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Workplace Design of Selected Rice Transplanters for Farm-women Operators

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ABSTRACT

Background: Modern self-propelled devices consider human factors such as space constraints, control placement, line of sight, comfort and ease of operation. These factors are linked to the operator's anthropometric and biomechanical parameters. Effective human-machine interface design can enhance productivity, comfort and safety.

Methods: An anthropometric survey was conducted among 450 female agricultural workers across three zones of Kerala. The dimensions and clearances of the operator workplace for a selected transplanter were measured based on the seat index and reference points. The data were compared with the anthropometric dimensions to assess the suitability of the transplanters for women operators.

Result: Based on the anthropometric data and spatial requirements, seat designs were proposed for Yanji and Redlands transplanters. Recommendations for the operator's seat include a 39 cm backrest height, 38 cm bottom width, 18 cm open area, 40 ± 3.4 cm length, 43 cm top width, 10 cm seat cushion height and 8 cm backrest cushion height. A 35 cm diameter circular seat is recommended for the helper.

Key words: Anthropometry, Empowerment, Human factors, Rice-transplanters, Seat-design.

INTRODUCTION

Kerala, known for its lush greenery and extensive rice fields, has seen a decline in rice production since the 1980s. The reduction in rice land, from 0.85 million ha in 1980 to 0.093 million ha in 2021-22, poses challenges for farmers who are now turning to other crops, potentially impacting food security (Agriculture Statistics and Paddy Outlook, 2022). Also, Women agricultural workers, integral to the workforce, endure strenuous manual tasks, such as transplanting rice seedlings. This labor-intensive work puts them at risk of health issues and despite being essential, their efforts often go unpaid (Potdar *et al*., 2020; Tamilselvi and Anantha Krishnan, 2016). To alleviate their burden and enhance efficiency, providing farm women with increased access to rice transplanters is crucial. To address these issues, there is a growing reliance on advanced agricultural machines, including imports from other nations. However, the shift to modern equipment may overlook ergonomic considerations, affecting operation efficiency, operator safety and comfort (Sam, 2013; Kamendra *et al*., 2022). Efforts by ICAR institutes and various organizations aim to develop and implement improved paddy transplanters, specifically designed to relieve women from agricultural labor (Mohanty *et al*., 2012; Gayathri and Sam, 2017). However, research indicates that transplanters primarily designed for male workers may not be suitable for women operators, emphasizing the importance of ergonomic considerations (Dewangan, *et al*., 2010; Syuaib, 2015).

Incorporating human aspects into design improves operator efficiency, comfort and safety. Control, visualand spatial requirements are functional factors in operator workspace design. The operator's anthropometric and biomechanical characteristics affect these factors. The operator's workstation is designed using anthropometric data to meet visibility and clearance requirements (John *et al.*, 2004). Anthropometric considerations in equipment design improve performance, efficiency, safety and comfort and prevent work-related injuries and accidents. Gender, race, ethnicity and age significantly impact anthropometric measures (Pheasant, 2003). Efforts are being made to collect anthropometric data in India by a few researchers and the dimensions included were specific to the Indian male agricultural workers (Dewangan *et al.*, 2008; Gite and Majumder, 2007; Ratn *et al.,* (2010); Agrawal *et al.*,

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2011, Vyavahare and Kallurkar, 2016). As far as the Indian female workers are concerned available information suggests that steps have been initiated only recently (Dixit and Namgial, 2012). In these studies, they conducted an anthropometric survey of India's Western and Northeastern (NE) regions. However, there is a lack of anthropometric data on the female population of this southern-western region. A little work observed in this region, Sam, (2013) collected 29 body dimensions and 1 strength parameter from 120 female agricultural workers.

Given the aforementioned, the present study aimed to (1) collect anthropometric data of women agricultural workers in SW Kerala to design and modify their workplace and equipment. (2) establish important anthropometric measurements for selected rice transplanters and compare them to male and female agricultural employees. (3) comparing selected rice transplanters' spatial and control requirements to IS and ISO redesign criteria based on anthropometric data and questionnaires.

MATERIALS AND METHODS

The study, conducted in 2022 at Kelappaji College of Agricultural Engineering and Technology, KAU, Tavanur, involved collecting anthropometric data from 450 women agricultural workers aged 18-60 from the northern, central and southern zones of Kerala, following the recommendations of AICRP on ESA, Bhopal. A sample of 150 women from each zone was selected and 79 physical measurements were recorded to aid ergonomic agricultural machinery design, including age, weight and strength. Of these, 49 measurements were taken while standing, 8 height and 8 transverse measurements while seated and 14 measurements were obtained in both positions, following the NASA 1978 anthropometric handbook standards. Body dimensions and strength were measured using the Integrated Composite Anthropometer (ICA) (Tewari *et al*., 2007), weighing scales, dynamometers and pinch gauges. Precautions were taken to avoid errors during measurement. Data were analyzed in Microsoft Excel, with adjustments for any errors. Descriptive statistics, such as minimums, maximums, means, standard deviations, standard errors and percentiles, were determined for body dimensions and strength. An unpaired Student's t-test compared body proportions between male and female transplanting agricultural workers.

Spatial and control requirements of selected rice transplanters

As demonstrated in Plate 1, this study used Yanmar, Redlands and Yanji self-propelled rice transplanters. These rice transplanters were ergonomically assessed with ten women subjects, based on age and anthropometric measurements that satisfied statistical standards from the study region's database. The ten participants were examined for normal health using blood pressure, electrocardiogram and bio-clinical analyses.

Participants were equally trained in operating the selected rice transplanters. The ergonomic evaluation was carried out by Gayathri and Sam (2017). During the

Plate 1: This study used (a) Yanmar, (b) Redlands and (c) Yanji 8-row self-propelled rice transplanters.

Table 1: Analyzed anthropometric data of female agricultural workers of SW-region-(Kerala), India.

Dimensions	Mean	Max	Min	SD	SEM	CV(%)	Percentile	
							5th	95th
Age	34.8	58	18	10.04	0.47	28.8	20	51.4
Weight	52.5	84.8	16.8	10.34	0.49	19.7	38	72.0
Stature	152.4	183.3	136	6.26	0.30	4.1	142	163.0
Vertical reach	194.2	233.6	170	8.01	0.38	4.1	181.8	208.6
Verticalgrip reach	185.6	224.7	163.5	8.16	0.38	4.4	173	199.3
Eye-height	143.9	184.8	124	8.17	0.39	5.7	132	159.3
Acromion-height	128.5	169.7	112	7.52	0.35	5.9	117	142.0
Elbow-height	96.8	138.9	80.2	7.48	0.35	7.7	86.0	110.1
Olecranon-height	95.3	132.9	84.0	6.88	0.32	7.2	86.2	108.4
Illio-crystale height	90.1	130.6	79.0	6.99	0.33	7.8	81.0	102.6
Illio-spinal-height	84.2	123.8	73.1	6.98	0.33	8.3	75.1	96.7
Trochanteric-height	77.7	119.6	66.6	6.98	0.33	9.0	68.6	90.2
Metacarpal-III height	62.2	105.6	51.1	7.07	0.33	11.4	53.1	74.7
Knee-height	41.7	86.9	30.6	7.16	0.34	17.1	32.6	54.5
Waistbackplength	40.3	56.2	6.2	5.18	0.24	12.9	32.0	49.6
Scapula to waist back length	52.7	80	34	6.61	0.31	12.5	44.0	64.2
Wall to acromion distance	8.9	85	6	5.29	0.25	59.7	6.50	12.0
Arm reach from wall	79.2	92.3	65	5.33	0.25	6.7	72	89.4
Biacromial breadth	29.3	47.6	17.1	4.07	0.19	13.9	24.5	38.0
Bideltoid breadth	35.8	54.1	23.6	4.07	0.19	11.4	31	44.5
Chest breadth	26.3	45.6	11.5	5.92	0.28	22.6	19.5	35.6
Chest depth	22	39	14	3.77	0.18	17.2	16.5	28.7
Interscye breadth	30.1	84	22	4.51	0.21	15.0	25	37.5
Waist breadth	31	45	21	5.48	0.26	17.7	22.8	42
Hip breadth	36	50	26	5.48	0.26	15.2	27.8	47
Wall to lumbo sacral joint distance	5.2	12	2.5	1.20	0.06	23.1	3.5	7
Abdominal extension to wall	24.5	43	15	4.41	0.21	18	17	33
Chest-circumference	84.3	109	60	9.32	0.44	11.1	70.5	101.3
Waist-circumference	85.3	112	58	11.65	0.55	13.7	64	104.4
Thigh-circumference	42.2	63	27	6.22	0.29	14.8	32.1	53.5
Calf-circumference	31.2	41	19	3.59	0.17	11.5	26	38.0
Wrist circumference	15.5	21	11	1.56	0.07	10.1	13	18.0
Vertical grip reach sitting	112.9	151.8	95.6	7.94	0.37	7.0	100.8	126.9
Sitting height	79	110.5	61.6	7.60	0.36	9.6	68.1	92.1
Sitting eye-height	72.5	100	55.1	7.42	0.35	10.2	62.2	85.8

Table 1: Continue....

Table 1: Continue....

Sitting acromion height	60	90.6	41	8.83	0.42	14.7	49	75.4
Elbow rest height	27.1	58.6	15	6.29	0.30	23.2	19	39.8
Thigh clearance height sitting	17.8	39.9	10	4.94	0.23	27.7	11.9	27.1
Knee-height sitting	46.3	77.3	28.4	7.63	0.36	16.5	35.6	59.6
Popliteal-height sitting	37.1	68	19.8	7.60	0.36	20.5	26.2	50.3
Coronoid fossa to hand length	36.9	44	3.5	3.20	0.15	8.7	33.1	41.6
Buttock-knee length	52.7	61.3	37	3.51	0.17	6.7	47	58.1
Buttock-popliteal length	45.1	54	33	3.38	0.16	7.5	39.5	50.5
Abdominal-depth sitting	25	38	13	5.16	0.24	20.7	15	33.5
Hip-breadth sitting	34	52	21.5	5.03	0.24	14.8	26	41.5
Elbow-elbow breadth sitting	39.8	52.1	26	5.64	0.27	14.2	29.7	48.5
Knee-knee breadth	18.9	27.6	10.2	3.78	0.18	20	13	25.2
Functional-leg length	93.6	110.7	72	7.53	0.35	8.0	82	106.5
Thumb-tip reach	69.4	85	54	5.75	0.27	8.3	57.2	78.0
Shoulder-grip length	64.1	78.8	44.2	7.09	0.33	11	50	73.6
Elbow-grip length	37.7	55.3	26.5	5.27	0.25	14	29.6	44.0
Hand-length	16	18.9	11.7	0.80	0.04	5.0	14.9	17.5
Forearm-hand length	42.7	49.6	37	2.49	0.12	5.8	39	47.7
Handbreadth-across thumb	8.6	93	4.6	4.17	0.20	48.5	6.9	10.8
Handbreadth at metacarpal-III	7	9.2	5.3	0.63	0.03	8.9	5.8	8.3
Hand-thickness at metacarpal-III	2.1	3	1.3	0.30	0.01	14.6	1.6	2.7
First phalanx digit-III length	5.3	10	1.6	0.82	0.04	15.3	4.2	6.5
Palm-length	8.5	12.1	4.3	0.99	0.05	11.6	5.9	9.8
Inside-Grip-diameter	4.3	6.3	2.6	0.70	0.03	16.3	3.3	5.7
Outside-Grip-diameter	8.2	10.6	4.5	1.08	0.05	13.3	6.2	10
Middlefinger palm grip-diameter	2.8	3.8	2.3	0.36	0.02	13.0	2.4	3.5
Grip-span	7	13.3	4.5	1.4	0.07	20.1	5.5	10.2
Maximum-grip length	11.7	16.5	5.7	1.91	0.09	16.3	7.8	14.6
Index-finger diameter	1.3	2.2	0.9	0.34	0.02	25.7	1	2.0
Span	160	185.5	148	7.36	0.35	4.6	149.8	173
Span-akimbo	86.3	105	71.6	6.32	0.30	7.3	76	96.0
Foot-length	22.3	29	15.2	1.7	0.08	7.6	20	25.1
Instep-length	16.9	23.7	9.9	1.74	0.08	10.3	14.2	20.3
Foot-breadth (ball of foot)	8.4	13.2	4.6	1.46	0.07	17.5	5.3	10.0
Heel-breadth	6	9.5	3.2	1.3	0.06	21.7	4	8.5
Medial-malleolus height	7	9	4.6	0.73	0.03	10.5	5.7	8.1
Lateral-malleolus height	6.2	9.5	3.8	0.76	0.04	12.3	5.1	7.5
Bimalleolar breadth	6	9.3	4.5	0.87	0.04	14.4	5.0	8

Table 1: Continue....

Table 1: Continue....

Head-length	17.8	24.8	12.5	2.42	0.11	13.6	14.0	22.6
Head-breadth	14.5	19.8	8.7	2.69	0.13	18.6	9.9	18.8
Menton to top-head	19.6	23.6	15.6	1.4	0.07	7.2	17.8	22.3
Bicep skinfold	0.4	3.1	0.1	0.34	0.02	86.9	0.1	1.3
Tricep skinfold	0.9	2.2	0.2	0.31	0.01	35.2	0.4	1.4
Subscapular skinfold	1.5	2.9	0.5	0.54	0.03	35.1	0.5	2.4
Superailiac skinfold	1.7	2.8	1.0	0.40	0.02	23.7	1.2	2.4
Right-hand push strength (sitting)	34.7	46	15.3	4.90	0.23	14.11	28.4	41
Right-hand pull strength (sitting)	43.2	57	16	8.73	0.41	20.21	27	55
Maximum right foot strength (sitting)	41.6	59	25.6	7.71	0.36	18.55	29	51
Right-hand push strength (standing)	53.1	89	16	18.08	0.85	34.07	25	78
Right-hand pull strength (standing)	46.6	85	15	16.38	0.77	35.17	23	75.4
Push-strength (both hands) standing	45.3	65	33	7.04	0.33	15.56	35	58
Pull-strength (both hands) standing	70	100	40	16.94	0.80	24.19	40	95
Hand-grip strength (right hand)	22	33.0	10	5.34	0.25	24.33	11.6	31
Hand-grip strength (left)	21.9	37.4	10	4.96	0.23	22.70	13.5	29.9
Pinch-strength	2.4	7.2	1.2	1.02	0.05	42.59	1.5	4.7

Measurements are in cm until otherwise specified. Min = Minimum, Max = Maximum, SD =Standard deviation, SEM = Standard error of mean, CV = Coefficient of variation.

operation, the operator performs multiple tasks like steering, observing the operation and controlling various parts. The tasks and workplace determine the postures and loading patterns of the body structures. After the experiments, participants provided feedback through a questionnaire, which considered workplace dimensions, controls and operations, visual requirements and the working posture of the operator.

The operator workspace dimensions and clearances of a chosen transplanter were measured using the seat index point (SIP) and seat reference point (SRP). The SIP is the point of interaction between a human torso and thighs through the center line of the seat's hypothesized pivot axis. The SRP is the location where the lower backrest's tangential plane and a horizontal plane cross in the central longitudinal plane of the seat. The SIP is situated 90 mm above and 140 mm in front of the SRP. In Tables 3, 4 and 5, geometric parameters and clearances of all selected rice transplanters were listed. The machine's suitability for women operators was checked by comparing measured values to anthropometric dimensions. Table 3 and 4 contain geometric parameters and clearances for all selected rice transplanters and anthropometric dimensions were used to determine the machine's suitability for female operators.

RESULTS AND DISCUSSION

A statistical analysis was performed on 450 female anthropometric data from Kerala. Table 1 shows the minimum, maximum, mean, SD, SEM, CV and 5th and 95th percentiles of 76 body dimensions and ten strength metrics, including age and body weight. The analysis is important to ensure equipment is designed with utmost precision due to significant variation in body dimensions among participants. Female individuals ranged in height from 136 to 183.3 cm, averaging 152.4 cm. Certain bodily measurements exhibit higher SEM and CV%, indicating increased variability among individuals. This variability can be advantageous while designing agricultural equipment, as it allows for the consideration of the 5th and 95th percentiles.

Table 2 shows significant differences in body dimensions between male and female agricultural workers in Kerala, India, except for waist, hip, sitting acromion, thigh clearance and elbow rest height. Rice transplanters must be designed for both genders to reduce discomfort for female workers. Lee (2000), Dewangan (2008) and others compared female agricultural workers' body measurements from North-East India and eight other countries. They found that Colombian and US women have similar physical measurements. However, Indian farm-workers need to adapt foreign tools and machinery, as they are designed based on foreign worker body measurements.

Participants were asked about the needs of rice transplanters after trials. Yanmar was comfortable and adjustable, but its platform was harder to access in muddy fields. Women operating Yanji and Redlands complained about seat and backrest dimensions. The backrest should support the upper lumbar area (Mehta, 2000), but had no vertical adjustment and was too short. However, hand and foot controls were within reach due to longitudinal seat adjustment and operating all controls required little force. The visibility criteria were met by upright sitting with simple head and upper body motions from front to side in chosen transplanters. The Yanmar transplanter's rear-view mirrors showed the backside transplanting region. Redlands and Yanji transplanters feature assistance on both sides and provide rear-view information. The display was likewise close to the operator's view, requiring minimal eye movements. Yanji and Redlands transplanters made greater noise and vibration, according to subjects. Working with chosen transplanters was more uncomfortable after 11 AM than before 9 AM (Gayathri and Sam, 2017). Each transplanter's workspace dimensions were measured from the operator seat index point to the machine controls. Table 3 and 4 display spatial dimensions for the operator seat index (SIP) and seat reference point (SRP) of selected rice transplanters, as described in ISO-5353(1984).

Table 3 shows, Yanmar self-propelled transplanter has a standard backrest width of 40 cm (bottom) and 25 cm (top). This falls within the 5^{th}-95^{th} percentile for female agricultural workers in study region. Seat pan width is 44 cm which is wider than the 95th percentile hip breadth of 41.5 cm. The adjustable seat makes it comfortable for all operators to sit and ride the transplanter. Transplanter's footrest-to-seat pan distance was 35 cm. Sitting women agricultural workers had 5^{th} percentile popliteal height of 35.4 cm. Thus, Yanmar transplanter operators found the

Table 2: Variation of anthropometric data between male and female agricultural workers of SW region (Kerala) India.

Dimensions	Female (n=450) Mean (SD)	Male (n=90)[a] Mean (SD)
Weight, Kg	52.5 (10.34)	62.2 (9.5)**
Stature	152.4 (6.26)	163.5 (7.1)**
Vertical-reach	194.2 (8.01)	209.9 (9.9)**
Verticalgrip-reach	185.6 (8.16)	199.2 (9.4)**
Eye-height	143.9(8.17)	152.7 (6.9)**
Acromial-height	128.5 (7.52)	137.7 (6.6)**
Elbow-height	96.8 (7.48)	104.2 (5.8)**
Olecranon-height	95.3 (6.88)	102.1 (8.3)**
Waistback-length	40.3 (5.18)	42.0 (3.9)**
Arm-reach from wall	79.2 (5.33)	85.6 (4.5)**
Waistbreadth	31 (5.48)**	30.1 (3.1)
Hipbreadth	36 (5.48)**	31.9 (2.9)
Sitting-height	79 (7.6)	84.1 (4.2)**
Vertical-grip reach sitting	112.9 (7.94)	120.5 (6.3)**
Sitting eye-height	72.5 (7.42)	75.0 (5.3)**
Sitting acromion-height	60 (8.83)**	58. (4.1)
Sitting popliteal-height	37.1 ((7.6)	45.5 (3.4)**
Knee height sitting	46.3 (7.63)	54.9 (3.6)**
Thigh clearance height sitting	17.8 (4.94)**	12.7 (2.0)
Elbow-rest height	27.1 (6.29)**	23.1 (4.3)
Buttock-knee length	52.7 (3.51)	55.6 (4.4)**
Buttock-popliteal length	45.1 (3.38)	45.9 (3.5)**
Knee- knee breadth	18.9 (3.78)	19.7 (2.8)**
Shoulder-grip length	64.1 (7.09)	70.3 (4.5)**
Elbow-grip length	37.7 (5.27)	40.1 (4.8)**
Hand-length	16 (0.8)	17.6 (1.2)**
Handbreadth at metacarpal-III	7 (0.63)	8.1 (1.0)**
Palm-length	8.5 (0.99)	9.7 (0.7)**
Inside-rip diameter	4.3 (0.7)	4.9 (1.6)**
Foot-length	22.3 (1.7)	24.1 (1.6)**
Foot-breadth	8.4 (1.46)	9.0 (1.0)**
Hand-grip strength (right)	22 (0.25)	34.9 (7.7)**
Hand-grip strength (left)	21.9 (0.23)	34.8 (7.1)**

Measurements are in cm until otherwise specified. **Significantly ($p<0.01$) higher. n =number of subjects. [a] Hameeda and Sam (2015).

seat height (from footrest to seat pan) comfortable. The steering wheel rim diameter was 3.5 cm, within the acceptable range for the 5th (3.3 cm) and 95th (5.7 cm) percentiles. Operator steering distance was 50 cm, meeting limitations for female agricultural workers. The steering height from the footrest was 55 cm, comfortable and within range (5th percentile seated knee height, including elbow rest, was 57 cm).

The acceleration pedal was toe-triggered, with the 95th percentile toe length of agricultural workers used for its construction. The minimal toe length was calculated as the difference between the 95th percentile foot length (25.1 cm) and instep length (20.3 cm), resulting in a 4.8 cm minimal toe length for women agricultural workers. The Yanmar rice transplanter's accelerator pedal length was 20 cm, exceeding the required toe length and the 5 cm pedal width was narrower than the recommended 95th percentile foot breadth. The pedal should be raised to provide stable heel support, prevent engine speed fluctuations and reduce foot and pedal vibrations when driving over obstacles. Hand and foot controls should be easy to operate while seated. Seat adjustments (15 cm fore-and-aft, 10 cm vertical) enhance mobility for larger operators. The Yanmar transplanter's step height was too high at 72 cm for women

Table 3: Existing machine part dimensions of Yanmar rice transplanter about anthropometric dimensions of women agricultural workers.

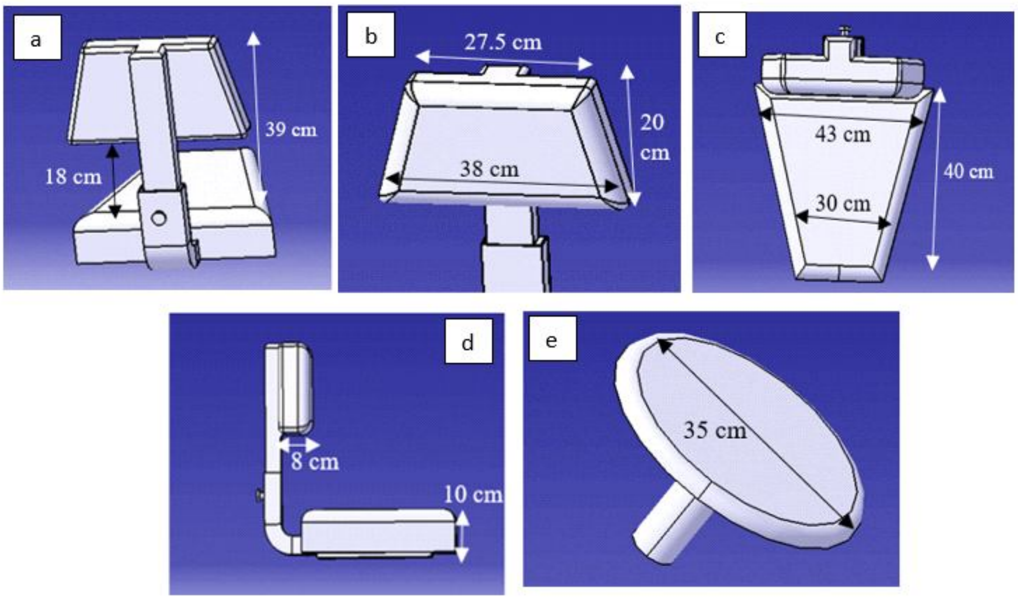
Machine dimensions		Measurements (cm)	Body dimensions	5th (cm)	95th (cm)	
Operator -seat	Backrest width (Top and bottom-side)	25 and 40	Interscye-breadth	25	37.5	Acceptable
	Seat-pan width	44	Sitting hip-breadth		41.5	Acceptable
	Seat-height	35	Popliteal-height sitting	35.4		Acceptable
Steering-wheel	Rim diameter	3.5	Middlefinger-grip diameter	3.3	5.7	Acceptable
	Backrest to steering wheel	50	Shoulder-grip length	50		Acceptable
	Steering-height from footrest	55	Knee height sitting + Elbow rest height	57		Acceptable
Hand controls		50-70	Shoulder-grip-length	50	73.6	Acceptable with longitudinal-seat adjustment
Hydraulic planting lever		70				
Main shifting lever		60				
Hill space shift lever		58				
Differential-lock paddle		60				
Parking-brake lever		55				
Speed control paddle		60				
Brake paddle		55				
Brake pedal length X width		7x5				
Hydraulic stopper		65				
Unit-clutch-lever		60				
	First					
	Second	63				
	Third	66				
Hydraulic sensing lever		67				
Planting-depth lever		58				
Seedlings adjustment lever		66				
Feed control-adjustment lever		68				
Planting-arm-shaft		70				
Foot-controls		50-70	Functional-leg length	82	93.6	Acceptable with longitudinal-seat adjustment
Accelerator-pedal	Length	20	Toe length = foot length - instep length		4.8	Acceptable
	Width	5	Foot-breadth		10	Not-acceptable
Brake-pedal	Length	5	Toe-length		4.8	Acceptable
	Width	5	Foot-breadth		10	Not acceptable
Step-height	Ground-to-step-height	72	Knee-height	35.6		Not-acceptable

Table 4: Existing machine part dimensions of redlands and Yanji rice transplanter about anthropometric dimensions of women agricultural workers.

Machine dimensions		Redlands measurements (cm)	Yanji measurements (cm)	Body dimensions	5^{th} (cm)	95^{th} (cm)	
Backrest	Breadth	16	16	Interscye-breadth	25.0	37.5	Not acceptable
	Height	28	28	Sitting-acromion-height	49.0		Not-acceptable
	Cushion	5	5				Not-acceptable (Mehta, 2000)
Seat-pan	Breadth (rear and bottom side)	30 and 22	30 and 22	Sitting-hip-breadth		41.5	Not-acceptable
	Length	40	37	Buttock-popliteal length	39.5±3.4		Acceptable
	Cushion	10	5				Acceptable
Seat-height		40	40	Popliteal height-sitting	35.4±7.6		Acceptable
Steering rim diameter		3.5	3.5	Middlefinger-grip diameter	3.3	5.7	Acceptable
Hand-controls		40-70	50-80				
Main shifting-lever		80	80				
Hydraulic-planting-gear		40	40				
Steering-wheel-tilt-lever		50	50				
Hill-space-shift-lever		80	80	Shoulder-grip length	50.0	73.6	Acceptable
Accelerator-lever		50	50				
Brake-lever		90	90				
Planting-depth lever		80	80				
Planting-arm shaft		80	80				
Foot-controls		40-70	50-80	Functional-leg length	82.0	93.6	Acceptable
Helper-seat diameter (Ø)		25	25	Hip-breadth sitting		41.5	Not-acceptable

Table 5: Suggested seat dimensions of Redland and Yanji transplanter.

Machine dimensions		ISO 12343,1998	Existing dimensions (cm)		Suggested dimensions (cm)	
			Redlands	Yanji	Redlands	Yanji
Seat backrest (Trapezoidal-shape)	Width × length × height		16×16×10	16×12×10	38×27.5×20	38×27.5×20
	Total height	>26	28	28	39	39
	Open area of backrest	12.5-20	15	10	18	18
	Cushion-height	8	5	5	8	8
Seat pan, (Trapezoidal-shape)	Width (Rear and bottom-side)	>45	30 and 22	30 and 22	43 and 30	43 and 30
	Length	40±5	40	37	40	40
	Cushion-height	10	10	5	10	10
Helper seat diameter (Ø) (Circular shape)			25	25	35	35



(a) Seat backrest height with adjustable mechanism (b). Trapezoidal seat backrest width (c). Seat length and trapezoidal seat pan width (d). Seat and backrest cushion height (e). Helper seat diameter.

Plate 2: Overall suggested main operator and helper seat dimensions of Redlands and Yanji rice transplanter.

to reach easily in muddy fields. The footstep height should be adjusted to 40±7.6 cm, in line with AIS 122/D2 (2015) standards, to prevent operator discomfort.

Table 4 shows, a comparison of Redlands and Yanji transplanter's part measurements to women farm workers' anthropometric dimensions. The dimensions of Redlands and Yanji rice transplanters were similar. Yanji and Redlands transplanters have 15 cm of fore-and-aft seat adjustments for bigger workers. Both 5th and 95th percentile operators can use all foot and hand controls. Table 5 shows non-anthropometric seats for Redlands and Yanji rice transplanters. A new seat design is proposed, based on female agricultural workers' measurements and workplace facilities.

Application of anthropometry in design of seats for Yanji and Redlands transplanters

Operator comfort depends on machine's seat. Anthropometric data is used to determine the appropriate width, depth and height. Transplanter seat is designed for all rice transplanter women operators. See Table 5 for recommended main operator and helper seat dimensions and also shown in Plate 2 as per BIS and ISO.

CONCLUSION

The study developed an anthropometric database of 450 women agricultural workers from southwest India, including 79 physical characteristics such as age, weight and strength, to aid in the design or modification of agricultural equipment. Significant variation was found in the physical measurements of both male and female workers. Comparing the dimensions and clearances of selected rice transplanters with the database showed that the seats were too large for women. Recommended seat dimensions are: 39 cm backrest height, 38 cm width, 27.5 cm top width, 18 cm open area, 40 ± 3.4 cm length, 43 cm width, 10 cm cushion height and 8 cm backrest cushion height. A 35 cm round seat is suggested for assistants. These findings may help design rice transplanters that reduce discomfort for both men and women in agriculture.

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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