https://doi.org/10.56093/ijas.v90i3.101505

Indian Journal of Agricultural Sciences **90** (3): 634–8, March 2020/Article

Quantification of drudgery and ergonomics assessment of weeding activity in vegetable production system

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Received: 18 December 2019; Accepted: 24 February 2020

ABSTRACT

Weeding activity in vegetable cultivation carried out by women is one of the drudgery prone activities. Women are regularly adopting poor and static posture while doing weeding for long hours by traditional equipment, resulting in various physical load on spine or lumbo-sacral region leads to drudgery coupled with work related musculoskeletal disorders (MSDs). The research paper aims to assess and quantify the drudgery with weeding activity by rural women in which physiological ergonomics evaluation was done for traditional method and with improved technological support with three replications of fifteen minutes work cycle without rest pause. Ergonomic parameters namely Heart Rate, Energy Expenditure Rate, Total Cardiac Cost of Work, Physiological Cost of Work, VO_2 Max were measured during the experiments. Observations were recorded on farm women worker with normal health, without any major illness, regularly involved in farm operations and were in the age group of 25 to 45 years. Weeding activity of farm women was quantified and a sample of 10 physically fit rural women having permissible limit of physiological parameters were selected for the study. It was found from investigation that there was reduction in human physiological parameters, viz. heart rate, energy expenditure rate, Total Cardiac Cost of Work, Physiological Cost of work, Blood pressure and Oxygen Saturation.

Key words: Load carrying activity, Ergonomics, REBA, Postural assessment, Fetching fuel

Human energy is essential to survival in the rural production system. Many agricultural operations seem to be simple and not too tedious with relatively less level of energy expenditure rate. But, the activities may pose threat to the worker because of the arduous and unnatural postures adopted by the worker throughout the task. One of such activity weeding in vegetable cultivation carried out by women is one of the drudgery prone activities. Drudgery in farming operations is an important gender issue and efforts are under way by research and development organizations and development agencies. As it is widely recognized that women are the major workforce in agriculture who predominantly sustain the life support system of the rural India. Because since dawn to dusk, they share abundant responsibilities and perform a wide spectrum of activities related to agriculture, household chores and allied. With the feminization of agriculture, scarcity of farm labour and outmigration of male, women are forced to carry out work previously done by men. Consequently women are increasing their workload and taking care of a wider scope of agriculture tasks, but the degree to which they have access to improved technologies need special consideration (Agarwal 2007). Rural Haryana provides an excellent example of the importance and magnitude of women through their active participation in agricultural development and farm management. Rural women's daily activities revolve around a mixture of tasks pertaining to domestic and productive work. It is estimated that during peak period, women work every day for about 8-9 hours in agriculture and 4 hours in household activities. Thus, time-saving in one sphere can directly affect time availability in the other, and vice versa. Energy and time saving technological interventions are need of an hour to reduce the work burden and increase efficiency (IFAD 2014).

Weed growth is a major problem in agriculture causing a considerable lower crop yield (Karthikeyan *et al.* 2009). Weeding is one of the most important intercultural operation

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in crop production system and it is mostly done by women. Weeding and inter-cultivation takes away 15 to 20 % of total man hours involved in crop production (Nag and Nag 2004). An estimate of 400-600 man hours per hectare is the normal man hour requirement of hand weeding which amounts to ₹ 2200 per ha which also depends upon weed infestation (Borah 2007). Bhan *et al.* (1999) estimated that weeds in India reduce crop yields by 31.5% (22.7% in winter and 36.5% in summer and kharif seasons). Weeding is an important but equally labour intensive agricultural unit operation. Majority of the farm women do weed control using traditional tools like sickle, khurpi and so on. The long hours and static squatting posture with frequent bending and postural efforts in weeding by traditional method with khurpi is the nightmare for the women in relation to drudgery involve in it. Although, conventional method of weeding proves useful as it covers sufficient weed mortality but it demands more labour , human energy and time and is full of drudgery. During weeding women adopt bending and squatting body posture due to which their physiological workload increases and also, they face many types of muscoskeletal problems as a result of which the efficiency of women to work decreases to a great extent (Sharma 1999). Unfortunately, the long, unrecognized hours spent by women on arduous, unhealthy, and unpleasant tasks are rarely perceived as a central issue in today's situation.

Biomechanical studies reports spinal loading during manual load carrying which results in degeneration of the disc and musculoskeletal disorder (Kuiper *et al.* 1999, Vuuren *et al.* 2005). Accelerated cervical spondylosis is also reported as a result of carrying load on head (Joosab *et al.* 1994 ; Jager *et al.*1997). Boocock *et al.* (1994) reported that tasks involving lumber extended postures (overhead work) are relatively common, may incur moderately high compressive loads on the lumbar spine, and are a potential source of occupationally related back pain.

MATERIALS AND METHODS

In the present investigation, under the Farmer FIRST project, weeding in vegetable crop by conventional method and improved tools has been conducted with on the basis of physiological and psychological ergonomics parameters, viz. Heart Rate, Blood Pressure, Energy Expenditure Rate, Total Cardiac Cost of Work, Physiological Cost of Work, Blood Pressure etc. A total of 10 farm women in the age group of 25-45 years, non pregnant, non lactating with no history of acute or chronic illness or cardio vascular diseases with random sampling technique were taken for data collection.

Before the subject started the experiment, her resting heart rate (HR) b/min for 5 minutes were recorded. During the activity the working heart rate/min and rating on perceived exertion (RPE) were measured. She was then given rest and recorded the Recovery Heart Rate/min and RPE for a minimum of 10 minutes or till complete recovery. Body mass index (BMI) was calculated by dividing square of height (m) to body weight (kg) of subjects. Based on body weight of subjects, aerobic capacity was estimated

Table 1 Classification of workload

Physical work load	Physiological variables			
	Energy expenditure (KJ/Min)	Heart beats (beats/min)	VO_2 max (%)	O_2 consumption, (l/min)
Very light	Up to 5.0	Up to 90	-	-
Light	5.0-7.5	91-105	< 25%	0-0.435
Moderate	7.6-10.0	106-120	Up to 50%	0.436-0.870
Heavy	10.0-12.5	121-135	Up to 75%	0.871-1.305
Very heavy	12.6-15.0	136-150	Above 75%	> 1.306
Extremely heavy	<15.0	Above 151	-	-

using (Singh *et al.* 2008) general equation.

$$\text{Aerobic capacity of farm women} = 33.18 \text{ mL kg}^{-1} \text{ min}^{-1}$$

Polar Heart Rate Monitor was used for recording heart rate of subjects during the course of study. The oxygen consumption of subject on their measured heart rate was estimated based on general equation as given by Singh *et al.* (2008).

$$Y = 0.0114X - 0.68$$

where, Y = oxygen consumption, l/min; X = heart rate. The energy expenditure was calculated using 1 l oxygen equivalent to 20.93 kJ.

$$\text{Energy Expenditure Rate (EER)} = 0.159 \times \text{Heart Rate (b/min)} - 8.72$$

Circulatory stress was evaluated from the cardiac cost of work and cardiac cost of recovery. The cardiac cost of recovery is the total number of heartbeats above the resting level occurring between the end of the work and return to the resting state.

Following formulae were used to calculate the total cardiac cost of work (TCCW) and physiological cost of work (PCW) (Singh *et al.* 2008).

$$CCW = \Delta HR \cdot tA$$

where, CCW = Cardiac Cost of Work Δ HR = Mean Working Heart Rate – Mean Resting Heart Rate tA = Duration of Activity.

$$CCR = (AHR \text{ recovery} - AHR \text{ rest}) \cdot tR$$

where, CCR = Cardiac Cost of Work AHR recovery = Average Recovery Heart Rate, AHR rest = Average Resting Heart Rate, tR = Duration of Recovery.

$$TCCW = CCW + CCR$$

where, TCCW = Total Cardiac Cost of Work.

$$PCW = TCCW/tA$$

where, PCW = Physiological Cost of Work.

Weeding efficiency of tool was also recorded with the following details. Weeding efficiency is a ratio of the number

of weeds removed by a weeder and the number present in unit area and is expressed as:

$$\text{Weeding efficiency (\%) } e = W1\text{-}W2 \times 100\ W1$$

where, W1 = Number of weeds before weeding, and W2 = Number of weeds after weeding.

Collected data was analyzed with the help of suitable statistical techniques, viz. percentage, arithmetic mean, standard deviation and two samples 't' test. Coefficient of correlation was computed by Karl Pearson's formula to determine the nature of relationship between independent variables and Total Cardiac Cost of Work (TCCW) of experimental subjects.

RESULTS AND DISCUSSION

Weeding activity with various agricultural implements

Different types of weeding tools were evaluated in vegetables crops (Brinjal, okra and bottle guard) (initial stage). Two plots with three different crops having two different weed populations, i.e. high and low weed intensity were taken were selected for assessment. Weeds count of 1 × 1 m area for three different plots before and after weeding was recorded. This procedure was done for all the three vegetable fields.

The average plant to plant spacing was 40-45 cm, row spacing was 40-60 cm and average height of plant was 16-23 cm. Test parameters were width of cut, depth of cut, fuel consumption. Actual operating time for vegetables crop ranges from 20-25 min with the area coverage of 500 m^2 depth of cut was aprox. 5-8 cm having approximately 30-35 cm. effective width of cut of the unit in one run. The Mechanized weeding was observed advantageous in terms of time, energy and cost effectiveness for all the crops.

Physiological characteristics

Physiological characteristics of subject (Table 3) were analyzed by using different parameters. The mean age of the subjects was 32.12 years with ± 8.42 standard deviation. The corresponding BP, pulse rate, BMI, PFI of the subjects was 118.56/71.2 mmHg, 71.12, 21.5, 127.97, respectively which is normal in Indian women. During the time of experiment the temp was ranges 26-35° C and relative humidity ranged 62%-76%.

Body Mass Index was derived by measuring weight and height of the respondents using the following formula;

$$\text{Body Mass Index (BMI) kg/m}^2 = \text{Weight (kg)/Height}^2\text{ (m)}$$

BMI scores of the respondents were categorized and it was observed from table 4 that 93 percent were normal BMI with corresponding the scores values.

Quantification of drudgery and ergonomics evaluation of weeding activity

The experiment was carried out in different modes (traditional method, with four wheel weeder and wheel hoe). The physiological parameters heart rate in resting, working and recovery was taken, time of recovery, Oxygen consumption , energy expenditure rate, Total Cardiac Cost of Work along with PCW were also taken into documented with different mode of activity by women. Measurement of Physiological stress was calculated with the help of

Table 2 Evaluation of weeding activity with various modes in vegetables crops

Parameters	Crops											
	Brinjal			Okra			Bottle gourd			Ave. range		
	FWW	TRD	WH	FWW	TRD	WH	FWW	TRD	WH	FWW	TRD	WH
Plant to plant spacing (cm.)	40	40	40	45	45	45	42	42	42	40-45	40-45	40-45
Row spacing (cm)	40	40	40	40	40	40	60	60	60	40-60	40-60	40-60
Height of plants (cm)	16	16	16	20	20	20	23	23	23	16-23	16-23	16-23
For 500 m^2 area coverage time required (min)	20	-	30	23	-	35	25	-	30	20-25	-	30-35
Depth of cut (cm)	5	3	4.5	6	3	5	8	3	6	5-8	3	5-6
Width of cut (cm)	30	15	15	32	17	15	35	15	15	30-35	15-20	15-20
No. of labour engaged (m)	1	1	1	1	1	1	1	1	1	1	1	1
No. of weeds before weeding (weeds/m^2)	302	302	302	232	232	232	386	386	386	200-400	200-400	200-400
No. of weeds after weeding (weeds/m^2)	76	134	100	47	107	68	81	147	105	45-90	100-150	60-110
Weeding efficiency (%)	74.83	55.62	66.88	79.74	53.87	70.68	79.01	61.91	72.79	70-80	50-65	65-75

Note: FWW- four wheel weeder, WH-wheel hoe, TRD-traditional method (khurpi)

Table 3 Physiological characteristics of the subject

Physiological characteristics	Mean± SD
Age, years	32.12 ± 8.42
Body weight , kg	54.18 ± 3.14
Height, cm	159.24 ± 3.54
Blood pressure (Sys/Dia)	118.56/71.2
Pulse rate (per min)	71.12 ± 2.34
BMI	21.5± 2.31
Physical fitness index (PFI)	127.79± 6.54
Body type	Mesomorphic
Ponderal index	24.9
Area covered (With wheel hoe)	0.01 (ha/hour)
Area covered (With four wheel weeder)	0.03 (ha/hour)
Environmental parameters	
Temp	26° C - 35° C
Humidity	62% - 76%

Table 4 Distribution of respondents as per BMI scores (N=10)

BMI Scores	Interpretation	%
< 16.0	*CED grade lll (severe)	-
16.0-17.0	*CED grade ll (moderate)	-
17.0-18.5	*CED grade l (mild)	-
18.5-20	Low weight normal	7.0%
20.0-25.0	Normal	93%
25.5-30.0	Obese grade l	-
> 30.5	Obese grade ll	-

*CED = chronic energy deficiency

suggested prediction equations given below:

$$O_2 \text{ consumption } (l.min^{-1}) = 0.01095 \times HR \text{ (beats. min}^{-1}) - 0.61694 \ (r^2 = 0.983)$$

where, HR = Heart Rate, r^2 = correlation coefficient.

Maximum oxygen consumption rate (Aerobic capacity), sets the limit for the maximum physical activity of the subject. For women, generally this value is considered as 75 % that of mwn. According to the data available for Indian workers, the value for women workers is about 1.5 liters/ min. Weeding activity was evaluated by traditional method (in squatting posture) and with improved tools and it was found from investigation that there was somewhat reduction in human physiological parameters, viz. heart rate , energy expenditure rate, Total Cardiac Cost of Work, Physiological Cost of work , Blood pressure and Oxygen Saturation. There is a marked difference in EER by traditional method of weeding by khurpi, Pusa wheel hoe and four wheel weeder with 0.05 and 0.01 level of significance. As the drudgery caused due to bending is reflected in terms of postural discomfort experienced by the workers. It can be interpreted that a good, natural and effortless posture is required to reduce the drudgery of work experienced by the worker. The Total Cardiac Cost of Work (TCCW) and Physiological Cost of Work (PCW) were also reduced from 682 to 595 and 45-39 respectively from improved technologies. Data for various other physiological parameters such as Percent increases in EER (Energy Expenditure Rate) from 10.91-9.15, and Pulse Rate 108.21 -102 were also reduced with improved technologies. Improvement and modifications in the existing tools, equipments, machinery and method of work has significant effect in minimizing in human strain and fatigue and increase farm productivity. The results of study was in line with Yadav *et al.* (2010) who studied the performance of the operator in different field operation can be assist on the basis of physiological responses. The physiological cost of male and female subjects on the basis of OCR was 15.87, 15.87, 16.08 and 15.87 kJ min^{-1} and 8.14, 8.35, 8.35 and 8.35 kJ min^{-1} for subjects 1, 2, 3 and 4 respectively. Similarly physiological cost for female worker during weeding operations by manual weeder was

Table 5 Ergonomics evaluation of weeding activity in vegetable cultivation practices (N=10)

Parameters	Traditional Method (Squatting posture)	With Pusa Wheel Hoe (Standing posture)	't' value	p-value	With four wheel weeder (Standing posture)	''t' value	p-value
Avg. HR b/m (rest)	78.5	74.9	2.6*	.001	73.2	4.05**	.0003
Avg. HR b/m (work)	123.5	114.5	4.14**	.003	112.4	4.53*	.0001
Avg. HR b/m (rec)	85.7	82.5	1.38**	.09	81.1	1.79^{NS}	.044
EER (rest)	3.76	3.18	2.16**	.008	2.91	3.52^{NS}	.051
EER (work)	10.91	9.48	3.84**	.003	9.15	4.49*	.003
EER (rec)	4.90	4.39	1.35**	.008	4.17	1.54**	.0001
TCCW	682.2	601.6	2.46*	.012	595.9	3.57*	.004
PCW	45.48	40.11	3.81*	.008	39.72	4.53*	.0081
O_2 Saturation (rest)	96.32	94.11	4.38*	.008	93.98	3.56^{NS}	.061
O_2 Saturation (work)	108.21	102.16	5.18^{NS}	.067	103.31	4.45*	.054
O_2 Saturation (Rec)	99.38	96.13	3.46NS	.041	95.89	3.52NS	.053

Note -* Table value for significance at 0.05 level, ** Table value for significance at 0.01 level and NS- Non significant

Table 6 Relationship between Total Cardiac Cost of Work (TCCW) and different independent variables

Variables	Correlation Co-efficient
Age	0.0025^{NS}
Education	0.766 ^{NS}
Land holding	0.131 ^{NS}
Heart Rate (working)	0.569**
Energy Expenditure Rate (Working)	0.567**
Body Mass Index	0.443*
Blood Pressure	0.524*
Oxygen Saturation (Working)	0.453**

* 5% level of significance, ** 1% level of significance, NS = Non significant, df-9.

13.57, 14.41, 14.20 and 14.41 kJ min^{-1} for subject 1, 2, 3 and 4 respectively.

Farmers were satisfied with the use of improved technology provided under farmer FIRST project which is time, human energy saving and fatigue reducing. Further relationship between Total Cardiac Cost of Work (TCCW) and other independent variables as age, education, land holding, heart rate, EER, BMI etc. were also analyzed (Table 6) and it was found that Total Cardiac Cost of Work is positively correlated with heart rate, EER, BMI.

Drudgery can be reduced by providing gender friendly farm tools and equipments which increase the productivity of worker with safety and comfort. Time scheduling and postural management are primary for achieving efficiency. A good working posture requires minimum static muscular effort. In the present investigation, Pusa wheel hoe and four wheel weeder were found ergonomically sound in vegetable production system as per physiological and subjective ergonomical parameters with reference to saving time, human effort, increasing work capacity and productivity resulting in improving quality of life. It was found to be compatible, easy to handle and applicable in field situation as well as most efficient for weeding vegetable fields. It was observed that use of weeder improved posture and efficiency of worker. The health of farmwomen is one of the important resources for sustainable agricultural development. Therefore, such drudgery reducing farm implements needs to be demonstrated to avoid occurance of health hazards among farm women.

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