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Ergonomic Assessment of Power Tiller Operators during the Testing of System of Rice Intensification Practices at Bakolori Irrigation Scheme, Zamfara State, Nigeria

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ABSTRACT: Nigeria is intensively working hard to achieving food security for its ever growing population. One of the strategies adopted was introduction of modern crop intensification practices and mechanization. In line with this, testing and evaluation of System of Rice Intensification (SRI) was conducted at Bakolori Irrigation Scheme (BIS), Zamfara State - Nigeria. Power Tiller was among the appropriate tools and machinery that were investigated. However, there is the need to match operator's efforts adopted. Both male and female operators were selected according the ergonomic practices from two farmer's groups selected for the study. These operators were calibrated using hand ergometer and stethoscope while calibration curves were developed. Weather of the days of the exercise were also documented. Similarly, the anthropometric data of operators were examined in order to compute the quetlets index. Ergonomic assessments of the operators was conducted for energy cost assessment with mouldboard plough, disc plough and puddler. The overall results indicated that: quetlets index of the male operators ranges 17.24 – 22.9, while that of the female was 17.86 – 21.00. The energy cost of the male operators for mouldboard plough ranges; 14 – 25kJ/min, disc plough; 13.2 – 23.1kJ/min and puddler; 10.3 – 15.8kJ/min. The female operators operated mouldboard plough, the energy cost ranges; 10.4 – 14kJ/min. It was observed that the energy cost of male mouldboard plough operator is almost twice that of the female in the same environment, soil condition and power tiller type.

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Mechanization in agriculture has changed the workload characteristics of the labour. The need for timeliness of operation and increased capacity, leads to higher speeds, bigger, and heavier machines. The operation of these machines that requires manual efforts to operate increases workload on the operators as well as occupational hazards which impair the performance of the operator (Bini, 2002). The ergonomic aspects of power tillers are of great importance as working with power tiller involves considerable physical strain to the operator. An operator has to walk behind the machine for a distance of about 15 km, merely to till one hectare of land (Mehta *et al.*, 1997). Besides walking, the strains resulting from stress factors due to noise, mechanical vibration, work load and exhaust emission also affects the performance of the operator (Kern and Muntzinger, 1986). On the other hand, due to heavy demand on the operator's biological systems, the power tiller operation results in clinical and anatomical disorders and in the long run affect the workers' health (Tiwari and Gite, 1998). The Institute for Agricultural Research, Ahmadu Bello University, Zaria - Nigeria was saddled with the testing and evaluating System of Rice Intensification (SRI) practices at Bakolori Irrigation Scheme (BIS). One of

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the objectives of the SBI-BIS research council system was to train farmers on application, operation and use of power tillers more especially as it relates to SRI method of rice production. The intention of the assessment was to generate information that could be used in matching the tillage job with the operator for optimum drudgery reduction. Severable parameters were employed in Man – Machine relation activities (Gavriel, 2012), anthrophometry and physiological work rate were used in this assessment. Therefore, the objective of this paper is to present the evaluation on ergonomic assessment of power tiller operators during the testing of system of rice intensification practices at Bakolori Irrigation Scheme, Nigeria.

MATERIALS AND METHODS

Study Area: The study area was Bakolori irrigation Scheme of Talata Mafara, Zamfara State, Nigeria. Bakolori Irrigation Scheme is made up of 8 sectors totaling about 20,000 ha of land and contains several water users associations, farmers' cooperatives for both male and female. Mechanization training schools were set up for the scheme, one at F-right sector of the scheme for male farmers and another at N-rice sector for Female farmers (Plates 1 and 2).

Plate 1: An Array of Male Operators

Plate 2: Female Power Tiller Operators

The Scheme comprises of sectors namely; Intake C, EL, F-rice Left, F-right, N-rice, N-rice down, M-rice, Rini; A total 1000 farmers were involved in the testing of the SRI practices. Both male and female farmers were sampled for the ergonomic assessment. Farm plots of 25 mm x 100 m were used during the assessment.

Instrumentation: Instruments used for the study were: Power tiller (Model/Make: Rungpetch, Power: 15hp, Engine speed: 2400rpm) Hand Ergometer, Digital height scale, Digital weighing balance (0.01g), Stethescope, 100 m Measuring tape, Disc pough, Mouldboard plough, and Puddler.

Sampling of operators: Operators (participant) that have not fall sick or medically treated within the last two weeks before the assessment day were prepared. Similarly, farmers of low age group (20 – 35 years) and physically textured were selected as suggested by William *et al*. (2006). A rapid appraisal method was used in screening the farmers to get those that conform to the recommendation. A total of 10 male farmers and 6 female farmers qualified and agreed to participate in the assessment.

Anthrophometry of the operators: Male operators/farmer were located at F-rice at Tajaye village. The selected male farmers reported to the field early and activity began by 10:00 am by taking the weather data. Farmers were confirmed to have taken their break as usual. The arm reach, overall height, waist height, hand length, pelvic height, hand width, elbow to floor of each operator were measured using the above mentioned instrument according to ISO (9886:2004) standards. Similarly, individual body masses (without shoe) were measured and ages were all documented. Operator's Body Mass Index (BMI) and Quetlets Index (QI) were also computed using the equations below (Bini, 2005).

$$BMI = \frac{W}{H^2} \qquad (1)$$

$$QI = BMI - 1 \qquad (2)$$

Where: BMI = body mass index; W = body mass (kg); H = body height (m); QI = Quetlets Index

Similar anthropometric measurements of the selected female operators at N-rice female farmer's field were documented. Best operator is one whose QI ranges from 20 – 25, according to Varghese *et al.* (1996).

Physiological work-rate of operators: Implements available for the land preparations were mouldboard plough, twin bottom disc plough and puddler. The 10 male selected operators were asked to voluntarily select the implement they wish to operate for the work-rate assessment, this minimized biasness in the experiment. A hand ergometer was used to calibrate their work-rates. The calibration gives the relationship between work done by an operator and equivalent heart rate in beats per minutes. The ergometer was set with masses ranging from 5 to 30 kg. A calibrated stethoscope was prepared for heart beat recording according to physiologist recommendation. An operator was selected and ask to wind the ergometer with hand at initial mass load of 5 kg, his heart beat per minute were recorded before starting the work. This was repeated after 5 minutes of starting the operation as suggested by Ali (1993). The operator repeated the experiment with mass increase of 5 kg up to 30 kg. Corresponding heart beats per minute (heart rate) were recorded. The corresponding works done in each winding for specific mass were computed from the following relationships:

$$Workdone = f \times d \quad (3)$$

$$f = mg \quad (4)$$

$$d = 2\pi rn \quad (5)$$

Where, f = force (N); d = distance moved by the mass (m); m = mass selected on the ergometer (kg); r = radius of ergometer wheel; n = number of revolutions within the time of winding; g = gravitational acceleration (m/s^2)

Similar calibration experiments were conducted with the remaining 9 male operators. Data generated was tabulated, calibration curves were plotted for each subject using SAS software. A 25 m x 100 m field was wetted and settled for the experiment.

Plate 3: Female farmer's calibration

After giving the operators 2hrs resting time and their heart rates stabilizes, they were prepared to operate the fully serviced power tillers with the selected implements. At the beginning and the end of the free 30 minutes operation, the heart rate of each operator was recorded.

Having the heart rate for the operation done for each subject corresponding work in Joules were computed from their respective calibration curve. The activities continue for a week so that those offered to operate two or three implements were given adequate rest time and the generated data were documented. Similar experiments were conducted for the female operators at Yar'kufoji field and data documented (Plates 3 and 4). All the experiments were conducted successfully.

Plate 4: Female farmer in field operation

RESULTS AND DISCUSSION

Measurement of heartbeat of Operators: Preliminary results obtained indicates the rate of heartbeat of an operator in relation to his work done. It shows that the work done by an operator increase with the increase of the selected mass of the ergometer.

This in turn increase the rate of heartbeat of the operator thereby subjecting him to more fatigue (Table 1 and Figure 1)

Anthropometric Data: The results obtained from the anthropometric measurements for both male and female farmers were presented in Tables 2 and 3, respectively. According to Varghese *et al.* (1996), the best operator to operate a machine with less drudgery is one whose QI values ranges between 20 – 25.

From the result (Table 3) only operators 1 and 3 are fit to operate the power tiller. These operators were between the ages of 20 – 30 years. From the field work observed, these same operators uses the Power Tiller to till their individual farms with great zeal.

Table 1: Measurement of heart beat and work rates of male subject 1

Heart rate (beat/minute)	**Mass** selected on the ergometer **(kg)**	**g (m/s^2)**	**R (m)**	π	**N Revolutions**	**Work rate (kJ)**
55	5	9.81	0.16	3.14	118.2	20
59	10	9.81	0.16	3.14	203	22
62	15	9.81	0.16	3.14	217	32
67	20	9.81	0.16	3.14	268	58.7
71	25	9.81	0.16	3.14	280	68.9
75	30	9.81	0.16	3.14	298	88.1

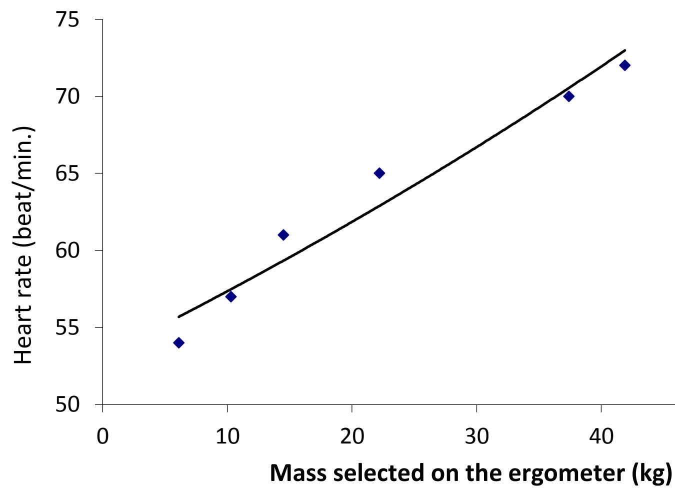

Fig 1: Calibration curve for work done by male operator 1

Table 2: Anthropometric Data of Male Operator

S/N	**Dimension/Body Part**	**Male Operator**									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1.	Weight (kg)	65.1	70	63.9	54.6	60.8	60	54.5	63	45	58.8
2.	Age (years)	30	40	21	27	22	25	25	25	19	22
3.	Height (cm)	165	185	174	173	175	179	168	185	167	175
4.	Arm reach (cm)	62	66	72	60	62	64	68	60	62	70
5.	Hand length (cm)	18	21	20	19	20	20	19	20	18	20
6.	Hand width (cm)	9	9	10	8	9	9	8	9.5	8	9
7.	Fore arm (cm)	30	33	38	30	32	32	31	30	29	28
8.	Arm (cm)	30	32	31	29	31	31	30	32	33	31
9.	Span (cm)	41	43	44	44	42	42	44	44	42	40
10.	Pelvic height (cm)	105	109	108	108	98	98	98	109	89	101
11.	Elbow to floor (cm)	100	113	105	105	110	110	101	116	99	109
12.	**BMI**	23.9	20.5	21.1	18.2	19.8	18.7	19.3	18.4	16.1	19.2
13.	**QI**	22.9	19.5	20.1	17.2	18.8	17.7	18.3	17.4	15.1	18.2

BMI=Body Mass Index; QI= Quetlets Index

Table 3: Anthropometric Data of Female Operator

S/N	**Dimension/Body Part**	**Female Operator**					
		1	**2**	**3**	**4**	**5**	**6**
1.	Weight (kg)	70	59.8	53.8	58.2	60	54.5
2.	Age (yrs.)	30	40	31	40	45	40
3.	Height (cm)	180	168	170	165	172	160
4.	Arm reach (cm)	64	69	68	62	70	66
5.	Hand length (cm)	20	18	19	18	19	19
6.	Hand weight (cm)	10	9	11	9	10	10
7.	Fore arm (cm)	32	28	29	30	32	30
8.	Arm (cm)	30	31	32	33	30	31
9.	Span (cm)	39	39	38	40	41	44
10.	Pelvic height (cm)	110	100	92	90	105	105
11.	Elbow to floor (cm)	101	105	100	98	110	101
12.	**Body Mass Index**	21.96	21.96	18.61	21.37	20.28	21.28
13.	**QI**	21	21	17.86	20.37	19.28	20.28

In contrast to the male operators, the female operator\s QI values (Table 3) indicated the operators 1, 2 4 and 6 were qualified to operate the power tiller with less drudgery. Their ages ranges between 30 - 40 years, a little older than the male. All of their pelvic height above 10 m and their height ranges between 1.6 to 1.8 m.

Physiological Work: The work done by an operator at the appointed time for the male subject is given in Table 2. Operator 3 has proven QI hypothesis in Table 4 being so resilient to have done three operations with substantial energy input. In Moldboard plough operation, operators 1, 3, 4 and 5 supply the highest energy, despite operator 1 did only single operation his QI qualifies him to be a good operator. Finally, operators 1 and 3 were the fittest operators among the 10 volunteered operators. In Mouldboard plough operation, operators 1 - 5 inputted energy ranging between 633 to 749 kJ while the remaining work rate ranges between 418 to 494 kJ. Same trend applies for disc plough and puddler. Among all the implement operated, Puddling consumes less operator's energy despite the high environmental temperature of 41 ^{o}C.

Table 4: Work rate per Operation of Male Operators (41 ^{O}C /65% RH)

Operation	Work (kJ)									
	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7	Operator 8	Operator 9	Operator 10
MBP	633.9	-	721	749	719	418	491	456	494	-
DP	-	618	666	694	657	396	423	429	-	462
PDL	-	473	632	-	-	308	394	349	-	-

MBP = Mouldboard Plough; DP = Disc Plough; PDL = Puddling

Energy cost of the male operators: The energy cost of an operation is the amount of energy that is required to earn the operation. Among the implements used, Mouldboard plough has the highest energy cost of 25 kJ/min (Table 5). This is in close agreement with Bani (2005) value range. Disc ploughing follows with 23.1 kJ/min and puddling recorded the least cost. The overall energy cost for male with the selected implements ranges between 10.3 to 25 kJ/min.

Table 5: The energy cost for male operators

Operation	Work Rate (kJ/min)									
	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7	Operator 8	Operator 9	Operator 10
MBP	21.3	-	24	25	24	14	16.4	15.2	16.5	-
DP	-	20.6	22.2	23.1	21.9	13.2	14.1	14.3	-	15.4
PDL	-	15.8	21.1	-	-	10.3	13.2	11.6	-	-

MBP = Mouldboard Plough; DP = Disc Plough; PDL = Puddling

Female Operators Work Rate: From the Table 6, operator 3 seems to produce more energy in the single operation selected but the QI of this operator indicated in-resilient. However, energy input of operators 1, 2, 4 and 6 shows some uniformity in energy input and their QI value has elevated them to good operators. Generally, looking at the male and female energy inputs in mouldboard ploughing from this assessment, most male inputted almost twice energy as the female. In other word, the male could produce twice the female produced. Then the operation time of the female should be a half of that of the male.

Table 6: Work rate per operation of female Subject (41 ^{O}c /65% RH)

Operation	Work Rate (kJ/min)					
	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6
MBP	350	345	420	370	313	342

MBP = Mouldboard Plough

Although the female operators selected only mouldboard plough for the exercise, their energy cost ranges between 10.4 – 14 kJ/min (Table 7). This is about half of the energy cost of male operators on the same implement.

Table 7: The energy cost for female operators

Operation	Work (kJ)					
	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6
MBP	11.7	11.5	14.0	12.3	10.4	11.4

Conclusion: The ergonomic assessment of operators of power tiller during the testing of SRI practices at the BIS was conducted with voluntary participation of both male and female farmers of the scheme. The anthropometric measurement of the male farmers showed that only two farmers satisfied the quetlets hypothesis of operation with less drudgery, whereas four female operators conformed to the hypothesis. It was observed that the energy cost of male mouldboard plough operator is almost twice that of the female in the same environment, soil condition and power tiller type.

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