial view of Cucumber, Tomato and Capsicum plants grown under HHT.

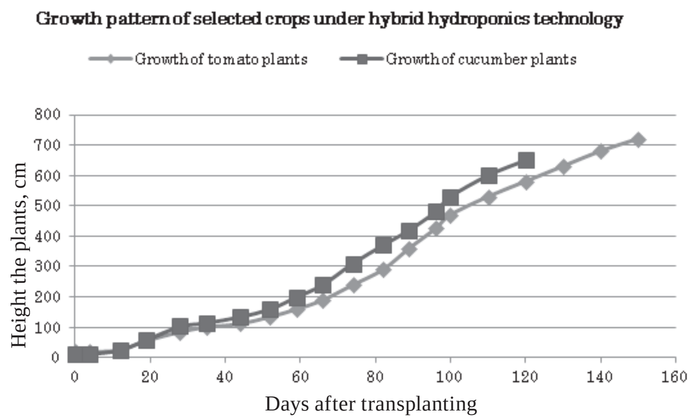

Fig. 2 Growth pattern of cucumber and tomato plants under Hybrid Hydroponics Technology during the full crop cycle.

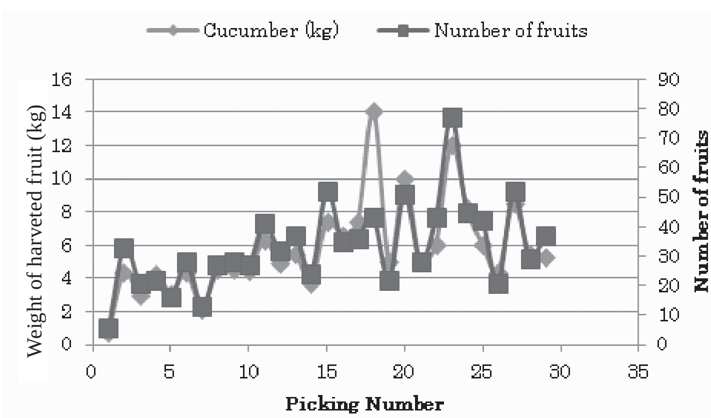

Fig. 3 Weight and number of harvested fruits during each picking (cucumber crop)

was operated 4 times a day. In this way 6.4 liter of solution was supplied in one day during different times of the day starting from 9:30 am (2 min), 11:30 am (2 min), 1:30 pm (2 min) and 4:30 pm (2 min). It is observed that in total about 13,500 liter of water was consumed for 150 days as compared to the total calculated consumption of about 116,000 liters in non-recovery system (open mode) (**Fig. 5**). The objective of supplying nutrient rich water solution 4 times in a day was to keep the nutrient level high and the higher oxygen supply due to replacement of void openings with fresh air during the photosynthesis period. In this way, it was observed that recirculation type hydroponics technology can save about 88 % of water as compared to the open hydroponics system during the whole cropping cycle.

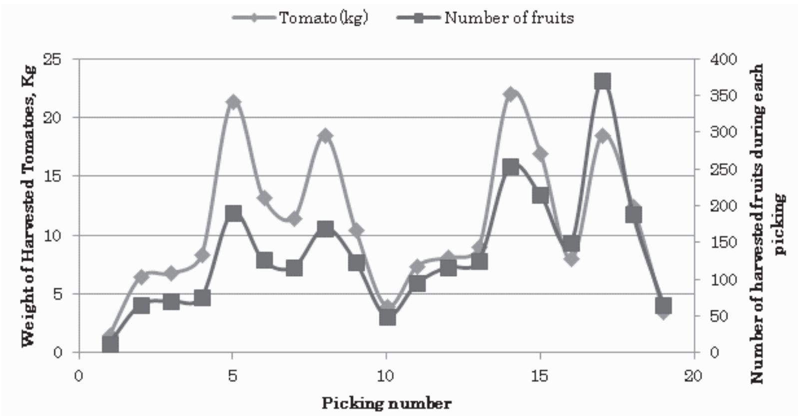

Fig. 4 Weight and number of harvested fruits during each picking (tomato crop)

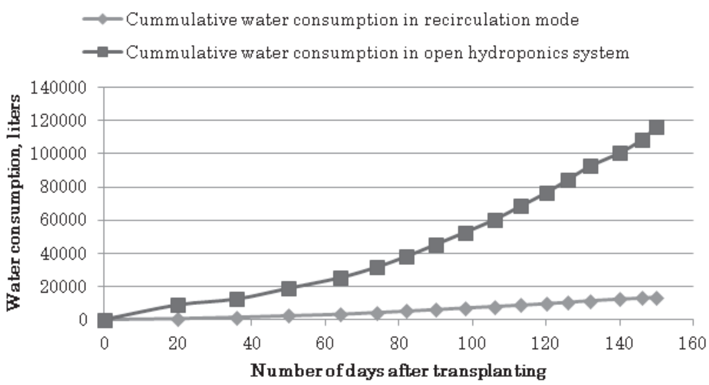

Fig. 5 Comparative of cumulative water consumption in recirculation and open system of hydroponics for 150 days period of crop cycle.

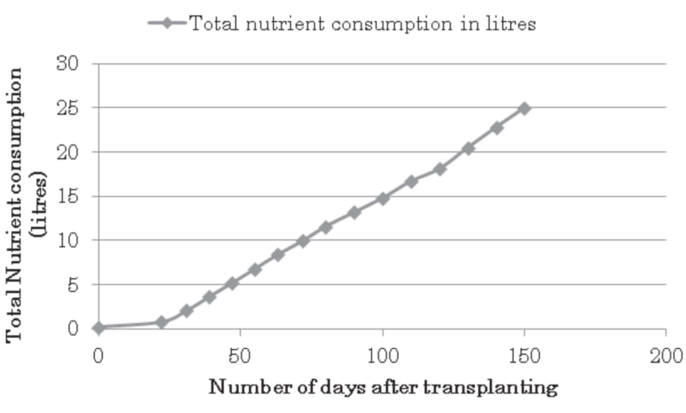

Fig. 6 Cumulative consumption of concentrated nutrients during the 150 days period of crop cycle for 250 plants in 100 m^2 greenhouse area

Cumulative Nutrient Consumption

In order to maintain proper supply of nutrients in the range of 600-650 ppm of total dissolved salts (TDS) during early stage, 1 litre of concentrated nutrients solution was mixed in 1,000 liters of water which was later on increased to 1.6 liter to maintain the TDS in the range of 900-1200 through the automatic dossier system. The measured parameters were TDS (in the range of 600-1200 ppm), EC (electrical conductivity in the range of 1.4-2.0 µs/cm and pH between 6.0-6.5 during different stages of crop growth. During early stages of plant growth, nutrient consumption was very small for growing, micro and bloom components. Initially, 400 ml of concentrated nutrients per 1000 litres of each component was added for the small seedlings. It was later on increased to 800 ml per 1,000 litres and 1,600 ml per 1,000 litres till the flowering stage of plants was attained. Finally, at the fruiting stage, the concentration of grow and bloom was increased to 3,200 ml per 1,000 litres, whereas the concentration of micro nutrients was increased only to 2,000 ml per 1,000 litres as per the recommendation of the nutrient manufacturing company.

In this way, total nutrient consumption for 225 plants during the 100 days period was about 25 liters and for 150 day period was about 45 liters which is equivalent to the cost of Rs 8,500 (**Fig. 6**). One kg of solid nutrient of each component was dissolved in 4 liters of water to make a concentrated solution. The collective cost of one kg of all three types of nutrient is Rs. 850 as per current market price.

Economic Evaluation

The economic analysis of the

indigenously developed Hybrid Hydroponic Technology was also been conducted to determine the scope of successful commercialization of this the technology. The complete constructional and operational details are given in **Table 1**.

To find out the break-even point of the whole technology, operational costs along with the projected crop yields are shown in **Table 2**.

Assuming that total net profit from three crop cycles in one year is about 80 % of Rs 120,650 (due to variation of average yield and other factors) which comes out to be Rs 96,580 ($ 1,486) , the whole cost of the indigenously developed HHT can be recovered in just about 5 years time for small scale commercial business. At the time of upscaling of HHT to full commercial levels of 500 m^2 or 1 acre for larger projects, the construction and operational costs will further come down and it will be very easy to earn high profits by producing high quality vegetables. Hence, it can be concluded that with the availability of the indigenous material and sys-

Table 1 Constructional and system costs of the micro-climatically controlled greenhouse based indigenously developed Hybrid Hydroponic Technology (1 $ = Rs 65 at current market prices).

Item	Quantity	Unit Cost (Rs)	Total cost (Rs)
Greenhouse construction of 100 m^2 area (Ridge roof design/ Asymmetric roof	01	100,000	100,000
Square pots of 12” × 12” size fitted with siphoning system and perforated plate along and root media	125	600	75,000
High pressure foggers (anti droplet technology) with pipings	40	800	32,000
Slow speed axial fans (36” diameter)	02	6,000	12,000
Nutrient dossier system for automatic supply of Grow, Micro and Bloom components	01	135,000	135,000
Operational electric motors	03 (1 hp each)	6,000	18,000
Water storage tanks	03 (1,000 L each)	6,000	18,000
Indigenously developed sensor based display panel for TDS, EC, ppm, Temperature and RH % measurement		45,000	45,000
Cyclic timers for automatic operations of fans foggers and dossier system		20,000	20,000
Drain and supply pipe lines with fitting along with polyethylene sheet spread on the floor to cutoff soil contact from ground.		25,000	25,000
Labour charges for the installation of whole technology			20,000
		Total cost (Rs)	500,000/- (= $7,693)

Table 2 Input operational cost and output yield of two crop cycles in one year for tomato (Cibellia variety) and cucumber crops (Velly star variety) obtained from 100 m^2 greenhouse area.

(1 $ = Rs 65 at current market prices)

Item	Quantity	Cost per unit (Rs)	Total cost (Rs) Input (−) Output (+)
First crop (Tomato) from October to mid March			
Total nutrient requirement for one crop cycle	10 kg each of grow, micro and bloom components along with Phosphoric acid	850/ kg	(−) 8,500/-
Total electricity consumption in kWh for operating the fan & foggers, nutrient supply and night heating for one crop cycle	1,000 kWh	6	(−) 6,000/-
Pesticides and other misc costs			(−) 2,000/-
Average yield per plant	6 kg × 250	40	(+) 60,000/-
Net profit from tomato crop (Rs)			(+) 43,500/- (= $ 670)
Second crop (cucumber) from mid March to mid June			
Nutrient requirement for one crop cycle	0.7 kg	850	(−) 5,950/-
Electricity consumption for operating the fan & foggers and nutrient supply	400 kWh	6	(−) 2,400/-
Pesticides and other misc costs			(−) 1,500/-
Yield per plant (seedless cucumber)	6.7 kg × 250	40	(+) 67,000/-
Net profit from cucumber crop (Rs)			(+) 57,150/- (= $ 880)
Third crop (any leafy vegetable of small duration) from July to September			
Net profit from leafy vegetable (spinach) after deducting all the inputs as mentioned above			(+) 20,000/-

tems, along with the proper training for skill development, HHT can be adopted as a future technology in developing countries including India and has the potential innovative features to make necessary improvements in the existing pot based substrate hydroponics technology available in many developed countries such as Holland, Israel, Australia USA and Japan etc.

Conclusions

1. The HHT effectively combines the features of substrate hydroponics technology and shallow water pond hydroponics technology by inducing the perforated plate and water retention and siphoning system.

2. The effect of the HHT was much higher on the growth and yield of cucumber and tomato plants and attained the fruiting stage 7 to 10 days earlier as compared to the existing SHT.

3. The average yield of cucumber crop under HHT was 6.7 kg per plant as compared to 5 kg per plant yield in SHT (Substrate Hydroponics Technology).

4. The average yield of tomato crop under HHT was 5 kg as compared to 3.5 kg per plant yield in SHT.

5. Water and nutrient savings under the HHT (closed loop recirculation type) are about 90 % and 60 % as compared to open non recirculation type hydroponics technologies.

6. Based on the estimated yields, the developed HHT has a break-even point of 4 to 5 years with the selected crop per year, thus making it an economically feasible technology for off season vegetable production inside micro-climatically controlled greenhouses particularly for developing countries.

Acknowledgements

The Authors are thankful to the Government of India for providing financial assistance under the Rastriya Krishi Vikas Yogna (RKVY) through the Director of Research, Punjab Agricultural University, Ludhiana and the necessary facilities given by the PAU authorities for completing this project. The Authors are also thankful to the authorities of PAU for safeguarding the innovative part of this new technology by filing the Indian patent on behalf of PAU entitled "Improved water and nutrient perforation and recirculation system for pot based substrate hydroponics" Patent No. 1567/DEL/2015. The authors also acknowledge the efforts of Dr Praveen K Saxena, Director, Gosling Research Institute of Plant Preservation (GRIPP), Ontario College of Agriculture, University of Guelph for inviting Dr. V. P. Sethi, Professor and Head, Department of Mechanical Engineering, PAU Ludhiana as 'Guest Faculty' to deliver a seminar on this innovative Hybrid Hydroponics Technology (HHT) and for evaluating its innovative features through the relevant faculty of GRIPP and greenhouse industry of Ontario state in Canada for possible improvements in existing hydroponic technology around the world.

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Present Status and Future Need of Mechanizing Sugarcane Cultivation in India

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Abstract

Sugarcane is an important agro-industrial crop of India which plays a crucial role in social and economical up-liftment of rural population. It is grown in an area of 5.03 million ha with production of 361.03 million tonnes. Uttar Pradesh State is largest producer of sugarcane as it contributes 43.65 % of the total area and 35.21 % of the total production of sugarcane in the country. In India, the majority of the farm holdings fall under small and marginal category (85 %) and the average size of land holding is about 1.16 ha. The average farm power availability is about 1.35kW/ha in Indian agriculture. The sugarcane cultivation involves different operations such as seed bed preparation, planting (seed setts cutting, furrow making, placement of seed setts, fertilizer and chemicals, soil covering over setts), weeding/interculture, spraying, harvesting including de-trashing and transportation. Most of these operations are being done with traditional tools and equipment which are very time, labour consuming (375 man-days/ha) and involve lot of drudgery that ultimately increases the cost of operation and reduces the net profit to the growers. In sugarcane agriculture, the mechanization is limited up to the land preparation and to some extent to planting and intercultural operations. The most laborious and tedious task of sugarcane agriculture is harvesting. A number of sugarcane machines for different operations have been developed at IISR, Lucknow and some other places/firms & commercialized. Many farmers are using these machineries and benefitted through mechanization. But still there need to make policies/strategies for mechanizing sugarcane cultivation by providing improved technology to the famers at reduced cost of operation and drudgery so that production and productivity could be increased.

Introduction

Sugarcane is an important agro-industrial crop of India which plays a crucial role in social and economic uplift of rural population. It is the main source of sugar, gur and khandsari in the country. It is cultivated in an area of about 5.03 million hectare with an average productivity of 71.66 tonnes/ha (**Table 1**). Total production of sugarcane has been has been increasing steadily from 230 million tonnes in 1993-94 to 361 million tonnes in 2011-12. Uttar Pradesh State is largest producer of sugarcane as it contributes 43.65 % of the total area and 35.21 % of the total production in the country but have the average yield less than the National average (**Table 2**). India's total sugar production in 2012-13 was 25.14 million tonnes, with Uttar Pradesh contributing 30 percent in the annual production. The energy consumption in production of sugarcane is highest as compared to many other crops such as potato, wheat, maize, paddy etc. This crop needs the highest labour

Table 1 Area, production of sugarcane in India

Year	Area, million ha	Production, million tonnes	Yield, kg/ hectare	Area under irrigation, %
2006-07	5.15	355.52	69,022	93.2
2007-08	5.06	348.19	68,877	93.5
2008-09	4.42	285.03	64,553	93.7
2009-10	4.17	292.30	70,020	93.5
2010-11	4.88	342.38	70,091	-
2011-12	5.03	361.03	71,666	-

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation as compared to any other crop requiring more than 375 man-days/ha for different operations. Considering the present trend of availability of labour for sugarcane production, it has been experienced that use of modern machinery is inevitable. Use of machinery helps in labour savings, ensures timeliness of operations, reduces drudgery, helps in improving quality of work, reduces cost of operation and ensures effective utilization of resources. In India considerable R & D work for design and development of agricultural implements and machinery for some operations of sugarcane viz. land preparation, planting, interculture and ratoon management have been carried out. However the adoptions of these implements and machinery have not been up to the desired level. The mechanization is limited up to the land preparation, planting and to some extent to intercultural operations. The most laborious and tedious task of sugarcane agriculture is harvesting. Thus, there is a considerable mechanization gap, especially in the area of sugarcane planting, interculture, plant protection, harvesting and ratoon management. As majority of the operational holdings (85 %) falls under marginal and small category that needs small improved machinery suits to local conditions (**Table 3**).

Therefore it is necessary that concentrated efforts be made for adoption, development and popularization of sugarcane machinery for various cultural operations for mechanizing sugarcane cultivation in the country for increasing production and productivity at reduced cost of operation.

Table 2 Major Sugarcane producing states in India

State	Area (million ha)	% to All India	Production (million tonnes)	% to All India	Yield (kg/ha)
Uttar Pradesh	2.13	43.65	120.55	35.21	56,596
Maharashtra	0.97	19.88	81.90	23.92	84,433
Karnataka	0.42	8.61	39.66	11.58	94,429
Tamil Nadu	0.32	6.56	34.25	10.00	107,031
Andhra Pradesh	0.19	3.89	14.96	4.37	78,737
Gujarat	0.19	3.89	13.76	4.02	72,421
Bihar	0.25	5.12	12.76	3.73	51,040
Uttarakhand	0.11	2.25	6.50	1.90	59,091
Haryana	0.09	1.84	6.04	1.76	67,111
Punjab	0.07	1.43	4.17	1.22	59,571
Madhya Pradesh	0.07	1.43	2.67	0.78	38,143
Others	0.07	1.42	5.16	1.51	60,833
All India	4.88	100.0	342.38	100.00	70,091

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2010-11)

Table 3 Number and size of operational holding by size group

Category of holdings	No. of holdings ('000 no.)		Area ('000 ha)		Average size of holdings (ha)	
	2005-06	2010-11	2005-06	2010-11	2005-06	2010-11
Marginal (< 1 ha)	83,694 (64.8)	92,356 (67.0)	32,026 (20.2)	35,410 (22.2)	0.38	0.38
Small (1.0-2.0 ha)	23,930 (18.5)	24705 (17.9)	33,101 (20.9)	35,136 (22.1)	1.38	1.42
Semi-medium (2.0-4.0 ha)	14,127 (10.9)	13,840 (10.1)	37,898 (23.9)	37,547 (23.6)	2.68	2.71
Medium (4.0-10.0 ha)	6,375 (4.5)	5,856 (4.3)	36,583 (23.1)	33,709 (21.2)	5.74	5.76
Large (10.0 ha & above)	1,096 (0.8)	1,000 (0.7)	18,715 (11.8)	17,379 (10.9)	17.08	17.37
All Holdings	129,222 (100.0)	137,757 (100.0)	158,323 (100.0)	159,180 (100.0)	1.23	1.16

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (Agricultural census 2010-11)

Need of Farm Mechanization

The principal advantage of mechanized agriculture is that it reduces the demand for labour and allows operations to be carried timely. Mechanization is needed to get over some of the major constraints to enhance productivity, to make farming less arduous and to make it attractive enough to enable educated youth taking willingly agriculture as profession. Mechanization also aims at increasing land labour efficiency by improving the safety and comfort of agricultural labour and to protect the environment by allowing precision operations and increasing the overall income.

Efficient machinery helps in timely farm operation, input use efficiency, increasing productivity by about 30 %. Development and introduction of high capacity, precise, reliable and energy efficient equipment and their judicious use can bring in precision and timeliness in field operations.

Constraints in Farm Mechanization in India

1. Small and scattered holdings
2. Lack of awareness about the technology/equipment
3. High cost of equipment and machinery
4. Lack of approach road/facilities for the movement of heavier farm equipment
5. Poor economic conditions of the cultivators
6. Lack of repair, maintenance and replacement facilities in remote rural areas
7. Use of costly equipment/machine

in a year for a crop/season only

8. Policies are not favouring the application of total mechanization

Challenges for Farm Mechanization in India

Small farmers need mechanization at the most to reduce their cost of cultivation, often burdened with higher labour wages, low capacity prime movers and low capital investment capacity. Small land holding pattern has a very complex set of challenges for mechanization. With the number of operational holdings increasing, alternative sources of income will be needed to sustain farm distress. Research, development and management options need to be evolved to meet requirement of small landholders. Equipment/technologies need to be suited to energy consumption pattern. Advancement in electronic and computation sciences, automated controls needs adoption in field of mechanization. Multi-tasking and radio-controlled machinery will be future generation of farm machines. Developed nations have succeeded mechanizing most of the unit operations in agriculture. They are using single run machines that can prepare seedbed, apply seed and fertilizers, herbicides in a single pass. Rising labour wages have forced them to develop radio-controlled machines for automatic dispensing of feed and fodder to the livestock. Such technologies need to be developed for Indian farmers for making agriculture profitable to farmers. Timeliness of operation and capacity suiting to save crops is needed to help farmers under abiotic and biotic stresses of crop on account of climate change, which needs to be worked out.

Mechanization of Sugarcane Cultivation

The cost of sugarcane cultivation accounts about 60-70 % of total cost of the sugar production. Sugarcane cultivation requires various operations like seedbed preparation, planting, interculture, earthing up, plant protection, harvesting, transportation and ratoon management. Of the above operations, land preparation is done as in the case of other crops by commonly used tillage implements. Planting, interculture, earthing up and transportation are in semi mechanized stage. Tractor use is gradually increasing for land preparation and haulage work. Still, to a large extent, all the operations involved in cane cultivation are performed by traditional energy intensive less efficient tools. Manual harvesting of sugarcane is in vogue. Different types of sugarcane harvesting knives of different sizes, shapes and weights are used for sugarcane harvesting at different places. Sugarcane harvesting is a highly labour intensive operation. About 150 man-days per ha is required for sugarcane harvesting including detrashing with the traditional tools. Non-availability of manpower during peak crop season is becoming a major problem in mechanization of sugarcane.

Some of the machines available and are used for sugarcane cultivation for different field operations is enumerated below. **Table 4** shows the average man days required per ha for sugarcane cultivation. Harvesting, interculture and planting are the most labour intensive operations.

Table 4 Average man power required per ha for sugarcane cultivation

Operation	Average man days/ha
Seed bed preparation	30
Planting	35
Weeding and other inter-cultural operations	100
Irrigation	20
Fertilization	10
Harvesting including de-trashing	150
Transportation and loading	30

Fig. 1 IISR tractor operated culti-harrow

Seedbed preparation

Sugarcane crop requires well-prepared seedbed. The many farmers are using the animal drawn ploughs and ridgers for the field preparation. But now a day's tractors has replaced animal power to a great extent and are playing key role for farming operation not only in sugarcane but also in all other agricultural operations. The equipments like, disc plough, mould board plough, cultivator, duck foot cultivator, disc harrows, leveler, ribber plough, rotovator, ridger, bund and channel former, etc are prevalently used in sugarcane cultivation. The seed bed preparation with culti-harrow developed by IISR, Lucknow (**Fig. 1**) have been found quiet effective as this implement can perform three operations viz. cultivating, harrowing and planking in a single pass thus thereby saving 23-35 % time and 17-28 % fuel as compared to conventional tillage practice (Singh P.R. et. al. 2013).

Treatment of Seed Cane

Sugarcane suffers from different types of seed born diseases like red rot, grassy shoot disease, ratoon stunting disease and mosaic etc. In order to control the diseases, seed cane is treated at a temperature of 54 ºC for about 2½ hours at a humidity level of about 95-99 % or at 50 ºC for a period of about 2 hrs in case of moist hot air and hot water treatment plants respectively. Moist hot air treatment unit developed by IISR (**Fig. 2**) is useful in treatment of seed cane and saves crop from seed borne diseases like RSD, Red rot, Leaf scald disease, GSD, smut etc.

Fig. 2 IISR moist hot air treatment unit (MHAT)

Sugarcane Sett Cutting

Sugarcane is a vegetatively propagated crop. It is planted in the form of cut setts of 2-3 buds. For preparing setts, manually operated hand tools and power operated sett-cutting machines are used. In conventional planting sugarcane sett cutting process is a pre-planting practice, while in mechanized system (sugarcane cutter planter) sett cutting is done simultaneously by the planter. This ultimately reduces time, labour and moisture loss in setts of sugarcane seed and helps in higher germination percentage.

Planting

Planting of sugarcane comprises many operations such as opening of furrows, seed setts cutting, placement of setts in the furrows and providing soil cover to setts. Most of the farmers are using manual practice of placing setts in the furrows that are made by tractor drawn or bullock operated ridgers. These methods consume a lot of time, energy and also resulted in increased drudgery and cost of operation. Different methods of planting are followed such as flat planting, trench planting, ring pit planting, furrow irrigated raised bed (FIRB) planting, staggered row planting and spaced transplanting. Most of the area in Northern India is flat planted. In the areas where sugarcane lodging takes place, trench planting is followed. Different rows spacing are maintained at different places ranging from 60-70 to 90-150 cm. IISR, Lucknow has developed various models of sugarcane planters viz. Semi-automatic, automatic and later cutter planters suited for tractors as well as bullocks. In addition IISR RBS (raised bed seeder) cane planter, paired row sugarcane planter and trench planter are gaining popularity among the farmers (**Fig. 3**). Thus to reduce drudgery and cost of planting and efficient utilization of seed, chemical, fertilizer, use of planters is advocated. For sugarcane production spaced transplanting technique is being followed in some parts of Maharashtra on large scale. Recently, trend of single bud sugarcane transplanting for the production of cane requires attention for development of a sugarcane transplanter. Poly bag planting/transplanting and mechanization of tissue culture seed production processes are new emerging areas.

Irrigation: Sugarcane is an intensively irrigated crop. However, under deficit water availability conditions, use of sprinklers, drip irrigation system and skip furrow method of irrigation and fertigation are practiced for economical and efficient use of water. Application efficiency is higher in case of drip, sprinkler irrigation than other methods. Skip furrow method of irrigation saves irrigation water by

3 rows planter (GW drive)

2 row planter (PTO drive)

Paired row planter (PTO)

Trench planter (PTO)

Fig. 3 IISR developed various sugarcane cutter planters

36.5 % and improves water use efficiency by 64 %.

Weeding and interculture: Number of interculture operations is required in sugarcane crop to control weeds, moisture conservation, microbial action and creation of better environment for overall growth of the plant. Farmers are using spade, khurpa for weeding manually. Bullock plough and tractor operated cultivators are also used for this purpose. Recently tractor operated three row rotary weeder has been introduced to Indian market for wide spaced crops. The efficient and high capacity equipment like self-propelled power weeders, power tillers, mini tractors of various makes and designs are available in the market for weeding and interculture operation. Multipurpose tractor operated equipment are also being used for this purpose.

Plant Protection: For control of insects and pests diseases, application of chemicals is done with the help of sprayers at the initial stage. In order to spray effectively and efficiently, use of wide swath spray boom is advocated. Wide swath spray boom may be operated by foot/hand/engine operated spray pumps. Self-propelled high clearance sprayers, tractor operated aero blast sprayers may also be used in a crop planted in a planned manner.

Earthing

The S.S. Furrower developed at IISR can be used for earthing operation in fields where row to row spacing is not more than 90cm. This equipment is tractor operated and can be used till cane formation height is not more than 40 cm.

Harvesting and Detrashing

Presently harvesting of sugarcane is done manually using different types of knives/tools giving an average output of 0.8 to 1.0 quintal per man-days (**Fig. 4**).

Sugarcane harvesting involves base cutting, stripping and detrashing, detopping, bundle making of 10-12 stalks, loading and finally transports of sugarcane to the sugar mills. Under the present scenario due to non availability of labour, the harvesting gets delayed affecting the production of sugar. The mechanization efforts in the country have been basically limited to the development of whole stalk harvesters for the partial mechanization of harvesting of sugarcane. IISR has developed tractor front mounted sugarcane windrower whole stalk harvester. It was reported that with this harvester, two rows can be cut simultaneously and windrowed at the centre of the rows (**Fig. 5**). Combine chopper harvesters have been imported at few places in Tamilnadu and Maharashtra. These harvesters are intended to mechanize the whole operation of sugarcane and found acceptability at few places at limited scale.

Large sized harvesters are prevalently used in the countries like Cuba, Brazil, USA, Australia and South Africa. These machines could be economically operated only if the sugarcane is planted in 1.5 m or more row spacing with furrow length of 250 m and above. However, in the eastern countries like Japan, China and Thailand sugarcane harvesting is practiced with medium sized machines where the sugarcane field sizes are more or less similar to that of Indian condition. Power operated detrasher was developed at IISR (**Fig. 6**) and PAU, Ludhiana for removal of removal of green top as well as dry trash from the harvester sugarcane (Shukla *et al*., 1991 & Singh and Sharma, 2009).

The main reason for non-popularization of big harvester in India is the row spacing. In north India, the row to row spacing ranges from 60-75 cm while in Central and South India the spacing is around 90-105 cm and some farmers now planting sugarcane at 120 cm spacing. For functioning of big harvester atleast, 120 cm spacing is required. The small size of field, cane purchase system, initial cost, field losses etc. are some other factors limiting the introduction of big sugarcane harvesters especially in northern India.

Loading and Transport

The harvested cane is transported to sugar mills for its processing using different modes of transportation viz. Bullocks carts, tractor operated trailers and trucks. The commercial loading and transport vehicles could be effectively used for moving the canes from the field to sugar mills for crushing and fur-

Fig. 4 Conventional practice of sugarcane harvesting

Fig. 5 IISR sugarcane harvester

Fig. 6 IISR sugarcane detrasher

ther processing.

Ratoon Management

The ratoon management involves the process of stubble shaving, off-barring the bunds and stirring and manipulating the soil for better crop establishment. In addition the sugarcane trashes are to be shredded for incorporating with the soil to enrich soil fertility. IISR developed Ratoon Management Device (**Fig. 7**) and Ratoon Manager can perform the following operations:

- Stubble shaving (Ratoon manager don't have)
- Deep tilling/breaking soil-hard-pan
- Application of inorganic and organic fertilizers/manures
- Dispensing insecticides near root zone.
- Earthing-up

The equipment viz., Tractor drawn ratoon manager and shredders of few designs are commercially available for use.

Future Mechanization Strategies

The mechanization package technology has to be eco-friendly, user friendly, facilitating the strenuous and hazardous farming operations in a safe and comfortable manner, increasing the area and productivity and facilitating custom hiring/contract farming. Low purchasing power, low literacy and resistance to change from traditional system, inadequate credit facilities and poor risk bearing ability, are some of the socio-economic and infrastructure constraints in sugarcane mechanization.

Fig. 7 IISR ratoon management device (RMD)

Some important aspects to formulate appropriate policy for successful sugarcane mechanization are discussed below.

- Development of cheaper machinery including sugarcane harvester for small and marginal farmers as majority of farmers are in this category having less than two hectares of land.
- There should be packages of improved sugarcane machineries for different categories of farmers and location specific.
- Financial assistance to cane growers should be given through Government and Sugar Industries for purchase of sugarcane machinery. Banks may liberalize their credit policy for farm mechanization in sugarcane for farmers/rural youths.
- There should be active participation of sugar mills and agro-industries service centres to build up an infrastructure for providing costly machineries and equipment to the growers through custom hiring services.
- Entrepreneurship development programmes (self-help groups) for manufacturing, repair & maintenance, marketing and custom hiring of the machinery should be started in sugarcane growing belts in rural areas.
- There should be a strong network of extension agencies for dissemination of improved sugarcane mechanization technology among the farmers through front line demonstrations, trainings, kisan melas/divas, TV/radio talk etc.
- There should be frequent training/short term courses on operation, utilization, repair & maintenance of sugarcane machineries for the farmers/cane growers.
- There must be collaborations between R&D institutions, manufactures, extension agencies and stake holders for better implementation of mechanization strategy.
- More support shall be provided by the government for coordination between development and implementation of agriculture machinery and technology in future.

Conclusions

Mechanisation of sugarcane could go a long way not only in enhancing the productivity but also in improving the quality of work for the rural labour. Many technologies for mechanisation of sugarcane cultivation have been developed and they have to be introduced appropriately in the sugarcane mechanization sector together with appropriate policy and implementing institutions for successful adoption. Mechanisation technology clubbed with appropriate mechanization strategy would help in achieving the goal of higher productivity in sugarcane.

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EVENT CALENDAR

◆ **常州農業機械展覧会 2016**
April 15-16, 2016, Changzhou, CHINA

◆ **VDI Conference**
—Connected Off-Highway Machines 2016—
May 10-11, 2016, Düsseldorf, GERMANY
www.vdi-internaional.com/offhighwaymachines

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

◆ **DLG-Feldtage**
June 14-16, 2016, Bavaria, Germany
http://www.dlg-feldtage.de/en/news/news/?detail/feldtage 2014/16/2/8322

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

◆ **4th CIGR International**
—AgEng Conference 2016− Robotics, Environment and Food Safety—
June 26-29, 2016, Aarhus, DENMARK
http://conferences.au.dk/cigr-2016/

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

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

◆ **The 4 th Edition of INAGriTech 2016**
August 25-27, 2016, Jakarta INDONESIA
http://www.inagritech-exhibition.net/#axzz3zFynVBGC

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

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

◆ **CIAME 2016**
—China International Automotive Manufacturing Technology & Equipment Exhibition—
October 28-30, 2016, Wuhan, CHINA
http://www.ciame.net/

◆ **EIMA International 2016**
November 9-13, 2016, Italy, BOLOGNA
www.eima.it

◆ **BICET 2016**
—6th Brunei International Conference on Engineering and Technology 2016—
November 14-16, 2016, Bandar Seri Begawan, NEGARA BRUNEI DARUSSALAM
http://www.itb.edu.bn/bicet2016/

◆ **KISAN SHOW** —India's Largest Agri Show—
December 14-18, 2016, Pune, INDIA
http://pune.kisan.in

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

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Experimental and Combined Calculation of Variable Fluidic Sprinkler in Agriculture Irrigation

by

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Abstract

To overcome the problems of repeated sprinkling and spraying beyond the boundary of the spraying area, a variable sprinkler irrigation system was developed. The variable sprinkler allows the pressure and flow to be change with sprinkler rotation. Experiments were carried out to determine the hydraulic performance and the characteristic parameters of variable irrigation systems. The results showed that as the inlet cross-section of the sprinkler increased, the flow rate, the sprinkler working pressure and the wetted radius also increased. Furthermore, the supply pressure of the system and the drop sizes at the end of the wetted radius decreased. A method to calculate the combined uniformity of a variable irrigation system was developed. The relationship between the distance of the sprinklers and the uniformity coefficient was obtained. For a square spray pattern, the data were analyzed using nonlinear regression. Under the square and triangular layouts, the combined space coefficients (combined space coefficients is the division for lateral space to wetted radius (R)) of the sprinklers (typed BPXH) BPXH20 and BPXH30 were 1.3R, 1.43R, 1.3R and 1.27R, and the uniformity coefficients were 74.3 %, 75.6 %, 66.3 % and 78.4 %, respectively.

Keywords: variable spraying system, sprinkler, hydraulic performance, uniformity

Introduction

Sprinkler systems are key equipment for saving water and machine automation in agricultural irrigation (Faci *et al*., 2001). Most sprinklers rotate in a circular pattern because the hydraulic performance and stabilization of these systems is good and they have been used widely across the world (Sourell *et al*., 2003). However, the circular spraying pattern is not suitable for square areas because water usually goes beyond or cannot reach the entire area (Zhu *et al*., 2002). The uniformity coefficient of circular spraying is reduced by repeated spraying (Li, 2000; King *et al*., 2000).

The superpose area is reduced when the sprinkler spraying pattern is square. At a given flow rate, the sprinkler number will be reduced thus saving energy. Variable sprinkler systems are used for irregularly shaped areas in garden irrigation, hypsography, and in application sites. Therefore, research on variable spraying systems is important for saving water.

Research on variable spraying systems is extensive both domestically and abroad. Fraisse (1995) analyzed a variable irrigation system to obtain the water distribution at different valve openings and for different pressure heads. The results indicated that using conventional sprinkler heads is a viable method of reducing the application of water below that determined by the speed of the machine. Han (2007) proposed a theoretical relationship between the parameters of the square spraying pattern and uniformity for variable spraying. The variable-rate contour-controlled sprinkler operational equation was derived in the study. The square wetted area sprinkler was used to illustrate the application of variable-rate contour-controlled sprinkler operational equation. These equations provide fundamental principles for the design of variable-rate contour-controlled sprinklers and square wetted area sprinklers. Both of the studies were indicated that high uniformity irrigation could be achieved by variable spraying.

Widespread research has been conducted on the sprinkler irrigation uniformity. The importance of sprinkler irrigation uniformity has been recognized as early as 1942 (Christiansen, 1942). Irrigation uniformity is defined as the variation in irrigation depths over an irrigated area and is an important performance characteristic of the sprinkler irrigation system (Heermann *et al*., 1992; Evans *et al*., 1995; Schneider, 2008). Andre (2010) analyzed the water distribution of an irrigation system at different pressures and determined the spraying hydraulic performance, and sprinkler network performance analyses carried out. The amount of applied water at different proportion of area adequately irrigated were also calculated. Lamaddalena (2007) indicated that the performance of the on-farm sprinkler network is greatly affected by the variation in the hydrant pressure head. Playan (2010) reported that experiments have been performed to characterize water application at different distances from an isolated sprinkler or in regular networks with different sprinkler spacings. Li (2003) investigated that the response of crop performance to non-uniformly applied water and fertilizers through field experiments and provided recommendations for the design of sprinkler irrigation system.

The uniformity of sprinkler irrigation depends on a number of factors, including the sprinkler and nozzle type, the irrigation layout and the environment (Dukes, 2006). Therefore, the ability of a sprinkler layout to apply water uniformly across the irrigated area is a major factor influencing crop growth and yield. The main factors influencing pipeline layout include landform conditions, plot pattern, farming and crop direction, wind direction, wind speed and water source position (Li *et al*., 2003). The spray pattern is an important factor when using various sprinkler combinations (Silva *et al*., 2007). The optimal space between the sprinklers must be determined, which is the key step for irrigation system design. The space between the sprinklers directly influences the investment, the quality of the irrigation, and the yield of the crops.

Previous studies have assessed the performance of on-demand water distribution systems, and some have simulated the sprinkler water distribution patterns under different working conditions (Yan *et al*., 2009; Zhu *et al*., 2009). However, research on network uniformity for variable spraying technology is limited.

The objectives of this research were (1): to determine the characteristics and the parameters of a variable spraying system and to perform hydraulic performance experiments, and (2): the determination and optimization of the impacts of sprinkler spacing on the uniformity of water application.

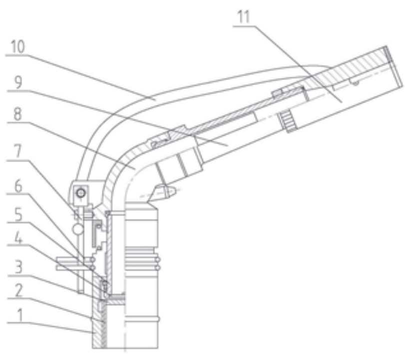
Materials and Methods

Working Theory

The system was designed for variable spraying that included a pump, valves, pipelines, and a new fluidic sprinkler. The fluidic sprinkler was developed by the Research Center of Fluid Machinery Engineering and Technology, Jiangsu University in China. The working theory of fluidic sprinkler was introduced by Liu (Liu *et al*., 2013; Zhu *et al*., 2012). A pressure adjusting device was added at the inlet of the fluidic sprinkler. As a result, the working pressure can be changed according to the inlet cross-sectional area. A drawing of the variable-rate fluidic sprinkler (BPXH) is shown in **Fig. 1**. The pressure of the sprinkler nozzle was changed when the sprinkler rotating and the wetted radius was changed. If the cross-section area designed following the recommendations of range of nozzle pressure, the wetted pattern for different shape will be obtained.

Experimental Setup

An experimental setup was designed according to the ASABE S398.1 standard (ASABE standard, S398.1, 2007) and is shown in **Fig. 2**. Water was pressurized by a centrifugal pump (IS80-50-250). A valve located at the outlet of the pump allowed for control of the flow rate. An electromagnetic flow meter (MF/E5001621100EH11) was used to estimate the sprinkler discharge. The precision degree was 0.5 and located upstream of the valve. A pressure sensor (MPM482) was located at the inlet of the sprinkler. The sprinkler was installed at a height of 1.2 m. The two types of sprinklers used in the setup were BPXH20 and BPXH30. The diameters of the sprinkler nozzle were 8 mm and 10mm, respectively, and the diameters of the sprinkler inlet section were 20mm and 30mm, respectively. The square and triangular wetted patterns were obtained and the working pressure, diameter coverage and flow rate changed during the sprinkler rotation. Another valve was located at the inlet of the sprinkler, and the pressure was controllable. The measure time was one hour. The tests were conducted at the indoor laboratory in Jiangsu University in China, and water drift and losses were avoided. The droplet size diameter was measured at the farthest distance from the sprinkler using the colored patches method. The colored splash was mixed with kermes and calcium carbonate in a 1:100 proportion (Salvador *et al*.,



1. swivel connection 2. connecting sleeve
3. static insert 4. movement insert
5. hollow shaft 6. location limit device
7. reversing device 8. spraying body
9. spraying pipe 10. plastic tube
11. nozzle

Fig. 1 The structure of the new fluidic sprinkler with a pressure-adjusting device.

2009).

The water distribution of an isolated sprinkler for square spraying was measured. The collectors used were 200 mm in diameter and 600 mm in height. The 144 catch-can locations were evenly distributed by a grid within a central sprinkler spacing (12 rows by 12 columns, with 2 m spacing). For example of a square wetted pattern, the wetted radius changed in each of the four quadrants when the sprinkler was rotating in a square spray pattern. Therefore, the water distribution in the third quadrant was measured, and the data from each water collector was used as the application rate. It was on the assumption that the same pattern of water application occur in each of the four quadrants. The symmetry of the data to the other three quadrants was then used to obtain the water distribution of the square spray pattern. For the triangular spray pattern, the water distribution of the second and fourth quadrants was measured, and symmetry was again used to obtain the water distribution. To analyze the parameters as the sprinkler rotated in different degrees, another experiment was performed. The zero degree was set as the shortest wetted radius. The catch-cans were located radially every 15 degrees.

Calculation Method

The irrigation performance indicator used was the coefficient of uniformity (CU) (Christiansen, 1942), and the amount of applied water at different areas was also calculated. The formula for uniformity is shown in **Eq. 1**.

$$CU = \left(1 - \frac{\sum_{i=1}^{n} |x_i - \bar{x}|}{\sum_{i=1}^{n}}\right) \times 100 \quad (1)$$

Where CU is the Christiansen uniformity coefficient (%), n is the number of collectors, $\bar{x}$ is the mean of all collector values (mm), and x_i is the individual reading of each collector i (mm).

The water collectors were arranged by a grid, and the points were made up of a matrix $u \times v$. The matrix can be defined as $E = [e_{ij}]\ u \times v$, where u is the number of rows in the matrix, v is the number of columns in the matrix, and e_{ij} is a factor of E. For the square spraying pattern, $u = v = n$ and i, j is the i row and the j column. In the formula $E = A' + B' + C' + D'$, a'_{ij}, b'_{ij}, c'_{ij}, d'_{ij}, are the factors of A', B', C', D', respectively. Therefore, $e_{ij} = a'_{ij}$, b'_{ij}, c'_{ij}, d'_{ij}, $(1 \leq i \leq u,\ 1 \leq j \leq v)$.

$$CU = \left[1 - \left\{\sum_{i=1}^{n}\sum_{j=1}^{n} \left|e_{ij} - \frac{1}{n \times n} \sum_{i=1}^{n}\sum_{j=1}^{n} e_{ij}\right|\right\} / \sum_{i=1}^{n}\sum_{j=1}^{n} e_{ij}\right] \times 100 \quad (2)$$

Spacing of Sprinklers

The layout design (**Fig. 3**) showed that the sprinkler was located in the centre of the square wetted area which is colored green. From **Fig. 3a**, there are four sprinklers, and the superpose part was the wetted area both the two sprinklers can be reached. The distance between the sprinklers is annotated as d, while the space coefficient is k, and $d = kR$, where R is the longest wetted radius of the square spraying pattern of the sprinkler.

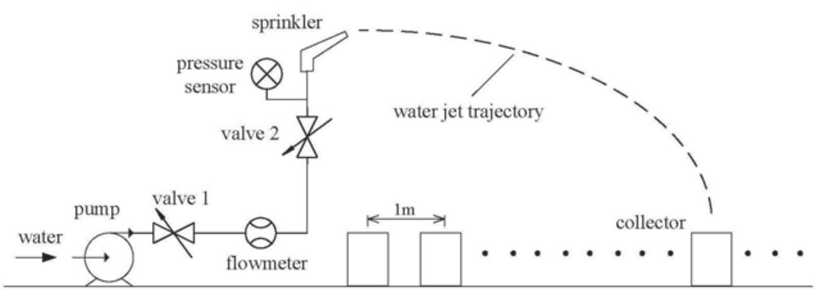
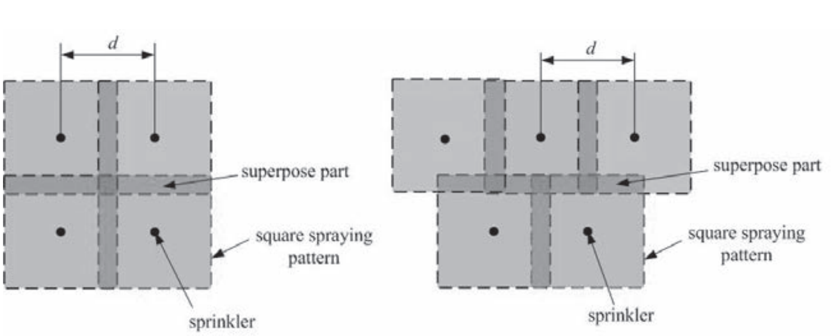


Fig. 2 The experiment system



(a) Square (b) Triangular

Fig. 3 Layout of the sprinklers in a square (a) and triangular pattern (b)

Results and Discussion

Relationships between flow rate, pressure and rotating degree

When the sprinkler was working, the system characteristics changed along with the pressure and flow rate.

The flow rate variation with rotating degree for different sprinkler types and patterns (**Fig. 4**) showed that the flow rate increased with the rotating degree. This indicates that the variation in parameters is determined by the inlet cross-sectional area. For example, for sprinkler type BPXH30, the range of flow rate is 23.2 % for the square spray pattern, and 34.8 % for the triangular spray pattern, respectively.

Regarding to the pressure variation with rotating degree in different sprinkler types and patterns (**Fig. 5**) showed that the supply pressure of the system (the pumping system pressure) decreases with the rotating degree. But the sprinkler working pressure was increased. Because of that the supply pressure of the system was upstream of the adjusting device and the sprinkler working pressure was downstream of the adjusting device. This indicates that the loss of pressure due to an adjusting device was reduced due to an increase in the working pressure.

Relationship between wetted radius, drop size and rotating degree

The effect of rotating degree on wetted radius and drop size is shown in the **Figs. 6** and **7**.

As the rotating degree increased, the wetted radius for two sprinklers type increased (**Fig. 6**). For example, for sprinkler type BPXH30, the wetted radius variation range for the square spray pattern is 20.7 % and is 25.3 % for the triangular spray pattern. In a round, the wetted radius changed with four or three periods as anticipated. However, the triangular spray pattern was not expected. **Fig. 7** shows the drop size variation with rotating degree. It indicates that with the increase in the pressure, the drop size became smaller. The drop size for triangular spray pattern was larger than the drop size for square spray pattern, and the drop size for BPXH30 was larger than the drop size for BPXH20.

Relationship between combination space and uniformity coefficient

The cumulative water distribution in different combination space was obtained and is shown in **Fig.s 8** to **11**.

Figs. 8 and **9** shows that when the BPXH20 sprinkler is used in the square combination, the uniformity coefficient is the highest when the spacing is 1.3 R. When the spacing was too large, the water distribution was low. The square spray pattern boundaries did not match well with each other as a result of the varying water distribution in different degree angles. The application rate is low when the wetted radius is large, and the square pattern is not perfect. Therefore, when the spacing is large, the application rate is low at the boundary. For BPXH30 sprinklers, the uniformity coefficient was high when the spacing was 1.1 R to 1.2 R. The water distribution was low when the spacing was larger than 1.5 R at the boundary of large wetted radius.

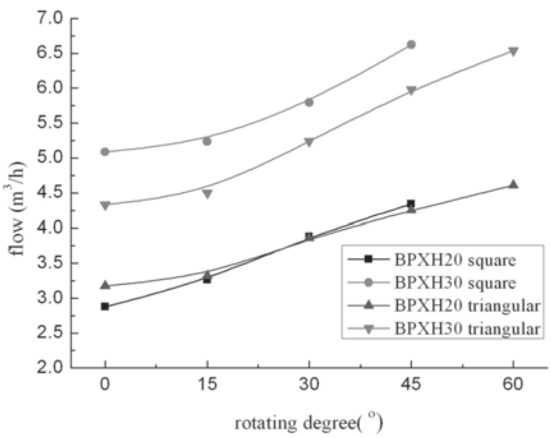


Fig. 4 Relationship between flow rate and rotating degree

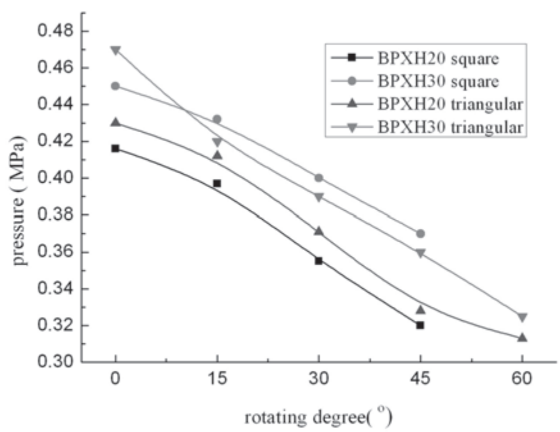


Fig. 5 Relationship between pressure and rotating degree

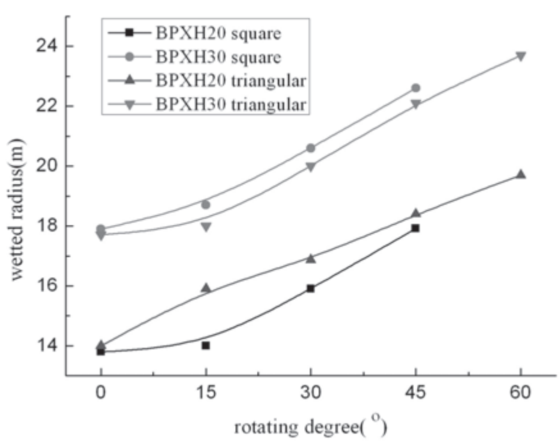


Fig. 6 Relationship between wetted radius and rotating degree

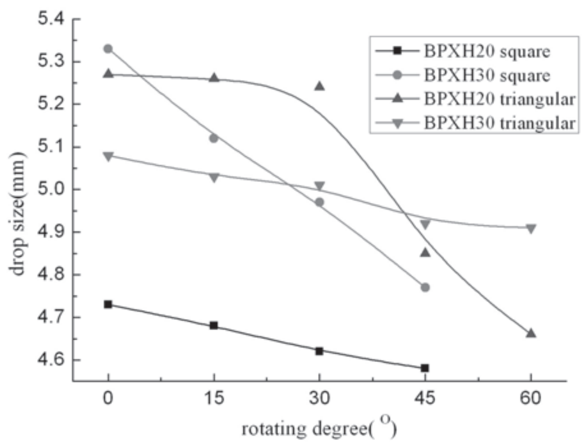


Fig. 7 Relationship between drop size and rotating degree

Figs. 10 and **11** shows that when the BPXH20 sprinkler type was placed in the triangular combination the uniformity coefficient was the highest when the spacing was 1.4 R. Furthermore, the water distribution was low when the spacing was larger than 1.8 R. The uniformity coefficient was the highest when the spacing was between 1.1 R and 1.3 R. The water distribution was low when the spacing was larger than 1.4 R.

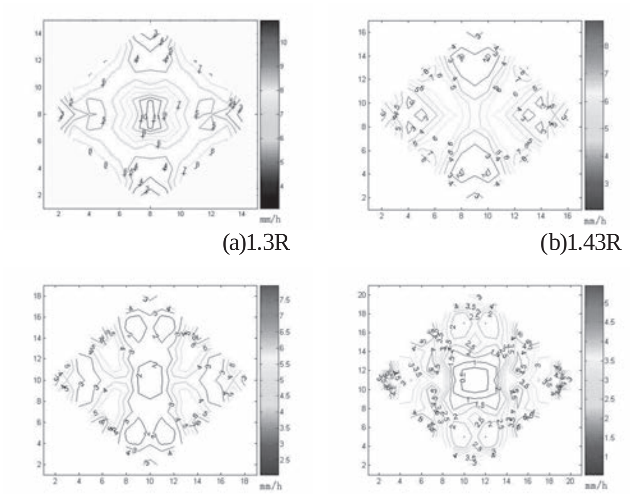
The uniformity coefficients for different spacing of square spraying patterns were calculated by **Eq. 2**, as shown in **Table 1**. To obtain the best spacing and the highest uniformity coefficient, the data were regressed by nonlinearity multinomial equation, as shown in **Table 2**.

From **Table 2**, x is the space coefficient, and y is the uniformity coefficient, R^2 is determination coefficient.

The determinations coefficients of the multinomial equation in **Table 2** were calculated, and the best spacing and uniformity coefficients for the different layouts and types of sprinkler were obtained. These results are shown in **Table 3**. **Table 3**

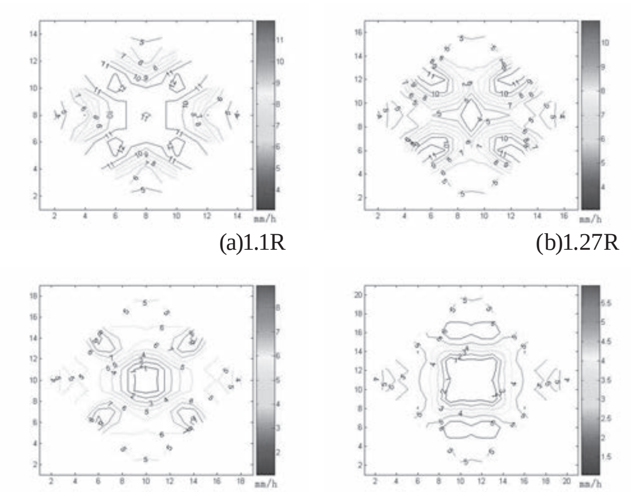
Table 1 Uniformity coefficient (%) in different combination space

Space coefficient	1.1	1.27	1.3	1.43	1.58	1.64	1.87
BPXH20 square layout			74.3	67.5		64.6	63.7
BPXH20 triangular layout	68.3	73.6		75.6	68.2		
BPXH30 square layout			66.3	64.2		62.7	51.7
BPXH30 triangular layout	68.3	78.4		67.1	–		



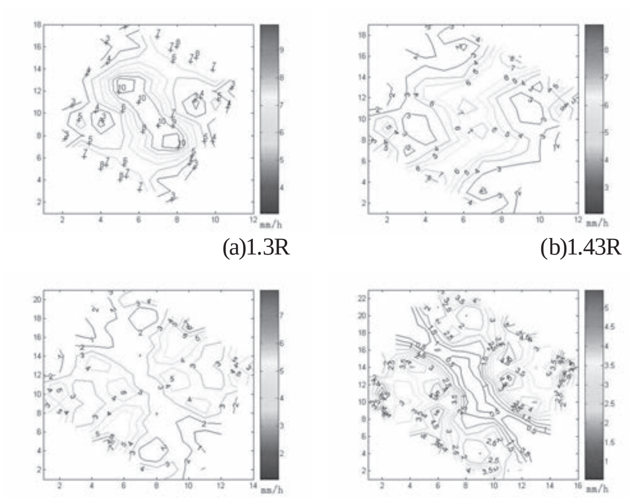
(a)1.3R (b)1.43R (c)1.43R (d)1.87R

Fig. 8 The square layout for cumulative water distribution of sprinkler type BPXH20



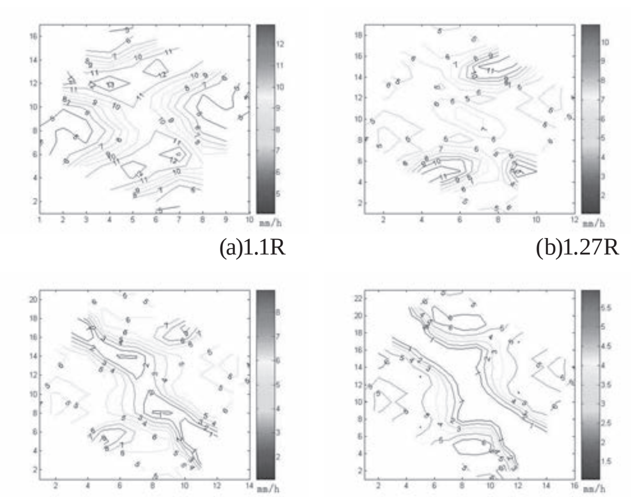
(a)1.1R (b)1.27R (c)1.64R (d)1.58R

Fig. 9 The square layout for cumulative water distribution of sprinkler type BPXH30



(a)1.3R (b)1.43R (c)1.64R (d)1.87R

Fig. 10 The triangular layout for cumulative water distribution of sprinkler type BPXH20



(a)1.1R (b)1.27R (c)1.43R (d)1.58R

Fig. 11 The triangular layout for cumulative water distribution of sprinkler type BPXH30 shows that the combination spacing coefficient is larger compared to the circular sprinkler. The uniformity coefficient was more than 65 %, and the uniformity coefficient for the triangular layout was larger than for the square layout.

The impact sprinkler system has been widely applied to variable-rate irrigation, and the comparison of the results of the fluidic sprinkler (BPXH) and the impact sprinkler (BPY) is shown in **Table 4**. As listed in **Table 4**, the atomization performance of BPXH was better than that of BPY.

Conclusions

1) The characteristics and the parameters of a variable spraying system were determined. When the cross-sectional area increased, the flow rate, the working pressure and the wetted radius increased. However, the supply pressure and the droplet size decreased. The application rate at the small rotating degree was higher than at the large rotating degree because of the rotating speed of the sprinkler.

2) The impacts of sprinkler spacing on the uniformity of water application were determined and optimized. A new method was adopted to calculate the combination uniformity of the variable irrigation system using matrices of the application rate. The relationship between the combination spacing and the uniformity coefficient was obtained. For the square layout, the combination spacing coefficient for both BPXH20 and BPXH30 was 1.3, while the uniformity coefficients were 74.3 % and 66.3 %, respectively. For the triangular layout, the combination spacing coefficients for BPXH20 and BPXH30 were 1.43 and 1.27, and the uniformity coefficients were 75.6 % and 78.4 %, respectively. The variable irrigation system uniformity was higher than the circular sprinkler, and the irrigated area could be increased. Furthermore, the engineering cost and the sprinkler number can be reduced. Thus, the variable irrigation system and the combined method can save both water and energy.

Acknowledgments

The authors gratefully acknowledge the National Natural Science Foundation of China No. 51309117 and 51109098, the China National High-Tech (863) Program Grant No. 2011AA100506, the Postdoctoral Science Foundation of China No. 2013M530239.

Abbreviations:

CU	the Christiansen uniformity coefficient (%)
n	the number of collectors
$\bar{x}$	the mean of all collector values (mm)
x_i	the individual reading of each collector *i* (mm)
u	the number of rows in the matrix
v	the number of columns in the matrix
e_{ij}	a factor of E
E	a matrix
i, j	the *i* row and the *j* column, respectively
d	the distance between the sprinklers
k	the space coefficient
R	the longest wetted radius of the square spraying pattern of the sprinkler
BPXH	fluidic sprinkler
BPY	impact sprinkler

Table 2 Relationship between the uniformity coefficient and various spacing in different layouts

Type and layout	Multinomial equation	Determination coefficient R^2
BPXH20 square layout	$y = 52.169\,x^2 - 182.7\,x + 223.14$	0.9707
BPXH20 triangular layout	$y = 26.503\,x^2 - 88.507\,x + 136.57$	0.9999
BPXH30 square layout	$y = -122.67\,x^2 + 330.07\,x - 146.68$	0.9373
BPXH30 triangular layout	$y = -394.05\,x^2 + 993.31\,x - 547.54$	0.9999

Table 3 The highest uniformity coefficient in the space

Type of sprinkler	Layout form	Combination space coefficient	Uniformity coefficient
BPXH20	square	1.3	74.3%
	triangular	1.43	75.6 %
BPXH30	square	1.3	66.3 %
	triangular	1.27	78.4 %

Table 4 The uniformity values for different sprinkler systems

Type of sprinkler	Layout form	Combination space coefficient	Uniformity coefficient
BPXH20	square	1.3	74.3 %
BPY20	square	1.3	65.2 %

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NEWS

◇ The Milan Charter for Mechanization EXPO MILANO 2015

Conclusion and Recommendations

Open Meeting of the Club of Bologna "Farm Machinery to Feed the World"

48 Members of Club of Bologna, all highly qualified international experts on agricultural machine and mechanization from 17 Countries and 3 Representatives of International Organizations (FAO, UNIDO and UN-ESCAP) attended the Open Meeting of the Club of Bologna - Farm Machinery to Feed the World held in EXPO Milano 2015 on September 21, 2015 in order to discuss the role of farm machinery and mechanization to the theme of EXPO 2015 "F*eeding the planet, energy for life*".

At the end of the meeting they have elaborated the following Conclusions and Recommendations.

Participants are aware that

- the major challenge facing humanity is to ensure sufficient food supply in a world whose population is growing exponentially and where today more than two billion people are undernourished and 800 million suffer from chronic hunger;
- natural resources, including land, water and forest, are a common heritage and as such should be respected and preserved for benefit of future generations;
- agriculture, together with fishery, is the main means for the production of food and its harmonious and rational development represents the only and indispensable factor in order to guarantee to everyone "the access to a sufficient quantity of safe, healthy and nutritious food "for years to come;
- the impacts of the effects of climate change will be global and severe. Agricultural production will have to adapt to mitigate these effects through the widespread adoption of climate-smart agricultural production practices which conserve natural resources whilst increasing agricultural production.

Participants recall that

- until the origin of human society the improvement of agricultural technologies has been the main driving force behind the development and welfare of mankind;
- all production methods, from traditional family farms to advanced industrial farming, are criticalfor future agricultural development and therefore an appropriate strategy tailored to social,cultural,economic and environmental aspects must be adopted;
- the improvement of agricultural processes in order to increase crop γield with lower use of inputs (energy, chemical and water) is the only effective strategy in order to raise food production without harming green resources of the planet;
- the world's population living in conditions of undernourishment is mainly concentrated in the poorest areas of developing countries where agricultural productivity is extremely low due to the absolute lack of technical means;
- according to United Nations economic growth originating in agriculture, in particular among small farmers, is at least twice as effective in benefiting the poorest as growth from non-agriculture sectors;
- the introduction of appropriate agricultural machines in less developed countries is crucial in order to improve efficiency of agricultural production.

Participants state that

- advances in scientific knowledge and technological innovations introduced in agriculture over the last two centuries have guaranteed nowadays the highest level of food availabilitγ in the history of mankind;
- thanks to the green revolution, the percentage of undernourished people decrease from 35 % in the 60s to around 11 % today despite the increase in world population from 2.5 to above 7 billion;
- R&D of the agricultural machinery sector in the last two decades was mainly focused on improving operational efficiency, reducing fuel consumption and developing site-specific distribution techniques in order to reduce chemicals to the minimum required joining high productivity and sustainability;
- advanced technologies in electronic and automatic control together with satellite positioning system, remote sensing and data gathering have led to the development of site specific farming techniques (Precision Agriculture - PA) able to tailor operating parameters to real crop demand;
- with the adoption of PA technologies, such as Automatic Guidance and Variables Rate Distribution and Irrigation, important reduction in fuel and water utilization may be achieved as well as avoidance of over- distribution of chemicals with respect to real crop needs;
- PA technologies allow to monitor and record the adopted farming operation thus allowing to implement the first step in the traceability chain that certifies the origin and conditions of the products;
- different successful examples in developing countries show how the adoption of appropriate mechanization technologies based to local socio-economic conditions substantially contribute to support farming and rural development;
- the national and international attention towards research and development in the agro-food sector has declined strongly over the last decades.

Participants unanimously stress the need that

- the central role of agricultural production and related technologies in order to guarantee everyone the availability of adequate and safe food supply is recognized;
- research in the area of agricultural machinery and mechanization, and more generally, of agro-food technologies,is considered a strategic priority as key factor in meeting the future food needs of the planet;
- appropriate measures aimed at assessing the environmental aspects of the existing machines and to promote the spread of modern machines designed according to new criteria of sustainability and traceability are taken by National and International Authorities;
- the development of an appropriate agricultural mechanization consistent with the local socio-economic conditions is considered the first step to promote agricultural production and rural development in developing countries in order to get poor nations economies up to national prosperity and welfare;

• research, education, extension, personal networking, information supply and international co operation in agricultural mechanization should get a much higher political priority regarding the huge importance for future mankind.

The Management Committee of the Club of Bologna

◇ DSSAT 2016 International Training Program

"Assessing Crop Production, Nutrient Management, Climatic Risk and Environmental Sustainability with Simulation Models" May 16-21, 2016

The DSSAT Foundation, in collaboration with Washington State University, the University of Florida, the International Fertilizer Development Center, the University of Georgia, and various other institutions, will host an International Training Program on DSSAT entitled DSSAT 2016 – "Assessing Crop Production, Nutrient Management, Climatic Risk and Environmental Sustainability with Simulation Models" from May 16 through May 21, 2016 at the University of Georgia Campus in Griffin, Georgia, USA. The overall goal of the workshop is to familiarize the workshop participants with the Decision Support System for Agrotechnology Transfer (DSSAT) and the Cropping System Model (CSM) for the simulation of crop growth and yield, soil and plant water, nutrient, and carbon dynamics, and the application of models to real world problems, such as crop and resource management, climate change and climate variability, carbon sequestration, food security, biofuels, and environmental sustainability.

For further information, please visit the DSSAT Foundation web site at www.dssat.net or the workshop registration web site at http://www.ugagriffincontinuinged.com/index.php/professional-courses/dssat.

◇ Dr. A. Q. Mughal

Congratulation!

Prof. Dr. A. Q. Mughal, AMA Cooperative Editor for Pakistan, was conferred by the President of Pakistan on the 67th Independence Day of Pakistan with 3rd highest Civil Award of Pakistan “Sitara-i-Imtiaz” for services in the field of Education and Research. He is one of the Foundation Member of Asian Association of Agricultural Engineering (AAAE). Currently he is serving as Research Professor at the Green wich University, Karachi Pakistan. ■■

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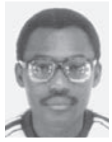
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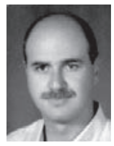
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(Vol.45, No.1, Winter, 2014-)

◇ ◇ ◇

Vol.45, No.1, Winter 2014

◇ ◇ ◇

Vol.45, No.2, Spring 2014

◇ ◇ ◇

Vol.45, No.3, Summer 2014

◇ ◇ ◇

Vol.45, No.4, Autumn 2014

◇ ◇ ◇

Vol.46, No.1, Winter 2015

◇ ◇ ◇

Vol.46, No.2, Spring 2015

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a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article needs to be sent to Co-operating Editor in the writer's neighboring country.
b. Contributors of articles for the AMA for the first time are required to attach a passport size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

Format/Style Guidance

a. Article must be sent on CD-R with MS DOS format (e.g. Word Perfect, Word for DOS, Word for Windows... **Absolutely necessary TEXT FORMAT**) along with two printed copys (A4). Or it must be sent by E-mail with Word File and PDF File attached.
b. The data for graphs and photographs must be saved into piecemeal data and enclosed (attached) with the article.
c. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features:
(i) brief and appropriate title;
(ii) the writer(s) name, designation/title, office/organization; and mailing address;
(iii) an abstract following ii) above;
(iv) body proper (text/discussion);
(v) conclusion/recommendation; and a
(vi) bibliography
d. The printed copy must be numbered (Arabic numeral) successively at the top center whereas the disc copy pages should not be number. Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
e. **The data for the graph must also be included. (e.g. EXCEL for Windows)**
f. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies in US dollars and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

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