RESULTS

CHAPTER-IV

RESULTS AND DISCUSSION

This chapter brings presents the findings of the study. The collected data have been analyzed using various statistical procedures in harmony with the stated objectives. The entire analysis of the survey data has been done on the basis of age of the women farmers. For this purpose, the entire sample was divided into two groups i.e. younger women (21-40) years and older women (41-60) years.

The findings have been presented under the following sub heads:-

I Descriptive Data

4.1 Background characteristics

4.2 Anthropometric characteristics

4.3 Information related to weeding operation

4.4 Discomfort experienced with traditional weeding tools

4.5 Testing of Hypotheses

II Experimental data

4.6 Physiological cost of work

4.7 Muscular stress

4.8 Postural stress

4.9 Weeding efficiency

4.10 Output (area weeded)

4.11 Testing of hypotheses

I. DESCRIPTIVE DATA

4.1 Background characteristics

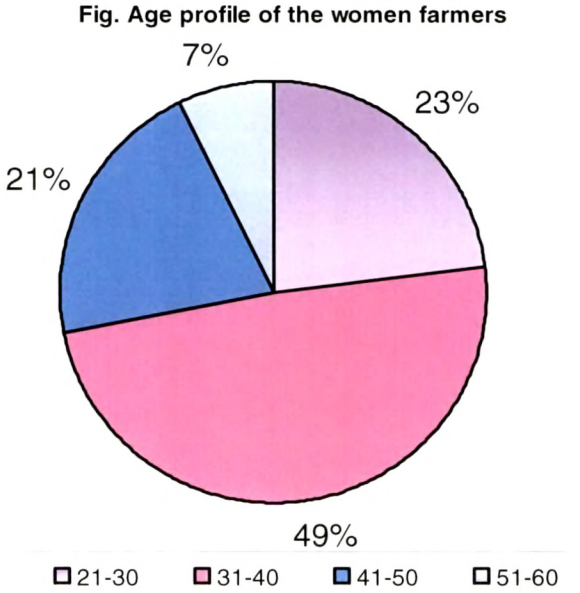
This section highlights background characteristics of a sample of women farmers. Background characteristics comprised personal and family characteristics of the women farmers. Personal characteristics encompassed age and educational level of the respondents. Family characteristics included

family size, family caste, family type, family income, occupation of respondents' husbands, agricultural and livestock details.

4.1.1 Age profile of the women farmers

To ascertain women belonging to which age bracket are more active with regard to weeding operation, data on age of the women farmers was gathered. An overview of the figure shows that women in the age ranging from 21 to 60 years were actively involved in the weeding operation. The average age of women farmers was found to be 37.44±8.88 years. For analysis age has been divided into four mutually exclusive categories viz., 21 through 30 years; 31 through 40 years; 41 through 50 years; and 51 through 60 years. Analysis revealed a little less than half of the women farmers (48.96 per cent) in the age category of 31 through 40 years. A little less than one fourth of the women farmers (22.92 per cent) were found to be in the age category of 21 through 30 years. Small percentage i.e. 7.29 per cent in the age category of 51 through 60 years was found to perform weeding operation. This shows that women irrespective of their age were performing weeding operation and the predominant age group was 31-40 years.

Fig. Age profile of the women farmers



4.1.2 Educational profile of the women farmers

Education is an important variable which influences the attitude toward and adoption of new technologies. Technology and educational level go hand in hand. The present study found that more than half (57.29 per cent) of the women farmers were literate as depicted in table 4.1. Almost forty three per cent of the women farmers were illiterate. Around twenty three per cent had been to school till primary level while 20.83 per cent had education till middle level. Comparison of the older and the younger age groups showed that more number of women in the older age group (70.37 per cent) were illiterate.

Table 4.1 : Educational profile by age of the women farmers

(Number)

S. No.	Educational level	Younger women (21-40 years)	Older women (41-60 years)	Total
1	Illiterate	22(31.88)	19(70.37)	41(42.71)
2	Primary	16(23.19)	6(22.22)	22(22.92)
3	Middle	19(27.54)	1(3.70)	20(20.83)
4	Matric	9(13.04)	1(3.70)	10(10.42)
5	Senior secondary	3(4.35)	-	3(3.12)
6	Total	69(100)	27(100)	96(100)

Figures in parentheses indicate percentage

4.1.3 Family characteristics of the women farmers

Family characteristics of the women farmers have been enclosed in Table (4.2). Data related to family characteristics such as family type, family size, family caste and family income were gathered.

Family Type: It is observed from the Table 4.2 that a majority (58.33 per cent) of the women farmers had nuclear families while 41.67 per cent hailed from joint families. Women in the younger age group mainly (63.77 per cent)

Figure 4.2 Educational profile by age of the women farmers

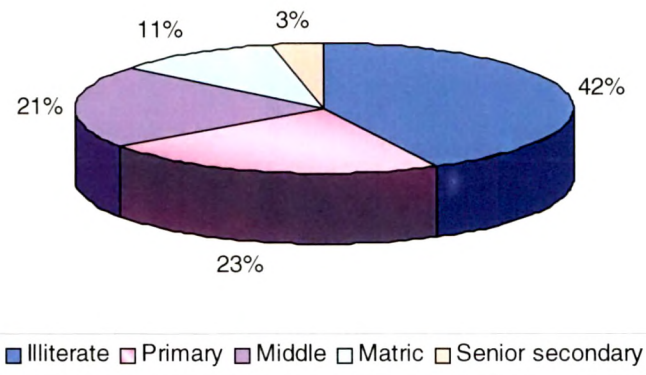
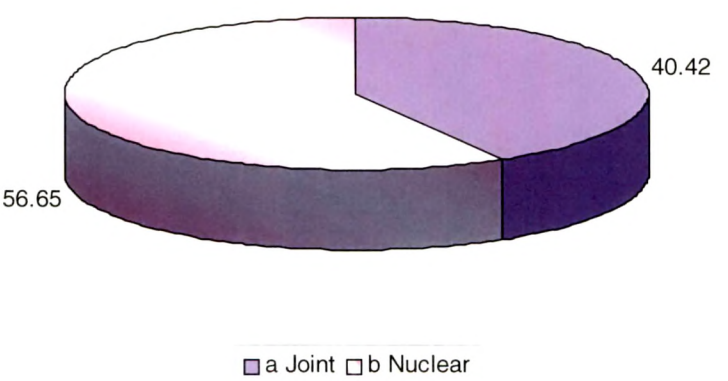


Figure 4.3 Family Type



belonged to the nuclear families, while those in the older age group in most of the cases (44.44 per cent) had nuclear families.

Table 4.2 : Family characteristics of the women farmers

(Number)

S.No	Family characteristic	Younger women (21-40 years)	Older women (41-60 years)	Total
1	**Family type**			
	a Joint	25(36.23)	15(55.55)	40(41.67)
	b Nuclear	44(63.77)	12(44.44)	56(58.33)
	Total	69(100)	27(100)	96(100)
2	**Family size**			
	Upto 4	26(37.68)	9(33.33)	35(36.46)
	5-8	37(53.62)	14(51.85)	51(53.12)
	above 8	6(8.69)	4(14.81)	10(10.42)
	Total	69(100)	27(100)	96(100)
3	**Family caste**			
	Saini	16(23.19)	5(18.52)	21(21.87)
	Choudhary	44(63.77)	17(62.96)	61(63.54)
	Rajput	3(4.35)	-	3(3.12)
	Brahmin	1(1.45)	1(3.70)	2(2.08)
	Bhatt	2(2.9)	2(7.41)	4(4.17)
	Gaddi	3(4.35)	2(7.41)	5(5.21)
	Total	69(100)	27(100)	96(100)

Figures in parentheses indicate percentage

Family size: The mean family size was found to be 5.79±2.67 members. A little more than half of the respondents (53.12 per cent) had family size ranging from 5-8 members. This was followed by 36.46 per cent women who had families having up to four members. In least number of cases (10.42 per cent) women reported family size, above 8 members. Similar pattern was visible across older and younger age groups. Most of the younger women (53.62 per cent) as well as older women (51.85 per cent) had families with 5-8 members. Small percentage, 8.69 per cent younger women and 14.81 per cent older women belonged to families having more than eight members. This shows that mostly the families were of moderate size, neither small nor large.

Family caste: As evident from Table 4.2 women farmers mainly (63.54 per cent) belonged to Choudhary caste. This was followed by 21.87 per cent

women farmers who belonged to Saini caste. Similar pattern was observed for younger and older age groups. Very few respondents belonged to the other castes such as Rajput, Brahmin, Bhatt, and Gaddi. Hence women farmers belonging to Choudhary caste followed by Saini caste emerged out to be actively involved in weeding operation.

Total Yearly family income: The total yearly family income has been calculated combining both agricultural and non-agricultural income. The total yearly family income was categorized into five categories (4.3). Analysis revealed that the total annual income of the families spread over three income ranges viz., (Rs 21,900-71,900), (Rs71, 900.1-121,900) (Rs121, 900.1-171,900). Less than half of the families (42.71 per cent) had income in the range of Rs21, 900-71,900, followed by 34.37 per cent of the families in the income range of Rs 71,900.1-121,900, 14.58 per cent in the income range of Rs121, 900.1-171,900. Small percentage that is 7.29 per cent had income in the range of Rs171, 900.1-221,900. Only one woman farmer reported to have income above Rs 221,900.1.The younger and older women farmers showed an almost similar pattern with respect to the family income. The mean family income was found to be Rs. 89978.54 ± 49927.55.

Table 4.3 : Total yearly family income

(Number)

S. No.	Total yearly income	Younger women (21-40 years)	Older women (41-60 years)	Total
1	21,900-71,900	28(40.58)	13(48.15)	41(42.71)
2	71,900.1-121,900	24(34.78)	9(33.33)	33(34.37)
3	121,900.1-171,900	11 (15.94)	3(11.11)	14(14.58)
4	171,900.1-221,900	5(7.25)	2(7.41)	7(7.29)
5	221,900.1 and above	1(1.45)	-	1(1.04)
6	Total	69(100)	27(100)	96(100)

figures in parentheses indicate percentage

Occupation of the husbands: The husbands of women farmers were occupied in a variety of jobs ranging from unskilled manual labour to skilled worker. As reflected from the analysis a little above one fourth of the women (27.08 per cent) reported their husbands to be labourers. A little below one fourth of women (20.83 per cent) reported their husbands to be engaged in government service. Followed by this were 17.71 per cent women who reported their husbands to be occupied in business activities. About 12.5 per cent reported their husbands to be fully occupied in agriculture, 11.46 per cent reported their husbands to be skilled workers in the capacity of driver, carpenter, tailor etc.

Table 4.4: Occupational pattern of respondents' husbands

(Number)

S No.	Occupation	Younger women (21-40 years)	Older women (41-60 years)	Total
1	Unskilled labourer	23(33.33)	3(11.11)	26(27.08)
2	Agriculture	1(1.45)	11(40.74)	12(12.5)
3	Business	11(15.94)	6(22.22)	17(17.71)
4	Skilled worker	10(14.49)	1(3.70)	11(11.46)
5	Government service	15(21.74)	5(18.52)	20(20.83)
6	Army	6(8.69)	-	6(6.25)
7	Unskilled government job	3(4.35)	1(3.70)	4(4.17)
8	Total	69(100)	27(100)	96(100)

Figures in parentheses indicate percentage

Agriculture and livestock details

Landholding size: The mean landholding size was 12.54±1.07 kanals. As reflected from the Table 4.5 Almost 60 per cent of the women farmers owned the landholding size in the range of 2-10 kanals, followed by 26.04 per cent women farmers who had landholding size in the range of 10.1-20 kanals. In least number of cases (13.54 per cent), women farmers owned landholding above 20 kanals A closer view of the younger and older age groups showed that around 62 per cent of the younger women had landholding in the range of 2-10 kanals and just 13.04 per cent had landholding above 20 kanals. Similar was the case with the women farmers belonging to the older age group.

Livestock: The data pertaining to livestock have been presented in Table 4.5. On an average the women farmers had 2.56±1.59 animals. The results indicated that more than half of the women farmers (56.25 per cent) had 1-2 animals. The various animals kept by farmers included cows, buffaloes, bullocks, sheep, goats and hens. This was followed by 31.25 per cent women farmers who had 3-4 animals. In least number of cases (8.33 per cent), women farmers had more than four animals. A study of data pertaining to younger and older women showed similar pattern of livestock ownership. More than 50 per cent of both younger women (56.52 per cent) as well as older women (55.55 per cent) had up to 2 animals. Forty per cent of older women and 27.14 per cent younger women had 3-4 animals. Ten per cent of younger women had more than four animals as compared to just one older woman who owned more than four animals. Four younger women reported that they do not possess animals.

Milk yield: Out of total, 40.62 per cent of women farmers reported milk yield to be 2.1-5 litres per day. A little more than one fourth of the women farmers (27.08 per cent) disclosed daily milk yield to be up to 2 litres. A little less than one fourth of the women farmers (23.96 per cent) reported milk yield to be above 5 litres. In four cases, there were only bullocks and in another four cases there were no animals. Therefore, in 8.33 per cent cases, there was no milk yield as they did not have any milk producing animal. The mean milk yield was found to be 3.63±2.82 litres/day.

The study of agriculture and livestock details shows that farmers owned small landholdings. As the size of landholding was small, number of livestock was also less. As to support animals plenty of grass is required.

Table 4.5 : Agriculture and livestock details

(Number)

S.No.	Landholding size (in kanals)	Younger women (21-40 years)	Older women (41-60 years)	Total
1	2-10	43(62.32)	15(55.55)	58(60.42)
2	10.1-20	17(24.64)	8(29.63)	25(26.04)
3	Above 20	9(13.04)	4(14.81)	13(13.54)
4	Total	69(100)	27(100)	96(100)
	No. of livestock			
1	Up to 2	39(56.52)	15(55.55)	54(56.25)
2	3-4	19(27.14)	11(40.74)	30(31.25)
3	Above 4	7(10.54)	1(3.70)	8(8.33)
4	No livestock	4(5.79)	-	4(4.17)
5	Total	69(100)	27(100)	96(100)
	Milk yield(in litres)			
1	Up to 2	17(24.64)	9(33.33)	26(27.08)
2	2.1-5	31(44.93)	8(29.63)	39(40.62)
3	Above 5	13(18.84)	10(37.04)	23(23.96)
4	No milk yield	8(11.59)	-	8(8.33)
5	Total	69(100)	27(100)	96(100)

Figures in parentheses indicate percentage

It is further observed from the table (4.5) that 44.93 per cent of the younger women reported milk yield in the range of 2.1- 5 litres as against 29.63 per cent older women. Nearly thirty seven per cent of the older women reported milk yield to be above 5 litres compared to 18.84 per cent younger women.

4.2 Anthropometric characteristics

Anthropometric measurements are useful in evaluating the interaction of workers with tasks, tools, and machines. Agricultural equipments and tools that are incompatible with the anthropometric characteristics of the farm workers have the higher probability of producing undesired injuries, serious health effects. To avoid any mismatch and misfit it is necessary to design the equipment or tool keeping in consideration the operators' capabilities and limitations. Anthropometry is influenced by sex differences, ethnic differences, growth and development, secular trends, aging, and social class and occupation (Pheasant, 1986). Most of the agricultural equipment is manufactured keeping in mind the characteristics of the men workers. Anthropometric data related to women agricultural workers need to be collected in order to fabricate equipment as per their physical characteristics. The present study endeavored to collect data related to some of the body dimensions of the women farmers residing in Kangra district. The anthropometric characteristics useful for the development of manually operated tools were measured. The minimum, maximum, mean, standard deviation, 95^{th} percentile, and 5^{th} percentile values of various characteristics have been presented in Table 4.6.

Weight: The weight of the women farmers ranged from 36-74kg with the mean of 47.83±7.72kg. The 95^{th} and 5^{th} percentile values were 60.53kg and 35.14kg respectively.

Stature: The mean standing height (stature) of the women farmers was found to be 151.77± 4.78 cm. The height of the women farmers varied from 135.5 to 166.8 cm with 95^{th} and 5^{th} percentile to be 159.63cm and 143.90cm respectively.

Shoulder height: The mean shoulder height of the women farmers was found to be 125.88 ± 3.92cm. The shoulder height of the women farmers varied from 115-139cm. The 95th and 5th percentiles were found to be 132.34cm and 119.43cm respectively.

Waist height: Analysis showed the mean waist height of the women farmers to be 96.41±3.95cm. The 95th and 5th percentile values were 102.91cm and 89.91cm respectively. The respective minimum and maximum waist height values were 86.5cm and 107.1 cm.

Elbow height: On an average the elbow height of the women farmers was found to be 95.38±3.89 cm. It varied between 87.1cm and 105.3 cm. The 95th and 5th percentile values were 101.77cm and 88.98 cm respectively.

Knee height: Analysis revealed the mean knee height to be 41.55 ± 3.02cm. The respective 95th and 5th percentile values were 46.52cm and 36.58 cm. The minimum knee height was 33.3cm while the maximum knee height was 48.5cm.

Waist back length: The waist back length of the women farmers varied between 29 and 40cm. The mean waist back length of women farmers was observed to be 34.07±1.98 cm. The respective 95th and 5th percentiles were 37.33cm and 30.81cm.

Forearm length: The mean forearm length of the women farmers was observed as 24.48±1.72cm. The respective 95th and 5th percentiles were 27.31cm and 21.64cm. The forearm length varied between 20cm and 28cm.

Table 4.6: Anthropometric characteristics of the women farmers

n=96

Dimensions	Minimum	Maximum	Mean	Standard Deviation	95th percentile	5th percentile
Weight	36	74	47.83	7.72	60.53	35.14
Stature	135.5	166.8	151.77	4.78	159.63	143.90
Shoulder height	115	139	125.88	3.92	132.34	119.43
Waist height	86.5	107.1	96.41	3.95	102.91	89.91
Elbow height	87.1	105.3	95.38	3.89	101.77	88.98
Knee height	33.3	48.5	41.55	3.02	46.52	36.58
Waist back length	29	40	34.07	1.98	37.33	30.81
Forearm length	20	28	24.48	1.72	27.31	21.64
Hand length	14.3	19.1	16.91	0.94	18.45	15.36
Forearm hand length	36.3	45.6	41.38	1.88	44.47	38.29
Palm length	7.5	11.8	9.54	0.72	10.73	8.34
Hand breadth across thumb	7	10.5	9.18	0.64	10.23	8.13
Hand breadth across metacarpal III	5.5	9.5	7.64	0.79	8.94	6.35
Wrist breadth	4.4	7.7	5.89	0.71	7.05	4.73

All dimensions in cm except weight in kg

Hand length: Analysis revealed mean hand length as 16.91±0.94cm. The respective 95th and 5th percentile values were 18.45cm and 15.36cm. The hand length of the women farmers varied between 14.3cm and 19.1cm.

Forearm hand length: On an average, the forearm hand length of the women farmers was 41.38±1.88 cm. The 95th and 5th percentile values 44.47cm and 38.29 cm. The forearm hand length of the women farmers varied between 36.3cm and 45.6 cm.

Palm length: The palm length of the women farmers varied between 7.5cm and 11.8 cm. The mean palm length of the women farmers was found to be 9.54±0.72cm. The respective 95th and 5th values were found to be 10.73cm and 8.34cm.

Hand breadth across thumb: Analysis of data showed the mean hand breadth across thumb to be 9.18±0.64cm. It varied between7cm and 10.5cm.The respective 95th and 5th values were 10.23cm and 8.13cm.

Hand breadth across metacarpal III: The mean hand breadth across metacarpal III was 7.64±0.79cm. The minimum and maximum values were 5.5cm and 9.5cm respectively. The 95th and 5th percentile values were observed as 8.94cm and 6.35 cm respectively.

Wrist breadth: Analysis of the data revealed the mean wrist breadth of the women farmers to be 5.89±0.71cm. It varied between 4.4cm and 7.7cm. The respective 95th and 5th percentiles were 7.05cm and 4.73cm.

4.3 Information regarding weeding operation

This section gives detailed information on weeding operation. A number of vegetables are cultivated such as cabbage/cauliflower, ladyfinger, potato, brinjal, gourds, carrot, radish etc which require weeding operation. Number of times for which weeding is carried varies according to the vegetables as shown in Table 4.7. Cabbage and cauliflower are mostly planted around first week of October. There are late sown varieties also. The cultivation of these two vegetables is carried till March. It was found that out of 56 women farmers who cultivate cabbage/ cauliflower, a majority (73.21 per cent) of the women

farmers carry out weeding operation thrice for cabbage and cauliflower, while 26.78 per cent carry out weeding twice.

Table 4.7 : Frequency of weeding per crop.

(Number)

S No.	Crop	Frequency of weeding			
		Once F	Twice F	Thrice F	Total
1	Cabbage/cauliflower	-	15(26.78)	41(73.21)	56(100)
2	Lady finger	-	37(66.07)	19(33.93)	56(100)
3	Potato	23(41.07)	33(58.93)	-	56(100)
4	Brinjal	1(1.78)	55(98.21)	-	56(100)
5	Gourds/pumpkin/cucumber	1(1.82)	49(89.09)	5(9.09)	55(100)
6	Turnip/ raddish/ carrot	3(6.00)	47(94.00)	-	50(100)
7	Onion/garlic	5(31.25)	11(68.75)	-	16(100)

Figures in parentheses indicate percentage

Ladyfinger is usually sown in April. A majority (66.07 per cent) of the women farmers perform weeding for ladyfinger twice and the remaining (33.93 per cent) perform weeding thrice.

A little above half of the women farmers (58.93 per cent) perform weeding twice for potato crop and the remaining 41.07 per cent farmers perform weeding once.

Out of 55 women farmers, 89.09 per cent reported to perform weeding operation in brinjal twice except one farmer who reported to perform once.
Out of 55 women farmers, majority (89.09 per cent) reported to perform weeding operation in gourds/pumpkin/cucumber twice followed by 9.09 per cent women farmers who reported to perform weeding operation thrice. One woman farmer reported to perform weeding operation only once.

Carrot, radish and turnip are sown in the month of September. Out of 50 women farmers who reported to cultivate these crops, 94 per cent said they perform weeding operation in these crops twice while remaining 6 per cent reported to perform weeding operation in these crops only once.

Out of sixteen women farmers women who reported to cultivate onion/garlic, 68.75 per cent reported to perform weeding operation twice and 31.25 per cent said that they perform weeding operation once.

Number of days after which weeding is performed in various vegetables:
Cabbage/cauliflower: A little below two fifth of the women farmers (37.5 per cent) perform first weeding 16- 20 days after planting cabbage/ cauliflower, while 28.57 per cent after 10-15 days of plantation. Nearly 18 per cent women farmers perform first weeding after 21-25 days (Table 4.8).

A little above half of the women farmers (55.36 per cent) perform second weeding 16-20 days after first weeding operation, followed by 25 per cent women who said that they perform second weeding 10-15 days after first weeding. Sixteen per cent perform second weeding 21-25 after first weeding. Least number of women farmers perform second weeding after 26-30 days of first weeding. Out of 56 farmers, 41 said that they perform third weeding. Out of 41, 51.22 per cent women reported to perform third weeding 16-20 days after second weeding operation, 31.71 per cent reported to perform 10-15 days after second weeding, 14.63 per cent reported to perform 21-25 days after second weeding. One woman farmer said to perform third weeding after 26-30 days of second weeding operation.

Table 4.8 : Number of days after which weeding is performed in various winter vegetables

(Number)

Number of days after which weeding is performed	First weeding	Second weeding	Third weeding
Cabbage/Cauliflower			
10-15	16(28.57)	14(25)	13(31.71)
16-20	21(37.5)	31(55.36)	21(51.22)
21-25	10(17.86)	9(16.07)	6(14.63)
26-30	9(16.07)	2(3.57)	1(2.44)
Total	56(100)	56(100)	41 (100)
Potato			
10-20	-	24(72.73)	
21-30	-	9(27.27)	
20-35	34(60.71)	-	
36-50	21(37.5)	-	
Above50	1(1.78)	-	
Total	56(100)	33(100)	
Radish/turnip/carrot			
10-15	35(70.00)	35(74.47)	
20	-	12(25.53)	
20-25	15(30)	-	
Total	50(100)	47(100)	
Onion/garlic			
15	-	8(72.73)	
20	-	1(9.09)	
25	2(12.5)	2(18.18)	
30	13(81.25)	-	
35	1(6.25)	-	
Total	16(100)	11(100)	

Figures in parentheses indicate percentage

Potato: About three - fifth of the women farmers (60.71 per cent) perform first weeding operation 20-35 days after sowing while 37.5 per cent perform 36-50

days after sowing. Just one woman farmer reported to perform first weeding after more than 50 days of sowing operation.

Out of 33 women farmers who reported to perform second weeding operation in potato, a majority (72.73) reported to perform second weeding operation after 10-20 days of first weeding operation. The remaining 27.27 per cent reported to perform second weeding operation 21-30 days after first weeding operation.

Radish/carrot/turnip: Out of 50 women farmers, majority (70 per cent) reported to perform first weeding operation 10-15 days after sowing. The remaining 30 per cent said that they carry out first weeding operation 20-25 days after sowing.

Out of 47 women farmers who reported to perform second weeding operation, 74.47 per cent said that they carry second weeding operation10-15 days after first operation. The remaining 25.53 per cent said that they perform second weeding operation twenty days after first weeding operation.

Onion/garlic: Out of 16 women farmers who perform weeding operation in onion/garlic, a majority (81.25 per cent) said that they usually perform first weeding operation 30 days after planting onion and sowing garlic. Two women farmers (12.5 per cent) said that they perform first weeding operation after 25 days and the remaining one women farmer said that she usually performs first weeding operation 35 days after sowing garlic and planting onion. Out of 11 women farmers who reported to perform second weeding operation 72.73 per cent said that they carry out second weeding operation 15 days after first weeding operation. Two women farmers (18.18 per cent) said that they perform second weeding operation 25 days after first weeding operation while one women farmer reported to perform second weeding operation 20 days after first weeding operation.

Table 4.9 : Number of days after which weeding is performed in various summer vegetables

(Number)

Number of days after which weeding is performed	First weeding	Second weeding	Third weeding
Ladyfinger			
10-15	-	8(14.3)	7(36.84)
16-20	28(50)	26(46.4)	11(57.89)
21-25	10(17.86)	6(10.7)	-
26-30	18(32.14)	16(28.57)	1(5.3)
Total	56(100)	56(100)	19(100)
Gourds/pumpkin			
15	-	18(33.33)	5(100)
15-30	-	36(66.67)	-
15-25	33(60.00)	-	-
26-35	22(40.00)	-	-
Total	55(100)	54(100)	5(100)
Brinjal			
15-20	34(60.71)	38(69.09)	-
25-30	22(39.28)	17(30.90)	-
Total	56(100)	55(100)	-

Figures in parentheses indicate percentage

Lady finger: Out of 56 women farmers, half of the women farmers said that they carry out first weeding operation for ladyfinger 16-20 days after sowing while 32.14 per cent perform first weeding 26-30 days after sowing. Nearly 18 per cent reported to perform first weeding operation 21- 25 days after sowing.

A little less than half of the women farmers (46.4 per cent) perform second weeding 16-20 days after first weeding operation. A little above one fourth of the women farmers (28.57 per cent) perform second weeding operation 26-30 days after first weeding, 14.3 per cent perform second weeding 10-15 days after first weeding. In least number of cases (10.7 per cent) women farmers

said that they perform second weeding operation in ladyfinger after 21-25 days of second weeding operation (Table 4.9).

Out of 19 women farmers, nearly 58 per cent reported to perform third weeding operation16-20 days after second weeding operation, 36.84 per cent women farmers perform third weeding 10-15 days after second while the remaining one women farmer reported to perform third weeding operation 26-30 days after first weeding.

Gourds/pumpkin/cucumber: Sixty per cent of the women farmers said that they carry out first weeding operation in gourds/pumpkin/cucumber 15-25 days after sowing. The remaining 40 per cent reported that they perform first weeding operation 26-35 days after sowing.

Fifty four women farmers reported to perform weeding operation in gourds/pumpkin/cucumber. Out of 54 women farmers, 66.67 per cent reported that they perform second weeding after 16-30 days of first weeding operation and 33.33 per cent reported to perform second weeding operation after 15 days of first weeding operation.

Only 5 women farmers reported to perform third weeding operation. All of them said that they do it after 15 days of second weeding operation.

Brinjal: Out of 56 women farmers, 60.71 per cent reported to perform first weeding operation 15-20 days after planting brinjal. The remaining 39.28 per cent said that they carry out first weeding operation 25-30 days after planting brinjal.

Out of 55 women farmers who reported to perform second weeding operation, majority (69.09 per cent) said that they do so 15-20 days after first weeding operation. Nearly 40 per cent said that they carry out second weeding operation 25-30 days after first weeding operation.

Number of years of weeding operation: It is discerned from Table 4.10 that most (40.62 per cent) of the women farmers had been performing weeding operation since 11-20 years. This was followed by 36.46 per cent women farmers who had been performing weeding operation for more than twenty years. A little less than one fourth of women farmers (22.92 per cent) had been performing weeding operation for ten years and less.

Table 4.10 : Number of years of weeding operation

(Number)

SNo.	Number of years	Younger women (21-40years)	Older women (41-60years)	Total
1	10 and<10	22(31.88)	-	22(22.92)
2	11-20	38(55.07)	1(3.70)	39(40.62)
3	Above 20	9(13.04)	26(96.29)	35(36.46)
4	Total	69(100)	27(100)	96(100)

Figures in parentheses indicate percentage

Posture assumed for weeding: Women perform weeding operation by squatting, bending at the back, and by altering between squatting and bending, thus, using both postures. Nearly half of the women farmers (51.04 per cent) reported to perform weeding operation using squatting posture. Nearly 38.54 per cent reported to use both squatting and bending posture while carrying out weeding operation.

Table 4.11 : Posture used by women while performing weeding operation

(Number)

SNo.	Posture used	Younger women (21-40years)	Older women (41-60years)	Total
1	Squatting	33(47.83)	16(59.26)	49(51.04)
2	Bending at the back	7(10.14)	3(11.11)	10(10.42)
3	Both(squatting and bending)	29(42.03)	8(29.63)	37(38.54)
4	Total	69(100)	27(100)	96(100)

Figures in parentheses indicate percentage out of total

Number of hours of continuous weeding: Table 4.12 encloses information related to number of hours for which women continuously perform weeding operation without taking rest. The average number of hours for which women farmers continuously perform weeding was found to be 1.87±0.83 hours. Analysis of data further revealed that most (53.12 per cent) of the women farmers reported to perform weeding operation continuously for 1.1 to 2 hours without taking rest. In 37.5 per cent cases, women reported to perform weeding operation continuously for 2.1 to 3 hours. In least number of cases (9.37 per cent), women reported to continuously perform weeding operation for one hour and less. Almost half of the younger women farmers reported that they mostly perform weeding operation continuously for 1.1 to 2 hours, while 42.03 per cent reported to carry out weeding continuously for 2.1-3 hours. On the other hand, a majority (62.96 per cent) of older women farmers reported that they usually perform weeding continuously for 1.1 to 2 hours. It could be concluded that by virtue of their age larger number of women farmers were performing weeding operation for longer duration of time.

Table 4.12 : Continuous weeding without taking rest

(Number)

SNo.	No. of hours	Younger women (21-40years)	Older women (41-60years)	Total
1	1 and <1	6(8.69)	3(11.11)	9(9.37)
2	1.1-2	34(49.27)	17(62.96)	51(53.12)
3	2.1-3	29(42.03)	7(25.92)	36(37.5)
4	Total	69(100)	27(100)	96(100)

Figures in parentheses indicate percentage out of total

Frequency of rest period: Most of the women farmers (54.17 per cent) revealed that they take just one or two rest periods in between weeding operation. A little more than one fourth of the women farmers (30.21 per cent) reported that they take three or four rest periods in between weeding operation.

Table 4.13 : Frequency of rest period

(Number)

SNo.	No. of rest periods	Younger women (21-40 years)	Older women (41-60years)	Total
1	1-2	43(62.32)	9(33.33)	52(54.17)
2	3-4	18(26.09)	11(40.74)	29(30.21)
3	5-6	6(8.69)	6(22.22)	12(12.5)
4	Above 6	2(2.9)	1(3.70)	3(3.12)
5	Total	69(100)	27(100)	96(100)

Figures in parentheses indicate percentage

Small percentage (12.5 per cent) reported to take five or six rest periods in between the operation. In least number of cases, women reported to take rest for more than six times.

Comparison of younger and older age groups showed that majority (62.32 per cent) of younger women reported to take one or two rest periods in between weeding. Nearly one fourth of younger women (26.09 per cent) said that they take rest for three or four times in between weeding. On the other hand, most of the older women (40.74 per cent) revealed that they take rest for three or four times in between weeding operation. A little less than one fourth of women farmers (22.22 per cent) reported to take rest for five or six times in between weeding operation compared to 8.69 per cent younger women farmers who reported 5 or 6 rest periods. This shows that older women farmers were more frequently taking rest compared to younger women farmers.

Duration of rest period: Analysis of data revealed that most of the women farmers (41.67 per cent) take rest for 10 minutes followed by 23.96 per cent women farmers who take rest for 15 minutes, 15.62 per cent women farmers who take rest for 20 minutes, 9.37 per cent women farmers who take rest for 20 minutes. Two women farmers reported to take rest for 45 minutes. Analysis of data pertaining to younger women showed duration of rest period for most of the younger women (36.23 per cent) to be10 minutes, followed by 26.09 per cent who reported duration of rest period to be 15 minutes, 17.39 per cent who reported duration of rest period to be 5 minutes. The study of data related to older women showed that a little more than half of the women farmers had been taking rest for 10 minutes.

Table 4.14 : Duration of rest period

(Number)

SNo.	Duration (in minutes)	Younger women (21-40 years)	Older women (41-60 years)	Total
1	5	12(17.39)	3(11.11)	15(15.62)
2	10	25(36.23)	15(55.55)	40(41.67)
3	15	18(26.09)	5(18.52)	23(23.96)
4	20	8(11.59)	1(3.70)	9(9.37)
5	30	6(8.69)	1(3.70)	7(7.29)
6	45	-	2(7.41)	2(2.08)
7	Total	69(100)	27(100)	96(100)

Figures in parentheses indicate percentage out of total

Total time spent on weeding in a day: A majority (63.54 per cent) of women farmers were found to perform weeding for 3.1 to 6 hours in a day. Thirty five per cent were found to perform weeding for 6.1 to 9 hours in a day. Just one woman was found to perform weeding for 1-3 hours

Table 4.15 : Number of hours in a day spent in weeding

(Number)

S.No.	Hours in a day	Younger women (21-40 years)	Older women (41-60 years)	Total
1	1-3	1(1.45)	-	1(1.04)
2	3.1-6	46(66.67)	15(55.55)	61(63.54)
3	6.1-9	22(31.88)	12(44.44)	34(35.42)
4	Total	69(100)	27(100)	96(100)

Figures in parentheses indicate percentage out of total.

Analysis further shows that majority (66.67 per cent) of younger women usually perform weeding operation for 3.1-6 hours against 55.55 per cent

older women who reported to perform weeding for 3.1-6 hours. More percentage of older women farmers (44.44 per cent) were performing weeding operation for 6.1-9 hours compared to younger women (31.88 per cent).

Help received: The information regarding family members who help respondent in weeding has been enclosed in Table 4.16. Analysis of data showed that 38.54 per cent of women farmers had one person to help them in carrying out weeding operation. Almost twenty per cent women farmers revealed that they were assisted by two more persons in addition. In just 5.21 per cent cases, three persons were helping respondents, while in 36.46 per cent cases, respondents were working alone.

Analysis further revealed that 11.46 per cent of women farmers had the help of children in performing weeding operation. In 9.37 per cent cases, daughters-in- law and in 8.33 per cent cases, mothers-in-law were performing weeding along with them. In 9.37 per cent cases, women had hired labour at their disposal. In equal number of cases (9.37 per cent) husbands were helping them.

A closer view of the table indicates that 29.63 per cent older women farmers get the help of their daughters - in- law in weeding operation and 14.81 per cent get the help of children. On the other hand 1.45 per cent younger women farmers reported that their daughters-in-law help them in carrying out weeding operation while 10.14 per cent told that children help them in performing weeding operation.

Eleven per cent older women reported to take the help of hired labour in performing weeding operation against 8.69 per cent younger women who said that they take the help of hired labour.

Table 4.16 : Help received by respondent in weeding

(Number)

S No.	Number of helping hands	Younger women (21-40) years	Older women (41-60) years	Total
1	One	26(37.68)	11(40.74)	37(38.54)
2	Two	11(15.94)	8(29.63)	19(19.79)
3	Three	3(4.35)	2(7.41)	5(5.21)
4	No help	29(42.03)	6(22.22)	35(36.46)
5	Total	69(100)	27(100)	96(100)
	Family members who help			
1	Mother –in –law	8(11.59)	-	8(8.33)
2	Daughter –in –law	1(1.45)	8(29.63)	9(9.37)
3	Sister-in –law	6(8.69)	-	6(6.25)
4	Children	7(10.14)	4(14.81)	11(11.46)
5	Husband	6(8.69)	3(11.11)	9(9.37)
6	Hired help	6(8.69)	3(11.11)	9(9.37)
7	Husband +hired help	1(1.45)	-	1(1.04)
8	Sister- in- law + mother – in- law	3(4.35)	-	3(3.12)
9	Husband+ other family members	2(2.90)	3(11.11)	5(5.21)
10	Respondent alone/no help	29(42.03)	6(22.22)	35(36.46)
11	Total	69(100)	27(100)	96(100)

Figures in parentheses indicate percentage

Total number of days spent on weeding in a year: Table 4.17 presents total number of days required to complete weeding in a year. The total number of days has been divided into four categories. Analysis showed that in 35.42 per cent cases, less than 20 days were spent in weeding, 33.33 per cent women farmers reported that 21-40 days were spent. A little less than

one fourth of women farmers (20.83 per cent) reported that 41 – 60 days were spent in weeding. In least number of cases (10.42 per cent), more than 60 days were spent in completing weeding operation.

Table 4.17 : Total number of days spent on weeding in a year

(Number)

S No.	Total days in a year	Younger women (21-40) years	Older women (41-60) years	Total
1	< than 20	21(30.43)	13(48.15)	34(35.42)
2	21-40	24(34.78)	8(29.63)	32(33.33)
3	41-60	16(23.19)	4(14.81)	20(20.83)
4	>than60	8(11.59)	2(7.41)	10(10.42)
5	Total	69(100)	27(100)	96(100)

Figures in parentheses indicate percentage

Area covered in a day: Analysis revealed that on an average women farmers cover 0.34±0.13 of a kanal in a day with traditional tools. Majority (71.87 per cent) of women farmers reported that they are able to weed an area in the range of 0.25 – 0.49 kanals in a day. It was followed by 15.62 per cent women farmers who said that they usually cover an area falling in the range of 0.50 – 0.74 kanal in a day. Small number of women farmers (10.42 per cent) reported to cover an area less than 0.25 kanals in a day. Just two women farmers (2.08 per cent) said that they are able to cover an area falling in the range of 0.75 – 1 kanals in a day. Comparison of younger and older age groups showed that majority of both groups i.e. 72.46 per cent younger women and 70.37 per cent older women generally cover an area falling in the range of 0.25- 0.49 kanals. None of the older women reported to cover area in the range of 0.75 – 1 kanal while 18.52 per cent women reported that they cover area in the range of 0.50-0.74 kanals in a day against 14.49 per cent younger women.

Table 4.18 : Total area weeded with traditional tools by women farmers in a day

(Number)

S No.	Area covered (in kanals)	Younger women (21-40) years	Older women (41-60) years	Total
1	< than 0.25	7(10.14)	3(11.11)	10(10.42)
2	0.25-0.49	50(72.46)	19(70.37)	69(71.87)
3	0.50-0.74	10(14.49)	5(18.52)	15(15.62)
4	0.75-1	2(2.90)	-	2(2.08)
5	Total	69(100)	27(100)	96(100)

Figures in parentheses indicate percentage

Frequency of falling ill: In order to have an idea about the health status of the women farmers, they were asked about how frequently they fall ill, suffer from common illnesses. Table 4.19 shows the frequency of suffering from common illnesses as perceived by the women farmers. It was found that a little above one third of the women farmers (37.5 per cent) fell ill 'once in a year' followed by one third of the women farmers who reported to fall ill 'once in six months', 16.7 per cent who reported to fall ill 'once in three months'. In least number of cases (12.5 per cent), respondents reported that they fell ill 'once a month'. Comparison of the younger and older women showed that 46.4 per cent of younger women farmers reported to have fallen ill 'once in a year' while 33.3 per cent older women farmers reported to have fallen ill 'once in six months'. Furthermore, 5.8 per cent younger women reported falling ill very frequently i.e. 'once a month' while 29.6 per cent of older women reported to falling ill 'once a month'.

Table 4.19: Frequency of falling ill according to the age of women farmers

(Number)

S No.	Frequency of falling ill	Younger women (21-40) years	Older women (41-60) years	Total
1	Once a month	4(5.8)	8(29.6)	12(12.5)
2	Once in three months	10(14.5)	6(22.2)	16(16.7)
3	Once in six months	23(33.3)	9(33.3)	32(33.3)
4	Once in a year	32(46.4)	4(14.8)	36(37.5)
5	Total	69(100)	27(100)	96(100)

Figures in parentheses indicate percentage

Type of weeding tool used: Results indicated that on the whole, majority (78.1 per cent) of women farmers were using 'khutti' for weeding (Table4.20). It is a short handled weeding tool with the blades of different shapes and sizes. In 12.5 per cent cases the women farmers were using both 'khutti' as well as 'phuara'. In just 9.4 per cent cases the women farmers were using only 'phuara' for weeding. It was further found that lesser number of older women farmers were using 'phuara' alone for weeding. 'Phuara' is a weeding tool with a handle longer than 'khutti' and operated in a bent posture as the handle is not long enough to avoid the bent posture. Blade of the 'phuara' appears squarish in shape. This weeding tool is generally used by the women farmers belonging to the villages of Bhagotla, Upper Menjha, Latwala where the farmers are more into cultivating potato which is grown making hedges.

Table 4.20 : Type of weeding tool used according to the age of women farmers

(Number)

S. No.	Tool used	Younger women (21-40) years	Older women (41-60) years	Total
1	Khutti	54(78.3)	21(77.8)	75(78.1)
2	Phuara	7(10.1)	2(7.4)	9(9.4)
3	Both khutti and phuara	8(11.6)	4(14.8)	12(12.5)
4	Total	69(100)	27(100)	96(100)

Extent of discomfort experienced by the women farmers in different body parts with the traditional tools

In order to determine extent of discomfort felt by women farmers while working with traditional tools they were asked to rate the discomfort on a 10 point scale ranging from 0 (for no discomfort) to 10 (for extreme discomfort) for each of the body part where they reported discomfort. Body map given by Corlett and Bishop (1976) was shown to women for the purpose. Table (4.21) shows twenty five different body parts as reported by women farmers where they feel discomfort while working traditional tools. They were left elbow, left forearm, left palm, left foot, left arm, left wrist, right elbow, right forearm, right palm, right arm, right wrist, right leg, right thigh, left thigh, left clavicle, right clavicle, left knee, right knee, left shoulder, right shoulder neck, mid back, upper back, lower back.

Out of total, 17.7 per cent reported discomfort in left elbow, 20.8 per cent reported discomfort in left forearm, 15.6 per cent reported discomfort in left palm, 18.8 per cent in left foot, 24.0 per cent in left arm, 13.5 per cent in left wrist, 29.9 per cent in right elbow, 30.2 per cent in right forearm, 19.8 per cent right palm, 26.0 per cent in right arm, 27.1 per cent in right wrist, 15.6 per cent right leg, 12.5 per cent in left thigh, 12.5 per cent in right thigh, 3.1 per cent in

left clavicle, 3.1 per cent in right clavicle, 40.6 in left knee, 40.6 right knee, 37.5 per cent left shoulder, 62.5 per cent in right shoulder, 12.5 per cent in neck, 33.3 per cent mid back, 17.7 per cent in upper back, and 95.8 per cent in lower back.

Table 4.21 : Extent of discomfort experienced by the women farmers in different body parts with traditional weeding tools

(Number)

S. No.	Body part	Frequency of women farmers	Mean discomfort score		
			Mild (0.3.3)	Moderate (3.4-6.6)	Severe (6.7-10)
1	Left elbow	17(17.7)	-	5.41	-
2	Left forearm	20(20.8)	-	5.50	-
3	Left palm	15(15.6)	-	5.60	-
4	Left foot	18(18.8)	-	5.72	-
5	Right foot	18(18.8)	-	5.72	-
6	Left arm	23(24.0)	-	5.78	-
7	Left wrist	13(13.5)	-	5.85	-
8	Right elbow	22(29.9)	-	5.86	-
9	Right forearm	29(30.2)	-	5.86	-
10	Right palm	19(19.8)	-	5.89	-
11	Right arm	25(26.0)	-	6.08	-
12	Right wrist	26(27.1)	-	6.15	-
13	Right leg	15(15.6)	-	6.20	-
14	Right thigh	12(12.5)	-	6.25	-
15	Left thigh	12(12.5)	-	6.25	-
16	Left clavicle	3(3.1)	-	6.33	-
17	Right clavicle	3(3.1)	-	6.33	-
18	Left knee	39(40.6)	-	6.36	-
19	Right knee	39(40.6)	-	6.36	-
20	Left shoulder	36(37.5)	-	6.36	-
21	Right shoulder	60(62.5)	-	6.57	-
22	Neck	12(12.5)	-	-	6.67
23	Mid back	32(33.3)	-	-	6.75
24	Upper back	17(17.7)	-	-	6.76
25	Lower back	92(95.8)	-	-	6.95

Figures in parentheses indicate percentage out of total

Furthermore, extent of discomfort was found to be the highest in lower back with the mean discomfort score 6.95. Other body parts where women farmers reported to feel severe discomfort after day long weeding work were neck, upper back, and mid back. The respective mean body discomfort score were 6.67, 6.76, and 6.75. In the rest of the body parts mentioned above, women farmers reported to feel moderate discomfort.

Testing of hypothesis

Ho: There is no significant relationship between the body discomfort experienced by the women farmers and their selected personal, family, and situational variables.

Karl Pearson correlation coefficients were computed between the body discomfort score of the women farmers and the selected personal, family, and situational variables to see whether extent of body discomfort is significantly affected by the selected variables or not. The correlation coefficients have been presented in Table 4.21. The value of correlation coefficient between **stature** of the women farmers and the **body discomfort** score ('r' value = - 0.141; not significant) indicated that the relationship is not significant. This means that height of the women farmers had no role to play in determining the discomfort experienced by the women farmers while performing weeding operation.

Significant positive correlation ('r' value = 0.492; significant at 1 per cent level of probability) was observed between the **age** of the women farmers and the extent of the **body discomfort** experienced by them. This suggests that as the age increased body discomfort experienced by the women farmers also increased. Therefore it could be said that as the women grew old the body discomfort experienced by them was greater. Due the increase in age women tended to feel more discomfort compared to their younger counterparts.

Furthermore, significant negative correlation ('r' value = - 0.463; significant at 1 per cent level of probability) was found between the health status in terms of **frequency of falling ill** and **body discomfort** experienced by the women

farmers. This means that women farmers who reported to fall ill less frequently had less body discomfort score which leads to the conclusion that better the health status less was the extent of body discomfort experienced.

Table: 4.21: Coefficient of correlation between extent of body discomfort and selected personal, family and situational variables

(Number)

S No.	Extent of body discomfort expereinced / Selected variables	Karl Pearson coefficient of correlation (r)	Level of significance
1	Stature	-0.141	NS
2	Age	0.492	0.01
3	Health status(frequency of falling ill)	-0.463	0.01
4	Health status(ponderal index)	0.205	0.05
5	Landholding size	0.207	0.05
6	Number of helping hands	0.201	NS
7	Total number of days spent in weeding per year	0.003	NS
8	Number of hours of weeding per day	0.337	0.01

A significant positive correlation ('r' value = 0.205; significant at 5 per cent level of probability) was found between **body discomfort** experienced by the women farmers and **ponderal index**. Therefore, it could be interpreted that women with endomorphic body type felt more discomfort. Conversely, women with ectomorphic body type felt less discomfort.

Significant positive correlation ('r' value = 0.207; significant at 5 per cent level of probability) was found between the **size of the landholding** owned by the women farmers and the **body discomfort** experienced by the women farmers. This suggests that larger the landholding more was the discomfort felt. This

could perhaps be due to the reason that with the increase in the size of the landholding workload on the women farmers increases in terms of the agricultural work to be performed.

The value of the correlation coefficient ('r' value = 0.201; not significant) between **the number of helping hands** and the **body discomfort** showed that the relationship between these two variables was not significant. This suggests that when the women farmers had other persons to help them in weeding operation their workload decreased but it did not reduce their discomfort. This is mainly due to the reason that generally when there was a large area under cultivation, only those were the cases where women had the privilege of getting help of other family members as it was not possible for them to complete weeding single handedly. This does not mean that they had to work less. That is probably why the extent of discomfort was not affected by the number of helping hands.

It was further found that there is no significant relationship between the **total number of days spent weeding in a year** and the **body discomfort** ('r' value = 0.003; not significant) experienced by the women farmers.

Chi-square was calculated for finding out the relationship between the **posture adopted** and the **body discomfort** experienced by the women farmers. The value of the chi-square (chi-square cal. =0.43, not significant) showed that the relationship between the posture adopted while doing weeding by women farmers and the discomfort experienced is.not significant.

Furthermore, it was found that there is significant relationship ('r' value = 0.337; significant at 1 per cent level of probability) between the **body discomfort** experienced by the women farmers and **the numbers of hours in a day spent** weeding by the women farmers. Therefore, it could be interpreted that more the number of hours spent weeding more was the discomfort felt by the women workers.

II Experimental Data

This section presents findings derived from the analysis of experimental data. The section contains findings related to physiological cost of working with different weeders in terms of heart rate and energy expenditure, muscular stress, postural stress, body discomfort, area covered, and weeding efficiency, and ergonomical analysis of the weeders using checklist. The results have been put forward using tabular and graphical representation supplemented with their appropriate description.

Ergonomical assessment of available weeding technologies and traditional weeding tool khutti

The present investigation attempted to assess weeding technologies along with traditional weeding tool khutti on the basis of ergonomical parameters and efficiency parameters. The ergonomical parameters included physiological cost of work in terms of heart rate and energy expenditure, muscular stress in terms of reduction in grip strength, postural stress, anthropometric dimensions, and body discomfort. The efficiency parameters included area covered (output) and weeding efficiency. The experimental trials were carried out in cabbage/cauliflower vegetable fields belonging to the experimental subjects. The experiment was conducted in a split plot design. Four weeders along with traditional weeding tool khutti were tested. Three replications were carried out. In total there were 120 trials. Eight healthy females, non pregnant, devoid of any serious illness, and who were willing to participate in the experiment were selected for the study. The height, weight, and other anthropometric dimensions of all the women subjects were measured and statistically analysed.

Table 4.22 : Age and physical characteristics of the women subjects

s.no.	Physical characteristics	mean±standard deviation
1	Age(years)	34.87±6.4
2	Height(cm)	154.31±5.31
3	Weight(cm)	50.44±7.63
4	Elbow height(cm)	98.79±3.04
5	Shouder height(cm)	129.25±4.93

All women subjects were mesomorphic except one who was endomorphic.

4.6 Physiological cost of work: The physiological cost of working with different weeders was assessed by measuring the heart rate and energy expenditure.

Heart rate: The heart rate of women subjects was measured in order to determine physiological cost of performing weeding using different weeders. Heart rate is the number of ventricular beats per minute. The heart rate is generated by the autonomous cardiac system and then modified by an inhibiting action of the parasympathetic vegetative nervous system or by an activating action of the sympathetic system. This implies that any action of the vegetative system has an effect on the heart rate: physical load, emotions, noise, and general mobilization of the organism. All this makes the heart rate a very interesting parameter for an ergonomist. The heart rate may be recorded without any inconvenience for the subject, and continued practically without any time limit. Literature related to the heart rate shows that it is a sensitive and fine discriminating measure for evaluating physiological strain of subjects in applied field situations. The ability to collect real time data from a working subject with minimal personal discomfort or disruption to their normal work routine ensures the collection of accurate and relevant data.

Keeping in view the importance and advantages of measuring the heart rate, this biological parameter was measured using Polar Heart Rate Monitor. For the measurement of the heart rate women subjects were given a rest of 30 minutes in sitting position followed by work with the weeder for 30 minutes. Table (4.) shows data on working heart rate of women subjects during operation of different weeders.

Working heart rate was derived by averaging the heart rate readings of 6^{th} to 30^{th} minute of weeding operation. This was repeated for all the subjects while working with different weeders. Table 4.gives the working heart rate of the subjects averaged over three replications. At the bottom of the table there is the mean of these values for eight subjects.

It can be seen from the Table (4.23) that the mean heart rate values for subjects ranged between 104.80 beats/min to 156.81 beats/min for wheel hoe; 106.33 beats/min to 149.8 beats/min for draw weeder; 105.48 beats/min to146.82 beats/min for v-blade hoe; 107 beats/min to 151.41 beats/min for falcon hoe; and 94.68 beats/min to 132.93 beats/min for khutti.

Table 4.23 : Working heart rate (HR in beats/min) of women subjects during operation of different weeders

Subjects	Heart rate(HR) Beats/min				
	Wheel hoe (W1)	Draw weeder (W2)	V-blade hoe (W3)	Falcon hoe (W4)	Khutti (W5)
S1	104.80	106.33	105.48	107.08	95.57
S2	136.56	132.53	129.93	109.72	114.53
S3	128.25	115.12	108.78	110.07	100.13
S4	106.44	111.68	114.95	109.89	94.68
S5	152.76	135.84	139.60	131.72	132.93
S6	156.81	137.80	146.82	131.97	123.43
S7	151.87	149.8	133.89	151.41	129.57
S8	151.61	139.44	143.07	141.11	119.96
Mean	136.14	128.57	127.81	124.12	113.85

Results indicated that the mean working heart rate for all the women subjects while working with wheel hoe was 136.14 beats/min; that was the highest. Followed by this was draw weeder with the mean working heart rate of 128.57 beats/min; v-blade hoe with 127.81 beats/min; falcon hoe with 124.12 beats/min. The lowest mean working heart rate i.e 113.85 beats/min was recorded while working with traditional weeder (khutti). This establishes that compared to traditional weeder khutti, heart rate responses while working with the weeders under assessment were quite high. The weeders used for the study vary in design and their operation requires different postures. These

factors contributed to the variation in heart rate responses. Except khutti, all other weeders required standing or a little bent posture. The low working heart rate during operation with khutti was recorded on account of the squatting posture. The high heart rate responses could also be attributed to the fact that women were more used to working with khutti with which they had been working for years unlike other weeders with which they had only few hours of practice.

Gite(1999) compared the heart rate responses of women workers during weeding in soybean crop with hand hoe and CIAE wheel hoe. Mean working heart rate for hand hoe and wheel hoe were found to by 101.6 beats/ min and 125.6 beats/min respectively.

Increase in heart rate (Δ HR in beats/min): The increase in heart rate of women subjects while working with different weeders was calculated by subtracting resting heart rate from the working heart rate. Table (4.24) shows average increase in heart rate (Δ HR in beats/min.) of women subjects above their resting rate during operation of different weeders.

Table 4. 24: Increase in heart rate (Δ HR beats/min) of women subjects during operation of weeders

Subjects	Increase in heart rate (Δ HR in beats/min)				
	Wheel hoe (W1)	Draw weeder (W2)	V-blade hoe (W3)	Falcon hoe (W4)	Khutti (W5)
S1	32.73	33.66	31.08	35.81	23.97
S2	61.43	53.67	49.00	31.78	34.13
S3	50.92	28.99	25.52	31.13	17.67
S4	36.11	39.68	42.68	37.63	20.35
S5	63.63	48.84	48.89	45.05	45.00
S6	61.81	48.67	58.76	43.64	35.16
S7	63.4	63.07	48.69	61.35	40.44
S8	66.15	51.37	55.45	57.51	34.89
Mean	54.52	45.99	45.01	42.99	31.45

As the experiment was spread over three months mean values of Δ HR were used for comparison of different trials to eliminate the effect of different days as well as the time of experiment during a day. It can be seen from Table (4.24) that the mean values of Δ HR for subjects ranged between 32.73 beats/min to 66.15 beats/min for wheel hoe; 28.99 beats/min to 63.07 beats/min for draw weeder; 25.52 beats/min to 58.76 beats/min for v-blade; 31.13 beats/min to 61.35 beats/min for falcon hoe, and 17.67 beats/min to 45.00 beats/min for khutti.

Results further shows that the mean value of Δ HR for all subjects for wheel hoe was 54.52 beats/min., this was the highest. It was followed by draw weeder with 45.99 beats/min; 45.01 beats/min for v-blade; 42.99 beats/min for falcon hoe, and 31.45 beats/min for khutti. This shows that while working with wheel hoe and other weeders/weeding technologies which were tested heart works faster or harder as the increase in heart rate is larger as against khutti.

Area weeded (output in m^2/h): Women subjects worked with different weeders for 30 minutes and after completion of each trial the length and the width of the area covered were measured using metallic tape and the area covered in m^2 was calculated. For statistical analysis the area covered for 30 minutes was multiplied by 2 to get the area covered in one hour. Table 4.25 shows area covered in one hour with different weeders. Results show that the area weeded while working with wheel hoe ranged between 78.78 m^2/h to 156.17 m^2/h. The area covered ranged between 38.81 m^2/h to 72.79 m^2/h for draw weeder; 33.93 m^2/h to 69.34 m^2/h for v-blade hoe; 40.09 m^2/h to 65.5 m^2/h for falcon hoe; and 16.47 m^2/h to 30.81 m^2/h for khutti.

Table 4. 25 : Area covered (output in m^2/h) by women subjects with different weeders

Subjects	Area covered (output in m^2/h)				
	Wheel hoe (W1)	Draw weeder (W2)	V-blade hoe (W3)	Falcon hoe (W4)	Khutti (W5)
S1	127.15	46.83	33.93	45.47	23.99
S2	121.65	43.91	56.03	61.14	24.19
S3	133.61	72.79	35.4	40.09	21.09
S4	142.67	38.81	64.81	50.00	16.47
S5	156.17	56.37	62.49	44.21	30.81
S6	148.88	51.32	69.34	56.05	26.59
S7	78.78	46.87	44.23	65.5	23.61
S8	82.98	50.24	43.03	51.91	20.23
Mean	123.99	50.89	51.16	51.8	23.37

Further, the results indicated that the mean area covered for all the subjects by wheel hoe was 123.99 m^2/h followed by falcon hoe with 51.80 m^2/h; v-blade hoe with 51.16 m^2/h; draw weeder with 50.89 m^2/h and 23.37 m^2/h for khutti. Therefore, weeding with khutti resulted in the lowest output. On the other hand weeding with the wheel hoe recorded highest output. Work with the remaining weeders resulted in more or less similar output but was larger than compared to khutti. The higher output on operation with the technologies could be attributed to the shape and size of the blade of the weeders, and the way the weeders are operated. The surface area of the blade in case of wheel hoe, draw weeder, v-blade, and falcon hoe was larger compared to khutti.

Gite (1999) found that the output with wheel hoe was 202.5 m^2/h as against 44.7 m^2/h.

Figure 4.6 Area covered (outpur in m^2/h) by women subjects with different weeders

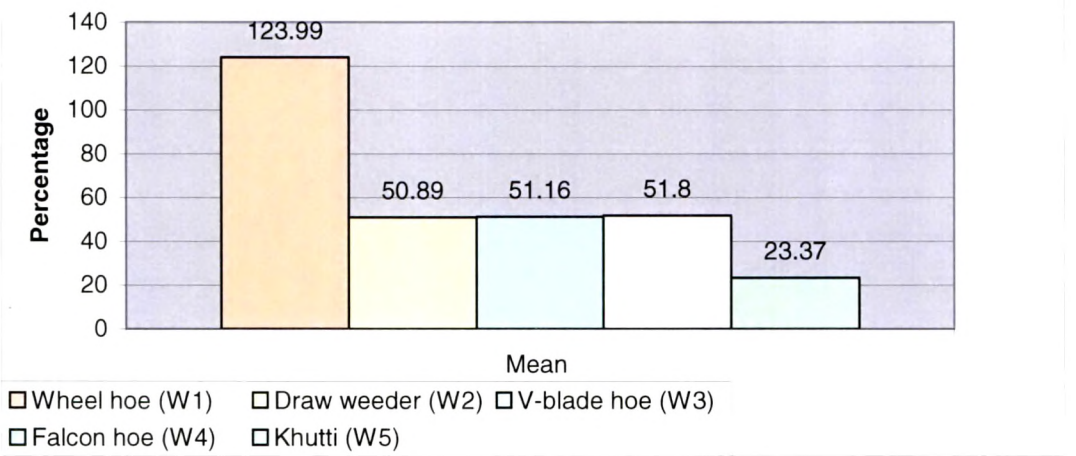
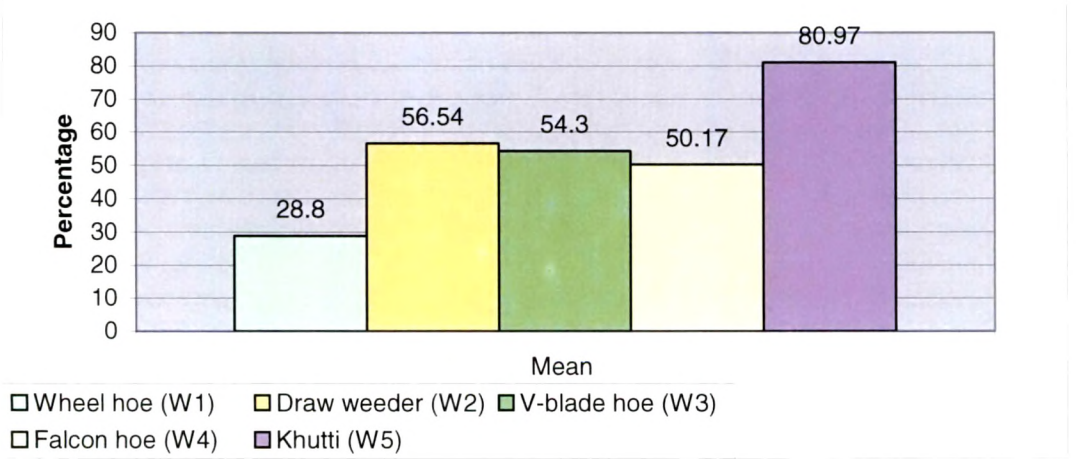


Figure 4.7 Increase in heart beats per metre square of area weeded (beats/m^2)



Increase in heart beats per metre square of area weeded (beats/m^2): Increase in heart beats per metre square of area weeded with different weeders is shown in Table (4.26). It was calculated by using following formula:

$$\textbf{Increase in heart beats/m}^2\textbf{ of area weeded} = \frac{\Delta HR \times \text{duration of trial}}{\text{Area covered}}$$

Results indicated that while working with wheel hoe the number of beats expended per metre square area weeded ranged between 15.5 beats/m^2 to 48.31 beats/m^2. In case of draw weeder the number of beats expended per metre square of area weeded ranged between 24.18 beats/m^2 to 76.36 beats/m^2; for v-blade hoe the range was 43.07 beats/m^2 to 78.93 beats/m^2; for falcon hoe the range was 31.13 beats/m^2 to 66.52 beats/m^2 and for khutti the range was from 49.15 beats/m^2 to 105.43 beats/m^2. In case of traditional weeder khutti the number of beats expended per metre square was very large.

Table 4.26 : Increase in heart beats per metre square of area weeded (beats/m^2)

Subjects	Increase in heart beats/m^2 of area covered, beats/m^2				
	Wheel Hoe (W1)	Draw weeder (W2)	V-blade hoe (W3)	Falcon hoe (W4)	Khutti (W5)
S1	15.50	43.25	55.26	47.08	58.93
S2	30.29	73.35	52.49	31.13	86.41
S3	23.20	24.18	43.07	46.69	49.15
S4	15.06	61.39	39.28	45.23	74.95
S5	24.82	51.44	46.77	61.71	87.67
S6	25.5	57.07	50.78	46.71	81.87
S7	48.31	76.36	67.80	56.27	103.34
S8	47.69	65.32	78.93	66.52	105.43
Mean	28.8	56.54	54.3	50.17	80.97

The mean increase in beats/m^2 calculated for all the subjects showed that while working with wheel hoe, there was an increase of 28.8 beats/m^2. The ascending order of the increase in beats/m^2 was falcon hoe with 50.17 beats/m^2, v-blade hoe with 54.3 beats/m^2, draw weeder with 56.54 beats/m^2 and khutti with 80.97 beats/m^2.

Therefore the lowest increase was recorded with wheel hoe and the highest increase was recorded with khutti. The heart rate data shows that the cardiac cost per unit time in the operation of the weeders under assessment was high. However as the output with these weeders were higher compared to the khutti, the cardiac cost per m^2 of area covered would be low.

Energy expenditure: The energy expenditure rates indicate the level of bodily stress.In relation to heavy work they can be used to assess the level of effort, to work out necessary rest periods, and to compare the efficiency of different tools and different ways of arranging the work (Grandjean,1980). As soon as physical work is performed, energy consumption rises sharply. The greater the demands made on the muscles by one's occupation, the more the energy consumed.

Energy consumption rate of a worker performing a job is calculated from the oxygen consumption rate data. The oxygen uptake during the performance of the work can be determined by collecting and analyzing samples of expired air. Indirectly the energy expenditure can be calculated by recording the worker's heart rate during the performance of the work. The direct measurement of the oxygen uptake of the individual worker while carrying out the actual work in question is the most accurate method.

For the present study the energy expenditure was estimated from the heart rate using formula developed by Varghese et al. (1994) as under:

Energy expenditure (kJ/min) = Average working heart rate (beats/min) x 0.159 - 8.72

Table (4.27) presents average energy expenditure of the subjects while performing weeding with five different weeders. It can be seen from the table that the values of energy expenditure ranged between 7.9 kJ/min to 16.2 kJ/min for wheel hoe. For draw weeder the range was from 8.2 kJ/min to 15.1 kJ/min The energy expenditure ranged from 8 kJ/min to 14.6 kJ/min for v-blade hoe, 8.3 kJ/min to 15.3 kJ/min for falcon hoe, and 6.3 kJ/min to 12.4 kJ/min for khutti..

Table 4.27: Energy expenditure (kJ/min) while working with different weeders

Subjects	Energy expenditure(kJ/min)				
	Wheel hoe (W1)	Draw weeder (W2)	V-blade hoe (W3)	Falcon hoe (W4)	Khutti (W5)
S1	7.9	8.2	8	8.3	6.5
S2	13	12.4	11.9	8.7	9.5
S3	11.7	9.6	8.6	8.8	7.2
S4	8.2	9	9.5	8.7	6.3
S5	15.6	12.9	13.4	12.2	12.4
S6	16.2	13.2	14.6	12.3	10.9
S7	15.4	15.1	12.5	15.3	11.9
S8	15.4	13.4	14	13.7	10.3
Mean	12.9	11.7	11.6	11	9.4

As shown in the Table 4.27 the mean energy expenditure for all the women subjects was highest while performing weeding with wheel hoe (12.9 kJ/min.); followed by draw weeder (11.7 kJ/min.); v-blade (11.6 kJ/min.); falcon hoe (11 kJ/min.). The lowest mean energy expenditure was recorded for traditional weeder, khutti (9.4 kJ/min).

Nag and Dutt (1979) studied the effectiveness of some simple agricultural weeders with reference to physiological responses and found that energy demand of weeding using hand tool in bent and squat posture ranges from 9.6-18.5 kJ/min for women workers. Energy demand of weeding with wheel hoe weeder ranges from 13.6-28.2 kJ/min for men workers (cited in Nag and Nag, 2004).

Per cent increase in energy expenditure (kJ/min): Per cent increase in energy expenditure while working with weeding technologies above resting level was calculated by following formula:

$$\frac{\text{energy expenditure at work} - \text{energy expenditure at rest}}{\text{energy expenditure at rest}} \times 100$$

The data related to % increase in energy expenditure have been presented in Table (4.28) It shows that increase occurred in the range of 159.7 % to 308.3 % for wheel hoe. Increase in energy expenditure above resting level occurred in the range of 96.5 % to 229.3 % for draw weeder, 89.2 % to 242.9 % for v- blade hoe, 131.3 % to 221 % for falcon hoe, and 70.6 % to 143.3 % for khutti.

Table 4.28 : Per cent increase in energy expenditure while working with different weeders

Subjects	%increase in energy expenditure(kJ/min)				
	Wheel hoe (W1)	Draw weeder (W2)	V-blade hoe (W3)	Falcon hoe (W4)	Khutti (W5)
S1	190.27	194.9	162.2	217.2	141
S2	308.3	225.7	188.6	140.7	143.3
S3	230.7	96.5	89.2	131.3	70.6
S4	242.2	229.3	242.9	217.8	107.3
S5	187.6	155.5	133.9	143.2	135.7
S6	159.7	143.3	177	131.9	104
S7	188.9	197.8	160.8	175.7	117
S8	219	155.6	168.8	221	116.7

Mean	215.83	174.82	165.42	172.6	116.95

The perusal of data related to the mean increase in energy expenditure for all the eight subjects showed that mean value was the highest for wheel hoe (215.834 %). Draw weeder followed wheel hoe with the mean increase in energy expenditure equivalent to 174.82 %, then falcon hoe (172.6 %), v-blade hoe (165.42 %), and khutti in the last with the mean increase in energy expenditure amounting to 116.95 %. This suggests that weeding with khutti leads to smaller increase in energy expenditure above resting level compared to the other weeders which resulted in higher increase in energy expenditure above resting level while weeding with them.

Total cardiac cost of weeding: The data pertaining to total cardiac cost of weeding have been presented in Table (4.29).

Table 4.29 : Total cardiac cost (beats/min) of weeding with different weeders

ubjects	Total cardiac cost (beats/min) of weeding				
	Wheel hoe (W1)	**Draw weeder (W2)**	**V-blade hoe (W3)**	**Falcon hoe (W4)**	**Khutti (W5)**
S1	1144	1110.4	1031.1	1240.5	814.5
S2	2169.8	1894	1651	1189.9	1161.1
S3	1813.9	921.6	777.5	1109.2	635.5
S4	1239.6	1277.5	1406.4	1244.5	632.4
S5	2237.4	1809.8	1656.3	1636.5	1591.7
S6	2134.2	1486.8	1930.7	1416.8	1148.4
S7	2139.9	2227.2	1718.8	2083.8	1390.7
S8	2351	1822.2	1867.8	1919.2	1099.3
Mean	1903.73	1568.69	1504.95	1480.05	1059.2

The perusal of the data shows that the total cardiac cost of weeding with wheel hoe ranged between 1144 to 2351 beats/min. With draw weeder total

cardiac cost ranged between 921.6 to 2227.2 beats/min, with v-blade hoe total cardiac cost ranged between 777.5 to 1930.7 beats/min, with falcon hoe the range was between 1109.2 to 2083.8 beats/min, and with khutti the total cardiac cost ranged between 632.4 to 1591.7 beats/min.

On averaging the total cardiac cost for all the eight subjects, it was found that for wheel hoe; mean value of total cardiac cost was 1903.73 beats/min, for draw weeder 1568.69 beats/min, for v-blade 1504.95 beats/min, for falcon hoe 1480.05 beats/min, and for khutti the mean value of total cardiac was 1059.2 beats/min.

Weeding efficiency: This parameter was used to determine the efficiency in terms of cleaning out the weeds prevalent in the fields. It is a ratio between the number of weeds removed by a weeder to the number present in a unit area, and is expressed as a percentage.

The following formula was used to calculate weeding efficiency:

$$\textbf{Weeding efficiency (\%)} = \frac{(W1-W2)}{W1} \times 100$$

Where W1= weed count in $1m^2$ before operation

W2= weed count in $1m^2$ after operation

The related to weeding efficiency with different weeders is given in Table 4.30 The results showed that the weeding efficiency ranged between 63.30% to 80.67% for wheel hoe, 65.03% to 86.34% for draw weeder, 65.15% to 81.45% for v-blade hoe, 68.41% to 88.89% for falcon hoe, and 82.84% to 94.2 for khutti.

Table 4.30 : Weeding efficiency with different weeders

Subjects	Weeding efficiency (%)				
	Wheel Hoe (W1)	Draw weeder (W2)	V-blade hoe (W3)	Falcon hoe (W4)	Khutti (W5)
S1	63.30	67.29	67.86	72.58	82.84
S2	73.09	84.74	65.15	88.89	93.49
S3	75.38	65.03	78.20	86.77	89.95
S4	80.67	80.53	69.56	81.61	90.73
S5	67.4	75.03	81.29	83.04	85.39
S6	77.63	79.10	81.45	85.94	94.2
S7	78.14	86.34	75.52	68.41	91.54
S8	79.43	79.72	76.84	78.41	92.11
Mean	74.38	77.22	74.5	80.71	90.03

Furthermore, analysis revealed that the mean weeding efficiency was highest for khutti with 90.03 % and the lowest for the wheel hoe with 74.38%. This perhaps due to the reason that the women subjects avoided bringing the weeder too close to the plant fearing it could damage the plant. Therefore weeds too close to the plant could not be weeded out.

Muscular stress: The muscular stress due to operation with different weeders was determined in terms of reduction in grip strength of the hand muscles. Grip strength, like any other kind of strength, is not a constant. It is highly individualistic. It varies according to the conditions in which it is examined. The factors which influence the grip strength most are grip size, posture and joint angle, type of gasp, use of gloves, anthropometry and sex (gender). The standardized method of measuring hand grip strength involves gripping and squeezing the handle of a handgrip dynamometer. For the present study also hand grip dynamometer was used. The grip strength of the hands of the women subjects operating weeders was measured using grip dynamometer before starting weeding operation, and again when the

operation for a period of 30 minutes was complete, and the decrease in the strength was determined.

The following formula was used for calculating the reduction in grip strength due to the operation with the weeder:

$$\text{\% reduction in grip strength} = {}^{Sr-Sw}/_{Sr} X100$$

where Sr =strength of hand muscles at rest

Sw = strength of hand muscles after weeding operation

Reduction in grip strength of left hand (LH in %): Table 4.31 presents reduction in grip strength (in %) of left hand (LH) after operation of different weeders

Table 4.31 : Reduction in grip strength (in %) of left hand (LH) after operation of different weeders

Subjects	Reduction in (LH) grip strength (in %)				
	Wheel hoe (W1)	Draw weeder (W2)	V-blade hoe (W3)	Falcon hoe (W4)	Khutti (W5)
S1	18.6	10.4	24	9.5	15.1
S2	12.2	12.4	21.1	10.7	20.4
S3	8.6	10.5	15.1	10.4	8
S4	14.2	8.9	14.3	12.3	7.2
S5	11.9	17.4	15	10.7	9
S6	11.1	13.8	17.4	21.9	16.8
S7	15.1	8.6	16.4	13.1	10.8
S8	11.2	6.4	11.3	11.8	7.5
Mean	12.86	11.05	16.82	12.55	11.85

It can be seen from the Table 4.31 that the reduction in the grip strength of the left hand ranged between 11.1% to 18.6 % for wheel hoe, 6.4% to 17.4% for draw weeder, 11.3% to 24 % for v- blade hoe, 9.5 % to 21.9 % for falcon hoe, 7.2 % to 20.4 % for khutti

Analysis further shows that mean reduction in grip strength of the left hand after working with V- blade hoe to the tune of 16.82%. This was followed by wheel hoe in which case mean reduction was recorded to the tune of 12.86%, falcon hoe followed with the average reduction of 12.55%. The mean reduction in grip strength of left hand was recorded to be lowest for draw weeder (11.95%). The mean reduction in grip strength of left hand on weeding with Khutti was 11.85%.

Reduction in grip strength of right hand(RH in %): Analysis revealed that the grip strength of the right hand ranged between 18.3% to 30.3 % for wheel hoe, 16% to 33.9% for draw weeder, 15.7% to 34 % for v- blade hoe, 13.1% to 42.4 % for falcon hoe, 9.9% to 35.3% for kutti.

Table 4.32 : Reduction in grip strength (in %) of the right hand (RH) after operation of weeders with different weeders

Subjects	Reduction in (RH) grip strength (in %)				
	Wheel hoe (W1)	Draw weeder (W2)	V-blade hoe (W3)	Falcon hoe (W4)	Khutti (W5)
S1	21	33.9	25.8	34.1	35.3
S2	26.7	28.8	25.5	13.1	24.9
S3	24.1	20.1	15.7	31.5	19.5
S4	21.7	25.9	34	26.6	16.3
S5	30.3	19.7	29.4	42.4	20.4
S6	25.2	32.1	18.3	19.5	20.8
S7	18.3	10.5	22.3	17.4	15.2
S8	18.6	16	23.7	21.8	9.9
Mean	23.24	23.37	24.34	25.8	20.29

The examination of the findings related to the reduction in grip strength of the right hand after operation of different weeders indicates highest reduction in case of falcon hoe; the reduction was recorded to the tune of 25.8%. The next in line was v- blade hoe in which case average reduction in grip strength of

right hand was recorded to the tune of 24.34%. Draw weeder followed it with 23.37% mean reduction in grip strength. The average reduction in grip strength recorded for wheel hoe was 23.24%. The last in the order was traditional weeder, khutti for which mean reduction in grip strength was recorded to the tune of 20.29%.

Reduction in grip strength of both the hands: Table (4.33) presents reduction in grip strength of both hands on operation with different weeders.

Table 4.33 : Reduction in grip strength of both hands (in %) after operation of different weeders

Subjects	Reduction in grip strength (in %)				
	Wheel hoe (W1)	Draw weeder (W2)	V-blade hoe (W3)	Falcon hoe (W4)	Khutti (W5)
S1	19.9	24.3	25	23.2	25.8
S2	19.5	20.9	23.4	12	22.6
S3	16.7	15.4	15.4	21.6	13.9
S4	18	17.5	24.1	19.9	12.2
S5	22.1	18.5	22.5	27.8	14.8
S6	18.9	23.5	17.9	20.4	18.8
S7	16.7	9.6	19.6	15.4	13.1
S8	15.1	11.4	17.6	16.9	8.7
Mean	18.36	17.64	20.69	19.65	16.24

It was found that the reduction in the grip strength of both the hands ranged between 15.1% to 22.1% for wheel hoe, 9.6% to 24.3% for draw weeder, 15.4% to 25 % for v-blade hoe, 12% to 27.8% for falcon hoe, 8.7% to 25.8% khutti.

Results further indicated that mean reduction in grip strength of both hands after operation with v-blade hoe was highest (20.69%). This was followed by

falcon hoe (19.65%); wheel hoe (18.36%); draw weeder (17.64%) and the last in the order was khutti (16.24%).

Postural stress: A good posture may be defined as one in which destabilizing moments are minimized and the posture is maintained by the resistance of the relatively incompressible bones as well as interleaved soft tissues such as the intervertebral discs. The tools used in the traditional farming systems mostly involve a number of postures which are injurious to health which need to be rectified or improved through technological intervention.

The comparison of the weeders was also done on the basis of the postural stress faced by each of the weeders. The data on postural stress has been reported in the Table 4.

Lower back: the related to postural stress in lower back is given in Table 4.34. Results indicated that on operation with wheel hoe % deviation in the lower back occurred in the range of 0.18% to 1.57%. On operation with the draw weeder % deviation in the lower back occurred in the range of 0.64 % to 5.43%. Working with the draw weeder resulted in the % deviation in the lower back in the range of 1.0% to 4.97%. Falcon hoe recorded the % deviation in the lower back in the range of 0.73% to 3.5%. Compared to these four weeders, the % deviation in the lower back was higher while working with the traditional weeder and it ranged between 3.67% and 9.76%. The analysis further revealed that the mean % deviation in the lower back while working the wheel hoe was 0.73%; that was the lowest. The respective mean % deviation while working with draw weeder, v-blade and falcon hoe were 2.84%, 2.57% and 1.76%. The mean % deviation while working with khutti was 6.14%.

Table 4. 34 : Postural stress in terms of % deviation in the lower back

Subjects	% deviation in the lower back				
	Wheel hoe (W1)	Draw weeder (W2)	V-blade hoe (W3)	Falcon hoe (W4)	Khutti (W5)
S1	0.64	1.09	2.46	1.37	4.82
S2	1.57	5.43	4.97	2.49	8.01
S3	0.64	2.66	1.56	2.12	3.67
S4	0.55	0.64	1.0	0.95	4.83
S5	0.46	0.82	2.29	0.73	4.3
S6	1.19	4.97	3.04	3.5	5.62
S7	0.64	1.84	3.96	1.01	9.76
S8	0.18	5.31	1.32	1.92	8.15
Mean	0.73	2.84	2.57	1.76	6.14

Upper back: Results indicated that % deviation in the upper back while working with wheel hoe ranged from 0.18% to 1.47%(Table 4.35). While working with draw weeder the % deviation in the upper back ranged from 0.64% to 3.59% and the respective % deviation in the upper back for v- blade hoe and falcon hoe ranged from 0.46% to 3.95% and 0.71% to 3.94%.while working with traditional weeder khutti % deviation in the upper back ranged from 1.34% to 5.01%. On an average, the % deviation in the upper back while working with wheel hoe was 0.60%, with draw weeder 1.69%, with v-blade hoe 2.02%; with falcon hoe 1.80%; and with khutti 3.14%. This suggests that working with traditional weeder resulted larger % deviation in the upper back compared to the technologies under assessment.

Table 4.35 : Postural stress in terms of % deviation in the upper back

Subjects	% deviation in the upper back				
	Wheel hoe (W1)	Draw weeder (W2)	V-blade hoe (W3)	Falcon hoe (W4)	Khutti (W5)
S1	0.72	1.9	1.99	2.81	2.54
S2	1.01	1.47	3.95	1.84	2.2
S3	0.18	1.22	2.29	3.94	4.48
S4	0.46	1.28	1.46	0.73	3.06
S5	0.27	0.71	1.25	0.71	1.34
S6	1.47	3.59	3.41	2.85	3.04
S7	0.54	2.72	1.36	0.72	3.44
S8	0.18	0.64	0.46	0.82	5.01
Mean	0.60	1.69	2.02	1.80	3.14

Overall body discomfort: Conceptually, discomfort is an attractive risk indicator as it uses the body's own feedback system to detect possible problems. Possible sources of discomfort resulting from musculoskeletal stress include: tension in muscles, nerves, blood vessels, ligaments, and joint capsules, compression of the same body tissues, local chemical changes associated with muscle fatigue, local chemical changes related to restricted blood flow and partial ischemia, disruption of nerve condition resulting from pressure. Discomfort is thought to be especially useful for assessing situations where the impact of physical mismatch may be greatest on small muscles and where static muscle activity is required. This is beneficial because small muscle problems are not detected well with other risk assessment tools, such as biomechanical modeling, and gross physiological indicators, such as heart rate and body temperature (Straker, 1999).

It was found that on operation with wheel hoe the overall bodily discomfort score ranged from 4.67 to 7.33 (Table 4.36). While working with draw weeder the overall body discomfort score ranged from 5 to 6.33. Furthermore, it was found that while weeding with v-blade the overall body discomfort score ranged from 4.67 to 6.67, for falcon hoe the score ranged from 4 to 5.67, and for khutti the score ranged from 4 to 5. The mean overall body discomfort score for wheel hoe was found to be 5.96. The respective mean overall body discomfort scores for draw weeder, v-blade hoe, and falcon hoe were found to be 5.54, 5.62, and 5.12 respectively. On operation with the traditional weeder the mean overall body discomfort score was found to be 4.46.

Table 4.36 : Overall body discomfort felt on operation with different weeders

Subjects	Overall bodily discomfort score				
	Wheel hoe (W1)	Draw weeder (W2)	V-blade hoe (W3)	Falcon hoe (W4)	Khutti (W5)
S1	4.67	5.00	4.67	5.00	4.00
S2	5.00	5.00	5.67	5.67	4.33
S3	5.33	5.00	5.00	4.00	5.00
S4	5.33	5.67	6.67	5.00	4.00
S5	7.00	6.00	6.33	5.33	5.00
S6	6.33	6.00	6.00	5.33	5.00
S7	6.67	5.33	5.33	5.00	4.00
S8	7.33	6.33	5.33	5.67	4.33
Mean	5.96	5.54	5.62	5.12	4.46

Extent of discomfort felt in different body parts on operation with different weeders

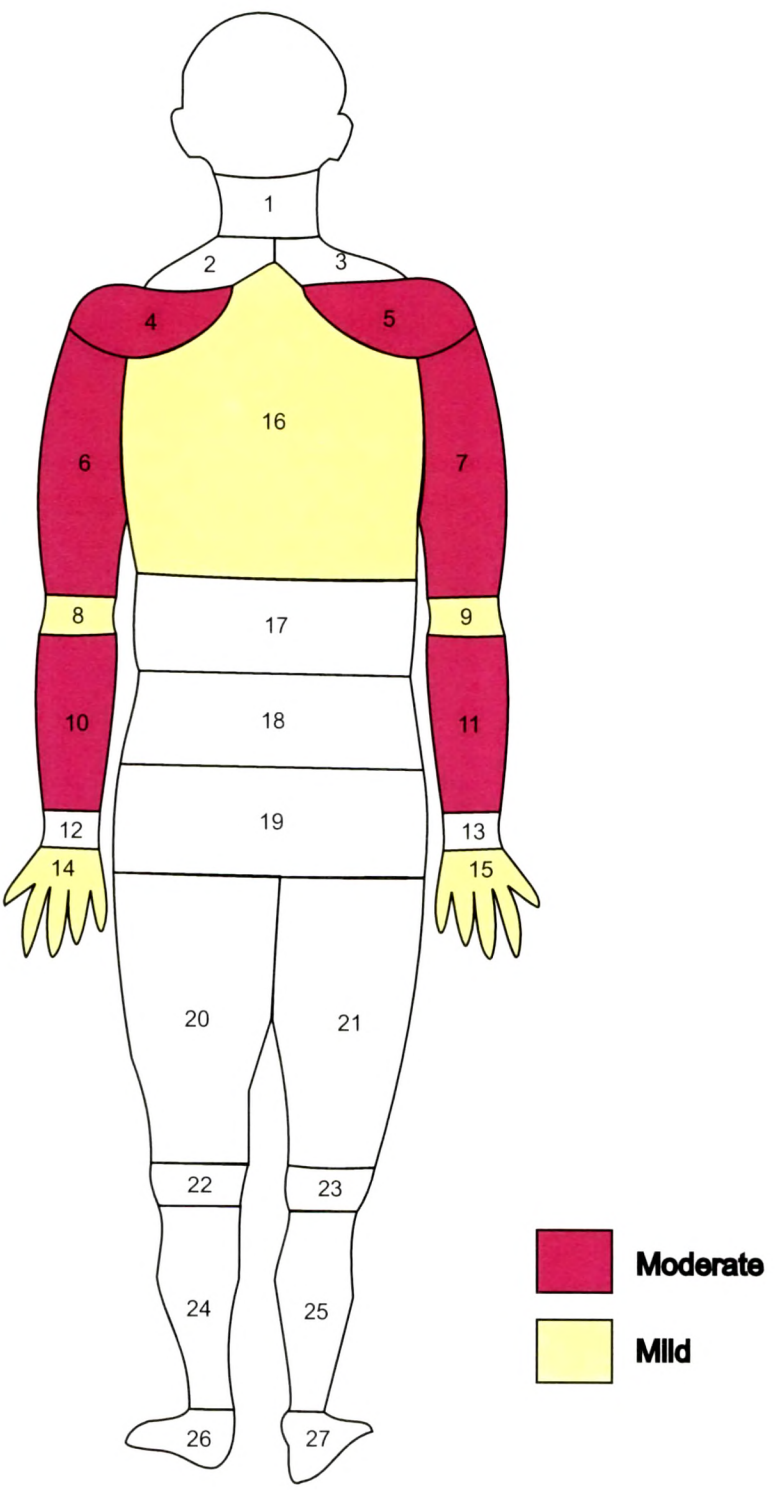
In order to determine which body parts are affected by the use of weeders and the intensity of the discomfort felt visual analogue discomfort scale ranging from 0 to 10 was used.

Table 4.37 : Extent of discomfort felt in different body parts on operation with wheel hoe

S.No.	Body regions	Mean body discomfort score (n=8)		
		Mild (0-3.3)	Moderate (3.4-6.6)	Severe (6.7-10)
1	Left shoulder	-	4.54	-
2	Right shoulder	-	4.54	-
3	Left arm	-	4.83	-
4	Right arm	-	4.83	-
5	Left forearm	-	4.46	-
6	Right forearm	-	4.46	-
7	Left palm	2.04	-	-
8	Right palm	2.04	-	-
9	Left elbow	1.5	-	-
10	Right elbow	1.5	-	-
11	Upper back	1.5	-	-
12	Mid back	-	-	-
13	Low back	-	-	-

It was found that while weeding with wheel hoe women subjects felt moderate discomfort in left and right shoulders, left and right arms, left and right forearms. The corresponding mean body discomfort scores were 4.54, 4.54, 4.83, 4.83, 4.46, and 4.46. Women subjects experienced mild discomfort in both the palms and both the elbows. The corresponding mean discomfort

Extent of body discomfort experienced by women farmers on operation with wheel hoe



scores were 2.04 and 1.5. In upper back also women subjects felt mild discomfort; the mean discomfort score was 1.5.

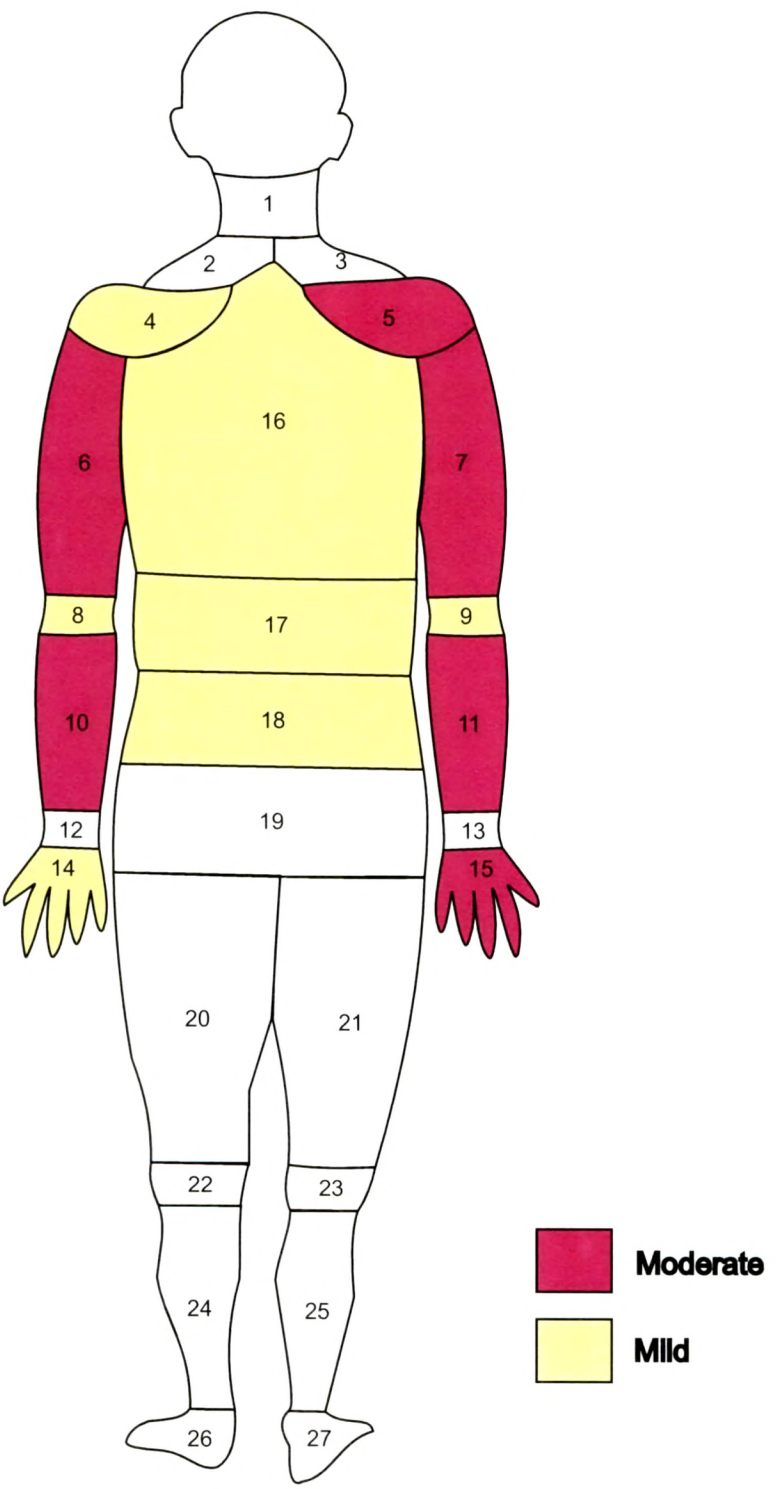
Table 4.38 : Extent of discomfort felt in different body parts on operation with draw weeder

S.No.	Body regions	Mean body discomfort score (n=8)		
		Mild (0-3.3)	Moderate (3.4-6.6)	Severe (6.7-10)
1	Left shoulder	2.83	-	-
2	Right shoulder	-	4.29	-
3	Left arm	-	4.17	-
4	Right arm	-	4.54	-
5	Left forearm	-	3.12	-
6	Right forearm	-	3.71	-
7	Left palm	1.21	-	-
8	Right palm	1.52	-	-
9	Left elbow	1.12	-	-
10	Right elbow	1.23	-	-
11	Upper back	0.95	-	-
12	Mid back	0.17	-	-
13	Low back	2.29	-	-

Table (4.) gives mean discomfort scores for different body parts on operation with draw weeder. It is observed from the table (4.) that women subjects experienced

mild discomfort in left shoulder, left palm, right palm, left elbow, right elbow, upper back, mid back and low back. The corresponding discomfort scores were 2.83, 1.21, 1.52, 1.12, 1.23, 0.95, 0.17, and 2.29. Furthermore, women subjects felt moderate discomfort in right shoulder, left arm, right arm, left

Extent of body discomfort experienced by women farmers on operation with draw weeder



forearm, and right forearm. The corresponding mean discomfort scores were 4.29, 4.17, 4.54, 3.12, and 3.71.

Table 4. 39 : Extent of discomfort felt in different body parts on operation with v-blade hoe

S.No.	Body regions	Mean body discomfort score (n=8)		
		Mild (0-3.3)	Moderate (3.4-6.6)	Severe (6.7-10)
1	Left shoulder	3.17	-	-
2	Right shoulder	-	4.04	-
3	Left arm	-	3.75	-
4	Right arm	-	4.00	-
5	Left forearm	-	4.04	-
6	Right forearm	-	4.33	-
7	Left palm	0.67	-	-
8	Right palm	0.69	-	-
9	Left elbow	0.50	-	-
10	Right elbow	0.62	-	-
11	Upper back	-	-	-
12	Mid back	-	-	-
13	Low back	1.75	-	-

Table (4.) gives mean discomfort scores for different body parts on operation with v-blade hoe. It was found that on operation with v-blade hoe women subjects felt mild discomfort in left shoulder, left palm, right palm, left elbow, right elbow, and low back. The corresponding mean discomfort scores were 3.17, 0.67, 0.69, 0.50, 0.62, and 1.75. It was further found that women subjects felt moderate discomfort in right shoulder, left arm, right arm, left forearm, and right forearm. The corresponding mean discomfort scores were 4.04, 3.75, 4.00, 4.04, and 4.33.

Extent of body discomfort experienced by women farmers on operation with v-blade hoe

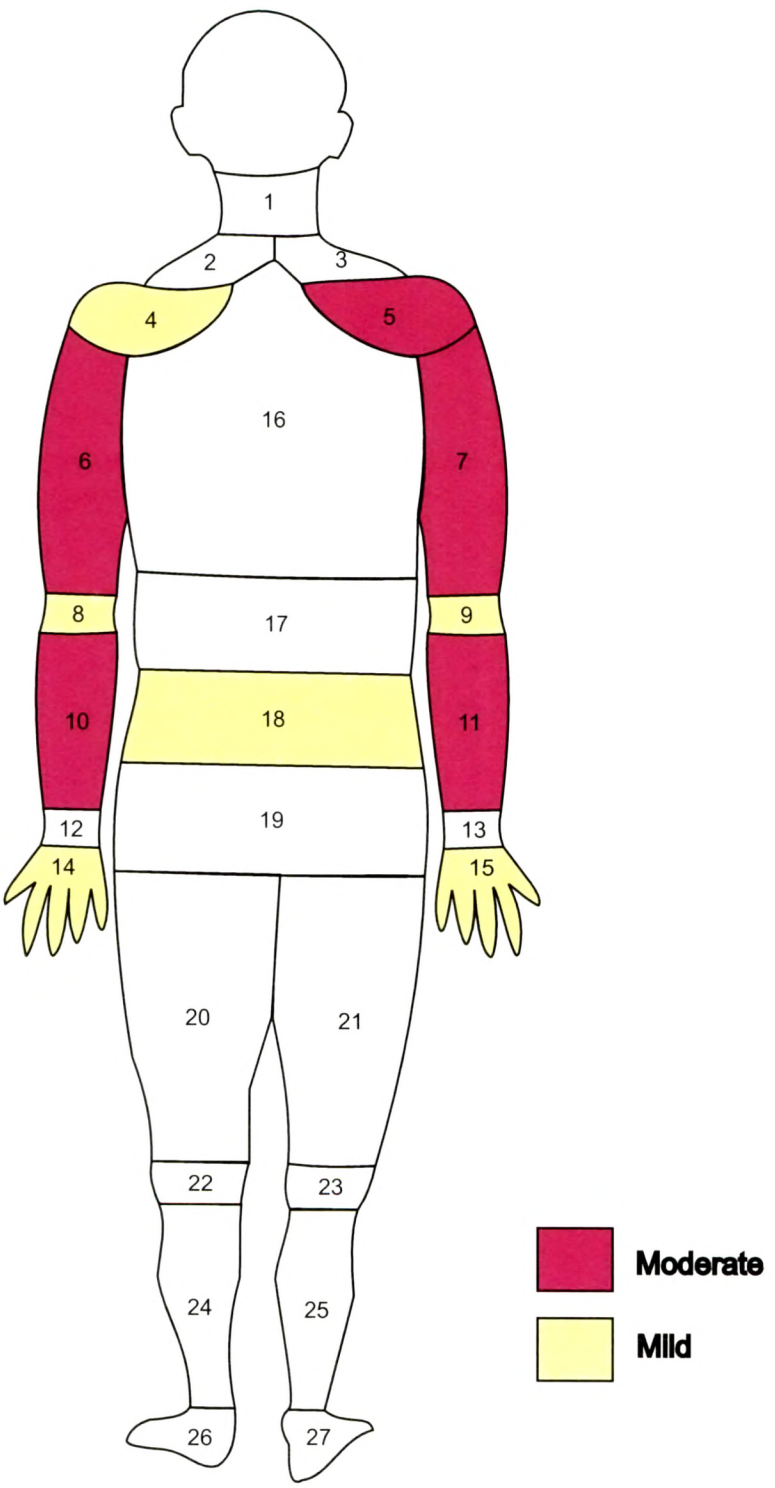


Table (4.) presents information on extent of discomfort felt in different body parts on operation with falcon hoe.

Table 4.40 : Extent of discomfort felt in different body parts on operation with falcon hoe

S.No.	Body regions	Mean body discomfort score (n=8)		
		Mild (0-3.3)	Moderate (3.4-6.6)	Severe (6.7-10)
1	Left shoulder	2.25		-
2	Right shoulder	-	3.54	-
3	Left arm	-	3.33	-
4	Right arm	-	3.46	-
5	Left forearm	-	4.33	-
6	Right forearm	-	4.50	-
7	Left palm	-	-	-
8	Right palm	-	-	-
9	Left elbow	-	-	-
10	Right elbow	-	-	-
11	Upper back	-	-	-
12	Mid back	-	-	-
13	Low back	1.54	-	-

It was found that women subjects felt mild discomfort in left shoulder and low back on operation with falcon hoe. The corresponding mean discomfort scores were 2.25 and1.54 respectively. Women subjects felt moderate discomfort in right shoulder, left arm, right arm, left forearm, right forearm. The corresponding mean discomfort scores were 3.54, 3.33, 3.46, 4.33, and 4.50.

Table (4.) gives mean discomfort scores for different body parts where discomfort is felt on operation with khutti.

Extent of body discomfort experienced by women farmers on operation with falcon hoe

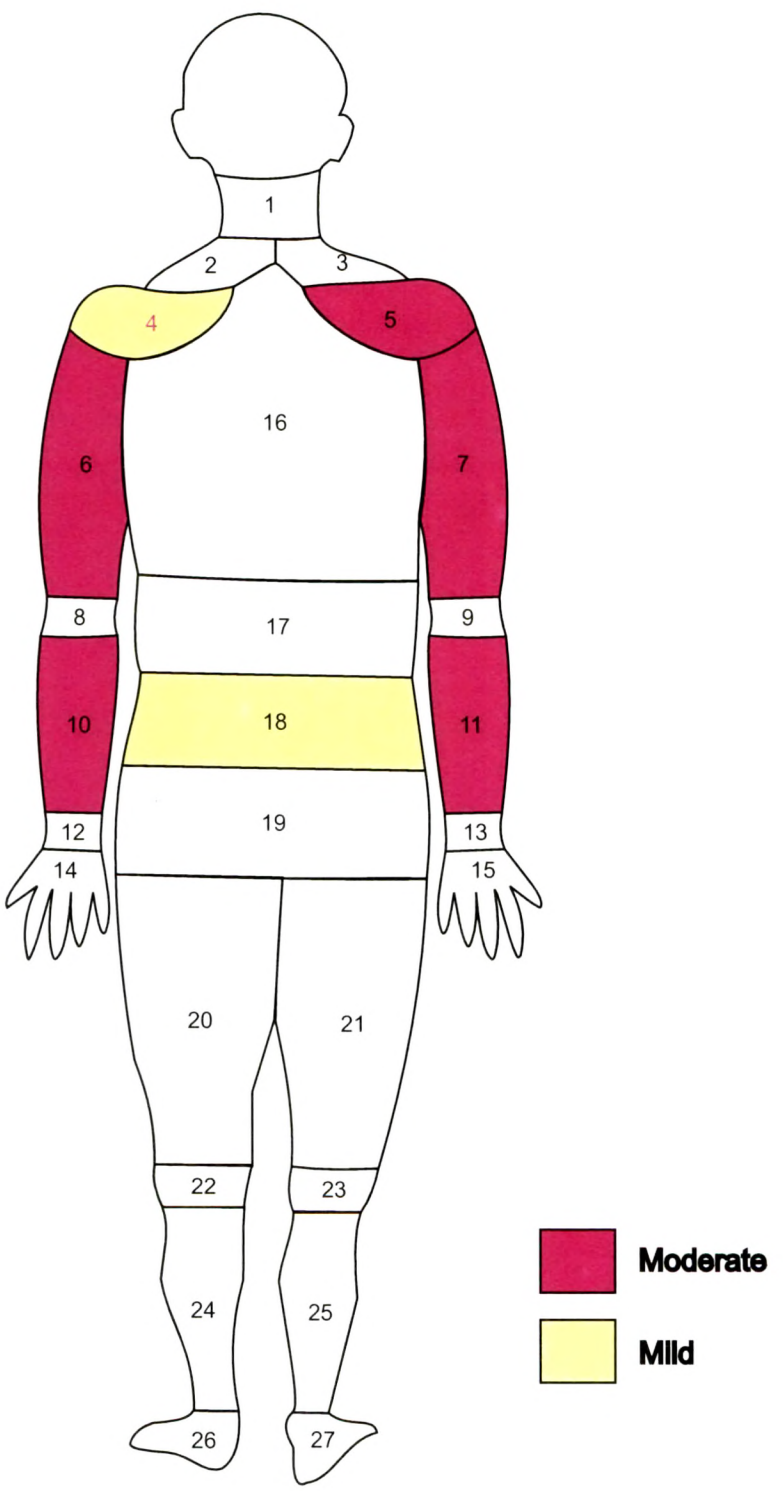
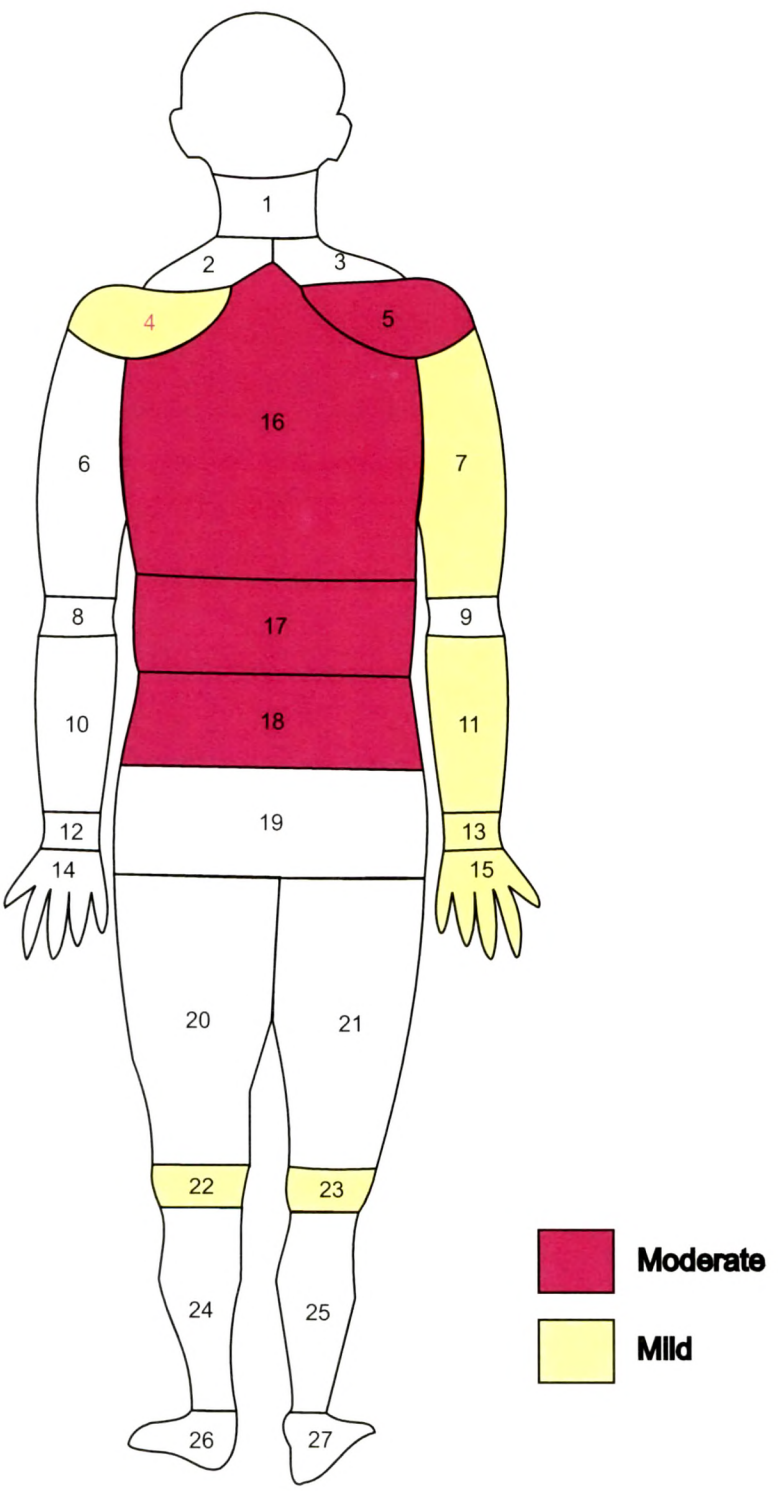


Table 4. 41: Extent of discomfort felt in different body parts on operation with khutti

S.No.	Body regions	Mean body discomfort score (n=8)		
		Mild (0-3.3)	Moderate (3.4-6.6)	Severe (6.7-10)
1	Left shoulder	2.08	-	-
2	Right shoulder	-	3.67	-
3	Left arm	-	-	-
4	Right arm	1.46	-	-
5	Left forearm	-	-	-
6	Right forearm	-	1.54	-
7	Right palm	1.42	-	-
8	Right wrist	1.42	-	-
9	Left knee	1.33	-	-
10	Right knee	1.33	-	-
11	Upper back	-	2.62	-
12	Mid back	-	0.50	-
13	Low back	-	4.21	-

On operation with khutti, women subjects reported mild discomfort in left shoulder, right arm, right palm, right wrist, left knee, right knee. The corresponding mean discomfort scores were 2.08, 1.46, 1.42, 1.42, 1.33, and 1.33. Moderate discomfort was reported by women in right shoulder, right forearm, upper back, mid back, and low back. The corresponding mean discomfort scores were 3.67, 1.54, 2.62, 0.50, and 4.21.

Extent of discomfort experienced by women farmers on operation with khutti



Ergonomical analysis of the weeders using checklist : Ergonomical checklist provided in the test code and procedure for ergonomical evaluation of manually operated weeders, was used for the ergonomical evaluation of the weeders.

Ergonomical assessment of CIAE wheel hoe: This is a manually operated push - pull type twin wheel weeder developed at Central Institute of Agricultural Engineering (CIAE), Bhopal, for women farmers. It uproots and cuts weeds in row crops. It is widely used in M.P. region for weeding in soybean crop raised at 250 mm or more row spacing.

Wheel hoe consists of twin wheels, frame, blade, clamp and handle. The length of the handle is 1m, 51 cm. The blade is to some extent v-shaped. The width of the handle is 50 cm. The women can work with this hoe at two heights. The depth of the blade can also be adjusted. The entire tool is made of iron.

Although operation with wheel hoe required heavy effort on the part of the women subjects, the postural stress was much lesser in terms of angle of deviation which was minimum in case of all the subjects while working with the wheel hoe. So it could be plausibly concluded that the back was the most comfortable on operation with wheel hoe. It could be hoped that with enough practice women can work with wheel hoe for many years without injuring the back. In the long run it is more convenient to work with wheel hoe.

The mean elbow height of the women farmers was 95.38±3.89cm.The 5^{th} and 95^{th} percentile values were 88.98cm and 101.77cm. The mean shoulder height of the women farmers was 125.88±3.92cm with respective 5^{th} and 95^{th} percentile values to be 119.43cm and132.34cm. According to Gite and Yadav (1990), 0.7 shoulder height to 0.8 shoulder height is the most suitable working height for operation of a push-pull type weeder from ergonomic considerations. It was found that at lower adjustment provision wheel hoe could be operated at the height of 103cm and at higher adjustment provision wheel hoe could be operated at the height of 107cm. If the working handle height is kept at 103cm,

WHEEL HOE

it will be 0.79 shoulder height of the 95th percentile woman and 0.86 shoulder height of the 5th percentile woman. In that case it is going above the prescribed limit of 0.8 shoulder height. It was observed that the height of the handle was a little longer than the comfortable height for working with the wheel hoe. This explains partly the heavy effort which shorter women subjects had to put while using wheel hoe.

Subjects	Shoulder height(SH)(cm)	If handle is kept at103cm working height it will be
S1	139.0	0.74 SH
S2	132.7	0.78 SH
S3	131.5	0.78 SH
S4	127.3	0.81 SH
S5	126.4	0.81 SH
S6	124.1	0.83 SH
S7	125.0	0.82 SH
S8	128.0	0.80 SH

It was found that the subjects could comfortably flex the fingers and thumb around the handle. They had no problem gripping the handle of the wheel hoe.

Subjects' feedback

Whether the wheel hoe is suitable to the body dimensions of the operator?

Except some subjects others found the wheel hoe to be suitable to their body dimensions.

Some subjects found the length of the handle a little longer.

Does the required operation of the equipment is within the acceptance limits of the operator?

Subjects said that they have to apply more force while operating wheel hoe compared to khutti. But it was within the acceptance limits of the subjects.

Does the operator face any problems during operations?

Occasionally, the uprooted weeds along with the mud tended to stick to the blade of the wheel hoe.

Is there any breakdown, repair and maintenance problem during work?

If the blade of the wheel hoe is not tightly clamped it very easily comes out.

Overall comments of the subjects about implement/ tool.

The subjects were happy with output with the wheel hoe. But they wanted the blade to go deeper inside.

Table 4.42 : Various dimensions of the CIA wheel hoe

SNo.	Questions	Remark
1	Name of the weeder	CIA wheel hoe
2	**Details of the handle**	
i	Length	1m,51cm
ii	Width	50cm
iv	Material	Iron
v	Provision for adjustment	Handle height can be adjusted
vi	Diameter	2cm
3	**Details of blade**	
i	Size and shape	Somewhat v-shaped
ii	Material	Iron
4	**Details of wheel**	Two wheels are present
5	**Tool as a whole**	
i	Shape and construction	Constructed in lengthwise
ii	Material	Iron
iii	Maintenance	Little maintenance required
iv	Weight	3800gm
v	Protection and safety	Keep out of rain, after use the tool should be cleaned

Ergonomical assessment of draw weeder: Draw weeder consists of a toothed blade attached to long handle. For the present study the draw weeder was modified to have single - edged toothed blade. The sharp toothed blade cuts weeds just below the soil surface. The draw weeder was made up of wood and iron with a long, light weighted handle made up of bamboo. As bamboo is locally available it is possible to have its handle made of a convenient length for women.

The design of the handle depends on the mode of operation, amount of effort required, anthropometric data of the working population, handle material, etc. (Gite and yadav, 1989). For operating draw weeder, women subjects had to grasp the handle by flexing fingers and thumb around the handle, which is a power grip. Anthropometrically, the diameter of the handle should be such that while an operator grips the handle, his longest finger should not touch the palm (Parikh, 1980). The diameter of the handle was 2.9cm. The handle had enough space to admit all four fingers and thumb and the longest finger was not touching the palm. The handle provided maximum contact with the surface of the hand.

While working with draw weeder subjects needed to bend slightly but the angle of deviation of the lower and upper back was less compared to the traditional weeder khutti.

The mean elbow height of the women farmers was 95.38±3.89cm.The 5^{th} and 95^{th} percentile values were 88.98cm and 101.77cm respectively. While working with draw weeder the subjects could conveniently hold the weeder. It was found that during working condition, the vertical height from the tip of the handle to the soil surface (around 1m) was well above the mean elbow height of the women farmers.

Subjects' feedback

Whether the draw weeder is suitable to the body dimensions of the operator?

The subjects found the draw weeder suitable to their body dimensions.

DRAW WEEDER

Table 4.43 : Various dimensions of draw weeder

SNo.	Questions	Remark
1	Name of the weeder	draw weeder
2	**Details of the handle**	
i	Length	1m, 10cm
iv	Material	Bamboo
v	Provision for adjustment	Bamboo can be cut short according to the height
vi	Diameter	2.9cm
3	**Details of blade**	
i	Size and shape	10x4 cm, rectangular in shape
ii	Material	Iron
4	**Details of wheel**	No wheel present
5	**Tool as a whole**	
i	Shape and construction	-
ii	Material	Iron and bamboo
iii	Maintenance	Little maintenance needed
iv	Weight	900 gm
v	Protection and safety	Should be kept dry and clean after use

Does the required operation of the equipment fall within the acceptance limits of the operator?

Yes, it was within the acceptance limits of the operator.

Does the operator face any problems during operations?

The weeds were getting stuck to the toothed blade of the weeder.

Is there any breakdown, repair and maintenance problem during work?

No such problem was encountered.

Overall comments of the subjects about implement/ tool?

They liked the tool. They found the tool helpful in covering the area around the plants with the soil. They were of the view that draw weeder is useful in weeding the crops sown in ridges. But they didn't like the toothed blade as

frequently uprooted weeds were getting stuck to this. As they had not worked with the long handles earlier they found it a little difficult to work with the tool. They hoped that with sufficient practice this difficulty could be overcome.

Ergonomical assessment of v-blade hoe: The v-blade hand hoe consistsof a long wooden or bamboo handle joined to sharpened, v-shaped blade. The length of the handle was 1m, 20cm. The diameter of the handle was found to be 2.9 cm. Like draw weeder, the v-blade hoe too required power grip. Handle allowed maximum contact with the surface of the hand.

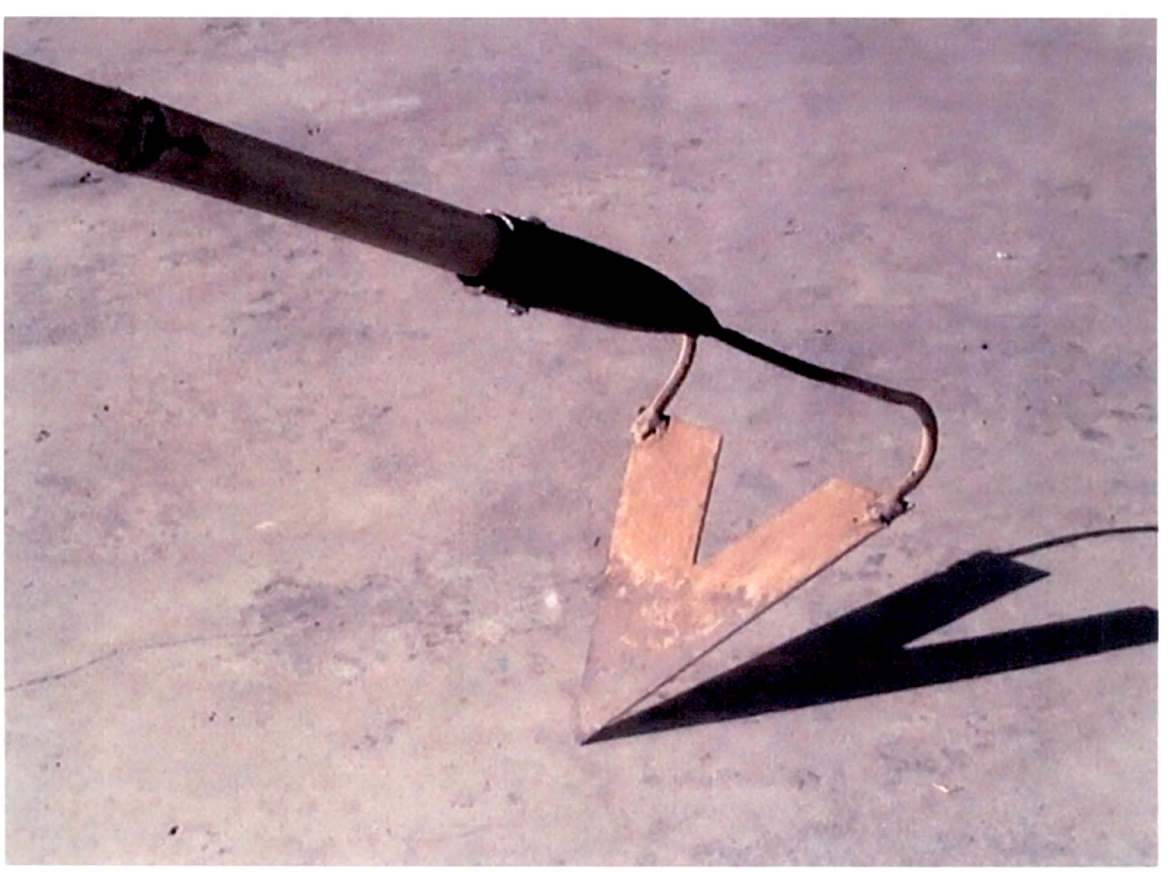
The working of the v-blade required women subjects to bend slightly but the change in the angle of deviation in the lower back and upper back was less compared to 'khutti', thus women subjects were in a better posture while working with the v-blade hoe. It is hoped that with sufficient practice the working posture could be further improved.

The mean elbow height of the women farmers was 95.38±3.89cm.The 5^{th} and 95^{th} percentile values were 88.98cm and 101.77cm respectively. It was found that during working condition, the vertical height from the tip of the handle to the soil surface (around 1m) was well above the mean elbow height of the women farmers.

Subjects' feedback

Whether the v-blade hoe is suitable to the body dimensions of the operator?

The subjects felt that the v-blade hoe is suitable to the body dimensions of the operator



V - BLADE HOE

Table 4.44 : Various dimensions of v-blade hoe

SNo.	Questions	Remark
1	Name of the weeder	v-blade hoe
2	**Details of the handle**	
i	Length	1m, 20cm
iii	Height	-
iv	Material	Bamboo/wood
v	Provision for adjustment	Handle can be cut short according to the user
vi	Diameter	2.9cm
3	**Details of blade**	
i	Size and shape	v-shaped,17cmx15cm
ii	Material	Iron
4	**Details of wheel**	No wheels present
5	**Tool as a whole**	
i	Shape and construction	-
ii	Material	Bamboo, Iron
iii	Maintenance	Low maintenance required
iv	Weight	900gm
v	Protection and safety	Should be kept clean, dry

Was the required operation of the equipment within the accepted limits of the operator?

Yes, the subjects felt that the required operation with v-blade hoe was in the accepted limits of the operator.

Does the operator face any problems during operations?

None whatsoever.

Is there any breakdown, repair and maintenance problem during work?

None

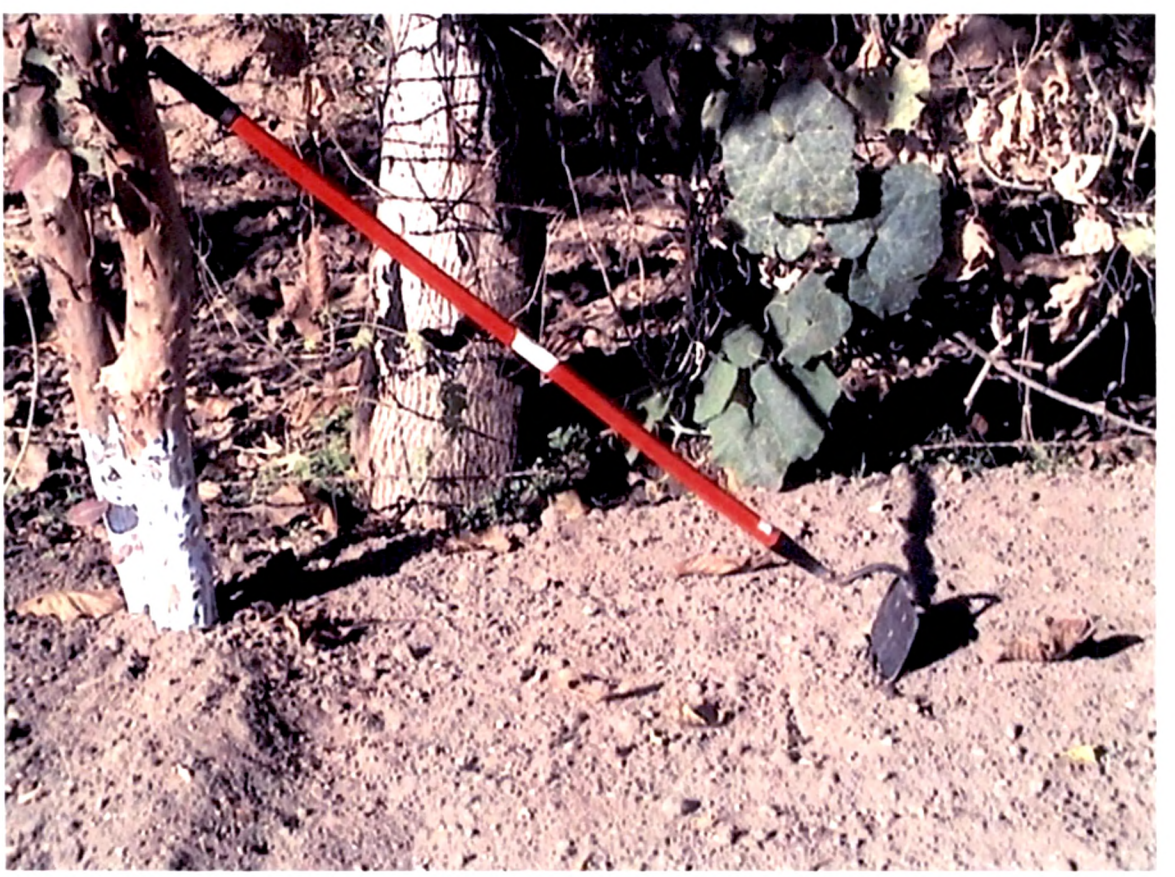
Overall comments of the subjects about implement/ tool?

The subjects found the tool helpful in covering the soil around the plants during weeding. They wanted the blade to be sharper. Besides, they also wanted the blade to go deeper inside.

Ergonomical assessment of falcon hoe: Falcon hoe is manufactured by falcon India, an ISO: 9001-2000 company manufacturing horticultural, forestry, gardening & agricultural tools and implements. This hoe consists of a trapezoid like blade attached to a long handle with the help of curved connecting part. The length of the blade was 10.2 cm. The width of the cutting edge of the blade was 16.3cm and the width of the smaller side of the blade attached to the connecting part was 12.9cm.

The operation of the weeder required power grip. The diameter of the handle was 2.8cm. the women subjects could easily flex their fingers and thumb around the handle. For firm and proper grip, the handle has been provided with rubber covering.

The mean elbow height of the women farmers was 95.38±3.89cm.The 5^{th} and 95^{th} percentile values were 88.98cm and 101.77cm respectively.The length of the falcon hoe was 1m 9cm. It was found that during working condition the vertical height from the tip of the handle to the soil surface was 94cm. But still the women subjects did not have to bend their backs so much compared to khutti. It was observed that weeding with the falcon hoe required improvement with regard to worker's posture.



FALCON HOE

Table 4.45 : Various dimensions of falcon hoe

SNo.	Questions	Remark
1	Name of the weeder	falcon hoe
2	**Details of the handle**	
i	Length	1m,9cm
iv	Material	Iron pipe
v	Provision for adjustment	Nil
vi	Diameter	2.8cm
3	**Details of blade**	
i	Size and shape	Trapezoid shaped,
ii	Material	Iron
iii	Protection and safety	Should always be kept clean of stuck weeds and mud
4	**Details of wheel**	No wheel present
5	**Tool as a whole**	
i	Shape and construction	-
ii	Material	Iron
iii	Maintenance	Low maintenance required
iv	Weight	1kg
v	Protection and safety	Requires little care

Subjects' feedback

Whether the falcon hoe is suitable to the body dimensions of the operator?

yes

Was the required operation of the falcon hoe within the accepted limits of the operator?

Yes, the required operation of the falcon hoe was within acceptable limits of the women subjects. Although the physiological cost of the operation was high compared to 'khutti' it could be improved by appropriately scheduling rest

pauses of adequate sizes in between work periods. With sufficient practice it could be further lowered down.

Does the operator face any problems during operations?

None.

Is there any breakdown, repair and maintenance problem during work?

None.

Overall comments of the subjects about implement/ tool?

The women subjects on the whole liked the tool. They were happy with the depth of the cut.

Ergonomical assessment of khutti: Khutti is a weeding tool which has been in use since many years. Therefore women subjects are immensely accustomed to use this tool. It is a short handled tool; the length of the handle is only 31.5cm. The diameter of the handle is 2.8cm. The width of the broader area of the blade is11.4cm and that of narrow area is 6.8cm. The length of the blade is 15cm.

Weeding with khutti requires squatting posture where women subjects have to flex their legs at the knees and keep moving forward. It was found that angle of deviation for the upper back and lower back was greater compared to other weeders. Women subjects felt discomfort in the lower back mainly due to the posture assumed.

It was found that after half an hour trial, output with khutti was very less. This shows that compared to other weeders weeding with khutti requires more time to weed a unit area of the field.

KHUTTI

Table 4.46 : Various dimensions of khutti

SNo.	Questions	Remark
1	Name of the weeder	Khutti
2	**Details of the handle**	
I	Length	31.5cm
Iii	Height	31.5cm
iv	Material	Wood
v	Provision for adjustment	No
vi	Diameter	2.8cm
3	**Details of blade**	
i	Size and shape	11.4cm for broader area, 6.8cm for narrow area
ii	Material	Iron
4	**Details of wheel**	No wheel present
5	**Tool as a whole**	
i	Shape and construction	
ii	Material	Wood and iron
iii	Maintenance	Low maintenance required
iv	Weight	900gm
v	Protection and safety	Should be kept dry so that to avoid the formation of rust

Subjects' feedback

Whether the khutti is suitable to the body dimensions of the operator?

No

Was the required operation of the equipment within acceptable limits of the operator?

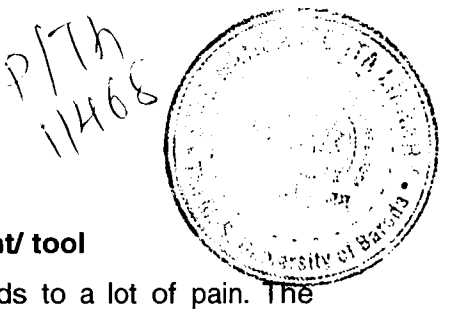
Yes

Does the operator face any problems during operations?

None.

Is there any breakdown, repair and maintenance problem during work?

No such problem was encountered



Overall comments of the subjects about implement/ tool

They were of the view that weeding with khutti leads to a lot of pain. The posture and long working hours resulted in complete body pain at the end of the day. They were interested in using new tools capable of reducing discomfort associated with traditional tools. They also wanted tools to be within their economic reach.

Testing of hypotheses

Hypothesis testing forms an important part of the research study wherein conceptualization, assumptions are put to test. This section presents the results related to the hypothesis testing. One main hypothesis was formulated in line with the aim of the study to arrive at the conclusions. It was split down into various null hypotheses for determining statistical significance.

H_o There is no significant variation among the weeding technologies with respect to

-physiological cost (in terms of heart rate and energy expenditure)

-muscular stress (per cent reduction in hand grip strength)

- area covered (m^2/hour)

-beats/m^2

-body discomfort experienced

-postural stress (% deviation in the lower back and upper back)

-weeding efficiency

H_o There is no significant variation among the weeding technologies with respect to the working heart rate (HR in beats/min).

Analysis showed significant variation among the weeding technologies with respect to the working heart rate (F-ratio=55.96; sig. at 0.01%). Critical difference (cd) per plot in beats/min for working heart rate was found to be 3.07.

Mean working heart rate in beats/min per plot in descending order for weeders

Wheel hoe	*Draw weeder*	*v-blade hoe*	*Falcon hoe*	*Khutti*
136.14	128.57	127.81	124.12	113.85

A horizontal line connecting means indicates that the difference between means was not significant.

Working heart rate (HR in beats/min) was found to be significantly higher while weeding with different weeding technologies under assessment than traditionally used khutti. In case of other paired comparisons viz., wheel hoe and draw weeder, wheel hoe and v-blade hoe, wheel hoe and falcon hoe, draw weeder and falcon hoe, v-blade hoe and falcon hoe, differences in the means were found to be higher than the critical difference. This demonstrates that working heart rate for wheel hoe is significantly higher than draw weeder, v-blade hoe, and falcon hoe. Furthermore, working heart rate on operation with draw weeder and v-blade hoe is significantly higher than falcon hoe. The difference between the means of draw weeder and v-blade hoe, was, however, found to be statistically not significant.

H_o There is no significant variation among the weeding technologies with respect to the increase in heart rate (Δ HR in beats/min).

Analysis showed significant variation among the weeding technologies with respect to the increase in heart rate (F-ratio=54.90; sig. at 0.01%). Critical difference (cd) per plot for mean increase in heart rate was found to be 3.15976 beats/min.

Mean increase in heart rate in beats/min per plot in descending order for weeders

Wheel hoe	*Draw weeder*	*v-blade hoe*	*Falcon hoe*	*Khutti*
54.52	45.99	45.01	42.99	31.45

A horizontal line connecting means indicates that the difference between means was not significant.

Mean increase in heart rate (ΔHR in beats/min) was found to be significantly higher for the weeding technologies under assessment compared to traditionally used khutti. Except for the mean difference between draw weeder and v-blade hoe, differences in the means in case of other paired comparisons were significant.

Table 4.47 : F-ratio and critical difference for various parameters for ergonomical evaluation of weeders

S.No.	Parameter	F-ratio	Critical difference at 5%
1	Working heart rate(HR in beats/min)	55.96**	3.07034
2	Increase in heart rate (Δ HR in beats/min)	54.90**	3.15976
3	Energy expenditure(kJ/min)	56.07**	0.487592
4	Per cent increase in energy expenditure	25.45**	19.7406
5	Total cardiac cost of work	38.78**	136.701
6	Area covered (m^2/hour)	342.78**	5.74757
7	Per cent reduction in grip strength of left hand (%)	3.45*	3.39490
8	Per cent reduction in grip strength of left hand (%)	1.04	NS
9	Per cent reduction in grip strength of left hand (%)	1.68	NS
10	Increase in heart beats/m^2 of area covered, beats/m^2	101.25**	5.22806
11	Overall bodily discomfort	53.86**	0.222049
12	% deviation in the lower back	615.23**	0.232249
13	% deviation in the upper back	100.25**	0.255263
14	Weeding efficiency (%)	23.29**	3.76342

** indicates 0.01 level of significance,* indicates 0.05 level of singificance

H_o There is no significant variation among the weeding technologies with respect to the energy expenditure (kJ/min)

Analysis showed significant variation among the weeding technologies with respect to the energy expenditure (F-ratio=56.07; sig. at 0.01%). Critical difference (cd) per plot for mean energy expenditure (kJ/min) was found to be 0.487592 kJ/min.

Mean energy expenditure (kJ/min) per plot in descending order for weeders

Wheel hoe	*Draw weeder*	*v-blade hoe*	*Falcon hoe*	*Khutti*
12.9	11.7	11.6	11	9.4

A horizontal line connecting means indicates that the difference between means was not significant.

Energy expenditure (kJ/min) while working with weeders under assessment viz; wheel hoe, draw weeder, v-blade hoe and falcon hoe was found to be significantly higher than the traditionally used khutti. The difference in the mean energy expenditure for draw weeder and v-blade hoe was found to be not significant.

H_o There is no significant variation among the weeding technologies with respect to the per cent increase in energy expenditure

Analysis showed significant variation among the weeding technologies with respect to per cent increase in energy expenditure (F-ratio=25.45; sig. at 0.01%). Critical difference (cd) per plot for per cent increase in energy expenditure was found to be 19.7406.

Mean values for per cent increase in energy expenditure per plot in descending order

Wheel hoe	*Draw weeder*	*Falcon hoe*	*v-blade hoe*	*Khutti*
215.834	174.825	172.6	165.42	116.95

A horizontal line connecting means indicates that the difference between means was not significant.

It was observed that the mean values for per cent increase in energy expenditure while working with the weeders under assessment were significantly higher than the mean value for the traditionally used khutti. The differences in the mean values for per cent increase in energy expenditure for draw weeder and v-blade hoe, draw weeder and falcon hoe, v-blade hoe and falcon hoe, were smaller than the critical difference. Therefore, it could be inferred that the differences in the mean values for per cent increase in energy expenditure for draw weeder, v-blade hoe, and falcon hoe were statistically not significant.

H_o There is no significant variation among the weeding technologies with respect to the total cardiac cost to work

Analysis showed significant variation among the weeding technologies with respect to the total cardiac cost of work (F-ratio=38.78; sig. at 0.01%). Critical difference (cd) per plot for total cardiac cost of work was found to be 136.701beats/min.

The mean values for the total cardiac cost of weeding with different weeders under assessment were found to be significantly higher than the traditionally used khutti.

Mean values for the total cardiac cost of work in beats/min per plot in descending order for weeders

Wheel hoe	*Draw weeder*	*v-blade hoe*	*Falcon hoe*	*khutti*
1903.73	1568.69	1504.95	1480.05	1059.2

A horizontal line connecting means indicates that the difference between means was not significant.

The differences in the mean values of the total cardiac cost of weeding for draw weeder and v-blade hoe, draw weeder and falcon hoe, and v-blade hoe and falcon hoe were smaller than the critical difference. This leads to the conclusion that the differences in the total cardiac cost of weeding with draw weeder,v-blade hoe and falcon hoe were not significant.

H_o There is no significant variation among the weeding technologies with respect to area covered in one hour (m^2/hour)

Analysis showed significant variation among the weeding technologies with respect to the area covered per hour (F-ratio=342.78; sig. at 0.01%). Critical difference (cd) per plot for area covered was found to be 5.74757 m^2/h.

Mean values for area covered, m^2 /hour per plot in descending order while working with weeders

Wheel hoe	*Falcon hoe*	*v-blade hoe*	*Draw weeder*	*Khutti*
123.99	51.80	51.16	50.89	23.37

A horizontal line connecting means indicates that the difference between means was not significant.

It was observed that the difference in mean values for area covered for wheel hoe and khutti, draw weeder and khutti, v-blade hoe and khutti, falcon hoe and khutti was higher than critical difference. This leads to the conclusion that area covered with all the weeding technologies under assessment was significantly higher than the area covered in one hour with traditional weeder

khutti. However, area covered while weeding with draw weeder, v-blade hoe and falcon hoe was found to be statistically not significant.

H_o There is no significant variation among the weeding technologies with respect to the reduction in grip strength of left hand in %.

Analysis showed significant variation among the weeding technologies with respect to the Critical difference per plot for reduction in grip strength of left hand which was found to be 3.3940 %.

Mean values for reduction in grip strength of left hand in % per plot in descending order

v-blade hoe	*Wheel hoe*	*Falcon hoe*	*Khutti*	*Draw weeder*
16.82	12.86	12.55	11.85	11.05

A horizontal line connecting means indicates that the difference between means was not significant.

Weeding with v-blade resulted in significantly higher reduction in grip strength of left hand as compared to traditional weeder khutti and other remaining weeders. On comparison of rest of the weeders with khutti it was found that the reduction in grip strength of the left hand was statistically not significant. Further, it was found that the differences in the reduction in the grip strength of left hand between wheel hoe and draw weeder, draw weeder and falcon hoe, wheel hoe and falcon hoe were not significant.

H_o There is no significant variation among the weeding technologies with respect to the reduction in grip strength of right hand in %.

Mean values for reduction in grip strength of right hand in % per plot in descending order

Falcon hoe	*v-blade hoe*	*Draw weeder*	*Wheel hoe*	*Khutti*
25.8	24.34	23.37	23.24	20.29

Analysis showed insignificant F-ratio. Hence, it could be inferred that weeding technologies did not vary with respect to the reduction in grip strength of right hand.

H_o There is no significant variation among the weeding technologies with respect to the reduction in grip strength of both the hands in %.

Mean values for reduction in grip strength of both the hands in % per plot in descending order

v-blade hoe	*Falcon hoe*	*Wheel hoe*	*Draw weeder*	*Khutti*
20.69	19.65	18.36	17.64	16.24

Analysis showed insignificant F-ratio. Therefore, it could be inferred that weeding technologies do not vary with respect to the reduction in grip strength of both the hands.

H_o There is no significant variation among the weeding technologies with respect to the increase in heart beats/m^2 of area covered, beats/m^2.
Analysis showed significant variation among the weeding technologies with respect to the increase in heart beats/m^2 of area covered (F-ratio= 101.25; sig; at 0.01%). Critical difference (cd) per plot for increase in beats/m^2 of area covered was found to be 5.22806 beats/m^2.

Mean values for increase in heart beats/m^2 of area covered, beats/m^2 per plot in descending order

Khutti	*Draw weeder*	*v-blade hoe*	*Falcon hoe*	*Wheel hoe*
80.97	56.54	54.3	50.17	28.8

A horizontal line connecting means indicates that the difference between means was not significant.

Paired comparisons showed that increase in heart beats/m^2 of area covered was significantly higher for khutti compared to wheel hoe, draw weeder, v-blade hoe, and falcon hoe. Increase in heart beats/m^2 of area covered for wheel hoe was significantly lower than all of the weeders. However, difference in increase in heart beats/m^2 of area covered was found to be statistically not significant for draw weeder and v-blade hoe. Comparison between v-blade hoe and falcon hoe also showed difference between mean increase in beats/m^2 to be not significant. However, difference in the means for draw weeder and falcon hoe was found to be significant.

H_o There is no significant variation among the weeding technologies with respect to the extent of the overall body discomfort.

Analysis showed significant variation among the weeding technologies with respect to the overall body discomfort felt by the women subjects (F-ratio=53.86; sig; at 0.01%). Critical difference (cd) per plot for overall mean body discomfort score was found to be 0.222049.

Mean values for overall body discomfort score per plot in descending order

Wheel hoe	*v-blade hoe*	*Draw weeder*	*Falcon hoe*	*khutti*
5.96	5.62	5.54	5.12	4.46

A horizontal line connecting means indicates that the difference between means was not significant.

Paired comparisons showed that overall body discomfort score for all the technologies under assessment was significantly higher than khutti. Further it was observed that overall body discomfort score for wheel hoe was significantly higher than draw weeder, v-blade hoe and falcon hoe. The difference between overall body discomfort score for draw weeder and v-blade hoe was found to be not significant. However, overall body discomfort score of draw weeder was found to be significantly higher than falcon hoe.

The overall body discomfort score of v-blade hoe was also found to be significantly higher than falcon hoe.

H_o There is no significant variation among the weeding technologies with respect to the postural stress (in terms of %deviation in the lower back)

Analysis showed significant variation among the weeding technologies with respect to the % deviation in the lower back (F-ratio=615.23; sig; at 0.01%). Critical difference (cd) per plot for postural stress in terms of % deviation in the lower back was found to be 0.232249.

Mean values for % deviation in the lower back per plot in descending order

khutti	Draw weeder	v-blade hoe	Falcon hoe	Wheel hoe
6.14	2.84	2.57	1.76	0.73

Paired comparisons showed that % deviation in the lower back for khutti was significantly higher compared to technologies under assessment viz., wheel hoe, draw weeder, v- blade hoe, and falcon hoe. Further, it was found that % deviation in the lower back for wheel hoe was significantly lower than all the other weeders. Moreover, % deviation in the lower back for draw weeder was significantly higher than v-blade hoe and falcon hoe, and % deviation in the lower back for v-blade hoe was found to be significantly higher than falcon hoe.

H_o There is no significant variation among the weeding technologies with respect to the postural stress (in terms of %deviation in the upper back)

Analysis showed significant variation among the weeding technologies with respect to the % deviation in the upper back (F-ratio=100.25; sig; at 0.01%).

Critical difference (cd) per plot for postural stress in terms of % deviation in the upper back was found to be 0.255263.

Mean values for % deviation in the upper back per plot in descending order for weeders

khutti	v-blade hoe	Falcon hoe	Draw weeder	Wheel hoe
3.14	2.02	1.80	1.69	0.60

A horizontal line connecting means indicates that the difference between means was not significant.

On comparing the means, it was observed that the differences in the % deviation in the upper back for khutti and all other weeders under assessment were higher than the critical difference. Hence, it could be inferred that % deviation in the upper back for khutti was significantly higher than all other weeders under assessment viz., wheel hoe, draw weeder, v-blade hoe, and falcon hoe. Further it was observed that % deviation in the upper back for wheel hoe was significantly lower than all other weeders. Furthermore, it was found that % deviation in the upper back for v-blade hoe was significantly higher than draw weeder. However, the difference in % deviation in the upper back for v-blade hoe was not significant with falcon hoe. The difference in % deviation in the upper back for falcon hoe and draw weeder was also not significant.

H_o There is no significant difference among the weeding technologies with respect to the weeding efficiency

Analysis showed significant variation among the weeding technologies with respect to the weeding efficiency (F-ratio=23.29; sig; at 0.01%). Critical difference (cd) per plot for weeding efficiency (%) was found to be 3.76342.

Mean weeding efficiency (%) per plot in descending order for weeders

Khutti	Falcon hoe	Draw weeder	Wheel hoe	v-blade hoe
90.03	80.71	77.22	74.38	74.5

A horizontal line connecting means indicates that the difference between means was not significant.

On comparing the means, it was observed that weeding efficiency with traditional weeder, khutti, was significantly higher than all the other weeders under assessment viz., wheel hoe, draw weeder, v-blade hoe, and falcon hoe. It was further observed that the differences in the mean weeding efficiencies for falcon hoe and draw weeder, draw weeder and wheel hoe, wheel hoe and v- blade hoe, draw weeder and v-blade hoe were not significant. The weeding efficiency for falcon hoe was found to be significantly higher than wheel hoe and v-blade hoe.

Conclusions and suggestions for improved use of technologies tested

In the light of the results and discussion presented in the preceding sections the following conclusions could be drawn:

► Although physiological responses (heart rate and energy expenditure) were high while working with technologies assessed viz., wheel hoe, draw weeder, v-blade hoe, falcon hoe, compared to traditional weeder khutti, area covered with these weeders was far high than with the traditional weeder. The area covered was about four times larger with wheel hoe as against khutti. Operation with other weeders also resulted in higher output which was about double the area weeded by the khutti. Therefore, cardiac cost/m^2 of area weeded with the technologies assessed is low. This means that increase in heart beats/m^2 of area weeded is low. Thus heart beats expended/m^2 of area weeded is much less while working with the technologies assessed compared with traditional weeder. Consequently, energy expenditure/m^2 while working with the technologies assessed would also be low.

► Further, to do away with or retrench the high physiological demands placed on the subjects by the technologies assessed appropriate short rest pauses may be inserted between working periods so that the physiological cost remain within reasonable limits and do not make the subjects too much fatigued that they are not able to work further.

► Working posture with the technologies which were assessed was better in terms of the angle of deviation which was higher in case of traditional khutti. But the associated overall bodily discomfort was greater in case of technologies assessed compared to khutti. The women subjects were not used to working with weeders which were assessed, and, probably this affected the way they operated the weeders. They just had a few hours of practice with the weeders before experimental trials were started. As the time for the experimental trials was limited more time could not be devoted to the practice sessions. Although prior to the experimental trials instructions were given as to how to work with the weeders it still it took time to work appropriately.

Regarding working posture it was perceived that though the tool had a long handle the worker had still to bend a little for ensuring the uprooting of weeds. The women subjects had to apply force upwards and towards their body because of which they felt discomfort in arms and shoulders. Yet there is scope for the improvement of the working posture. The main reason behind discomfort is perhaps the way they used the weeder. They felt discomfort in the arms because they were using arms and back to generate movement in guiding the hoe. The arms are relatively weak and as a result back is subject to strain. In addition, this posture compresses breathing, which further adds to physical discomfort. Enough practice and improvement in the working posture can help to do away with this problem.

The posture could be improved by keeping the body well aligned with full breathing while generating power by the use of legs and hips. By altering the way the weeder is held i.e. first by holding the weeder with left arm up and right arm down and after sometime changing the position of the hands by keeping the right arm up and the left arm down the handle so that the same muscles are not in use.

► Weeding is very much dependent on time. If timely weeding is not done it severely affects the crop yield and it also affects the amount of effort required to uproot the weeds as small weeds are more easy to weed out compared to full grown ones. Therefore, weeder which allows working faster is more desirable.

►Weeding efficiency of the weeders under assessment was found to be less compared to khutti. But it could be argued that if all the space, between the rows as well as interplant space in the row is weeded with the wheel hoe or other weeders and the area around the plant is weeded using the short handled khutti the efficiency could be increased. If most of the soil had been loosened by the weeders, it might not be necessary to work by exerting the same power. As a consequence it would be possible to have a posture which is not too stressful for the back, increasing the weeding efficiency at the same time.

► To sum up, technologies which were assessed viz., wheel hoe, draw weeder, v-blade hoe, and falcon hoe placed high physiological demands on the subjects but at the same time had higher output in terms of the area weeded and provided better working posture compared to the traditional tool khutti. As the time needed to cover one metre square is less women farmers don't have to work for long hours in hard environmental conditions. With the traditional weeder women farmers have to drudge for long hours in the field due to the low output. As more area is covered in lesser duration of time women have a surplus of time which they could utilize in another important activity. Also more area can be put under cultivation which can increase the production and income of the farmers. It is quite possible that with the increase in the familiarity with the use of the weeder women would work with the weeder with lesser discomfort. As these weeders enables women to work in more erect posture in the long term there are less chances for the women to develop strains in their back and as a result can work more efficiently. This in turn would affect their health status which would be better.

As operationalized in the present study drudgery refers to the amount of hard work put in and difficulties faced by the women farmers while doing weeding. With the traditional weeding tool khutti women has to spend more time on the fields doing weeding. Therefore difficult posture has to be kept for longer duration of time, that too under harsh environmental conditions. This happens repeatedly for days together until weeding is complete. All this contributes to the drudgery of the women farmers. Technologies assessed in the present study reduce the time spent by the women on the fields doing weeding. Uncomfortable posture continuously for long hours is avoided and the output is more.Therefore the drudgery is reduced and the efficiency is increased.