Development and Testing of Low Cost Drudgery Reducing Hand Wears for Soybean Harvesting

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Abstract: *To prevail over the problems involved in Soybean harvesting, hand wears i.e. Mittens for protecting hands and arms were designed, developed and tested .Results indicated that average physiological cost of Soybean harvesting activity was reduced by 5 heart beats/min in improved method i.e. by using mittens over existing. On an average 7 & 4 b.min^{-1} reduction of heart rate was observed in case of improved method when mittens were used for performing collecting and bundling of soybean plants respectively. There was increase in pace of work by 4.4 to 16.8 percent in case of cutting soybean plants with sickle and 25 per cent in collecting and bundling of soybean plants (increase in area by 16-56 sq.mt/h) when it was performed by improved method. Similarly, Drudgery reduction was higher i.e. 39 to 48 per cent for both the selected soybean harvesting activities when performed by using developed mittens*

Keywords: Drudgery, harvesting, heart rate, physiological cost, sickle

1. Introduction

Harvesting is the operation of cutting, picking, plucking, digging or a combination of these operations for removing the crop from under the ground or removing the useful part or fruits from plant. Soybean harvesting is performed manually only by the farmwomen. It is tedious and drudgery prone activity. No safe technology is available for Soybean harvesting. Traditional Sickle made by local artisan is used for Soybean harvesting. Harvesting of Soybean was found to be very difficult activity for farm workers due to pricking of dried pods and prickle and skin contact of allergen/ grass and insecticide to the fingers and arms. Injuries due to sickle, skin irritation, scratches and punctures, rashes, insect bite, itching and sunburn were common problems faced by farm workers while performing harvesting of Soybean. Quirina *et al.* (2008) had reported the skin problems among farm workers in North Carolina, such as pimples, or acne, rash, including skin sunburn, itching and insect bite. They suggested to using the personal protective equipment and change in work practices. These were the reasons affecting work efficiency of farm workers.

Excessive physical strain has been associated with injury events in women. The farm women adopt bending postures and repetitive motion of body part for harvesting activity which increases the musculoskeletal problems, so they perform the activity in their own convenient postures without realizing the harmful effect on the body. Farm women have anatomical and physiological differences that may place them risk for farm injuries (*Engber, 1993*). The use of conventional tool and method for the work of harvesting add further to their drudgeries. When a person does any physical work, he/she use muscle power (energy and skeletal tissues) to do so. During the muscular activity one's physiological responses i.e. energy expenditure and heart rate increases. This increase in physiological responses is related to the type, intensity and duration of work and thus sets limits to the performances of heavy work. Therefore, measurement of effort and physiological responses are important for designing work method. Nag and Chatterjee (1981) suggested that the work levels for 8 hr activities for men and women should not exceed beyond 35 and 28 per cent of one's aerobic capacity. Use of mechanically powered equipment in harvesting is limited. Since the use of human power is extensive in cultivation of crops, the accidents occur due to highest point of various factors viz. strain, fatigue and lack of safety aspect in the traditional equipment, interference of the labourers during the use of long slashing equipment, misuse of equipment, steep slopes, landslides etc. It is very necessary to ensure that workers are using the proper size tools for the task. To increase the productivity of the women's work, there is a greater need for the ergonomic analysis of the activities performed by women and to study the circulatory stress and the physiological cost of vegetable harvesting activity (Hasalkar et al. 2004).

Keeping this into mind the present study was initiated where farm women's perceptions were measured by preparing questionnaire to find out difficulties during soybean harvesting. The following were the objectives of the work.
1) To analyze posture of farm workers involved in soybean harvesting
2) To design and develop low cost protective mittens for Soybean harvesting
3) Ergonomic assessment of soybean harvesting activity by improved & existing method.

2. Methodology

Ergonomic evaluation of selected farm activity : Total 30 healthy, farm workers (22 female and 6 male) working in the field for 4-8 hrs/ day and 6days/ week and having minimum five years experience of work in soybean harvesting were selected for the study. Study was conducted by traditional and improved method i.e. by using soybean mittens as improved method. For this study Polar heart rate monitor for

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continuous heart rate record, Anthrop meter, Sphygmomanometer (B.P.apparatus), Hygrometer, Dialed Thermometer, Suryamapi

Average working Heart Rate (b.m^{-1}) (AWHR): Working heart rate was recorded with the help of heart rate monitor at every three minutes till the completion of activity.

Average Peak Heart rate (b.m^{-1}) (APHR): It was noted down while performing the activity.
a) Average & peak energy expenditure (kj.m^{-1}) (AEE & APEE): It was calculated by using following formula.
    EE (kj.m^{-1}) = 0.159 X Heart rate (b.m-^{1}) -8.72

b) Total cardiac cost of work (TCCW): TCCW was calculated by using the following formula
  TCCW = Cardiac cost of work + Cardiac cost of recovery
where,
Cardiac cost of work (CCW) =(Average working heart rate – Average resting heart rate) X duration
Cardiac cost of recovery (CCR)=(Average recovery heart rate– Average resting heart rate) X duration

c) Physiological cost of work (PCW) : It was calculated by following formula
            PCW = TCCW / Total time of work

d) RPE (Rated perceived exertion) was measured by five point scale i.e. Very light (1) , Light (2), Moderately light (3) , Heavy (4) and Very heavy (5) (Varghese *el al* 1994)

e) Work related drudgery experience was also measured by five point scale viz. Very demanding (5), Demanding (4),Moderately demanding (3), Less demanding (2) and Very less demanding (1)

f) Postural analysis: Response rate of farm workers was recorded for Localized postural discomfort and Perceived Postures
- Localized postural discomfort was measured by six-point scale viz. No discomfort (0), some discomfort (1), minor discomfort (2), major discomfort (3), severe discomfort (4), very severe discomfort (5)
- Perceived Postures were measured by seven points scale such as Very favourable (1), Intermediate response b/w 1 and 3 (2), Favourable (3), Intermediate response b/w 3 and 5 (4), Unfavourable (5), Intermediate response b/w 5 and 7 (6) and Very unfavourable (7)
- Criticality Index was the calculated by using following formula: (Balraj et al, 2005)

$$\text{Criticality Index} = \frac{\Sigma X_1 Y_1}{\Sigma X_1}$$

Where, Y_1=Perception of the farm workers in specific category
X_1=Weight age given to each point on scale

3. Results

Designing and development of protective Mittens:
Perception of farm workers was recorded by using a questionnaire, containing different modules, such as

perceived postures, and localized postural discomfort & endurance limit.

Localized postural discomfort responses (Table 1&2) were collected and criticality index for all these discomfort regions were calculated. It was found that most critical parts, which are having high degree of discomfort while Soybean harvesting was, discomfort of fingers, neck, right shoulder and back. Considering all the critical parts, it was found that there was a vital need to protect the fingers and arms while harvesting Soybean. Hence, mittens with long sleeves were developed for Soybean harvesting.

Variables considered while designing and developing the mittens were

a. Anthropometric measurements of workers b. Cost and availability of material for making mittens c. Characteristics of Fabric material and d. Discomfort responses of the workers.

Rated perceived exertion (RPE): Rated perceived exertion score indicated that all the selected Soybean harvesting activities i.e. cutting and bundling of Soybean plants by existing method was perceived as heavy activity by the selected farm workers. Farm worker's perception regarding these activities was as moderately light activity when these activities were performed by improved method. Statistically results were highly significant. It indicated that there was significant reduction in perceived exertion when mittens were used while Soybean harvesting.

Physiological workload while performing the soybean harvesting by female workers

a. **Cutting Soybean plants with sickle:** In case of Soybean harvesting, when it was performed by improved method (Table 3) i.e. by wearing mittens, there was reduction in average working and peak heart rate by 6 and 7 b.min^{-1} respectively than the existing method but statistically significant difference was not found. Total cardiac cost of work was found higher in case of existing method. There was reduction in total cardiac cost of work by 153 beats but statistically results were non significant. Average physiological cost of Soybean harvesting activity was reduced by 5 beats in improved method over existing.

b. Collecting and bundling of soybean plants: Physiological workload of farmwomen while performing Soybean harvesting by existing and improved method i.e. wearing newly developed mittens is shown in table 4. It is observed from the table that average working heart rate (115b.min^{-1}) and peak heart rate (124 b.min^{-1}) were noted higher for existing method of soybean harvesting than the improved method (108 and 120 b.min^{-1} respectively). On an average 7 & 4 b.min^{-1} reduction of heart rate was observed in case of improved method when mittens were used for performing collecting and bundling of soybean plants. Total cardiac cost of work was reduced by 208 beats. The similar trend was followed in case of average peak energy expenditure, PCW but no significant difference was found when 't' test was applied. Highly significant reduction was found in rated perceived exertion in improved over existing

method of soybean harvesting activity- collecting and bundling of soybean plants.

Physiological workload while performing the soybean harvesting by male workers

a. **Cutting Soybean plants with sickle :** Physiological workload of male farm workers while performing cutting soybean plants with sickle by traditional and improved method i.e. wearing newly developed mittens is shown in table 5. It can be noted from the table that all the measured values of selected parameters for physiological workload of farm workers are lower in improved method than traditional method. Regardless of hand wear worn, workload of farm workers was not reduced significantly in case of all the selected parameters when statistical test was applied.

b. **Threshing of Soybean plants (with thresher):**Subjective perception of male farm workers was recorded while threshing of soybean plants with thresher. Scores indicated that there was 39 to 47 per cent reduction in the drudgery perceived by farm workers when work was performed by improved method. (Table 6)

Work output while performing Soybean harvesting with traditional and improved method

Work output was measured in terms of work area covered under soybean harvesting. It was found that there was increase in pace of work by 4.4 to 16.8 in case of cutting soybean plants with sickle and 25 per cent in collecting and bundling of soybean plants when it was performed by improved method (16-56 sq.mt/h). Similarly, Drudgery reduction was higher that is 39 to 48 per cent for both the selected soybean harvesting activities by improved method.

Useful features of developed soybean mittens for harvesting

- Low cost
- Simple design for stitching
- Made out of locally available material and by local artisan
- Useful for increasing speed of work
- Long sleeves of mittens gives protection to the skin of arms
- Convenient sticking flip belt makes possible to adjust the mitten to any size of wrist and arms

4. Conclusion

There was reduction in physiological cost of work(12-14%) , body discomfort ratings, drudgery perception(39-48 %) and health hazards of female and male workers, when harvesting soybean(cutting plants manually by using sickle and collecting plants and bundling)was performed by wearing soybean mittens. Hence, developed soybean mittens are recommended for increasing work output (4.4 - 25%/h) and reduction of drudgery involved in soybean harvesting activity.

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Soybean Harvesting Mittens (Improved method)

Soybean Harvesting Mittens

Table 1: Perception of farmwomen about localized postural discomfort while performing soybean harvesting

Level of localized postural discomfort	A		B		C		D		E		F		G		H		I	
	T	I	T	I	T	I	T	I	T	I	T	I	T	I	T	I	T	I
No discomfort (0)											5	5	10	10	10	10		
Some discomfort (1)			10	10			5	5			9	9	1	1	1	1	5	5
Minor discomfort (2)	8	8	1	1	30		12	12			1	1	5	5	5	5	12	12
Major discomfort (3)	22	22	8	11			9	9	18	18	10	10	9	9	9	9	9	9
Severe discomfort (4)			11	8			4	4	10	10	5	5	5	5	5	5	4	4
Very Severe discomfort (5)					30				2	2								
Critically Index	7.5	7.5	5.3	5.1	10	4	4.8	4.8	6.9	6.9	4.0	4.0	3.9	3.9	3.9	3.9	4.8	4.8

Description of parameters **:** A- Discomfort of Neck , B- Discomfort of Back, C- Discomfort of Fingers, D- Discomfort of Left Shoulder / Neck, E- Discomfort of Right Shoulder / Neck, F- Discomfort of Left Leg, G- Discomfort of Right Leg, H- Discomfort of Feet, I- Discomfort of Whole Body

Table 2: Response rate of women farm workers for perceived postures while performing soybean harvesting

Parameters	A		B		C		D		E		F		G		H		I		J	
	T	I	T	I	T	I	T	I	T	I	T	I	T	I	T	I	T	I	T	I
Very favourable,																				
Intermediate response b/w 1 and 2																				
Favourable			1	1																
Intermediate response b/w 3 and 5	17	17	7	7	6	6			6	6			5	5	5	5				
Unfavourable	10	10	16	16	13	13	10	10	13	13	5	5	10	10	10	10	5	5	5	5
Intermediate response b/w 5 and 7	3	3	6	6	6	6	10	10	6	6	10	10	5	5	5	5	15	15	15	15
Very unfavourable					5	5	10	10	5	5	15	15	5	5	5	5	10	10	10	10
Criticality Index	4.8	4.8	5.2	5.2	4.8	4.8	6.4	6.4	5.7	5.7	6.8	6.8	4.8	4.8	4.8	4.8	6.6	6.6	6.6	6.6

A- Posture of neck, B-Posture of back, C-Posture of left shoulder, D- Posture of right shoulder, E- Posture of left upper arm, F- Posture of right upper arm, G- Posture of left lower leg, H- Posture of right lower leg, I- Posture of left foot and J- Posture of right foot, T- Traditional method I- Improved method b/w - between

Table 3: Physiological workload of <u>female</u> workers while performing the soybean harvesting activity by traditional method and by using mittens *(Cutting soybean plants with sickle) N:22*

Physiological parameters	Existing method (Mean ± SD)	Improved method (mean ± SD)	Significant reduction in Improved over existing	't' test
Working heart rate (bm^{-1})	114+16.9	108 +15.8	6 (5.26)	NS
Peak heart rate (bm^{-1})	124 ± 16.8	117 ± 16.1	7 (5.64)	NS
Energy expenditure (kjm^{-1})	9.3 ± 2.6	8.5+2.5	0.8 (8.6)	NS
Peak energy expenditure (kjm^{-1})	10.9 ± 2.67	9.9 ± 2.56	0.73 (6.86)	NS
CCW(Beats)	1072+393.5	919+363	153(14.24)	NS
CCR(Beats)	36+33	24+27.75	12(31.85)	
TCCW (Beats)	1108 ± 409	943 ±380	163(14.7)	NS
PCW (bm^{-1})	36.9 ±13.6	31.4 ±12.6	5(14.8)	NS
Average RPE	4.4 ± 0.63	2.66 ± 0.89	1.74 (39.54)	6.21**

Table 4. Physiological workload of <u>female</u> workers while performing the soybean harvesting activity by traditional method and by using mittens **(** *Collecting and Bundling of soybean plants) N:22*

Physiological parameters	Existing method (Mean ± SD)	Improved method (mean ± SD)	Significant reduction in Improved over existing	't' test
Working heart rate (bm^{-1})	115+14.7	108+12.5	7 (6.08)	NS
Peak heart rate(bm$^{-1)}$)	124 ±13.8	120 ± 14.6	4 (3.2)	NS
Energy expenditure (kjm^{-1})	9.59 ± 2.3	8.53+1.9	1.06 (11)	NS
Peak energy expenditure (kjm^{-1})	11 ± 2.2	10.3 ± 2.3	0.66(5.9)	NS
CCW(Beats)	1120+393	920 + 301	200(17.8)	NS
CCR(Beats)	35.8+48.7	27.9 + 36.9	7.9(22.0)	NS
TCCW (Beats)	1156 ± 436.9	948 ± 329	208(17.9)	NS
PCW (bm^{-1})	38+14.5	31+10.9	7(18)	NS
Average RPE	4.4 ± 0.63	2.66 ± 0.89	1.74 (39.54)	6.21**

**Significant at 1% level, Ns- Non significant, CCW- Cardiac cost of work, CCR- Cardiac cost of recovery TCCW -Total cardiac cost of work, PCW - physiological Cost of work, RPE-Rated perceived exertion. Figures in parenthesis indicates percentages

Table 5: Physiological workload of <u>male</u> workers while performing the soybean harvesting activity by traditional method and by using mittens *(Cutting soybean plants with sickle) N:6*

Physiological parameters	Existing method (Mean ± SD)	Improved method (mean ± SD)	Significant reduction in improved over existing	't' test
Working heart rate (bm^{-1})	115+9	110+6.65	5 (4.3)	NS
Peak heart rate (bm^{-1})	125 ±8	119 ± 10	6 (4.8)	NS
Energy expenditure (kjm^{-1})	9.5 ± 1.4	8.73+1.05	0.83 (8.7)	NS
Peak energy expenditure (kjm^{-1})	11.2 ± 1.3	10.3 ± 1.6	0.9(8.13)	NS
CCW(Beats)	1237+286	1080 + 256	157(12.7)	NS
CCR(Beats)	17.1+16.6	17.5 + 14.8	0.38(2.21)	
TCCW (Beats)	1255 ± 273	1097 ± 265	157(12.5)	NS
PCW (bm^{-1})	42+9.1	37+8.8	5(12.5)	NS
RPE	4.2± 0.86	2.2 ± 0.86	2 (47.61)	6.451**

Ns- Non significant, CCW- Cardiac cost of work,
CCR- Cardiac cost of recovery TCCW -Total cardiac cost of work,
PCW - physiological Cost of work, RPE-Rated perceived exertion.
Figures in parenthesis indicates percentages

Table 6: Work output of Soybean harvesting with traditional and improved method

Name of the activity	Parameters for observation	Traditional method	Improved method	Percentage change due to technology	't' test
Female farm workers					
Cutting soybean plants with sickle	Work done / unit time (sq. mt/ 30 min)	164.9+ 48.4	192.6 + 60.9	16.8	NS
Collecting and Bundling of soybean plants	Work done / unit time (Kg/ 30 min)	120	150	25	
	Drudgery score	3.73 ± 0.59	1.93 ±0.45	48	10**
Male farm workers					
Cutting soybean plants with sickle	Work done / unit time(sq. mt/ 30 min)	170.7+69.8	178+ 68.9	4.4	NS
	Drudgery score	4.4 ± 0.82	2.33 ±0.60	47	8.07**
Threshing	Drudgery score	4.33 ± 0.61	2.63 ±0.73	39.3	7.08**

**Significant at 1% level