Development and Field Evaluation of Khus Root Digger

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ABSTRACT

Vetiver (Khus) is a premier aromatic crop yielding valuable essential oil from its long roots, which has multiple industrial uses like medicinal, soap, cosmetics and perfumery industry. Khus root digging is one of the important unit operations in cultivation. Conventionally Khus roots are harvested manually using traditional tools like spade (phawara), narrow spade (Kudali), etc which causes significant damage and root losses (approx. 30-40%). Besides, this method requires huge involvement of drudgery full manual labour (345-350 man days/ha). These factors necessitated development of efficient implement for harvesting of Vetiver roots. To solve the above problems, a low cost, single tine tractor operated vetiver root harvester was developed at the Central Institute of medicinal and aromatic plants (CSIR- CIMAP) , Lucknow for making the Khus root digging process efficient and economical. The performance of developed equipment was evaluated at the farmers field and the field capacity and root recovery of Khus digger were found to be 0.05 ha/h and 85-90%, respectively. The Khus digger was found to be highly efficient and useful and it could be effectively operated by medium power range tractors (25-35 hp) and 5-6 times more efficient as compared to conventional method of Khus root digging. Besides it reduces 98% of labour input involved in vetiver root digging process and minimizing the root losses.

Key words : *Vetiver, Root digger, Khus*

INTRODUCTION

Khus (Vetiver) is a very important and useful aromatic crop having its multiple uses. Generally Vetiver grows wild in some states but in some states like Andhra Pradesh, Uttar Pradesh, Tamil Nadu and Kerala its cultivation is practiced on limited scales also. The Khus roots have been traditionally used in India for its uses in soft drinks during summer and its valuable essential oil is used in various industries like, pharmaceuticals, cosmetics, perfumery and soap. The essential oil from Khus roots is extracted using distillation process. Realizing its commercial value, now the farmers of north Indian states have started commercial cultivation of vetiver being one of the most potential, commercially viable profitable aromatic crops. To promote its cultivation, the CSIR-CIMAP Lucknow has developed several high oil yielding varieties of Khus like SIM- VRIDDHI and KS-1 which are being widely used by farmers. Most of these varieties are ready for root harvesting within 12 months with better oil recovery (approx. 15 -20 l/ha). The market price of quality Khus oil varies from Rs. 12000/- - 16000/- per litre. Total khus oil production in India is approx. 25 ton /annum and it has annual export demand of approximately 150 ton/ yr in international market (Tiwari (2011).

About 60% of total cultivation cost of Khus , works out to be involved in root digging which is being traditionally carried out manually. There is no specific implement so far developed for Khus root digging and farmers are facing intricate problems in digging of its roots due to high labour in put (Approx. 350 Man days/ha) and significant root losses. Therefore, there is very urgent need for engineering intervention to mechanize the process of Khus root harvesting which may result in higher productivity and profitability through timeliness in operation, reduction in operational cost, minimizing the post harvest losses, value addition and reduction in drudgery of agricultural workers. Keeping in view the constraints faced by farmers in Khus cultivation, an efficient, low cost multipurpose, Khus root digger was developed and evaluated at different locations on the farmers fields under actual conditions. The paper describes the various steps undertaken in the development of Khus root digger by the CSIR-CIMAP, Lucknow.

MATERIAL AND METHODS

To solve the prevalent problems being faced in Khus root digging, one unit of Khus root digger was designed for harvesting of the Vetiver roots sown in lines on raised bunds at the bund pacing of 60x60 cm suitable especially for low, marginal & small lay outs and experimental plots. The mounting frame of first model (Fig. 1) was fabricated using robust MS angle iron (50 x 50 x 6 mm) and two tines were fabricated using 10 mm MS flat having shovel width of 380 mm. The total weight of equipment was 83 kg. The shovels were mounted on the frame using suitable clamps. This equipment could be operated using tractors having power range of 35-50 hp commonly available in the Uttar Pradesh.

Fig. 1: Prototype of double tyned Khus digger

Field trials of the developed prototype were conducted at Rajapur Village of Bachharawan Block (Rae Bareilly district) and the study revealed that the tool was only suitable for Khus grown on ridges having light soils and tractor more than 35 hp required for its operation. Besides this, continuous digging was also not feasible with developed prototype due to frequent clogging of harvested root bio mass in between tines and tool frame resulting unnecessary load on the tractor causing poor field efficiency. It was also noticed that farmers are normally adopting in line plantation of Khus on well prepared plain field at the plant to row spacing of 450 x 550 mm for better root yield and oil recovery of improved varieties of Vetiver. Hence, need was felt for incorporating modification in the developed equipment for uses in large scale commercial cultivation , to enhance the digging efficiency by using medium range of available tractors i.e. 25 to 35 hp.

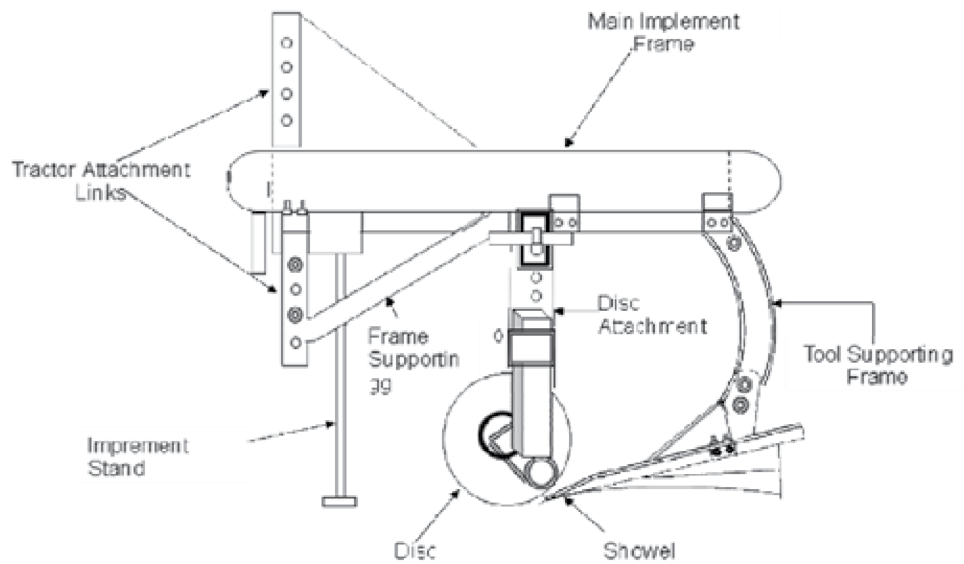
Keeping in view of the observed problems in its earlier developed Khus root digger was further modified. The modified Khus digger (Fig. 2) contains only single detachable tyne and wider cutting blade/ share made up of high carbon steel. The robust mounting frame was made up of heavy section of 10 mm MS pipe with rear mounting attachment system capable of sustaining the thrust of traction force involved in digging and throwing/turning of the harvested roots for continuous field operation. The shovel blade is quite sustainable and wear resistance made of high carbon steel provided with robust mould board curvature plate of 10 mm thick M.S iron and tool frame adds for its sturdy design to handle the heavy tractive force exerted during vetiver root digging. Disc attachment has been provided at a desired angle for minimising the load on the tractor as it makes a smooth pre-cut line of furrow for easy penetration of shovel

Fig. 2: Prototype of modified single row khus root digger

and simultaneously for providing smooth turning of harvested Vetiver root. The length, breadth and height of modified equipment were 1150, 850 and 1200 mm, respectively. The schematic diagram of the various components of the modified Khus digger is depicted in Fig. 3. The weight of the modified Khus digger was 102 kg and the digger could effectively be operated with more than 25 hp tractor, which is easily available with farmers in the villages of Uttar Pradesh.

RESULT AND DISCUSSION

The feasibility testing of the modified equipment under actual field conditions revealed that it is a suitable alternative to laborious, time consuming and expensive manual digging of Khus roots. The total digging operation was found quite satisfactory and operation can be made more efficient with cutting of Vetiver stem up to 152-254 mm from the soil surface by using manual sickle or power cutter to avoid unnecessary biomass clogging on the shovel frame. The field capacity of digger was 0.4 ha/day as compared to 0.003 ha/day manually. The comparative digging cost of Khus roots have been presented in Table 1. It can be seen from Table 1 that considering initial cost of the developed too, its depreciation and operating cost etc, the expenditure on digging of khus roots was found to be Rs. 10,000/ha as compared to manual digging by using traditional tools like phawara and kudali



KHUS DIGGER

Fig. 3: Schematic diagram of various components of the single row Khus digger

Table 1: Comparative cost economics for Khus root harvesting by various methods

Mechanize harvesting (Prototype – II)	Contractual rate of digging	Manual digging
06 man days for collection during digging with tractor @ Rs. 150/- per day = Rs. 900/-	@ Rs. 8.00/Kg root (5600 Kg root/ha)	345 man days @. 150/ per man day
20 h tractor operation @ 350/h = Rs. 7000/-		
Separation of roots from stem 14 man-days/ha @150 /- per day = Rs. 2100/-		
Total Digging Cost = Rs. 10,000/-	Total Digging Cost Rs. 44,800/-	Total Digging Cost = Rs 51,750/-

(Rs 51,750/ha). Thus saving of Rs 41,750/- per ha (80.67%) in digging cost of the Khus roots and 98.26% labour saving was observed as compared to traditional method. The developed tractor mounted implement is robust and sturdy in construction and reduces the digging cost by six folds apart from saving the time. Digging of vetiver crop roots was quite satisfactory as there was no substantial root losses found, observing 90% root recovery in actual field conditions.

CONCLUSION

Khus root digging is one of the important unit operations in cultivation. Conventionally Khus roots are harvested manually using traditional tools like spade (phawara), narrow spade (Kudali), etc which causes significant damage and root losses (approx. 30-40%). Besides, this method requires huge involvement of drudgery full manual labour (345-350 man days/ha). A low cost, single tine tractor operated Khus root harvester was developed at the Central Institute of Medicinal and Aromatic Plants (CSIR- CIMAP), Lucknow. The performance of developed equipment was evaluated at the farmers field and the field capacity and root recovery of Khus digger were found to be 0.4 ha/day and 85-90%, respectively. The Khus digger was found to be highly efficient and useful and it could be effectively operated by medium power range tractors (25-35 hp) and 5-6 times more efficient as compared to conventional method of Khus root digging. Besides it reduces 98% of labour input involved in vetiver root digging process and minimizing the root losses.

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Comparative Performance of Different Rice Establishment Methods for Sustainable Rice Production in Deogarh District of Odisha

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ABSTRACT

An experiment was conducted during the Rabi season of 2010-11 at farmer's field to evaluate the yield and economics of different rice establishment methods for sustainable rice production in Deogarh district of Odisha. The experiment was carried out in RBD with six methods of planting viz. manual transplanting, line transplanting, sowing sprouted seed by pre-germinated paddy seeder, machine transplanting by self propelled rice transplanter, transplanting by System of Rice Intensification (SRI), sowing sprouted seed by SRI marker with four numbers of blocks or replication. Overall performance of different rice establishment methods studied indicated that machine transplanting and SRI recorded higher benefit: cost ratios of 1.95 and 1.80 respectively and the lowest Benefit: cost ratio was recorded by manual transplanting (1.33). SRI method recorded maximum gross return (Rs. 54,800/ha) and net return (Rs. 24,400/ha) followed by transplanting by self propelled rice transplanter (Rs. 49,800/ha and Rs. 24,250/ha). Lowest gross return (Rs. 39,500/ha) was registered in pre-germinated paddy seeder and lowest net return (Rs.9, 950/ha) was observed in manual transplanting.

Key words: *Rice transplanter, Pre-germinated paddy seeder, SRI, Sprouted, Grain yield*

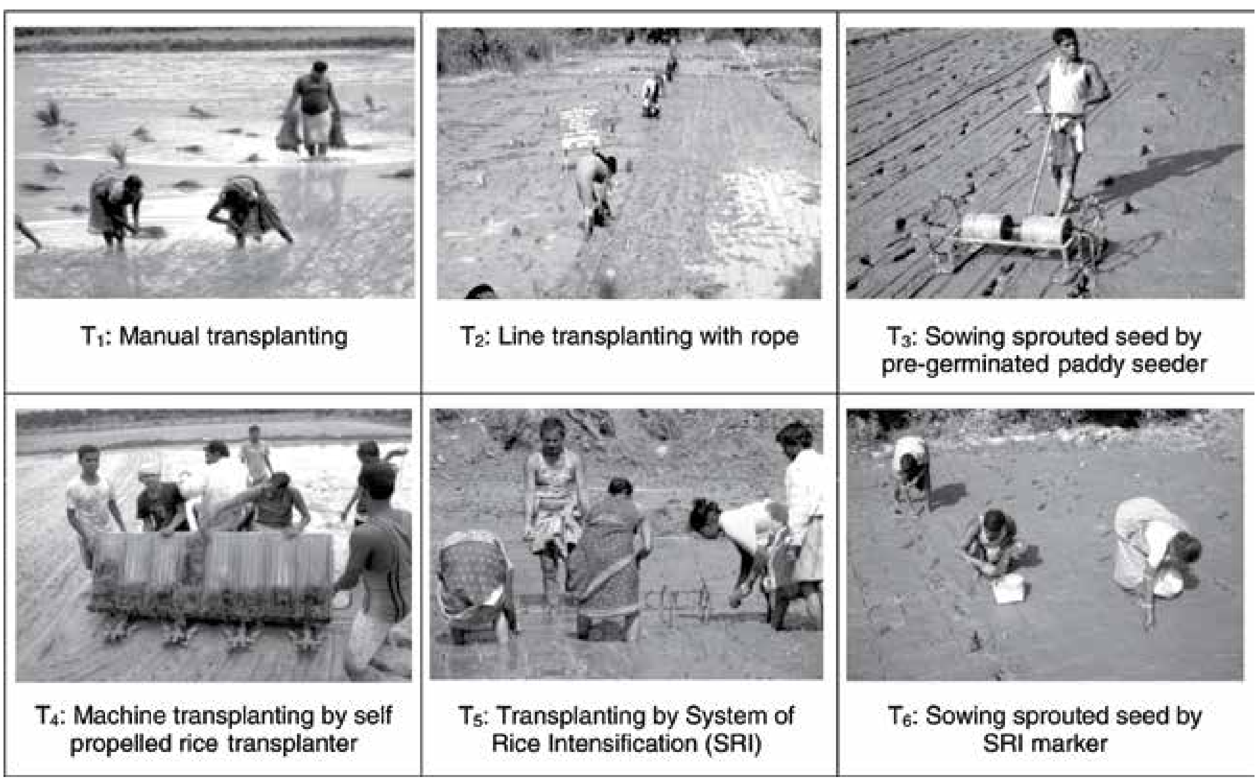
INTRODUCTION

Rice is one of the most important cereal crops, which plays a key role for food security. India is the second largest producer and consumer of rice in the world. Rice production in India crossed the mark of 100 million MT in 2011-12 accounting for 22.81 % of global production in that year. Rice is grown on an area of 43.97 m. ha with a production of 104.32 MT (Anon, 2013). There are two common methods of growing rice: direct seeded rice and transplanted rice. Transplanting method of growing rice is more popular among farmers because of 10-15% increase in yield than direct seeded rice. In recent years, the area under rice crop is decreasing year by year due to low profitability. But demand for rice is growing every year and it is estimated that in 2025 AD the requirement would be 140 million tonnes. To sustain present food self-sufficiency and to meet future food requirements, India has to increase its rice productivity by 3 per cent per annum (Thiyagarajan and Selvaraju, 2001). Manual transplanting of rice is one of the laborious and time consuming operations requiring about 300-350 man-h/ha, which is roughly 25% of the total labour requirement of rice production. Analysis of rice transplanting reveals that a worker is expected to perform tedious task of planting in bending posture moving backward under puddled soil condition. During transplanting season, often there is an acute labour shortage. This results in increased labour wages and delayed transplanting operation. Transplanting at right time has a pronounced influence on rice yield. A delay in transplanting by one month reduces the yield by 25% and delay by two months by 70% (Rao and Pradhan, 1973). Also the labour transplants non-uniformly and tends to transplant a lower plant population in the centre of the field.

Plant population is an important parameter of yield maximization. In rice, the planting methods have an impact on the growth and yield besides cost of cultivation and labour requirement. To get maximum returns, the cost of cultivation has to be reduced through the minimization of the dependence on labour for transplanting. The application of machines in agricultural production has been one of the outstanding developments in agriculture across the globe. Mechanization in transplanting through rice transplanter using mat nursery reduces the cost of cultivation since large area can be transplanted within a very short period. Mechanically transplanted rice compared to hand transplanted rice gave higher benefit-cost ratio of 34.46% (Mohanty *et. al*., 2010). Owing to increasing water scarcity, a shifting trend towards less water demanding crops against rice is noticed in most part of the India and this warrants alternate methods of rice cultivation that aims at higher water and crop productivity. There are evidences that cultivation of rice through system of rice intensification (SRI) can increase rice yields by two to three fold compared to current yield levels (Yamah, 2002). The present study was undertaken to study the effect of different transplanting methods for economic feasibility in rice.

MATERIALS AND METHODS

The experiment was conducted at Kailsah village of Deogarh district of Odisha during Rabi season of 2010-11 by Krishi Vigyan Kendra, Deogarh to study the effect of different methods of rice cultivation in sandy loam soils with pH 6.2, having available N 282 kg ha-1, P_2O_5 24.8 kg ha-1 and K_2O 180.96 kg ha-1. The experiment was carried out in RBD with six methods of planting viz. manual transplanting (T1), line transplanting (T2), sowing sprouted seed by pre-germinated paddy seeder (T3), machine transplanting by rice transplanter (T4), system of rice intensification (SRI) T5, sowing sprouted seed with SRI marker (T6) in four numbers of blocks or replication (Fig. 1). The rice variety, selected for the experiment was 'Lalat' with a duration of 135 days. A common dose of N, P_2O_5 and K_2O @ 80:40:40 kg ha-1 was used in all the treatments. Full dose of phosphorus and half dose of nitrogen



T_1: Manual transplanting

T_2: Line transplanting with rope

T_3: Sowing sprouted seed by pre-germinated paddy seeder

T_4: Machine transplanting by self propelled rice transplanter

T_5: Transplanting by System of Rice Intensification (SRI)

T_6: Sowing sprouted seed by SRI marker

Fig. 1: Different treatments used in experiments

and potassium were applied as basal and the remaining half dose of nitrogen and potassium were applied as topdressing at tillering stage. In manual transplanting and line transplanting 25 days old seedlings raised in nursery was transplanted at random and with the help of marked rope in 28 x 12 cm spacing respectively on puddled and levelled field. The machine transplanting was done at 23.8 x 14 cm spacing using eight row self propelled Yanji rice transplanter. For machine transplanting rice seedlings were raised in mat nursery and 18 days old seedlings were used for transplanting. 25 cm x 25 cm spacing was used for SRI method. Eight days seedlings were used in SRI whereas direct seeding of pre-germinated paddy seeds were used by pre-germinated paddy seeder and sprouted seeding by using SRI marker. Observations were recorded for yield and yield attributing characters. The economics of different treatments were worked out by considering the present market price of the inputs and produces.

RESULTS AND DISCUSSION

As far as yield attributing characters are concerned, SRI method of paddy cultivation recorded higher number of average tillers (31 /hill) followed by transplanting by self propelled rice transplanter (28/ hill). Whereas, sowing by pre-germinated paddy seeder recorded the least number of average numbers tillers per hill (17) and manual transplanting i.e. traditional method (18 numbers/hill), Table 1. Highest numbers of grain per panicle (150) was

Table 1: Results of different planting methods

Sl. No.	Particulars/ Villages	Kailash					
		T_1	T_2	T_3	T_4	T_5	T_6
1.	Area, acre	0.4	0.4	0.4	0.4	0.4	0.4
2.	Variety	LALATA	LALATA	LALATA	LALATA	LALATA	LALATA
3.	Date of transplanting	26.02.11	28.02.11	05.02.11	22.02.11	11.02.11	05.02.11
4.	Date of harvesting	06.06.11	06.06.11	02.06.11	28.05.11	07.06.11	02.06.11
5.	Age of seedlings, days	25	25	Sprouted seed	18	8	Sprouted seed
6.	Seed rate, kg/ha	75	60	50	50	5	5
7.	Row spacing, cm	Random	28	23	23.8	25	25
8.	Hill to hill spacing, cm	Random	12	15	14	25	25
9.	Depth of planting, cm	1.-2	1-2	On the puddled soil surface	2.-3	1-2	On the puddled soil surface
10.	No, of seedlings/hill	3-4	3-4	2-3 sprouted seed	2-3	1	2-3 sprouted seed
11.	Plant population at the time of transplanting, hill/m2	38	32	30	35	25	25
12.	Seedling height at the time of transplanting, cm	10.5 m	11.2 cm	sprouted seed	8.4 cm	6.1 cm	sprouted seed
13.	No. of tillers /hill	18	20	17	28	31	22
14.	No. of effective tiller/hill	14	18	16	27	28	17
15.	Length of panicle, cm	23.6	25.4	24.75	25.9	27.3	24.8
16.	Test weight of grain, gm	22	23	22	23	23	22
17.	No. of grain/panicle	108	143	117	146	150	131
18.	Cost of cultivation, Rs/ha	29650	30220	22340	25550	30400	25800

observed in case of SRI followed by self propelled rice transplanter (146) and line transplanting with rope (143). Lowest numbers of grains was observed in manual transplanting (108 per panicle).

Overall performance of rice-rice system under different rice establishment methods studied indicated that the maximum grain productivity (54.8 q/ha) were recorded with SRI method of paddy cultivation (T_5) followed by T_4 (49.8 q/ha), T_6 (45.2 q/ha), T_2 (44.9 q/ha), T_1 (39.6 q/ha) and least productivity of grain (39.50 q/ha) was noticed incase of sowing by pre-germinated paddy seeder method (T_3), Table 2. The higher yield realized with SRI method may be due to the use of younger seedlings, which preserves a potential for more tillering and rooting. Also wide planting i.e., in square pattern (25 cm x 25 cm) provides more room for both canopy and root growth and for subsequent grain filling. The increase in the grain yield of SRI method was attributed to large root volume, profuse and strong tillers with big panicles, more and well filled spikelets with higher grain weight (Satyanarayana and Babu, 2004). Similar findings were recorded by Jayadeva, *et al.* (2008).

Among different rice establishment methods tried, SRI method fetched the maximum gross returns (Rs. 54800/ha) and net profit (Rs 24400/ha) but machine transplanting fetched more B: C ratio (1.95), Table 2. This is due to low cost of cultivation in case of machine transplanting (Rs. 25550/ha) than SRI method of rice cultivation (Rs.30400/ha). Least net profit (Rs 9950/ha) and B:C ratio (1.33) were recorded in manual transplanting (T_1). Least gross return (Rs. 39500/ha) was recorded in case of sowing by pre-germinated paddy seeder but net return (Rs. 17160/ha) is more than manual transplanting (Rs. 9950/ha) and line transplanting by rope (Rs. 14680/ha).This is again due to low cost of cultivation i.e. Rs. 22340/ha than all other methods of sowing and transplanting. Even though the grain yield of manual transplanting was comparable with that of pre-germinated paddy seeder its labour requirement was less compared to manual transplanting, which resulted in reduced net return for manual transplanting. Though the gross return in pre-germinated paddy seeder was low, it registered a more net returns compared to line transplanting and manual transplanting because of the low cost incurred in cultivation. In case of sowing germinated paddy seeds in SRI (T_6), the grain yield, gross return and net returns are 45.2 q/ha, Rs. 45200/ha and Rs.19400/ha respectively. Thus, among the different rice establishment methods tried SRI method and machine transplanting were more productive, economical and sustainable. It enhances rice yield and fetches higher returns. Machine transplanting and SRI recorded higher benefit: cost ratios of 1.95 and 1.80 respectively followed by T_3 (1.77), T_6 (1.75), T_2 (1.48) and manual transplanting (T_1) registered the lowest benefit: cost (B: C) ratio (1.33). This might be due to the low labour requirement for machine transplanting compared to manual and line transplanting.

Table 2: Effect of planting methods on yield and economics of rice

Treatments	Grain yield, (q/ha)	B:C ratio	Gross return, (Rs)	**Net return, (Rs)**
T_1	39.6	1.33	39600	9950
T_2	44.9	1.48	44900	14680
T_3	39.5	1.77	39500	17160
T_4	49.8	1.95	49800	24250
T_5	54.8	1.80	54800	24400
T_6	45.2	1.75	45200	19400
LSD at 5%	5.33	0.106078	3140.1	2942.59
SEm+-	2.50	0.0497684	1473.23	1380.56
CV	7.74953	4.14966	7.671057	10.5664

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Performance Evaluation and Scope of Adoption of Rotary Power Weeder in Vegetable Crops

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ABSTRACT

An effective mechanical weeder is expected to encourage subsistent farmers in increasing the production and thereby reducing cost of cultivation. In this study a BCS make self propelled rotary power weeder was examined in wide row line sown vegetable crops tomato (Solanumlycopersicum), yard long bean (Vignasesquipedalis) and okra (Hibiscus esculenta) at Research Farm of Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur, West Bengal. The effective field capacities were 0.092, 0.08, 0.096 ha/h at forward speed of 2.3, 2.0 and 2.4 km/h in tomato, yard long bean and okra, respectively. With the average effective working width of 400 mm, the depth of weeding was observed as 53, 46, and 50 mm for tomato, yard longbean and okra, respectively. Weeding efficiency in tomato, yard long bean and okra was found as 97, 96 and 97%, respectively. Plant damage was found as 1.6, 2.8 and 1.9% in tomato, yard long bean and okra, respectively. The machine was found to be ideal and effective in carrying out the weeding operation in vegetable crops.

Key words: *Vegetables, Weeder, Rotary power weeder, Weeding efficiency*

INTRODUCTION

Vegetables gave more yield and farm income than other traditional crops. They play an important role in human diet with rich sources of vitamins and other essential nutrients.Vegetable crop establishment is necessary to eliminate the effect of weeds, pests and disease infestation and to provide suitable conditions for optimum yield. Weeds are the bounding factors of agricultural production, which compete crop plants with their rapid growth (Tamado and Milberg, 2000). Weed control measures must be put in place to check the growth and propagation of weeds. Chemical and mechanical weed control methods are viable alternatives; however, the environmental impacts of herbicides make chemical methods not sustainable. Weeding is viable solution for the removal of unwanted plants in the crop production. Cost of weed management is highest in total crop production. It is one of the tedious operations in vegetable production. The earliest, simplest and most popular weed management method is manual weed control, where, a person is bending down and using his hands to pull weeds out of the soil. Now advanced hand tools like khurpi, wheel hoe, hand hoe, etc are mostly used in weeding and intercultural operations. These methods are expensive, time consuming and difficult to organize labourer for weeding (Weide *et al.*, 2008). There is an acute labor shortage, which results in increased labor wages and delay in the weeding operation.

The introduction of chemical weed control methods has reduced the undesirable factors associated with manual weeding. However, the emergence of herbicide-resistant weeds gives bad impact on environment. The increasing demand for chemical free foods has led to investigate the alternative methods for weed control. Mechanical weed control is very effective and best suitable alternative with reduced drudgery in manual weeding. It removes the weeds ensuring soil aeration and water intake capacity of soil surface. Keeping in view of the above facts, number of engine operated weeders were designed, developed and tested in field by many researchers. Rangasamy et al. (1993) evaluated the performance of power weeder and reported the field capacity of the weeder as 0.04 ha/h with weeding efficiency of 93% for removing shallow rooted weeds. Rotary power weeder works better in respect of working depth (5.67 cm) which is 16.67% more than bullock drawn blade (Padole, 2007). Goel *et al*. (2008) reported that the plant damage increased with decrease in moisture content below 11.63%. Senthilkumar (2003) compared the rotary hand weeders with the common methods of weeding in pulse crop production.

Mechanical weeding has advantage of 10.9% of increase per hectare in yield of crop rather than using hand weeding. Mechanical weed control significantly increased the grain yield of rice plants (Alizadeh, 2011). There has been many studies conducted on performance of manual, animal and power operated weeders in grain crop. But no study has been conducted on self-propelled rotary weeder performance in vegetable cultivation. Hence, this study was taken up to evaluatethe performance and the scope of commercialization of self-propelled rotary weeder in line sown vegetable crops in the State of West Bengal.

MATERIALS AND METHODS

In this study a self propelled rotary power weeder was selected. This weeder was fitted with 4 kW air cooled diesel engine with3 forward and 2 reverse speed transmission systems. Weeder was attached with 12 number of L shape tine in four rows and total weight of unit was 84 kg. Handle height of weeder was adjustable according to height of operator between 400-1140 mm from the ground level. Three wide row line sown vegetable crops, tomato (*Solanumlycopersicum*), yard long bean (*Vignasesquipedalis*) and okra (*Hibiscus esculenta*) were selected in this study at Research Farm of Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur, West Bengal. An area of 0.5 ha plot was selected for the field trials of each crop. The soil type was lateritic sandy clay loam soil (upper plastic limit 17.2%, lower plastic limit 12%). Row to row spacing of tomato, yard long bean and okra planting was 650, 700 and 600 mm, respectively. Trials were carried out after 22 days of planting of tomato and after 24 days of sowing of okra and yard long bean. The field was infested mostly with grassy weeds such as *Echinochloacrusgalli, Trifoliumrepens* and *Cyperusrotundus.* The crop height and the density of weeds and crop were measured with a standard quadrat at ten places and the average was worked out. Soil moisture, cone index and bulk density were also measured and recorded.

Bulk density of soil was measured by core cutter method and cone index was measured by a digital cone penetrometer. Three soil samples were collected from each test plots with the help of soil sampling auger for moisture measurement. Initial weight (W_1) of each sample was taken on digital balance and dried it at 105°C for 8 hours. Dried sample collected from oven and final weight (W_2) was taken. Moisture content (MC) on dry basis has been calculated by

$$MC\ (db) = \frac{W_1 - W_2}{W_2} \times 100 \quad ...(1)$$

To determine the weeding efficiency in each plot randomly, ten patches of 1 × 1 m size was taken and the number of weeds were counted before and after weeding operation. The weeding efficiency was calculated by

$$WE = \frac{N_1 - N_2}{N_2} \times 100 \quad ...(2)$$

where, WE is the weeding efficiency of the weeder (%), N_1 and N_2 are the number of weeds before and after weeding operation, respectively.

The damaged plant percentage was calculated by counting the numbers of damaged plants by random selecting 1 m length of crop row in ten positions of each plot. Then, the percentage of damaged plants, as a quality of work done, was obtained by (Tewari et al., 1993)

$$DP = \frac{Q_1}{Q_2} \times 100 \quad ...(3)$$

where, DP is the damaged plants (%), Q_1 and Q_2 are the total number of damaged plants and plants per sq. m, respectively.

The travel speed of the weeder during operation was determined by recording the needed time for covering 40 m length. Effective field capacity (C_e), field efficiency (F_e) and work capacity (W_c) were calculated by (Hunt, 1995)

$$Ce = \frac{S \times W \times E}{10} \quad ...(4)$$

$$Fe = \frac{Te}{Tt} \times 100 \quad ...(5)$$

$Wc = \frac{1}{Ce}$ where, C_e is the effective field capacity (ha/h), S is the travel speed of the weeder (km/h), W is the width of operation (m) , F_e is the field efficiency of the weeder (%) , T_t and T_e are the total and useful working time (h) , respectively.

The potential of equipment could be harnessed effectively by demonstration to the target group. For this, a questionnaire was framed for getting feedback from limited farm workers and vegetable grower (respondents) regarding adoption of self propelled rotary weeder over conventional methods. The response of 35 respondents on operation of this equipment and reasons for adoption and purchasing were obtained. The cost of operation per hour for operating self-propelled rotary weeder was carried out as per the method described by Singh (2007).

RESULTS AND DISCUSSION

Soil moisture content of the test field was found as 15.42% (db). Bulk density of the field after operation was 1.32 g/cc. Effective width of weeder was 400 mm and average depth of operation in tomato, yard long bean and okra was 53, 46, and 50 mm respectively (Table 1). Weeding depth in yard long bean was less due to hardness in soil. The effective field capacity of the power weeder was 0.092, 0.08,

Table 1: Results of the performance evaluation of self propelled rotary weeder in different vegetable crops

Parameters	Unit	Performance		
		Tomato (Solanumlycopersicum)	Yard long bean (Vignasesquipedalis)	Okra (Hibiscus esculenta)
Soil type		Sandy clay loam	Sandy clay loam	Sandy clay loam
Cone index (before testing)	k Pa	270	285	260
Cone index (after testing)	k Pa	90	110	90
Bulk density (after testing)	g/cm^3	1.32	1.32	1.32
Theoretical width of operation	mm	460	460	460
Effective Width of operation	mm	400	400	400
Depth of weeding	mm	53	46	50
Row to row spacing of crop	mm	650	700	600
Forward speed	km/h	2.3	2.0	2.4
Theoretical field capacity	ha/h	0.106	0.097	0.11
Effective field capacity	ha/h	0.092	0.08	0.096
Field efficiency	%	86.7	82.4	87.2
Work capacity	h/ha	10.9	12.5	10.4
Weeding efficiency	%	97	96	97
Plant damage	%	1.6	2.8	1.9
Fuel consumption	l/h	0.40	0.43	0.40
Fuel consumption	l/ha	4.36	5.4	4.16
Labour requirement	man-h/ha	12	14	12
Cost of operation	Rs/ha	594	608	589
Cost of operation	Rs/h	45	45	45
Saving in labour for weeding	%			

and 0.096 ha/h for tomato, yard long bean and okra, respectively. The effective field capacity and field efficiency in yard long bean was quite less than tomato and okra due to tilted crop and high weed infestation. The field efficiency of weeder was 86.7, 82.4, and 87.2%, in tomato, yard long bean and okra field, respectively. Minimum time required for weeding in line sown crop was 10.4 h/ha in okra. The average fuel consumption was relatively high (0.43 l/h and 5.4 l/ha) in yard long bean and almost same consumption was recorded in tomato and okra crop weeding. The weeder have small turning radius which was 0.7 m, helpful in weeding in vegetable fields.

Weeding quality and cost of operation: Damages like cuts, uproot and graze etc to the vegetable plant stems and leaves during operation with weeder were also observed. No stem damage was found in whole weeding operation due to higher row to row spacing of crop. Plant damage was higher in yard long bean crop due to the more branches and tilted crop. Plant damage was found as 2.3% in long yard bean and minimum in tomato (1.6%) crop. It was observed during operation that the weed became entangled in both end of shaft and obstructed clean weeding. In the same time there was no clogging of weeds observed in middle portion. No Mechanical damage was observed in the weeder. Cost of weeding in vegetable cultivation per hour in traditional method was based on wage rate of farm workers as Rs 20/- and weeding per hectare was Rs 1280/-. The cost of operation of weeder in different crops was calculated by considering fixed cost and variable cost. The lowest cost of operation in Rs/ha was observed for okra. This may be due to higher field capacity and lower cost of the developed weeder.

Scope for commercialization: Feedback data on usability of this equipment by the target group indicated their interest to use this equipment over the traditional method (Table 2). The machine was designed and developed using Indian farm worker's anthropometric dimensions that helped the operator to operate for longer duration. This study supported the view expressed by Jafry and O'Neill (2000) about addressing the ergonomic issue in design of tools and equipment. It was observed that the majority of the respondents could work with the self-propelled weeder easily (95%) with appreciable safety in operation (93%). Higher output, negligible plant damages and easiness in operation by any farmer etc may be attributed for main reason of adoptions. The machine is simple in field operation and can be repaired by any category of local garage mechanics after a formal training. Custom hiring would be the right solution for the target group (96%) in West Bengal. The weeder price was Rs 88000/- (1470 US$) and this cost could be reduced by 12% after its commercialization.

Table 2: Feedback from respondents on adoption of power weeder in vegetable crop

Feedback of respondents	Average response of subjects (N = 35), %	
Operation of equipment	Ease in operation	95
	Safety in operation	93
	Fatigue in operation	11
Reasons for adoption	Higher output	100
	Negligible plant damages	94
	Cost effective	95
	Ease in movement	89
	Less chances of weed trapping/entangling	95
	Suitable for other than weeding	100
Purchasing the equipment	Higher cost	86
	Custom hiring	96

CONCLUSIONS

The performance evaluations were conducted to investigate the effect of weeder in three different vegetables crops. Power weeder worked satisfactorily and the weeding efficiency was found to be more than 96%. The machine covers only one row with a width of 400 mm which resulted in lower field capacity. Effective field capacity of weeder was higher in okra (0.096 ha/h) and lower in yard long bean (0.08 ha/h). Turning radius of power weeder is small (about 0.79 m) which was helpful in taking short turn without damaging the crop in the field.

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Performance Evaluation of Solar Operated Snapsack Sprayer

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ABSTRACT

Various types of knapsack sprayers produce different impacts on agriculture in terms of protection. These parameters describe their advantages and disadvantages. Solar operated knapsack sprayer using 37 watt solar panel facilitate to operate it on both modes independently i.e. on battery mode and on directly solar panel mode. Overall model design provides weight of panel as well as weight of sprayer on operator shoulder, which facilitate effortless operation. Solar panel provides shadow on the head of the operator which gives protection from high solar intensity. Sprayer can run 2.5 hours more after 5 hours of operation in full solar intensity which ultimately provides spraying operation facility at night. Rate of flow of liquid through sprayer is influenced by the liquid head. Sprayer is capable of spraying the liquid 360 liter/ha in 4.00 h at a walking speed of 0.7 m/s. Discharge rate of sprayer is 0.0267 liter/s but there is a slight chances of variation in the discharge capacity due to lack of constant walking speed of operator during the field operation.

Key words: *Knapsack sprayers, photovoltaic, Electrical Power, Flow rate*

INTRODUCTION

Pesticide use is an important aspect of the modern agriculture to protect plants by insects, fungus, virus parasites and weeds which are unfavourable for agricultural plant growth (Singh, 2007). Sometime weeds can be destroyed by effective cultivation, but pests and diseases have to be kept under control with chemical spray and powder application. Knapsack sprayer is the best selection of the farmers for chemical spraying. Knapsack sprayers are generally used for spraying low crops, vegetables and trees up to 2.5 m height. Various types of knapsack sprayer produce different impacts on agriculture in terms of protection. The most prevalent types of knapsack sprayer in India are mechanical and battery operated type. Mechanical type sprayer requires operator to move their hands continuously in order to spray the liquid which ultimately cause fatigue on the operator back, shoulder and the muscles of the hand. Battery operated sprayer requires charging of the batteries before operation and its application is limited where electrical source is not available. Therefore article presents an innovative approach to develop solar operated knapsack sprayer which will facilitate to operate pump on solar energy; it will eliminate drudgery of the operator and reduce charging hours of the batteries by using 37 watt solar panel.

MATERIALS AND METHODS

The main parts of the machines are photovoltaic panel 37 Watt, 16.4 V DC, STC 25^{0}C & 1000 Watt/m^2, the backpack 12 liters tank, 12 volts 7.0 AH dry lead battery, battery operated water pump, battery case, filter and sprayer handle with lance and nozzle (Fig. 1). The top opening with a cover is for filling and refilling of liquid. An outlet orifice at the bottom of the tank is for discharge of liquid and pipes strips of aluminimum metals as fitting accessories.

Electrical power: Electrical power is defined as the amount of electric current flowing due to an applied voltage. It is the amount of electricity required to start or operate a load for one second. Electrical power is measured in watts (W).

Fig. 1: Photovoltaic panel and backpack arrangement.

Power = voltage x current ...(1)

$$W = V \times A$$

Where, V = voltage (V), I = current (A), P = power (Watt)

Efficiency of solar cells: Efficiency of a solar cell is defined as the ratio of the energy output to the energy input from the sun.

$$\text{PV Efficiency \%} = \frac{Output\ Power\ (Watt)}{Input\ Power\ (Watt)} \times 100 \quad ...(2)$$

$$= \frac{Voltage\ produced\ (v) \times current\ developed\ (A)}{Corresponding\ solar\ intensity\ \left(^{watt}/_{m^2}\right) \times area\ of\ the\ array\ (m^2)} \times 100$$

The energy output (watt-hour) indicates the amount of energy produced during the day. Most of the sun's energy reaching a solar cell is lost before it can be converted into useful electricity. The minimum amount of energy necessary to free an electron from its band varies with different semiconductor materials. Since solar cells are unable to respond sunlight's entire spectrum, the solar cells cannot be 100% efficient. Another factor that limits cell efficiency is the inadvertent recombination of electrons and holes before they can contribute to an electric current. The natural resistance to electron flow in a cell also decreases cell efficiency. Its efficiency is also affected by temperature. Solar cells work best at low temperature as determined by their material properties. All cell materials give less efficiency as the operating temperature rises. Thus, efficiency of the solar cell is affected by several losses (Table 1). Some of these losses are avoidable and other cannot be avoided under normal conditions of production and utilization.

Table1: Losses for retarding efficiency of solar cell

Sr. No.	Nature of losses	Contribution in percentage
1	Top surface constant losses	3
2	Losses due to reflection at the top surface	1
3	Photons not utilized due to their lower energy content than the band gap	23
4	Excess energy of photons lost as heat	33
5	Quantum efficiency losses if thickness of the cell is less than the minimum required thickness	0.4
6	Collection losses: to minimize collection losses better design need to be developed	Varies
7	Voltage factor loss	20
8	Curve factor loss	4
9	Series resistance loss	0.3
10	Shunt resistance loss	0.1
	Power left to be delivered	20 approximately

Source: Rathore *et al.,* 2007

Pumping efficiency: Pumping efficiency is defined as the ratio of power needed to deliver water to the power supplied by the array.

$$\text{Pumping efficiency \%} = \frac{Power\ needed\ to\ dilever\ water\ (watt)}{Power\ supplied\ by\ the\ array\ (watt)} \times 100 \quad ...(3)$$

and thus,

System efficiency % = $\left(\frac{PV\ efficiency\ (\%)}{100} \times \frac{Pump\ efficiency(\%)}{100} \times 100\right)$ ... (4)

Flow rate (Q) was determined by

$$Q = A \times V \quad \text{... (5)}$$

$$= a \times v \quad \text{... (6)}$$

Where,

Q = Flow rate of discharge (m^3/sec) or (Lit/sec)

A = Area of cross section of pipe (m^2)

V = Velocity of flow in pipe (m/sec)

a = Area of the nozzle outlet (m^2)

v = Velocity of the flow at the nozzle outlet (m/sec)

Static head (H_{stat}) was determined by

$$Hstat = hs + hd \quad \text{... (7)}$$

Where,

H_{stat} = Static head (m)

hs = Static suction head (m)

hd = Static delivery head (m)

Velocity head ($\boldsymbol{Vh}$) was determined by

$$Vh = \frac{V^2s}{2g} + \frac{V^2d}{2g} \quad \text{... (8)}$$

Where,

$\frac{V^2s}{2g} =$ Velocity in suction head (m)

$\frac{V^2d}{2g} =$ Velocity in delivery head (m)

$g =$ Acceleration due to gravity, usually values 9.81 m/sec^2

Friction head ($\boldsymbol{hf}$) was determined by

$$hf = \frac{4fLV^2}{D \times 2g} \quad \text{... (9)}$$

Where,

hf = Head lost in the pipe (m)

f = Co-efficient of friction for the pipe

L = Length of the pipe (m)

V = Velocity of flow in the pipe (m/sec)

g = Acceleration due to gravity usually, values 9.81 m/sec^2

D = Diameter of pipe (m)

Total pump head (H) was determined by

$$H = H\,stat + hf + \frac{V^2d}{2g} \quad \text{... (10)}$$

Where,

H = Total pump head (m)

Pump pressure (P) was determined by

$$P = \frac{F}{A} \quad \text{... (11)}$$

Where,

P = Pressure (N/m^2)

F = Force (N)

A = Cross section area of the pipe, (m^2)

$$A = \frac{\pi}{4} \times d^2 \quad \text{... (12)}$$

Where,

D = Diameter of the pipe (m)

but, $P = W \times H$

Where,

W = Specific weight of the liquid (N/m^3)

H = Pump total head (m)

Determination of flow rate (Laboratory Test): A conical flask was used for collecting the volume of liquid discharged into it in ml per minute. A measuring cylinder was used together with the conical flask for accurate measurement of the discharged liquid. A digital time (stop watch) was used for the recording of time. The procedure was repeated four times and the varying liquid heads were noted. The mean flow rate was calculated and presented in a tabular form.

Determination of application rate (Field Test): A 12 liter capacity tank was filled up with a liquid. The tank was mounted at the back. The electrical system was switched "on" and the liquid was sprayed using the pressuring of the pump. The effective performance of the developed electrically operated knapsack sprayer was determined by practical trials in the field. The field test was made in an open field measuring 4 m by 25 m. The operator walked within a space of 0.7 m/s through the test field (Fig. 2). The discharged volume in liters per minute was recorded. The procedure was replicated four times and the mean value was determined.

Calibration of sprayer: Sprayer was calibrated as below:

$$\text{Area of test plot} = \text{Length} \times \text{Breadth} \quad \text{... (13)}$$

$$\text{Area rate of sprayer} = \frac{\text{Area of test plot (ha)}}{\text{Time taken (hr)}} \quad \text{... (14)}$$

$$\text{Volume rate} = \frac{\text{Volume collected (L)}}{\text{Time (hr)}} \quad \text{... (15)}$$

$$\text{Application rate } (L/ha) = \frac{\text{Volume rate } (L/hr)}{\text{Area rate of sprayer } (ha/hr)} \quad \text{... (16)}$$

RESULTS & DISCUSSION

Solar operated knapsack sprayer sprayed liquid when the D.C. pump was directly connected with the solar panel. Liquid head of the sprayer fluctuated when the shadow of the field trees came across the solar panel. This device sprayed liquid for 4 hours continuously without changing its liquid head after battery was fully charged through 37 watt solar panel in full solar intensity for 5 hours before operation. This highlights the battery charging quality through 37 watt solar panel. When the liquid head was at 320 mm, the corresponding discharge capacity was 1600 ml, when it was reduced to 300 mm, the discharged volume came to 1485 ml, and again reduced to 280 mm, the discharged volume dropped to 1100 ml. It indicated that the rate of flow of liquid was influenced by the liquid head. The mean discharge volume

Fig. 2: Field testing of solar operated knapsack sprayer

Table 2: Field test results of knapsack sprayer

Replications	Discharge volume (l) (a)	Time taken (s) (b)	Discharge rate (l/s) (a/b)	Area covered per unit time (m^2/s)	Application rate (l/ha)
1	3.8	142	0.0267	0.69	380
2	3.6	135	0.0266	0.69	360
3	3.5	131	0.0267	0.68	350
4	3.5	131	0.0267	0.68	350
Mean	3.6	134	0.0267	0.685	360

was 3.6 liters and mean time taken to spray 100 m^2 was 134 second (Table 2). Discharge was 0.0267 l/s. The equivalent hectare coverage of this device was 360 l/ha. There was variation in the discharge capacity recorded due to lack of constant walking speed during the field test operation.

CONCLUSION

Overall design of solar operated knapsack sprayer puts weight of panel as well as sprayer on shoulder, which ultimately provides effortless operation. Solar panel provides shadow on the head of the operator which gives protection from high solar intensity. Solar panel facilitates to use it for other applications. Sprayer can run 2.5 hours more after 5 hours of operation in full solar intensity which ultimately provides spraying operation facility at night also. There is a facility of charging a battery through electrical source which some time needed during spray operation in rainy days. The spray efficiency decreased with decrease in voltage of the battery. Rate of flow of liquid through sprayer was influenced by the liquid head. Discharge rate of sprayer was 0.0267 lit/s but there is a chance of variation in the discharge capacity due to lack of constant walking speed of operator during the field operation.

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Hydraulic Performance of Drip Irrigation System under Different Operating Pressures

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ABSTRACT

Efficient water application through drip irrigation depends upon a careful study of hydraulic parameters of the system in the field which indicates the effect of pressure on coefficient of variation, emitter flow variation, emission uniformity, uniformity coefficient and irrigation efficiency. Among these, the experiment was conducted at the levelled field to evaluate the hydraulic performance of drip irrigation system with emission device viz. inline emitters 1.3 lph and 2.4 lph for varying pressure viz. 0.7, 0.9, 1.2 and 1.5 kg/cm^2. Experimental set up was installed for determination of coefficient of variation, emitter flow variation, emission uniformity, uniformity coefficient, application and distribution efficiency. The result revealed that different hydraulic measures such as coefficient of variation (0.047 and 0.029) and emitter flow variation (14.23% and 8.73%) was found minimum at 1.5 kg/cm^2 pressure for both 1.3 and 2.4 lph emitters respectively. These parameters were found maximum at 0.7 kg/cm^2 for both emitters. Similarly, emission uniformity (94.68% and 96.66%), uniformity coefficient (95.3% and 97.1%), application efficiency (92.98% and 96.07%) and distribution efficiency (95.3% and 97.1%) was found maximum at 1.5 kg/cm^2 pressure for both 1.3 and 2.4 lph emitters respectively. These parameters were found minimum at 0.7 kg/cm^2 pressure for both emitters.

Key words: *Hydraulic performance, drip irrigation, emission uniformity, irrigation efficiency*

INTRODUCTION

Water is one of the primary inputs in agricultural production. This vital resource is becoming a scarce commodity day by day; therefore it requires to be planned, developed & managed with utmost care. This can be achieved by adopting methods having higher water application and distribution efficiencies. Drip irrigation can potentially provide high application efficiency and achieve high application uniformity. Both are important in producing uniformly high crop yields and preserving water quality when both water and chemicals are applied through the irrigation system. Drip irrigation delivers water directly to small areas adjacent to individual plants through emitters placed along a water delivery line or the lateral. Typical requirements for a drip system include a pump, filters, chemical/ fertilizer injectors, main and sub-main lines, laterals and emitters. Accurate emitter manufacturing is necessary in order to achieve a high degree of system uniformity. However, the complexity of emitter and their individual components make it difficult to maintain precision during production (Hezarjaribi *et al.,* 2008). The emission uniformity is essential for determination of total depth of irrigation. An efficient irrigation system must apply water uniformly throughout the field (Changade *et al.*, 2009). The small amounts of water improve the water-use efficiency (WUE), provide greater yield and enhances crop quality. Uniform distribution of water means that all the plants have equal access to water. This is only possible when accurate emitter manufacturing is provided by the company (Tagar *et al.*, 2010).

MATERIALS AND METHODS

Field experiment was carried out during the year 2011-12 in summer season at research field of Precision Farming Development Centre (PFDC), Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). Raipur is situated in the central part of Chhattisgarh at Longitude 81.36^0 E and Latitude 21.16^0 N at an Altitude of 289.56 meters above the mean sea level.

Experimental setup of drip irrigation system with 1.3 and 2.4 lph emitters: Drip irrigation system having a lateral size of 16 mm of 50 m length with 1.3 lph emitters (inline) at 30 cm spacing was used for the study of hydraulic performance. Three laterals from the submain line and twenty emission devices having discharge of 1.3 lph were selected randomly over these laterals for the study. The flow rate or discharge of emitter was collected in catch cans and then measured in measuring cylinder. The pressure was adjusted by using the bypass valve. The discharge of emitter at various pressures i.e. 0.7 kg/cm^2, 0.9 kg/cm^2, 1.2 kg/cm^2 and 1.5 kg/cm^2 was measured with the help of measuring cylinder. After that same procedure was followed with 2.4 lph emitters.

Coefficient of variation (C_V) and emitter flow variation (Q_{var}): Coefficient of variation defines as the ratio of the standard deviation of flow to the mean flow for a sample number of emitters. Coefficient of variation (C_v) is a statistical parameter expressed as:

$$C_v = \frac{S_q}{Q_{avg.}} \times 100 \qquad ...(1)$$

Where,

C_V = coefficient of variation

S_q = standard deviation of the discharge rate for the sample

Q_{avg} = average discharge rate

Standard deviation (S_q) = $$S_q = \sqrt{\frac{\sum (Q_q - Q_{avg})^2}{N}} \qquad ...(2)$$

Where,

Q_i = emitter discharge, lph

Q_{avg} = mean emitter discharge, lph

N = no. of emitters

General criteria for point source type emitter, C_v values are less than 0.05 (good), 0.05 to 0.10 (average), 0.10 to 0.15 (marginal) and greater than 0.15 (unacceptable). Similarly, for line source type emitter, C_v values are less than 0.10 (good), 0.10 to 0.20 (average) and greater than 0.20 (marginal). Emitter flow variation (Q_{var}) was calculated by

$$Q_{var} = 100\left[1 - \frac{Q_{min}}{Q_{max}}\right] \qquad ...(3)$$

Where, Q_{var} = emitter flow variation in percentage

Q_{min} = minimum emitter discharge rate in the system, l/h

Q_{max} = average or design emitter discharge rate, l/h

General criteria for Q_{var} values are 10% or less (desirable) and 10 to 20% acceptable and greater than 25%, not acceptable.

Emission uniformity (EU_f) and uniformity coefficient (U_s): The EU_f during the field test is the ratio expressed as a percentage of average emitter discharge from the lower 1/4th of emitter to the average discharge of all the emitters of the drip system. The average of lowest 1/4th of emitter was selected as a practical value for minimum discharge, as recommended by the United State Soil Conservation Services for field evaluation of irrigation systems and is expressed by the equation:

$$EU_f = \frac{q_n}{q_a} \times 100 \qquad ...(4)$$

Where,

EU_f = the field test emission uniformity, percentage

q_n = average of the lowest 1/4th of the field data emitter discharge, l/h

q_a = average of all the field data emitter discharge, l/h

General criteria for EU_f values are 90% or greater (excellent), 80 to 90% (good), 70 to 80% (fair) and less than 70% (poor). Statistical uniformity coefficient given by the

$$U_s = 100(1 - V_q) = 100\left(1 - \frac{S_q}{q_a}\right) \quad ...(5)$$

Where,

U_s = Statistical uniformity coefficient (%)

V = coefficient of variation emitter flow

S_q = standard deviation of emitter flow

q_a = mean emitter flow rate

General criteria for U_s values are 90% or greater (excellent), 80 to 90% (very good), 70 to 80% (fair), 60 to 70% (poor) and less than 60% (unacceptable).

Application efficiency and distribution efficiency: The application efficiency is defined as the ratio of water required in the root zone to the total amount of water applied. It shows how well irrigation water is applied that is, what percentage of water applied is stored in the root zone as required and is available for plant use. The water required in the root zone is assumed to be applied at the minimum flow rate and over the total irrigation time. Therefore, application efficiency can be expressed as,

$$E_a = \frac{N.Q_{\min}.T}{V_w} \times 100 \quad ...(6)$$

Where,

E_a = application efficiency, %

N = total number of emitter

$Q_{\min}$ = minimum emitter flow rate, l/h

T = total irrigation time, h

V_w = total volume of water applied, l

Since, the mean emitter flow (Q_{avg}) is,

$$Q_{avg} = \frac{V_w}{N.T} \quad ...(7)$$

The application efficiency can also be expressed as,

$$E_a = \frac{Q_{\min}}{Q_{avg}} \times 100 \quad ...(8)$$

The distribution efficiency determines how uniformly irrigation water can be distributed through a drip irrigation system into the field. It can be determined from the emitter flow variation along a lateral line (or sub main) in a drip irrigation system layout in the field and can be expressed by the equation,

$$E_d = 100\left[1 - \frac{\Delta q_a}{q_m}\right] \quad ...(9)$$

E_d = distribution efficiency

q_m = mean emitter flow rate, l/h

Δq_a = average absolute deviation of each emitter flow from the mean emitter flow.

RESULTS AND DISCUSSION

Drip irrigation system was operated under different operating pressures to study the different hydraulic parameters of drip irrigation system. For this purpose, drip irrigation discharges were measured at different operating pressures for both 1.3 and 2.4 lph emitters. For 1.3 lph emitters, the average discharge values 1.296, 1.163, 1.002 and 0.801 lph were found under 1.5, 1.2, 0.9 and 0.7 kg/cm^2 pressure respectively. Similarly, for 2.4 lph emitters 2.394, 2.156, 1.997 and 1.443 lph average discharge values were found under 1.5, 1.2, 0.9 and 0.7 kg/cm^2 pressure respectively.

The coefficient of variation (0.133) and emitter flow variation (41.39%) for 1.3 lph emitter was found maximum at 0.7 kg/cm^2 operating pressure and minimum 0.047 and 14.23% at 1.5 kg/cm^2 operating pressure (Table 1). While for 2.4 lph emitter, the coefficient of variation (0.067) and emitter flow variation (20.99%) was found maximum at 0.7 kg/cm^2 and 0.9 kg/cm^2 operating pressure respectively and minimum 0.029 and 8.73% at 1.5 kg/cm^2 operating pressure. Thus, for a particular spacing, coefficient of variation and emitter flow variation decreased as the operating pressure increased for all emission devices. To decide whether the system is good, average, marginal and excellent, it was necessary to determine the manufactures coefficient of variation either point source or line source. From the table it is evident that when the operating pressure of drip irrigation system is increased, coefficient of variation and emitter flow variation decreases means that pressure directly affect the discharge rate of emitter.

Emission uniformity of the system decides the uniformity distribution of discharge by each emitter or uniformity distribution of water to each crop. The emission uniformity (94.68%) and uniformity coefficient (95.3%) for 1.3 lph emitter were found maximum at 1.5 kg/cm² operating pressure and minimum 80.65% and 86.7% at 0.7 kg/cm² operating pressure (Table 2). While for 2.4 lph emitter, the emission uniformity (96.66%) and uniformity coefficient (97.1%) were found maximum at 1.5 kg/cm² operating pressure and minimum 90.23% and 93.3% at 0.7 kg/cm² operating pressure. Thus, for a particular spacing, emission uniformity and uniformity coefficient increases as the operating pressure increases for all emission devices. The increase in emission uniformity is mainly due to increase in the ratio of minimum rate of discharge to the average rate of discharge. At a particular spacing, the ratio of minimum rate of discharge to average rate of discharge increases as the operating pressure is increased due to constant emission point per unit length of lateral, and thus the emission uniformity increased as the operating pressure increased for all emission devices.

The application efficiency, (E_a) of drip irrigation system was estimated for 1.3 and 2.4 lph emitters under different operating pressure. The application efficiency (92.98%) and distribution efficiency (95.3%) for 1.3 lph emitter were found maximum at 1.5 kg/cm² operating pressure and minimum 68.08% and 86.7% at 0.7 kg/cm² operating pressure. While for 2.4 lph emitter, the application efficiency (96.07%) and distribution efficiency (97.1%) were found maximum at 1.5 kg/cm² operating pressure and minimum 86.63% and 93.3% at 0.7 kg/cm² operating pressure. Thus, for a particular spacing application efficiency and distribution efficiency increases as per the operating pressure for all emission devices. The results are in conformity with the findings of Popale *et al.* (2011), SAFI *et al.* (2007) and Kumar and Singh (2007).

CONCLUSION

A study was conducted to evaluate the performance of drip irrigation system under different operating pressure. In the experiment it was observed that at a particular spacing, the emission uniformity, uniformity coefficient and irrigation efficiency increases as the operating pressure increases while coefficient of variation and emitter flow variation decreased for all emission devices. Performance of 2.4 lph emitter was found better compared to 1.3 lph emitter under study.

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Adoption Status of Roto Seed Drill In Punjab

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ABSTRACT

Wheat is the second most important cereal crop in India after rice. There are several methods by which sowing of wheat is done in the country which include sowing by conventional technique, no-till drill, happy seeder and roto seed drill. The survey was conducted on roto seed drill, which included questions related to the pros and cons of the machine in respect of yield obtained, inputs required and the economies of the machine. The details of the farmers were taken from fairly trusted manufacturers of agricultural machinery. Random sample of 80 farmers who owned this machine were selected and surveyed. During the survey it was observed that the machine was owned by farmers having land area more than 2 ha. A high percentage of farmers (24%) believed that the use of this machine makes the crop more susceptible to weed growth. A large number of farmers i.e. 68% believed that the crop yield remained the same with the use of this drill, 19% said that the yields obtained by this machine were higher than that obtained by other methods, while the remaining 13% farmers said the yields obtained by sowing with this method resulted in lesser yield. Maximum (61%) farmers said that they were satisfied with germination of crop sown by the roto seed drill, 21% believed that the germination was good and the remaining 18% farmers reported that they were not satisfied with the crop germination. The use of this machine has led to early sowing of the next crop which resulted in higher profits as the harvest was achieved at an early stage.

Key words: *Rotavator, Roto seed drill, Seed drill, Sowing, Wheat*

INTRODUCTION

Wheat (*Triticum* spp.) is the most important winter cereal crop in India. Wheat crop contributes substantially to the national food security by providing more than 50% of the calories to the people who mainly depend on it. About 92.2% of the wheat is produced in Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan and Bihar. Uttar Pradesh with 24.4 million tonnes is the highest producer of wheat followed by Punjab (14.8 mt) and Haryana (9.2 mt). Higher contributions from Haryana and Punjab is due to high productivity (3800 to 4300 kg/ha), Anonymous, 2013a and 2013b. The sowing of wheat crop has short window period of 21 days and it is difficult to complete manual sowing. Different size of seed drills are used to sow the crop within the available time. There are several methods by which sowing of wheat is done in the country which include sowing by conventional technique, no till drill, happy seeder and roto seed drill.

Sidhu *et al.* (2008) conducted experiments on straw management and during the study it was observed that millions of tonnes of rice straw is burnt each year in the north-western Indo-Gangetic Plain for preparation of seed bed for wheat sowing. Straw burning results in severe air pollution, loss of nutrients and organic matter, leading to the decline in soil organic carbon levels to very low values. The majority of the rice is harvested by combine harvesters, leaving standing stubble and windrows of loose straw that interfere with tillage and seeding operations for wheat. The development of the happy seeder commenced in 2001. The combo happy seeder combines the straw handling and sowing units into a single, lightweight, compact machine, while the combo + happy seeder includes strip tillage in front of the inverted -T sowing tines. The turbo happy seeder solves the problems of excessive dust and visibility created by Combo machine by eliminating the chute and chopping the straw finely in front of, and feeding it past, the tines. Extensive testing of the combo happy seeder has shown that wheat yields are maintained or increased with direct drilling into rice stubble in comparison with the farmers' practices of straw burning followed by tillage or direct drilling. Vatsa and Singh (2010) conducted a study on various available seed drills/planters and compared with traditional methods for wheat sowing. The effective field capacities were 0.039, 0.036, 0.12, 0.035 and 0.024 ha/h with manual seed drill, manual multicrop planter, power tiller multicrop planter, dropping seed behind hand plough and sowing behind animal plough, respectively. The labour requirement was higher for the hand plough and sowing behind the plough than for the seed drills. The cost of operation was 2-4 times lower for the seed drills. The yield was about 15-18% higher with seed drills and planters and significantly higher compared to traditional method. It was concluded that power operated and animal operated equipment were better than manual operated for sowing wheat crop. Bertocco (2007) discussed various models of combination seed drills. In Italy the most popular models combine the seed drill with a rotary cultivator. Most models tilled only the top 10-15 cm of soil and could incorporate residues of a previous crop. The roller, which levels the surface, was placed between the cultivator and the drill. Combination machines are beneficial to the farmer as the components can be used separately if required; they reduce the number of operations and so low the danger of soil compaction and also reduce labour and cost.

Roto seed drill, one of the latest machinery for sowing, has been very popular in the past few years among the farmers in different parts of Punjab and elsewhere in the country. It doesn't need field preparation before sowing and therefore next crop can be immediately sown after the harvesting of previous crop. It is extensively used for sowing a wide variety of crops like maize, wheat, pea, mustard etc. It has a great demand by the farmers due to its durability, performance and low energy consumption. Therefore a study was undertaken to assess its performance on farmers' field.

MATERIALS AND METHODS

The roto seed drill is a combination of a rotavator and a seed drill which gives a new dimension to the sowing operations. The two most important components of the roto seed drill are rotavator and seed drill (without tines). The components of the roto seed drill are frame, seed and fertilizer boxes, seed tubes, seed metering mechanism, fertilizer metering mechanism and rotavator (Fig. 1). The frame is made of high quality steel with suitable braces and brackets to withstand all types of loads. The seed and fertilizer box is made of mild steel or galvanized iron with a suitable cover. A small agitator is provided for mixing of the seed and the fertilizer

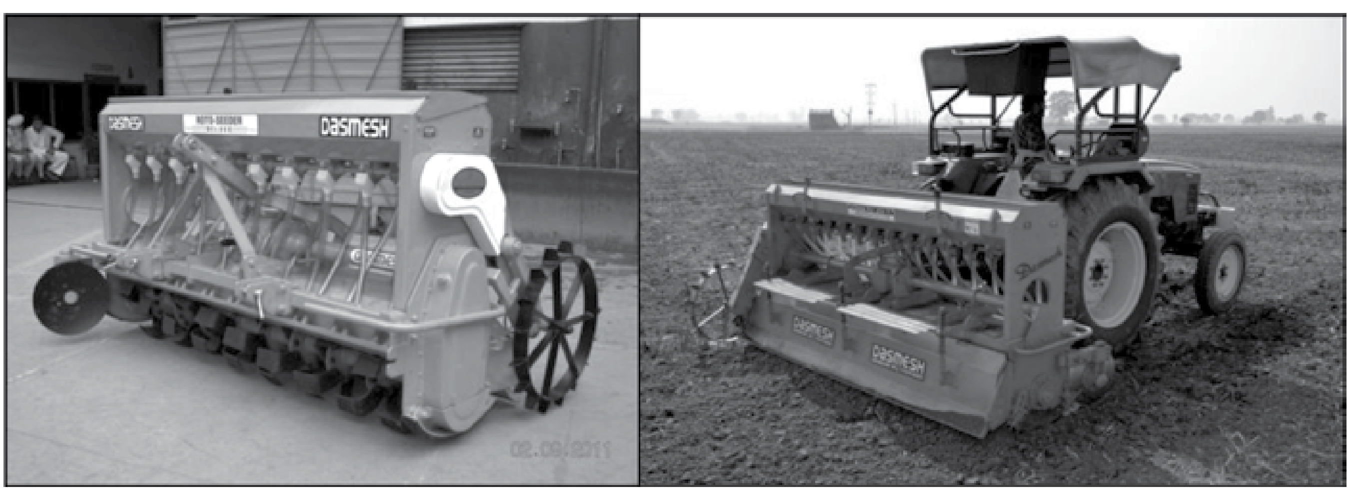

Fig. 1: Tractor operated roto seed drill

and to prevent the clogging of the mixture. The purpose of the seed tube is to deliver the metered seed rate to the surface.

The roto seed drill works on the fluted feed type metering mechanism. In this the adjustable fluted rolls are present to collect and deliver the seed into the seed tube. Traction wheel for operating seed and fertilizer metering mechanism is provided on side. The fertilizer metering is generally done by two methods namely, cell feed mechanism and auger feed mechanism. The cell feed mechanism is a mechanism in which seeds are collected and delivered by a series of equally spaced cells on the periphery of a circular plate or wheel. The auger feed mechanism is a distributing system consisting of an auger which cause the fertilizer to flow evenly in the field, through an aperture at the base or on the side of the hopper. Many of the fertilizer drills of the country have an auger feed mechanism. The rotavator is a P.T.O driven implement. It is equipped with a gearbox and driven forward, or held back, by its wheels. The gearbox enabled the forward speed to be adjusted while the rotational speed of the blades remains constant which enabled the operator to easily regulate the extent to which soil is engaged. The roto seed drill is customized according to the requirement of the customer and mostly manufactured in two standard sizes i.e. 1.83 m and 2.13 m. Brief specifications of the machines are given in Table 1.

Table 1: Brief specifications of different sizes of Roto Seed Drill surveyed

Parameters	Rotavator I	Rotavator II
Overall Size, m	1.83	2.13
Width, m	2.032	2.490
Height, m	0.940	0.940
Length, m	1.346	1.346
Working width, m	1.829	2.137
Working depth, m	0.150	0.150
Power required, hp	50-55	50-60
Number of flanges	Eight	Nine
Number of blades	42	48
PTO speed, rpm	540	540
Rotor speed, rpm	270	270
Weight, kg	425	450

Random sample of 80 farmers, who owned this machine were selected and surveyed. Personnel visit were conducted for few and the rest were telephonically surveyed about the performance of the machine on the factors like fuel consumption, crop yield and economies etc to get a dependable review from them about the performance of the machine on the basis of questionnaire. The details of the farmers were taken from fairly trusted manufacturers of agricultural machinery. The collected data from the survey of the farmers was evaluated and analyzed to get meaningful outcomes so that it could be justified that the roto seed drill was able to solve the farmer's problems of economy, shortage of labour, and shortage of time effectively. During the survey it was observed that this machine was owned by farmers having land area more than 2 ha. The size of the drill chosen was dependent on the size of land holding of the farmer. It was observed that 21.25% farmers (17 out of 80) had a 1.83 m roto seed drill and 78.75% farmers (63 out of 80) 2.13 m.

RESULTS AND DISCUSSION

It was observed that most of farmers using the roto seed drill put their fields to fire (complete burning) before operating this machine. Farmers operated the seed drill of 1.83 m and 2.13 m efficiently by using tractors with 50-60 hp. A high percentage of farmers (68%) believed that there was no difference in the yields obtained by sowing with the roto seed drill and the conventional seed drill, 19% said the yields had increased as compared to the conventional seed drill, and remaining 13% said the yields had decreased as compared to the conventional seed drill. It was observed, that majority of the farmers (72.5%) owing these machines were following the wheat and paddy cropping pattern. There were still a few who grow maize and wheat (9.25%), potato and moong together comprise the remaining (18.25%) in their fields.

The seed rate required for the roto seed drill was observed to be higher than the other methods of sowing. As the seed was not planted but it was broadcasted that led to increased losses of the seeds. The seed rate required for wheat sowing by other seed drills and traditional methods remains between 100-112.5 kg/ha but in case of roto seed drill it was observed to be between 112.5-150 kg/

ha. It was also observed that the maximum yield (63.3 q/ha) was reported at a seed rate of 150 kg/ha followed by 137.5 kg/ha (61.8 q/ha), 125 kg/ha (56.4 q/ha) and minimum for 112.5 kg/ha (53.6 q/ha).

Most of the farmers reported that the fertilizer requirement did not vary much in regards to the other methods of sowing but the irrigation requirements of the crops sown with the roto seed drill was reported to be higher than the ones sown by other methods. It was seen that the first irrigation was provided after 3 weeks of sowing, the second was provided after 5 to 6 weeks of first irrigation and third (if needed) as per requirement around 5 to 6 weeks of second irrigation. It was observed that 61% farmers were satisfied with the germination, 21% reported that the germination was good for the crop sown by roto seed drill while the remaining 18% farmers were unsatisfied with the performance and responded that the crop grown by this machine did not germinate.

According to the farmers, the machine was simple and easy to operate and handle. Around 23.75% farmers reported excessive weeds problem, 15% farmers reported termite attack and 5% told about rodent attacks when sowing was done with this machine. Yellow colour of crop was observed by 22.5% farmers and 10% farmers observed compaction of soil. The common observation among the farmers was that it became important to put the field to fire before sowing the crop using the roto seed drill as if it was not done the crop becomes highly susceptible to termite and rodent attack. One other common problem faced by the farmers was wastage of land where the seed drill takes a turn, which leads to the formation of dead furrows.

Economics was the major concern during selection of a machine as the roto seed drill prices varied between Rs. 1, 00,000 - 1, 20,000. The fuel consumption of the tractor increased drastically while operating the roto seed drill. An economic comparison was done between the different treatments i.e., different methods of sowing of wheat. When sowing was done with roto seed drill, the cost of operation was minimum (Rs. 2122/ha) followed by no till drill i.e., chopper + rotavator + no till drill (3414/ha), happy seeder (Rs. 2822/ha) and was maximum (Rs. 5340/ha) for conventional method (1 pass of stubble shaver + 2 pass of cultivator + 2 pass of harrow + 1 pass of planker + no till drill). It was observed that the sowing done by Roto seed drill comes out to be the most economical; it costs almost three times less than the conventional method of sowing. Average fuel consumption for 1.83 m roto seed drill was 6.5 – 7.5 l/h and and for 2.13 m 8 – 9 l/h. Most of the farmers believed that the machine had an advantage for preparing seed bed and sowing in a single operation which helped them in saving of labour and fuel

CONCLUSIONS

During the survey it was observed that the roto seed drill was owned by farmers having land area more than 2 ha. The size of the drill was dependent on the size of land holding of the farmer. A high percentage of farmers put their farms to complete/partial burning before operating the roto seed drill this causes a large amount of environmental pollution. A large number of farmers i.e.68% believed that the crop yield remained the same with the use of this drill, 19% said that the yields obtained by this machine were higher than that obtained by other methods, while the remaining 13% farmers said the yields obtained by sowing with this method resulted in lesser yield. Maximum (61%) farmers said that they were satisfied by germination of crop sown by the roto seed drill. The use of this machine has led to early sowing of the crops which resulted in higher profits as the harvest was achieved at an early stage.

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Development of a Poly-cum-shade Net House for Capsicum Cultivation for Saurashtra Region of Gujarat State

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ABSTRACT

A poly-cum-shade net house of 9.2 m x 5 m x 3.6 m covered with 50% green shade net on periphery and roof covered with 200 UVS PE sheets was developed for capsicum cultivation. Environmental parameters like temperature, relative humidity, and light intensity and crop parameters such as plant height, number of leaves, number of fruits, crop yield were recorded during the experimentation. Inside the structure temperature decreased around 1-2^{0}C and 4-5^{o}C while Rh increased 5.5-2.1% and 3.7-3.0% during winter and summer season, respectively as compared to open field condition. The light intensity during winter was varied from 1520 to 41,590 lux inside the structure and 2450 to 73,560 lux in open field whereas for summer season, it was varied from 4720 to 22,090 lux and 10,110 to 91,170 lux for inside and open field respectively. The crop parameters such as plant height (84 cm), number of fruits per plant (39), crop yield (44.6 t/ha) were found maximum for 0.8 IW/CPE while number of leaves per plant (105) was recorded maximum for 1.0 IW/CPE. Net profit for capsicum cultivation in poly-cum-shade net house was estimated at Rs. 4,01,870 per hectare with 1.32 benefit-cost ratio.

Key words : *Poly-cum-shade net house, IW/CPE, capsicum cultivation*

INTRODUCTION

Capsicum (Capsicum annum var. grossum) belongs to the family Solanaceae and is an important member of chilli group. Green pepper is reported to be the native of tropical America. Capsicum is rich source of vitamin A and C and consumed by almost every Indian. It is consumed as vegetable, salad, in pizza etc due to its mild pungency and taste.

The climate of Gujarat particularly in Saurashtra region is hot during the summer time and in the month of May sometimes temperature touches to 45^{o}C. Normally, vegetable crops are required winter climate or mild temperature (in most cases less than 35^{o}C) for flowering and setting fruits. The capsicum crop is difficult to grow outside because of adverse climate as well as problem of insects & pests. Therefore, greenhouses are used to grow this crop. Cooling energy is the major factor in greenhouse cultivation as well as in natural ventilated greenhouse, it is difficult to bring down the temperature particularly when outside temperature is 40^{o}C; hence net house is another option for cultivation of this crop. Crop production in greenhouse is more but not found profitable due to high energy consumption. Whereas in net house, less light intensity is received due to completely covered with shade net which affects adversely on crop production. Hence, with the view to increase the light intensity in the net house, the roof of the structure has been covered with UV stabilized plastic-sheet (200 μ) and a study was conducted to study the environmental parameters of poly-cum-shade net house and the effect of structure on crop parameters.

Jeevansab (2000) reported that the fruit yield of capsicum differed significantly with the growing environments and obtained highest fresh fruit yield (30.50 t/ha) under polyhouse followed by open condition (12.00 t/ha). Atre *et al.* (2003) studied the yield and water use efficiency of capsicum grown under poly house. Though the yield of capsicum was more with more application of water, the water use efficiency was greater with application of water equivalent to 70 per cent of pan evaporation through drip irrigation system in poly house. Silvoy *et al*. (2009) determined the effect of shading levels on bell pepper under black plastic film mulch in the spring and found that yield increased with increase in shading levels up to about 27% to 34% and then decreased with increase in shading levels. Ilic *et al*. (2010) evaluated the influence of different coloured shade nets on the plant development, yield and quality of bell pepper and observed that the fruit yields (t/ha) under the coloured shade nets were higher by 113 to 131%, relative to the open field. Patel and Patel (2010) conducted a study on cultivation of capsicum in net house, greenhouse and open field. The production of crop was recorded highest in greenhouse, but due to huge consumption of electric energy in greenhouse the cultivation of crop was not found profitable. Net house is another alternative structure for cultivation of capsicum, but in net house, less light intensity is received due to completely covered with shade net.

METHODOLOGY

The field experiment was conducted by constructing poly-cum-shade net house as shown in Fig. 1 at the nursery of AICRP on APA, Department of Renewable Energy and Rural Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh. The single span, arc type, GI pipe framed poly-cum-shade net house was covered with 200 µm thick UVS polyethylene sheet at the roof and 50 % green shade net on the periphery. The geometrical dimensions like length, width, eve height and ridge height were kept as 9.2 m, 5.0 m, 2.3 m and 3.5 m respectively. The poly-cum-shade net house constructed with continues stone foundation and 8 numbers of Galvanized iron column pipes (2.54 cm diameter) of 3.0 m height were erected length wise (4 numbers on each side) in foundation such a way that eve height and pole to pole distance were maintain as 2.3 m and 3 m respectively. The hoops made of 25.4 mm diameter GI pipes welded to the top end of column pipes to support the covering and raise the ridge height up to 3.5 m from the plinth level. A door, 0.95 m x 1.85 m size made from MS angle was fitted East end facing North direction. To control the temperature and light intensity during the summer period, provision for manual shading with 50% white shade net was kept at eve height.

Fig. 1: Poly-cum-shade net house at APA nursery (Length: 9.2 m, Width: 5.0 m, Height: 3.6 m)

The experiment was conducted for two years i.e. 2010-11 and 2011-12. Fertile soil and farmyard manure was mixed and then insecticide phorate was added to control the termite. Initially experimental plot was irrigated and after four days it was tilled manually by using Kudali to pulverize the soil. Raised bed of 0.80 m width and 3.5 m length were prepared with a furrow of 0.45 m between two beds. Farm yard manure was applied @ 20 t/ha at the time of preparation of experimental field. Recommended dose of fertilizer N_2: 240 kg/ha, P_2O_5: 120 kg/ha and K_2O: 120 kg/ha were applied during crop cultivation. The seedlings of capsicum were raised in earthen pots. The media was prepared with black soil, farmyard manure, vermin compost and coco-pit. Seeds of the crop were sown in the earthen pots during last week of August. After placing seeds in earthen pots, light watering was done to provide sufficient moisture in earthen pots for germination of seeds. The transplanting of seedlings of capsicum was carried out after 55 days on bed at 0.45 m × 0.30 m spacing.

Initially for 15 days irrigation was applied manually and later on through drip irrigation system considering IW:CPE of 0.6, 0.8 and 1.0. To study the effect of inside environment i.e. temperature, relative humidity and light intensity on crop growth and production, environmental and crop parameters were recorded. Temperature and relative humidity were measured with digital thermo-hygrometer and light intensity was measured using digital lux meter. Environmental parameters were recorded daily at regular interval of 3 h (9:00, 12:00, 15:00 and 18:00 h) at the center of the poly-cum-shade net house and plant canopy height. For recording various crop parameters six replications each of four plants were selected from all the treatments.

RESULTS AND DISCUSSION

Temperature: It can be observed from the Fig. 2 that temperature inside poly-cum-shade net house during the month of December varied from 19.8°C to 31.1°C whereas outside it was recorded as 20.6 ° to 33.1°C. Thus, a difference of 2°C between inside and outside temperature was observed which may be attributed to the favorable condition inside poly-cum-shade net house. During the month of January, maximum and minimum temperature inside the structure was recorded as 28.4°C and 18.1°C respectively as against outside temperature of 18.9°C to 31.3°C. In February month, the temperature inside poly-cum-shade net house varied from 20.9°C to 29.9°C, while the outside temperature was found in the range of 24.2°C to 33.0°C. Thus, temperature drop of around 3.1°C between inside and outside temperature was recorded. During the month of March, hot summer started. Hence, 50% shade-net was provided inside the structure at eve height to reduce the temperature and light intensity. Temperature inside and outside poly-cum-shade net house varied from 22.2°C to 31.2°C and 24.5°C to 34.9°C respectively. Due to shade-net, temperature difference of around 3.7°C was recorded between inside and outside temperature. The temperature difference between inside and outside was observed less during morning and evening hours whereas it was observed maximum at 12:00 h. Maximum temperature was recorded at 12:00 h and minimum temperature was recorded at 9:00 h inside and outside of the structure during February, March and April. During the month of April, inside and outside temperature varied from 27.1°C to 34.5°C and 28.5°C to 37.8°C respectively.

Relative humidity: It is clear from the Fig. 3 that relative humidity inside structure during the month of December varied from 41.3% to 62.6% whereas outside it was recorded 32.2% to 60.5%. During January, inside the structure maximum and minimum relative humidity was recorded as 52.8% and 33.3% respectively whereas outside relative humidity varied from 28.6% to 49.3%. In February month, relative humidity inside structure varied from 34.1% to 55.2%, while outside it was observed 29.7% to 51.1%. Relative humidity was recorded lower outside structure than inside structure. During the month of March hot summer started. Hence, shade-net was provided inside structure. Relative humidity inside and outside the structure varied from 25.0% to 43.4% and 22.8% to 39.6% respectively. Relative humidity inside and outside of structure varied from 23.8% to 47.1% and 20.1% to 44.1% respectively during the month of April. Maximum relative humidity was recorded at 9:00 h and it was recorded minimum at 15:00 h.

Light intensity: From the Fig. 4, it is apparent that

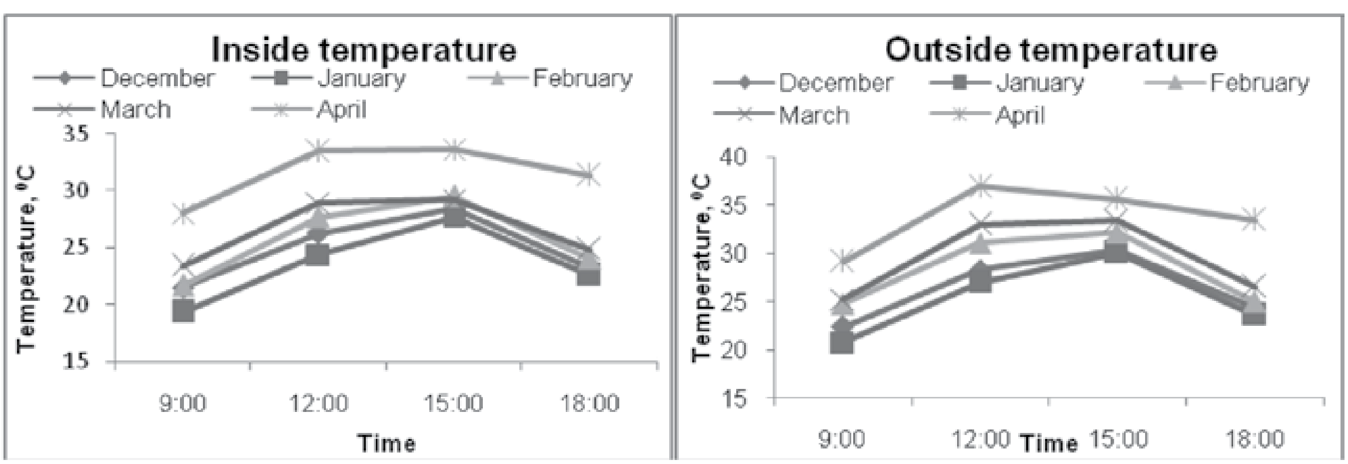

Fig. 2: Monthly average inside and outside temperature

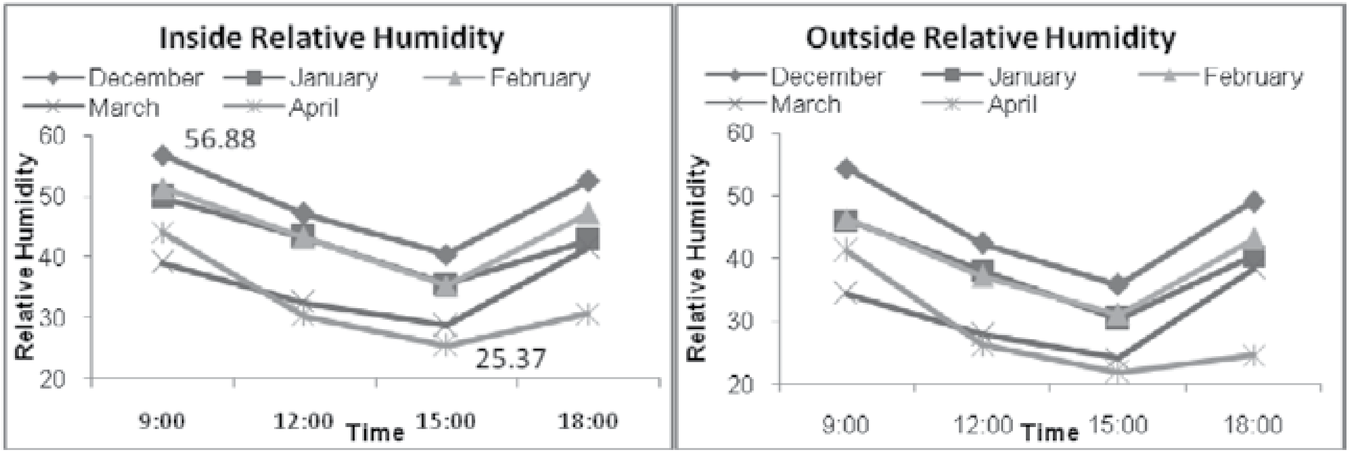

Fig. 3: Monthly average relative humidity

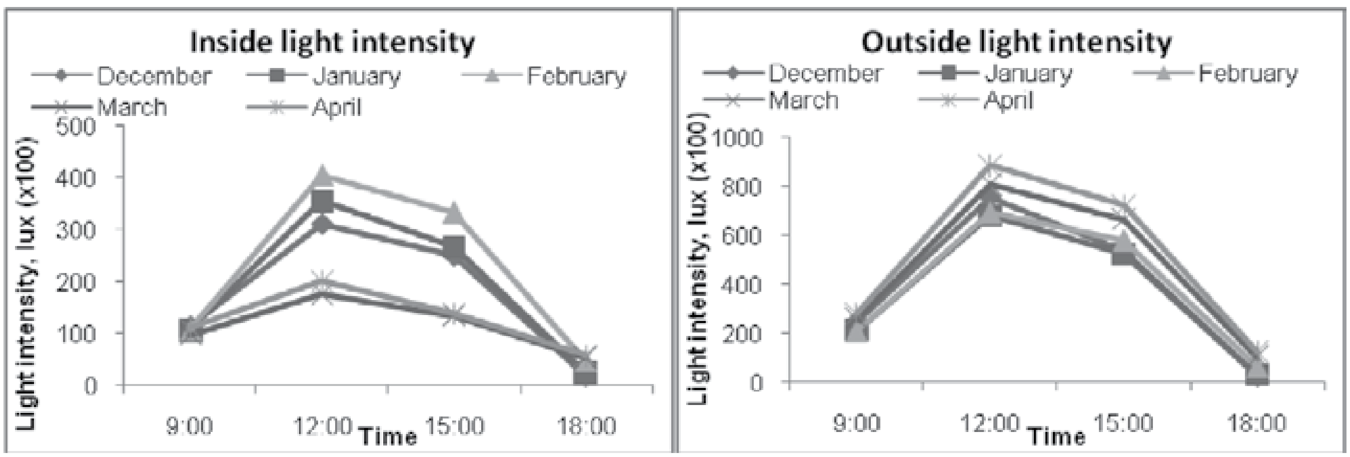

Fig. 4: Monthly average light intensity

light intensity inside structure during the month of December varied from 1520 lux to 32,400 lux whereas outside it varied from 2450 lux to 78,980 lux. It was observed that from 9:00 h onwards, up to 12:00 h, the light intensity increased and from 15:00 h onwards there was recorded abrupt downfall in it. Light intensity reached its peak at 12:00 h and it was recorded minimum at 18:00 h. During the month of January, maximum and minimum light intensity inside structure was recorded as 41,290 lux whereas light intensity was 2140 lux. Light intensity outside structure varied from 2570 lux to 71,360 lux. In February month, light intensity inside structure varied from 4010 lux to 41,590 lux, while the outside light intensity varied from 5120 to 73,560 lux. During the month of March, hot summer started. Hence, 50% shade-net was provided inside structure at gutter height. Light intensity inside and outside structure varied from 4720 lux to 19,410 lux and 9530 lux to 85,540 lux respectively. Due to shade-net, light intensity was abruptly decreased inside structure (25,000-30,000 lux). During the month of April, light intensity inside and outside structure varied from 5610 lux to 22,090 lux and 12,650 lux to 91,170 lux respectively. Maximum light intensity was recorded at 12:00 h and it was recorded minimum at 18:00 h inside and outside of structure during the month of April.

Crop parameters: The observations of crop parameters were analyzed and pooled result of two years is presented in Table 1. Only a few plants survived in the open field conditions, so it was not included in the statistical analysis. Minimum crop parameters viz., plant height (30.4 cm), number of leaves per plant (38), number of fruits per plant

Table 1: Effect of irrigation levels on different crop parameters

S. No.	Treatments	Plant height, cm	No. of leaves per plant	No. of fruits per plant	crop yield (t/ha)
1	I_1 = 0.6 IW/CPE	77	90	28	30.5
2	I_2 = 0.8 IW/CPE	84	102	39	44.6
3	I_3 = 1.0 IW/CPE	82	105	33	38.0
S.Em. ±		1.84	5.06	1.27	1.44
CD at 5%		5.30	NS	3.66	4.17
CV %		7.86	17.71	13.20	13.28
Y*T S.Em ±		2.60	7.15	1.79	2.04
Y*T CD at 5%		NS	NS	NS	NS

(4), yield of crop (2.8 t/ha) were recorded in open field condition. It is evident from the Table 1 that plant height of capsicum crop for 0.8 IW/CPE (84 cm) was found significantly higher than 0.6 IW/CPE (77 cm) and it was at par with 1.0 IW/CPE (82 cm). It might be due to optimum irrigation level (0.8 IW/CPE) for acceleration of plant height. Similar findings were also reported by Lakpal *et al.* (2007) for spice crops. Interaction of Y*T was found non-significant in pooled analysis. The effect of irrigation level on number of leaves per plant was found non-significant. However maximum number of leaves per plant (105) was recorded at 1.0 IW/CPE and minimum at 0.6 IW/CPE (90). It might be due to higher vegetative growth found at higher irrigation level (1.0 IW/CPE). Ahmed (1991) also reported that increasing irrigation will increase the vegetative growth for capsicum. Interaction of Y*T was found non-significant in pooled analysis. The numbers of fruits per plant for 0.8 IW/CPE (39) was found significantly higher than 0.6 IW/CPE (28) and 1.0 IW/CPE (33). So, 0.8 IW/CPE was found superior for providing highest numbers of fruits per plant. Interaction of Y*T was found non-significant in pooled analysis. The yield of capsicum crop for 0.8 IW/CPE (44.6 t/ha) was found significantly higher than 0.6 IW/CPE (30.5 t/ha) and 1.0 IW/CPE (38.0 t/ha). It might be due to higher yield found at optimum irrigation level (0.8 IW/CPE) and adverse effect at higher irrigation level. These results are in conformity with the findings reported by Spehia *et al*. (2007). Interaction of Y*T was found non-significant in pooled analysis.

Annual cost of cultivation of capsicum in poly-cum-shade net house was estimated (Rs. 4275) by considering the material cost for construction of structure, cost of cultivation of capsicum crop, life span of structure, annual depredation, maintenance cost and interest. The total yield of capsicum crop cultivated in poly-cum-shade net house of 35 m^2 area was recorded as 126.25 kg. Total revenue generated for the structure of 35 m^2 area was calculated as Rs.5681 by multiplying the crop production (126.25 kg) and prevailing market rate (Rs. 45/kg). Net profit was found as Rs. 1407 by subtracting annual cost of cultivation of capsicum from total revenue generated. Benefit-cost ratio (1.32) was calculated by dividing total revenue generated (Rs.5681) with annual cost of capsicum cultivation in poly-cum-shade net house (Rs. 4275). Cost of capsicum cultivation in poly-cum-shade net house for one hectare area basis was also worked out and found profitable and a farmer can fetch net profit of Rs. 4,01,870 per hectare.

CONCLUSIONS

Temperature inside the structure decreased around 1-2^{0}C and 4-5^{o}C while Rh increased 5.5-2.1% and 3.7-3.0% as compared to open field during winter and summer season, respectively. Light intensity for winter (November to February) ranged from 1520 to 41,590 lux in poly-cum-shade net house and 2450 to 73,560 lux in open field, while for summer season (March and April), light intensity ranged from 4720 to 22,090 lux in the structure and 10,110 to 91,170 lux in open field. The crop parameters such as plant height (84 cm), number of fruits per plant (39), crop yield (44.6) were found maximum for 0.8 IW/CPE while number of leaves per plant (105) was recorded maximum for 1.0 IW/CPE. Net profit for capsicum cultivation in poly-cum-shade net house was estimated Rs. 4,01,870 per hectare with 1.32 benefit-cost ratio.

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Performance Evaluation of Animal Drawn Improved Equipment for Puddled Seedbed in Terrace Condition- A Case Study in Sikkim

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ABSTRACTS

The total cultivated area (80,000 ha) is covered using animate power sources in Sikkim. The average area dependable on a pair of bullocks is 3.36 ha. The rice (14,740 ha) is produced using traditional implements under animal based farming system. The average annual use of bullocks is 43 days and average custom hiring is performed for 28 days in terrace cultivation of Sikkim. The improved equipment for different unit operations was developed to enhance sustainable production of rice. For puddle seedbed improved wedge plough, wing plough, clod crusher-leveler-planker-puddler, peg type puddler and helical blade puddler were developed and evaluated in terrace condition and later these were promoted through frontline demonstration in different districts of Sikkim. The improved wedge plough and wing plough showed work rate of 0.025 ha/h and 0.02 ha/h respectively. The maximum puddling index was found for peg type due to more rotations of rotary resulting in to better churning in terrace condition. The other two improved puddlers e.g. improved helical blade puddler and clod crusher-leveler-planker-puddler showed work rate of 0.082 ha//h and 0.07 ha/h respectively.

Key words: *Animate, Annual use, Custom hiring, Performance index, Work rate, Churning*

INTRODUCTION

In India, agriculture is a way of life accounting for nearly 70% of the country's employment, about 14% of the GDP and nearly 20% of the export earnings. About 60% of net sown area is under rainfed agriculture where the gap between actual and potential productivity is quite large. The half of the total crop production is attributed by rainfed areas. The area under assured irrigation is less than 5% in the state of Sikkim. The net cultivated area of about 80,000 ha is covered using bullocks for different unit operations in terrace cultivation. The rice is sown in 14,740 ha in Sikkim and average yield is 1.53 t/ha. The maximum rice (5,500 ha) is sown in west Sikkim district. The total rice production is 22,690 tonnes in the state which is through use of traditional equipment and methods by taking two crops of rice in 60% of the net sown area being highly rainfall hill state. The traditional equipment commonly used in seedbed preparation on terraces was traditional plough of 12 kg weight and traditional leveler (*Dande*) of 20 kg weight. The rice crop grown in state was transplanted manually and weeding was also performed manually thrice in entire crop season. The local sickles were used for harvesting which showed work rate of 0.005 ha/h. Presently the seedbed is prepared using traditional plough (3 operations) followed using leveling by traditional leveler (2 operations) causing tremendous human drudgery in terraces of 2-4 m width and 10-30 m in length. The improved puddlers were developed considering criteria of light weight (less than 20 kg) which could be transported from one terrace to another conveniently. The unit cost of improved puddlers were also within affordable range (below Rs 5,000/-) of rice growers in Sikkim.

Some animal drawn improved puddlers were developed at AAU, Jorhat, OUAT Bhubaneshwar, TNAU Coimbatore, PAU Ludhiana & CIAE Bhopal for shallow puddling in rice cultivation such proven designs showed higher work (0.06-0.10 ha/h) rate and saved labour, time and cost of operation over traditional tillage practice existing in their respective region (Singh *et al.,* 1996). Gupta and Sinha (2000) evaluated different puddlers viz. triangular bladed puddler, straight rib puddler, rectangular angle bladed puddler, rectangular angle bladed puddler with an operator seat and disc harrow. The rectangular angle bladed puddler with an operator seat consisted of 225 x 140 x 3 mm rectangular blade and it showed maximum performance index (74 %) than other puddlers. Srivastava and Datta (2005) evaluated animal drawn improved rotary puddler under wet sandy loam soil conditions. The puddling index and draft requirement were 67.9% and 42.3 kg respectively. The cost of puddling for two passes was Rs. 224/ha. Das (2006) evaluated five bullock drawn puddlers viz. the implement factory puddler, the CAET puddler, the APAU puddler, the UP Agro Industries harrow-cum-puddler and the rotary blade puddler. The CAET puddler was found to be the best with puddling index of 83.10%, energy requirement of 4.38 kW/ha, field capacity of 0.14 ha/h, field efficiency of 70.19% and operating cost of Rs. 129/ha. The net energy saving per hectare for this puddler over the country plough was found to be 71.41%.

Dixit (2006) evaluated CIAE animal drawn peg puddler in respect of puddling quality and economic aspects under wet silt loam soil condition. The field capacity, field efficiency and cost of puddling were 0.10 ha/h, 71.42% and Rs. 182/ha respectively. Anonymous (2007) mentioned about the test trial of animal drawn improved lugged wheel puddler (size: 1020 x 1360 x 1200 mm), weight: 60 kg). The test of such puddler (working width: 1140 mm) showed work rate of 0.1 ha/h. The animal drawn *patella* puddler (weight: 40 kg) was developed at CIAE, Bhopal which showed draft of 600 N and effective field capacity of 0.15 ha/h. The equipment was found suitable for shallow puddling with higher mechanical dispersion of soil. The labor requirement and cost of operation were 7 man-h/ha and Rs. 185/ha respectively (Anonymous, 2008). The animal drawn improved puddler (size: 760 mm) with seat arrangement for operator and transport wheels was developed and evaluated in loamy soil. The draft requirement was 515 N which were within the draft ability of local bullocks. The specific energy of puddling was 8.64 kJ/m^3 which was much lower than mould board plough (Anonymous, 2009). The animal drawn improved puddler (IIT Kharagpur design) was evaluated by BAU Ranchi centre of AICRP on UAE which showed work rate of 0.10 ha/h and draft of 485 N. The use of puddler saved 60% in cost of operation over traditional practice of seedbed preparation in Jharkhand. The cost of operation was Rs. 357/ha (Anonymous, 2013).

MATERIALS AND METHODS

The cost effective animal drawn improved equipment for puddling were developed at College of Agricultural Engineering and Post Harvest Technology, Ranipool (Sikkim) with the objective to prepare puddle seedbed on terraces suiting to the local bullocks. The five improved equipment of wet tillage were improved wedge plough (weight: 10.7 kg size : 230 mm), improved wing plough (weight: 8 kg, size: 200 mm), clod crusher-leveler-planker-puddler (weight: 18.5 kg, size: 750 mm,), improved helical blade puddler (weight: 19.6 kg, size: 630 mm) and improved peg type puddler (weight: 12 kg, size: 700 x 785 x 953 mm) which were compared with traditional wedge plough (weight: 12 kg, size: 100 mm) for preparing puddle seedbed on terraces. The average of five readings of performance parameters related with equipment performance, soil, and bullocks were recorded. On the basis of evaluating existing traditional equipment [traditional plough followed by traditional leveler (*dande*)] which requires more labour and time (40-45% more); a light weight, reduced size puddlers were developed and tested for feasibility trials. In puddling operation traditional plough and traditional leveler showed work rate of 0.016 ha/h and 0.05 ha/h respectively. As per feedback from farmers in rice cultivated region of Sikkim, light weight, durable, cost effective and energy efficient improved equipment were developed and evaluated for their feasibility assessment. The improved wedge plough is an improved version of traditional plough made of mild steel which provides more working width 0f 230 mm. The improved wedge plough of 10.7 kg served the purpose of primary tillage to open hard pan up to 200 mm depth and it was also found suitable for shallow puddling up to 100 mm depth due to its light weight, higher work rate and durability. The observation were recorded related with soil and equipment which included size of terrace, total duration, soil moisture content (dry basis), speed of operation, working width, average depth of operation, and draft value (Table 1).

RESULTS AND DISCUSSIONS

The field capacity and cost of operation of wedge plough were 0.025 ha/h and Rs. 1500/ha respectively. The improved wing plough showed work rate of 0.020 ha/h in preparing the puddled seedbed in terrace condition. The cost of operation was Rs. 1875/ha as indicated in Table 1. The improved helical blade puddler was tested in terrace condition as given in Fig. 1. It showed work rate of 0.082 ha/h and cost of operation of Rs. 458/ha as shown in Table 2. The animal drawn improved clod crusher-leveler-planker-puddler showed low work rate (0.070 ha/h) and higher cost of operation (Rs. 536/ha) during puddling on terraces. The draft of improved helical blade puddler was 40.5 kg which was 5.5 kg less as compared to clod crusher-leveler-planker-puddler (Table 2).

Table 1: Comparative performance of animal drawn improved wedge plough and improved wing plough for puddling operation

S. No.	Parameters	Values	
		Wedge plough	Wing plough
1	Terrace area covered, ha	0.116	0.116
2	Depth of standing water, mm	58	60
3	Working width, mm	230	200
4	Average depth of puddling, mm	160	100
5	Speed of bullocks, km/h	1.83	2.0
6	Draft, kg	50	45
7	Effective field capacity, sq.m/h	0.025	0.020
8	Field efficiency, %	60	55.6
9	Puddling index	0.42	0.48
10	Performance index	0.60	0.68
11	Cost of operation, Rs./ha	1500	1875

Table 2: Comparative performance of animal drawn improved helical blade puddler and improved clod crusher-leveler-planker-puddler in puddling operation in terrace condition.

S. No.	Parameters	Values	
		Improved helical blade puddler	Improved clod crusher-leveler-planker-puddler
1	Terrace area covered, ha	0.15	0.15
2	Depth of standing water, mm	70	67
3	Working width, mm	630	750
4	Bullock speed, mm	2.25	1.83
5	Depth of puddling, mm	88	90
6	Draft, kg	40.5	46
7	Effective field capacity, ha/h	0.082	0.070
8	Field efficiency, %	57.9	51.0
9	Puddling index	0.51	0.48
10	Performance index	0.73	0.70
11	Cost of operation, Rs./ha	458	536

Fig. 1: Improved helical blade puddler and peg type puddler in operation

The animal drawn improved peg type puddler was developed for shallow puddling up to 100 mm depth (Fig. 2). The rotary of peg type puddler of 200 mm diameter was obtained by fitting square pegs of 10 mm size in four rows. Each row of rotary consisted of four square pegs. The low diameter (200 mm) of rotary provided more number of revolutions which helped for better churning of the soil. It was provided with platform of mild steel rods which floated behind the puddler to facilitate leveling operation in a single pass. Due to light weight, it was easy to turn at headlands and no fatigue symptoms of bullocks in terms of changes in respiration rate, pulse rate and body temperature were observed in continuous operation of three hours. The cost effective and energy efficient unit showed higher work rate of 0.094 ha/h and cost of operation of Rs. 417/ha. Its draft requirement was 30 kg which was 60% lower as compared to puddling (3 operations) by traditional plough (draft: 56 kg) as indicated in Table 3.

The ultimate aim of improved puddlers was its application on terraces due to its benefit of light weight, more working width and work rate for shallow depth of puddling. The peg type puddler showed higher work rate in preparing puddle seedbed ensuring saving in time of operation and cost of operation on terraces. The shallow puddling

Table 3: Comparative performance of animal drawn improved peg type puddler with traditional plough on terraces

S. No.	Parameters	Values	
		Improved peg type puddler	Traditional plough
1	Terrace area covered, ha	0.080	0.080
	Previous field operations	Ploughing by improved wedge plough & leveling by leveler (Dande)	Ploughing by traditional plough followed by lever (Dande)
2	Depth of standing water, mm	60	60
3	Depth of puddling, mm	100	180
4	Working width, mm	700	100
5	Draft, kg	30	56
6	Puddling index	0.58	0.38
7	Performance index	0.76	0.48
8	Effective field capacity, ha/h	0.094	0.018
9	Field efficiency, %	72	54
10	Cost of operation, Rs./ha	417	2084

depth (100 mm) could be achieved using improved puddlers. The puddling index and performance index was better for improved peg type puddler as compared to other puddlers/plough under investigation. The more number of rotation of rotor in case of peg type puddler resulted in better churning of soil as compared to helical blade puddler of bigger diameter. The puddled beds for wing plough and wedge plough were prepared by two operations and the output capacity of such plough in puddling was only 1/3 as compared to improved helical blade puddler and improved peg type puddler. The draft required was also minimum for improved peg type puddler and maximum draft (50 kg) was for improved wedge plough. The effective field capacity of improved wing plough was low (0.020 ha/h) due to its less working width (200 mm) compared to effective field capacity (0.025 ha/h) of improved wedge plough having working width of 230 mm.

The traditional plough used for test trial on terraces showed lowest work rate (0.018 ha/h) with draft requirement of 56 kg. For the average depth of operation (180 mm) traditional plough showed maximum draft value (56 kg) among tested puddling test trials. The improved helical blade puddler showed higher work rate (0.082 ha/h) and puddling index as compared to improved clod crusher-leveler-planker-puddler which might be due to rotary movement of helical rotor fitted with pegs resulting into better churning of soil. The draft of improved clod crusher-leveler-planker-puddler was higher (46 kg) as compared to improved helical blade puddler which could be due to no rotary arrangement and its bigger size.

The unit price of puddling equipment was no hindrance due to benefits of higher work rate and light weight. The cost of operation of improved wedge plough and improved wing plough were approximately 3-5 times as compared to improved helical blade puddler, improved clod crusher-leveler-planker-puddler and improved peg type puddler. The weight of improved wing plough and improved wedge plough were approximately half as compared to other improved puddlers. The command area per season of improved wing plough and improved wedge plough is just half (1.5 ha) as compared to other three improved puddlers.

CONCLUSION

The cost effective and energy efficient improved peg type puddler showed work rate of 0.094ha/h and cost of operation of Rs. 417/ha respectively. The puddling index (0.58) and performance index (0.76) were highest in case of puddled bed prepared by improved peg type puddler. Its draft requirement was 30 kg which was 60% lower as compared to puddling (3 operations) by traditional plough. The draft required was also minimum for improved peg type puddler and maximum draft value was for improved wedge plough. The performance indicators showed merits in all respect for improved peg type puddler over other improved equipment in wet tillage on terraces in Sikkim condition.

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Computerized Human Manikins for Development and Fabrication of Ergonomic Products - A Review and Concept for Comprehensive Software

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ABSTRACT

Farm mechanization has played a key role in increasing production and productivity of farm and farmers in the country with suitable farm equipment/ machineries for most of the unit farm operations. The developed farm equipment/ machinery are being used by the farmers, particularly men while women farmer are still in passive role in agriculture. This might be due to lack of addressing the gender issues in it. Attempt is being done at various research organizations but same could be more effective, if at source, the gender issues are being taken up. Use of human manikins is started in developed country on the basis of anthropometric data and interfacing with product/ work place during the design process. Scope of this technology can be effectively incorporated in developing farm equipment and thereafter its lab testing to produce gender-friendly farm equipment/ machines. Anthropometric data, physiological data, strength data, biomechanics, working environment and soil conditions may be integrated in developing comprehensive software attached with human manikin for development of ergonomic products and their fabrication. After that it may be linked with product manufacturing software for refining the product in gender perspective. This would have advantage of developing/ producing ergonomic farm equipment which will help in reducing the cost of cultivation by encouraging passive farm workers (women) to active mode.

Key words: *Human models, ergonomics, farm equipment, gender, virtual environment*

INTRODUCTION

Farm mechanization has played a key role in addition to other agricultural inputs for increasing production and productivity of farm and farmers in the country with suitable farm equipment/ machineries for most of the unit farm operations. The suitable farm equipment helps in improving the quality of life and respect in society with reduced drudgery in addition to timeliness of field operations and efficient uses of critical inputs. The Indian agriculture is powered by human beings (12.17 million kW), draft animals (20.01 million kW), tractors (102.18 million kW), power tillers (1.439 million kW), diesel engines (47.35 million kW) and electric motors (61.68 million kW) (Singh *et al.,* 2011). About 0.9 million pump sets 0.45 million sprayers & dusters and a large number of different types of agricultural farm tools & machinery are introduced annually (Anon., 2006). The adoption level of improved farm tools and equipment by the farm women was observed to be 4.87 per cent in Madhya Pradesh (Singh *et al*., 2006). As per Census 2011, farm workers are about 54.6% of total workers in the country. Of this, 37.1% are farm women. In agricultural activities, the role of women workers are passive in the use of machines as development of most of equipment was centered on male workers, even for those operations, which were traditionally performed by farm women and as a result these equipment are not found suitable by them. This might be due to lack of addressing the gender issues in it. Farm equipment and machines can be suitable for workers (both men and women) effectively by incorporating the latest techniques. The latest technique in this direction may be through human modeling solution which can create digital humans in a three-dimensional environment for analysis of a variety of ergonomic and human factors involved in human, machine and environment interface. In the present paper, discussion is on human manikins, human modeling tools, software programme for digital human models, CAD software, motion tracking device, human modeling in farm machinery, scope of computerized human manikins in ergonomic farm machinery and concept of comprehensive software for development of ergonomic product (farm equipment/ machine), fabrication and testing.

PRESENT LEVEL OF HUMAN MANIKINS

An ergonomic tool ‘human modeling’ is used to simulate workplaces in order to solve ergonomic related problems. This study includes different aspects of the human behavior and provides platform for area of new research. Use of human manikins is started in developed countries on the basis of anthropometric data and interfacing with product/work place during the design process. A manikin is a life-sized anatomical human model used in education. Three-dimensional, transparent model of a human being is also created and used for medical instructional purposes. Digital human modeling reduces the product design and manufacturing task cycle time by eliminating the need to construct physical setup. A digital human model is a virtual human in 3D space that can be moved and manipulated to simulate real and accurate movements of people and are meant to simulate human functions. This is basically a part of software programme.

In the early 1960s computer aided design (CAD) software became available, Hickey *et al.* (1985), and aerospace and automotive manufacturers saw the potential for much of the design process to take place in a virtual environment. Porter *et al*. (1990) stated that first Man, widely reported as the first human modeling tool, was developed by the Boeing Company in the late 1960s to assess pilot accommodation in aircraft cockpits and later became known as Boeman. They also stated that the development of CAD modeling software meant that designs could be created on a greatly reduced timescale, while at the same time allowing for the exploration of a wider range of design solutions. To support ergonomic analysis, Combiman could produce field of view plots and determine the reach of the pilot, taking into account the effect of clothing and harnesses. Furthermore, strength predictions could be made based on empirical data.

Porter *et al.* (1993) stated that digital human tools assist ergonomists to visualize human vehicle interaction which was earlier done by using physical mock ups which was time consuming and expensive process are now evaluated by digital human model tools. Integration of human factors which was earlier carried out in laboratories is replaced by digital humans interacting with machines in virtual environment. Hickey *et al*. (1985) reported survey of 30 human modelling tools which had a diverse range of uses, such as cockpit accommodation analysis and the modelling of humans in automotive accidents. It is further stated that the Boeman mannequin, had 23 joints and its size was based on anthropometric data for a 50th percentile man. The segment lengths could be scaled to any dimension, although the depth and breadth of the segments could not be changed. The input describing the mannequin and environment was entered in batch mode and the output was displayed on a plotter as graphics capable terminals were not common in the late 1960s. Using Combiman (As stated by Dooley, 1982 that further development of Boeman software for military aircraft design, evaluation and evolved into the Computerized Biomechanical Man Model), a mannequin could be created based on anthropometric data from six military databases.

In addition to the aviation environment, models have been developed to assist automotive design since the 1970s. One of the first was the Cybernetic man-model (Cyberman), which was developed in the 1970s by the Chrysler Corporation for the in house design and evaluation of automobiles (Das and Sen Gupta, 1995). Alternatively, a mannequin could be created by specifying 12 body dimensions. They further expressed to recognize the potential to accelerate the design process and at the same time optimize the human machine interface that was based on digital human modelling tools which emerged in the late 1960s in the automotive and aviation industries.

Kilpatrick (1970) made a first attempt to generate a computer model to predict seated postures during manual tasks and had a provision to scale by using anthropometric database existing at that time. Badler and Chaffin *et al.* (1993) stated that use of digital human model technology reduced cost and shortened time of making products as it helps in eliminating the need of physical prototypes and further testing. Bowman (2001) stated that this technology sets a way to initially check the rough designs which further helps to eliminate problems related to ergonomics. Abdel- Malek *et al*. (2006) had improved to make it realistic looking human graphic embedded in 3-D CAD system with deformable skin. Farrington *et al*. (2004) describes a new sweating manikin and a numerical model of the human thermoregulatory system that evaluates the thermal response of an individual to transient, non-uniform thermal environments. The physiological model of the human thermoregulatory system controls a thermal manikin, resulting in surface temperature distributions representative of the human body. The surface temperatures of the extremities are cooler than those of the torso and head. The manikin contains batteries, a water reservoir, and wireless communications and controls that enable it to operate as long as 2 hours without external connections. The manikin has 120 separately controlled heating and sweating zones that result in high resolution for surface temperature, heat flux, and sweating control. The physiological finite element model uses approximately 40,000 solid thermal and blood network elements to represent the human body. The manikin and physiological model demonstrate their value in evaluating the thermoregulatory response of a person in a protective uniform. They can also be used to evaluate the effectiveness of personal cooling systems.

Rugh and Lustbader (2006) presented the results of validation testing of NREL's thermal comfort tools indicate the manikin with physiological model control yields human-like skin temperature distribution. Comparison with subject data shows the predicted skin temperature distribution of the manikin and model is similar to that of the human subject except for the hand and foot. The manikin and subject data were used in NREL's VCCL to assess the impact of an automotive ventilated seat on thermal comfort and fuel economy. Results show an improvement in thermal comfort with the ventilated seat. This yields a potential 7% reduction in A/C compressor power and 7.5 % reduction in vehicle fuel use. Conti and Erlandson (2009) have assessed the different DHM fidelity levels which can be used as Low Fidelity Model (which uses a generic manikin created in DHM Software without any anthropometric modifications), Medium Fidelity Model (which represents a specific person and the manikin is created from DHM software with anthropometric measurement modifications.), High Fidelity Model (which is representing a specific person and their specific motions). The manikin is created from laser body scanning and motion from motion tracking equipment and Super-High Fidelity Model which would be model that would be used in the movie industry representing a specific person and their very specific motions and facial.

Medland *et al*. (2009) stated that manikin can be instructed to undertake a range of activities extending from simply that of pointing at an object through to gripping, such as occurs when a manual powered wheel chair is in use. Digital human model software is used in a variety of fields, automotive, aerospace, military, clothing and uniform design, heavy machinery (earth movers/mining equipment/ etc.), boats, cruise ships, cargo ships, locomotives, and many others (Anon., 2010a; Anon., 2010b; Anon., 2010c). The different DHM software programs all have typically the same functions and capabilities. A list of the most common capabilities and functions which they contribute to (i) the ability to create customizable 3D manikins; (ii) the ability to move the manikins in predefined motions; (iii) reach analysis; (iv) posture analysis; (v) push/pull analysis; (vi) carrying analysis and (vii) rapid Upper Limb Analysis based motion (RULA).

MODERN HUMAN MODELING TOOLS

There are many different type of digital human model software programs which are commercially available for ergonomic analysis, human factors analysis, processing, and timing versions are included in Computer Aided Design (CAD) systems, while others are full stand-alone versions that rely on CAD and Computer Aided Engineering (CAE) systems for all other objects, or the virtual environment (VE), the 3D manikin and the motion are created in the software, but the vehicle geometry is imported from a CAD or CAE system. Depending on the user-set parameters for the analysis, the different colour bands on the arms, legs, and torso convey information such as muscle exercitation, angular displacement, or whatever physical parameter is being analyzed for being a safe posture. The widely used modern human modeling tools used for ergonomic analysis are MannequinPro, Jack, RAMSIS, Safework and SAMMIE. MannequinPro is a PC based human modelling tool available since 1990. Mannequins can be created based on a range of percentile statures from 2.5 to 97.5 percent. The mannequin's joints have a realistic range of motion. A range of ergonomic assessment tools are available, such as the graphical display of field of view and reach envelopes, along with the ability to calculate joint forces.

Jack (originally called Tempus) was developed at the Centre for Human Modelling and Simulation at the University of Pennsylvania in the mid 1980s (Philips *et al.,* 1988). This was initially developed for the analysis of human machine interfaces (Badler *et al*., 1993). The main impetus for the development of Jack was to support the design and development of workspaces, with the emphasis on optimizing the human machine interface. Realistic anthropological mathematical system for interior comfort simulation (RAMSIS) was developed in year 1980 as a co-operative arrangement between German automobile manufactures, Tecmath and the Technical University of Munich, Germany (Chaffin *et al*., 2001). It is used extensively in the automotive industry for the design of vehicle interiors and exteriors.

Safework is also widely used in the automotive, manufacturing and defense industries and this was originally developed at the Ecole Polytechnique, Canada, in the 1980s and is now developed by Dassault system's (Chaffin, 2001). System for aiding man-machine interactive evaluation (SAMMIE) was originally developed at the University of Nottingham and subsequently at Loughborough University (Porter *et al*., 1990). The model has been applied to a diverse range of problems in areas such as tram driver workstation and aircraft cockpit design. These tools have complex kinematic linkages that closely resemble the human skeletal structure, joints that obey physiological range of motion restrictions and a geometric shell which closely resembles the human shape (Raschke, 2004).

DIGITAL HUMAN MODEL (DHM) SOFTWARE PROGRAMS

Computer software used to generate the human models, now called computer manikins, was complemented with algorithms for ergonomics evaluations. The major digital human model (DHM) software programs available are Delmia, Tecnomatix, RAMSIS, SantosHuman and HADRIAN & SAMMIE. Delmia – Dassault Systemes is widely used in industrial manufacturing and product design in multiple industries including: automotive, aerospace, defense, heavy machinery, etc. In the automotive industry, it is used in the complete life-cycle of the vehicle (Concept, Product Design, Product Assembly and Product Servicing). Tecnomatix – Siemens, like Delmia, is widely used in industrial manufacturing and product design in multiple industries including: automotive, aerospace, defense, heavy machinery, etc. Its capabilities and uses closely mimic Delmia's. An important historical note though: Tecnomatix is based on the first DHM program designed and used for NASA in the early 1980's called JACK. RAMSIS – Human Solutions GMBH is very impressive and can be incorporated inside Dassault system's program CATIA (RAMSIS does not have its own CAD system). The digital human models created by RAMSIS appear to be much more user-friendly, easier to control, and can be manipulated and constrained faster than in Delmia.

Santos Human Inc. are high-fidelity models using biomechanics, physics optimization, and clinical evaluation to simulate human activities with ergonomic analysis, human performance, human performance analysis, and human systems integration with predictive posture analysis (Anon., 2010b). Human Anthropometric Data Requirements Investigation and Analysis (HADRIAN) are a 3D human modeling and task analysis tool that works together with SAMMIE. This is to develop the products that meet the needs of people with disabilities and the elderly (Marshall *et al.,* 2009).

It was initially developed to support the design of kitchen and shopping based tasks for people with disabilities and the elderly, but has evolved to include transport related tasks (Porter *et al*., 2008). SAMMIE is also a DHM system, but specializes in the assessment of driver's seat adjustability ranges, visibility of controls and displays.

MannequinPRO from NexgenErgo NexGen Ergonomics, Canada is also available to construct mannequins corresponding to the 5th, 50th and 95th percentile values of anthropometric data (Anon. 2013c). The firm_has also come up with their two models of Human CAD i.e. Human CAD2 and Human CAD 2 Modules. Human CAD 2 aids users with the design of products and workplaces by determining what humans of different sizes can see, reach, or lift. Ergonomic evaluation tools provide data on potential injury risk and postural analysis. Other human factor tools aid in the determination of reach, vision, comfort and fit requirements. In addition to basic functions of DHM software like, creation of a virtual human, building a virtual environment, appropriate posture to model and its interface to product or workplace, vision analysis, reach (horizontal and vertical) analysis and seating accommodation, the software has also other functions for comfort/discomfort analysis, fatigue analysis, posture analysis, lower back analysis, metabolic energy expenditure, static strength prediction etc.

There are many CAD software programs on the market that have the capabilities of creating basic Digital Human Models and performing simple motion and reach studies, but their DHM capabilities are limited. CAD software is needed for creation of other objects for placement in the DHM specific software, such as wheelchairs and other ATs, office equipment, or factory equipment. The CAD systems that are most widely used are CATIA UG (Unigraphics), and ProE. Most widely used motion tracking systems are Functional Assessment of Biomechanics (FAB) System–Biosyn Systems Inc and Flock of Birds (FOB)–Ascension Technology Corporation which are suitable for application to the target population. Both are having similar systems.

HUMAN MODELING IN FARM MACHINERY

Deisinger *et al.* (2000) carried out a pilot project (with collaboration of John Deere Company in Mannheim, Germany) for analysis of reach envelope, visual field and force isodyne using ERGONAUT tool in a Virtual Environment (VE) for analysis of virtual and real data in a mixed mock-up. Gao *et al*. (2008) proposed that using the open database interface procedure in CATIA to establish human body database which designs in view of the farm machinery design, and reading the human body data to Ergonomics module of CATIA can product practical application hypothesized person, using Human Posture Analysis and Human Activity Analysis module analysis the Ergonomics in farm machinery, thus a new analysis farm machinery ergonomics method can be realized.

Fathallah *et al*. (2009) investigated the abilities of varying anthropometric characteristics of youth operators to reach farm tractor controls by using SAMMIE CAD. Ying *et al*. (2010) designed tractor cab and a combine harvester cab using OpenGL 3D computer graph software. The cabs were evaluated by a manikin of 50th percentile for various hand and foot controls using virtual environment through the mixture of OpenGL and Multigen Vega Prime. Wu *et al.* (2012) studied the human factor related problems of the power carrier through computer-aided simulation analysis technique to assess the issues regarding controllability of driving, driver's degree of comfort in driving, and the lumbar force condition of the operator while lifting cargo from the cargo bench of the carrier. Human models of 5th, 50th, and 95th percentile male and female, respectively, were developed with Jack. The digit human models were integrated with the imported power carrier models to form "human-machine models" in vehicle-driving operation. Results showed that the present design assures satisfactory driving controllability for all ranges of drivers, both male and female. However, the present design seemed to be too confined for most operators, especially for the larger ones. Set the driver's seat and the driving handles backward 10 cm can improve this problem to allow all but the 95% male workers to operate the carrier comfortably. Lifting cargo weighted under 25 kg can assure that the worker's lumbar force will not exceed the safety limit, 3400 N, defined by the NIOSH, US, for all range of workers. Raising the height of the present cargo bench 4 cm will further reduce the lumbar force. The machine and the human computer models can be used for future ergonomic study of the power carrier.

Dooley (2012) discussed about physical and cognitive aspects of ergonomics in modern product development including agricultural vehicle. He inserted digital manikin in operator workplace (seat) and prescribed the relationship of pedals and steering wheel to floor and seat index point. Anonymous (2013a) investigated agriculture worker-tractor interfaces for safe tractor operation, using three-dimensional human and tractor-scan information during period 2000-2003. Specifically, the project developed approaches to quantify 3-D human shapes and sizing information for assessing machine and equipment accommodation level, representative human body models for machine design applications, and anthropometric criteria for the design of farming tractors and rollover protective structures (ROPS) to increase the safety of farming-tractor operation. The research results were shared with the SAE J2194 standard committee for possible revisions to the tractor-cab-dimension standard, which will have a potential impact on the design of next-generation tractor cabs for better protection of tractor/farming machine operators. In another project, NIOSH studied hand anthropometry of workers for designing better fitting protective gloves during the period 2001-2006 (Anonymous, 2013a). It collected and analyzed hand anthropometry of male and female meat processing workers measured at a pork processing plant in the United States, with an emphasis on the Hispanic subsample in the study population.

SCOPE OF COMPUTERISED HUMAN MANIKINS IN ERGONOMIC FARM MACHINERY

The ergonomics word comes from the Greek word, 'ergos' mean work and 'nomos' mean natural law which can be briefly defined as a branch of the science of work (of the people who do it and the way it is done, tool and equipment they use, the places they work in, and the psychosocial aspect of the working situation), Pheasant *et al*. (2006). Contini and Drills (1966) defines biomechanics as the science which investigates the effect of internal and external forces on human and animal bodies in motion and at- rest.

Ergonomical considerations in the design of agricultural tools and equipment started in the country in late sixties/ early seventies in the academic organizations (Datta, 1979) and to upgrade the faculty/scientist engaged in academic and research organizations, a faculty programme in human engineering covering all aspects was organized by Punjab Agricultural University (PAU), Ludhiana (Anonymous, 1979). Addressing the female worker in agricultural work was started by Nag and Chatterjee (1981). Rahman (1993) stated that many agricultural projects aimed at men with the assumption that they will somehow automatically benefit women. Since year 1996, Council has established an AICRP on Ergonomics and Safety in Agriculture at CIAE, Bhopal with number of cooperating centres and National Research Centre on Women in Agriculture (presently Directorate) at Bhubaneswar. Ergonomics study w.r.t. gender perspective are mainly on development, modification, refinement and evaluation of farm tools and equipment, collection of anthropometric & strength data, safety devices, occupational health hazard, aerobic capacity, bio-mechanic and subjective evaluation related to posture, injury, safety etc (Singh *et al*., 2007; Moharana *et al*., 2011 and Anonymous, 2013b). An empirical equation has also been developed. Gite *et al*. (2009) compiled the anthropometric data (75 body dimensions and 4 skin folds) of 12525 farm workers (64.1% male & 35.9% female) from 12 states and 16 strength parameters for 5937 farm workers (57.7% male & 42.3% female) from six states. Considerable amount of ergonomics related work is also being carried out in an AICRP on Home Science through its nine co-operating centres (Anonymous, 2012).

The review on digital human models indicated very less or few attempts have been made to use DHM and latest techniques in ergonomic farm machines. The available software is mostly on the parameters and data of the developed countries where it was developed while number of studies has been conducted in the country. The computerized human manikins and software needs to be developed based on the Indian data.

CONCEPT OF COMPREHENSIVE SOFTWARE

As per the review, it is observed that the digital human models and software are available. Digital human models can be suitably incorporated as per the available anthropometric data on various percentiles. The software available for comfort/ discomfort analysis, fatigue analysis, posture analysis, lower back analysis, metabolic energy expenditure, static strength prediction etc is need to be revised/ modified based on Indian data so open ended software may be needed or develop the new software. As per the review, no software was found for soil condition and working environment. Keeping this in view, a comprehensive software including DHM and its linking to product making CAD software, need to be developed for quality research work on farm machinery ergonomics including tractor and combine workplace as rightly pointed out by Axelsson (1995) and Eklund (1995) that product quality has degraded to the extent of 30-50% to the total quality resulted due to ergonomic related problems, therefore, tools like human model have been introduced in the design process to facilitate an effective production. The path for making comprehensive software is shown in Fig. 1.

In the figure, the arrow coming 'out' from the box indicates towards desired output while arrow coming 'in' to box indicates towards relook of certain parameters. The ultimate output of the comprehensive software would be the gender-friendly ergonomic product (farm tools/ machines) from virtual environment which may lead to comfort of the workers. A protocol for each parameter related to human manikins, farm machines and evaluation (working environment & field/ lab analysis) will be needed to develop for success of this concept. All the analysis will be based upon different algorithm which will be derived from statistical model. Implementation of the concept could be met by formation of a group of team comprising of statistician, software developer, and private party of ergonomic equipment and ergonomic research to make the comprehensive software compatible for the purpose as per the shown pathway. The fidelity of the developed software will depend on its use by the research and academic scientists with their field data.

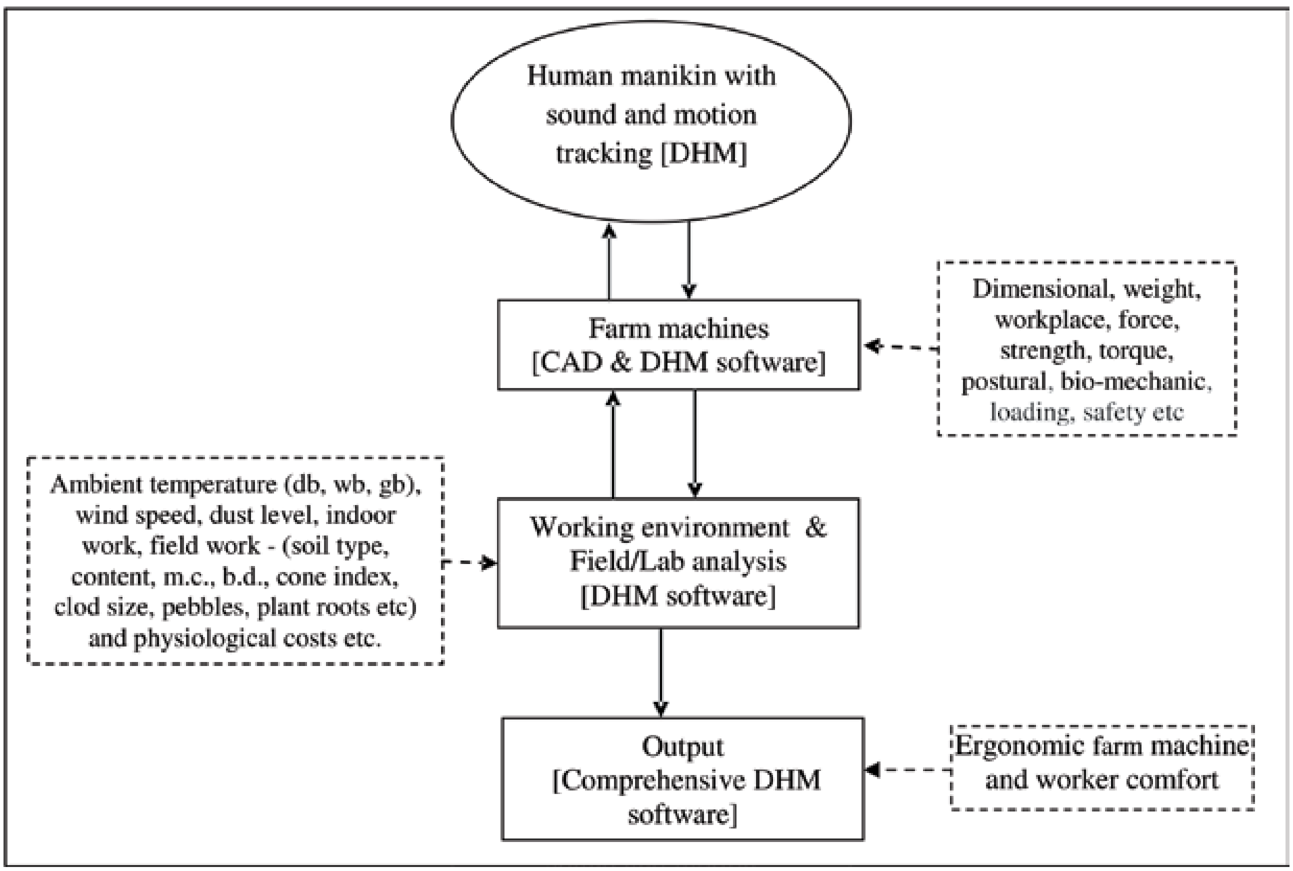

Fig. 1: Pathway for development of Comprehensive Computerized Software of manikins.

CONCLUSIONS

The use of comprehensive software for developing ergonomic farm tools and machines with digital human manikins having sound and motion tracking system will be a new researchable area which enable academic and research scientists/teachers in a new dimensions of a virtual environment.

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