



## Comparative performance and ergonomic assessment of different types of weeder for better adaptability of machine

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The research was planned to predict the performance and ergonomic assessment of different types (tractor operated weeder, the engine operated inter-row rotary weeder, tractor-drawn high clearance cultivator, and manual hand hoe) weeder in cotton crop. The experimental study consists of five treatments. Weeding operations were done at three stages (pre-square, square and flowering) of the cotton crop and the performance parameter was recorded. The highest weeding efficiency was found in manual hand hoe (Kasola) with 85.50-89.59% whereas efficiency varied from 74-76% in tractor operated weeders. Crop parameters were also recorded. Plant height and canopy at the flowering stage differ significantly and plant height was found significant at the square stage also. In all treatments, after weeding pulse rate varies from 104-122 beats/min. The engine operated power weeder resulted in more blood pressure (142/90) than the manual weeder (135/88). So from the results obtained, the tractor operated inter-row rotary weeder (M2) was found best and recommended.

**Keywords:** Cotton, Crop parameter, Hand hoe, Pulse rate, Weeder

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Cotton is the most important fiber crop cultivated worldwide. A major portion of production is contributed to tropical and sub-tropical areas throughout the world. It is grown in more than seventy countries in the world including USA, China, Brazil, Australia, and India. These countries share more than 70% of total production. India and China are also major cotton consuming countries. India has different agro-ecological regions and a more significant part of the geographical area is used for agriculture where a lot of varieties of crop are grown<sup>1</sup>. The agriculture sector of India has occupied 43% of India's geographical area and is contributing 17% of India's GVA<sup>2,3</sup>. Cotton is a major cash crop of India. India continued to maintain the largest area under cotton and second largest producer of cotton next to China with 34% of world area<sup>4</sup>. Cotton was sown over 4.80 lakh ha in Punjab with highest productivity 744 kg/ha and 6.14 lakh ha in Haryana with productivity of 692 kg/ha<sup>5</sup>. Punjab and Haryana account for nearly 13-14% of India's total cotton production.

Based on the nature and intensity of weeds, losses occur in the cotton crop in the range of 40-45%<sup>6</sup>. If weeds are not controlled at the initials, stage losses

can be 80-90% and can cause total crop failure. Weeding is very labour intensive as well as expensive operation in cotton production. Due to weeds, approximately 4200 million rupees is being lost in India annually<sup>7</sup>. The cost of inter-culture for weeding in crop comes of Rs. 3000/ha<sup>8</sup>.

Farmers in India prefer mechanical weeding over chemical weeding due to the high cost, hazardous and selective nature of chemical weeding. Weeding operations are performed manually, despite its very arduous operation. Hand hoe (Kasola) is used for weeding which resulted in back pain to labours. Nearly 300-1200 man h/ha is required for the entire season of the crop as 3-4 times weeding is necessary. Traditional methods are also time-consuming and very costly. On the other hand, bullock-drawn implements have certain drawbacks like low field capacity, high maintenance cost, limitations of adverse weather conditions, etc. and are therefore not affordable to the farmers. The most practicable and effective way of mechanical weeding emerges to be powered machines or advanced hand tools over traditional methods of weeding. The availability of agricultural labour is decreasing continuously. Additionally, wages are rising. Instead, automobiles are becoming more and more common as a source of

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power, and engine-powered devices are replacing labor-intensive and expensive manual tasks.

The efficient weeding technique is much required for farmers. Njoku<sup>9</sup> reported that the quantity and quality of crop hampered by the weed growth while overall investment also increases due to the untimely weeding operations. Change in soil quality and residual effect has occurred in herbicides weeding. Flame weeding is also not popular in India as it is costly and produces intensive heat. Mechanical weeding results in soil moisture and better aeration as tillage makes soil surface loose<sup>10</sup>. Tractor-operated weeders can save 75% time and 20% cost as compared to bullock drawn weeder as there are more plant damage and wastage in head lands<sup>11</sup>. Cost of power tiller farming is about 44.4 and 11.4% less than bullock and tractor farming respectively but power tiller farming increases heart beat rate of the operator during inter-culture operation up to 140 beats/min and overall discomfort rating for an operating duration of 30 min was found 4.5 on 10 point VAD scale<sup>12</sup>. The cost of weeding by engine operated weeders comes to only one third of weeding cost by manual labour<sup>13</sup>. Usually, tractor mounted cultivators are used for weeding and inter-culture operations. Therefore, the different methods of inter cultivation are practiced in cotton crops and there is a need to evaluate these methods.

## Material and Methods

### Location of study

Work was carried out at Cotton Research Farm in 2014-15, CCS Haryana Agricultural University Hisar.

### Field evaluation

The field experiment was carried out to evaluate the performance of five different weeders as described in Table 1 and also shown in Fig. 1 (i-v). Four replication of each treatment was taken.

### Soil type

Samples were taken from upper layer of 15 cm soil depth from the experiment site. The soil samples were analyzed in the laboratory of Soil Science Department

Table 1 — Treatment used in study

Treatment	Machine used
M1	Tractor operated inter row rotary weeder (Operating width = 1440 mm)
M2	Tractor operated inter row rotary weeder (Operated width = 1540 mm)
M3	Tractor operated high clearance cultivator
M4	Walk behind engine operated power weeder
M5	Hand Hoe i.e., Kasola



Fig. 1 — Plate (i-v) showing treatment

College of Agriculture, CCS Haryana Agricultural University Hisar.

**Crop parameters**

**Crop**

Two varieties of cotton crop were selected, namely:  
 1. Desi Cotton (HD-123)  
 2. American Cotton (1098)

**Plant height, cm**

Five plants were randomly selected in each treatment for both varieties and their height were measured in centimetre from collar region to the tip of the main stem for each replication. The plant height was measured with the help of the measuring scale at three different stages of plant growth (pre square formation, square formation and flowering stage).

**Canopy of plant, cm<sup>2</sup>**

Five plants were randomly selected in each treatment for both varieties and horizontal projection of the outermost perimeter of the natural spread of foliage of plants was measured.

**Weed population, no./m<sup>2</sup>**

Number of weeds per square meter area at different location in each treatment for both varieties was recorded before and after operation.

**Number of bolls per plant**

Five plants were randomly selected from each treatment and number of bolls per plant was counted.

**Lint yield, g/plant**

Five plants were randomly selected and lint yield per plant was recorded.

$$\text{Lint yield (g)} = \frac{\text{Seed cotton yield (g)} \times \text{Ginning out turn in percent}}{100}$$

**Weeding efficiency, per cent**

$$\frac{W_1 - W_2}{W_1} \times 100$$

Where,

w1 = numbers of weeds in one square meter area before operation

w2 = numbers of weeds in one square meter area after operation.

**Ergonomical data**

**Pulse rate, Heart beats/min**

The pulse rate was measured by counting pulse per minute. Pulse rates were measured before and after operation by digital pulse recorder.

**Blood pressure, mm of Hg**

The pressure of the blood in the circulatory system, often measured for diagnosis since it is closely related to the force and rate of the heartbeat and the diameter and elasticity of the arterial walls. Blood pressure

- (i). Tractor operated inter-row rotary weeder (M1)
- (ii). Tractor operated inter-row rotary weeder (M2)
- (iii). Tractor operated high clearance cultivator (M3)
- (iv). Walk behind engine operated power weeder (M4)
- (v). Hand operated hoe, Kasola (M5)

was recorded by using a digital blood pressure recorder.

**Analysis of the data**

The data were quantified according to standards laid down and tabulated to draw meaningful inferences. In order to see the significance of results, the data were subjected to the statistical analysis by the analysis of two variable split plot method. The test of significance was made at 5% level of significance.

**Results and Discussion**

**Soil type**

The analysis of soil was done in the laboratory of department of soil science, College of Agriculture, CCS Haryana Agricultural University and type of soil was found sandy loam having 75.4% sand, 12.4% clay and 12.2% silt. The value of N, P, K and OC in the soil was found 104.8 kg/ha, 0.14 kg/ha, 20.97 kg/ha and 0.23% respectively. The average moisture content at all the three stages of weeding in American cotton (H1098-i) field was 12.06 to 12.36% and in Desi cotton (HD123) field it was same (11.18 to 11.62%). It was because of the reason that at all the three stages of weeding; there was a rainfall before weeding operation performed.

**Crop parameters**

The crop parameters were recorded after using different types of weeders selected under the study in cotton crop.

**Plant height, cm**

The selected weeders were operated in the field to predict their performance on cotton crop. The average data of plant height of cotton crop at different stages i.e., pre square, square and flowering are presented in Table 2. Plant height was in the range of 19.25 to 20.25 cm, 39.58 to 46.00 cm and 87.70 to 92.78 cm in American cotton (H1098-i) at three different weeding

stages, respectively. For Desi cotton (HD123) variety, plant height ranged from 15.58 to 15.88 cm, 49.63 to 58.20 cm and 98.73 to 104.33 cm at three different weeding stages, respectively. The average plant height was non-significant at pre square stage in both the selected varieties with the use of different weeders. Maximum average plant height at square formation was observed 46.00 cm in treatment M2 and 58 cm in treatment M2 for American cotton (H1098-i) variety and Desi cotton (HD123) variety respectively. At flowering stage, maximum average plant height was recorded 92.78 cm for treatment M2 and 104.33 cm for treatment M2 for American cotton (H1098-i) variety and Desi cotton (HD123) variety, respectively. The data clearly revealed that the maximum height of plant was found in treatment M2 under both the varieties with the use of tractor operated inter row rotary weeder. The statistical analysis of result indicates that the plant height was non-significant at pre square formation and it was found significant at square and flowering stages with the use of different weeders. The average plant height at square formation was 52.10 cm and at flowering stage 98.56 cm with the use of treatment M2 in both the varieties.

The plant height was significant in treatment M2 in comparison to other treatments. However, the plant

height was affected significantly among treatment in the both the varieties. It is evident from Table 2 that plant height was non-significant with the use of different weeders at pre-square formation. The plant height recorded at square and flowering stage had significant difference with the use of different weeders. The plant height was maximum with the use of treatment M2 and it was highly significant in comparison to other treatment. The higher depth of cut (95 mm), better soil pulverization and uniform levelling of soil in rows of cotton plants were also observed. The tractor operated rotary weeder used in treatment M2 had a shape of trapezoidal section behind the rotary weeder unit for levelling. This resulted in uniform depth of irrigation water applied and better aeration. Therefore, the plant height was more with the use of treatment M2. There was no significant difference in plant height with the use of treatment M1, M2 and M4 whereas the difference in plant height among treatment M2 and M5 was highly significant.

#### Canopy of plant, cm<sup>2</sup>

The average data of canopy of plant of cotton crop at different stages that is pre square, square and flowering are presented in Table 3. Canopy area of plant ranges from 514.50 to 8826.59 cm<sup>2</sup> in American

Table 2 — Plant height of cotton crop at different stages, cm

Treatments	Pre square			Square			Flowering		
	H1098-i	HD123	Mean	H1098-i	HD123	Mean	H1098-i	HD123	Mean
M1	19.25	15.88	17.57	44.31	55.13	49.72 <sup>b</sup>	91.10	102.13	96.62 <sup>c</sup>
M2	19.62	15.80	17.71	46.00	58.20	52.10 <sup>c</sup>	92.78	104.33	98.56 <sup>d</sup>
M3	20.00	15.58	17.79	43.38	52.82	48.10 <sup>b</sup>	90.11	100.60	95.36 <sup>bc</sup>
M4	20.25	15.73	17.99	42.53	53.00	47.77 <sup>b</sup>	89.08	100.68	94.88 <sup>b</sup>
M5	19.75	15.88	17.82	39.58	49.63	44.61 <sup>a</sup>	87.70	98.73	93.22 <sup>a</sup>
Mean	19.77	15.77		43.16	53.76		90.15	101.29	
C.D. factor V		0.96			1.33			1.07	
C.D. factor T		NS			2.26			1.63	

Where V= variety parameter T= treatment parameter

Table 3 — Canopy of plant at different stages, cm<sup>2</sup>

Treatments	Pre square		Mean	Square		Mean	Flowering		Mean
	H1098-i	HD123		H1098-i	HD123		H1098-i	HD123	
M1	515.00	390.50	452.75	2111.52	1528.47	1820.00	8819.88	4390.33	6605.11 <sup>bc</sup>
M2	516.50	391.00	453.75	2193.18	1549.98	1871.58	8826.59	4433.37	6629.98 <sup>c</sup>
M3	514.50	389.50	452.00	2002.66	1474.98	1738.82	8483.06	4249.86	6366.46 <sup>a</sup>
M4	515.00	388.50	451.75	2074.41	1469.18	1771.80	8474.81	4229.81	6352.31 <sup>a</sup>
M5	516.00	389.50	452.75	2003.36	1437.25	1720.31	8402.54	4117.57	6260.06 <sup>a</sup>
Mean	515.40	389.80		2077.03	1491.97		8601.38	4284.19	
C.D. factor V		13.74			124.19			355.33	
C.D. factor T		NS			NS			186.37	

Where V= variety parameter T= treatment parameter

cotton (H1098-i) variety and for Desi cotton (HD123) variety its ranges from 388.50 to 4433.37 cm<sup>2</sup>. The data revealed that average plant canopy area was maximum in treatment M2 i.e., 516.50 cm<sup>2</sup> and 391.00 cm<sup>2</sup> at pre square formation for American cotton (H1098-I) and Desi cotton (HD123) variety respectively. Maximum average plant canopy area at square formation was observed 2193.18 cm<sup>2</sup> and 1549.98 cm<sup>2</sup> in treatment M2 for American cotton (H1098-i) and Desi cotton (HD123) variety respectively. At flowering stage, maximum average plant canopy area was recorded 8826.59 cm<sup>2</sup> and 4433.37 cm<sup>2</sup> for treatment M2 in American cotton (H1098-i) and Desi cotton (HD123) variety, respectively. The data clearly revealed that the maximum plant canopy area was found in treatment M2 under both the varieties with the use of tractor operated inter row rotary weeder.

The statistical analysis of results indicates that there was significant difference in plant canopy area in both the varieties at flowering stage whereas plant canopy area was non-significant at pre square and square formation with the use of different weeders. It is reported in Table 3 that there was no effect on the canopy of plant at pre-square and square formation with the use of different weeders whereas statistically significant difference was observed on the canopy area of plant with the use of different weeders at flowering stage. There was no significant difference on the canopy area of plant in treatment M3, M4 and M5. Similarly, there was no significant difference on canopy area of plant with the use of treatment M1 and M2. However, the canopy area of plant was (6629.98 cm) highly significant in treatment M2 in comparison to other treatment. It was because of better up take of nutrients due to better pulverization and aeration up to more depth which created a favourable condition for better root development at later stage of crop i.e., flowering.

**Weeding efficiency, per cent**

The maximum weeding efficiency in the range of 85.16 to 89.64% was observed in treatment M5 at different stages and under both the selected varieties followed by treatment M2 where the weeding efficiency was in the range of 74.05 to 76.70% at various the stages & varieties. The minimum weeding efficiency (64.16 to 66.09%) was under treatment M3 at all the stages and varieties Table 4. The result clearly revealed that the weeding efficiency under selected varieties was non-significant whereas weeding efficiency was significantly affected with the use of different type of weeders at all the stages of crop in both the selected varieties. The weeding efficiency was non-significant at all the three stages with the use of treatment M1, M2 & M4. The weeding efficiency was maximum (88.45% at pre square, 88.61% at square and 85.50% at flowering) and was highly significant at all the three stages with the use of treatment M5 in comparison to other treatment.

The weeding efficiency was more in manual hand hoe because of the reason that the weeds between the plants were also uprooted whereas in mechanical weeders it was not possible to uproot the weeds grown in between the plants. There was no effect of weeding efficiency by growing different cotton cultivars (variety). Various study<sup>14-17</sup> reported that the weeding efficiency was found maximum (80%) with the use manual hand hoe as with the use of tractor operated weeders it was 65-85%.

**Number of bolls per plant**

The maximum bolls per plant (41.75) were found in Desi cotton variety (HD123) with the use of treatment M2 whereas the minimum bolls per plant were recorded 33.25 in American cotton (H1098-i) with the use of treatment M3 presented in Table 5.

Table 4 — Weeding efficiency at different stages in per cent

Treatments	Pre square		Mean	Square		Mean	Flowering		Mean
	H1098-i	HD123		H1098-i	HD123		H1098-i	HD123	
M1	74.48	74.88	74.68 <sup>b</sup>	75.75	76.43	76.09 <sup>b</sup>	74.00	74.35	74.17 <sup>b</sup>
M2	74.69	75.05	74.87 <sup>b</sup>	75.94	76.70	76.32 <sup>b</sup>	74.05	74.44	74.24 <sup>b</sup>
M3	65.08	66.08	65.58 <sup>a</sup>	66.09	66.08	66.08 <sup>a</sup>	64.16	65.11	64.63 <sup>a</sup>
M4	74.48	74.85	74.66 <sup>b</sup>	75.73	76.53	76.13 <sup>b</sup>	73.93	74.28	74.10 <sup>b</sup>
M5	88.63	88.28	88.45 <sup>c</sup>	89.59	89.64	89.61 <sup>c</sup>	85.16	85.84	85.50 <sup>c</sup>
Mean	75.47	75.83		76.62	77.07		74.26	74.80	
C.D. factor V		NS			NS			NS	
C.D. factor T		0.75			0.76			1.51	

Where V= variety parameter T= treatment parameter

In American cotton (H1098-i) variety, number of bolls per plant was in the range of 33.25 to 34.50 with the use of different treatments. The statistical analysis of results indicates that there were no significant differences in bolls per plant with the use of different weeders. There was significant difference on bolls per plant among both the variety. There was significant difference on number of bolls per plant when different varieties were grown i.e., American (H1098-i) and Desi (HD123) cotton. The results clearly indicate that the bolls per plant significantly affected when different cotton cultivars were grown.

#### Lint yield, g/plant

The lint yield per plant was almost similar among all the treatment in variety H1098-i. The same behaviour was observed in variety HD123 (Table 5). Seed cotton yield per plant was recorded in grams under each treatment. Lint yield was determined after ginning of each sample. The lint recovery in American cotton variety (H1098-i) was 34% and in Desi cotton variety (HD123) was 38%. The lint yield in American cotton variety was almost similar 39.56 g/plant to 41.05 g/plant in different treatments whereas in Desi cotton it ranged from 36.10 g/plant to 39.66 g/plant. The yield was non-significant with the use of different treatment whereas among variety the difference in lint yield was found significant.

It evident from the results given Table 5 that in American variety, the number of bolls per plant were

less whereas the weight of one boll was more (3.5 g) and in Desi it was 2.5 g. The numbers of bolls per plant were more in Desi cotton (HD123) but due to less weight of one boll, the lint yield (gram per plant) was less in Desi cotton (HD123) as compared to American cotton (H1098-i).

#### Ergonomics

The mechanical weeders were operated by same person, whereas in treatment M5 different person were used for weeding. The pulse rates of the person who operated mechanical weeders were taken in each treatment before and after operation. The pulse rates of the person engaged in operating mechanical weeders, was recorded and reported in Table 6. The pulse rate of all the person before start of weeding operation was in the range of 72 to 76 beats/min. The maximum pulse rate after weeding operation was observed in treatment M4 i.e., 122 beats/min and minimum was recorded in treatment M3 (104 beats/min). The pulse rate of the person engaged for manual weeding, after operation was observed in the range of 113 to 120 beats/min. The blood pressure of all persons was recorded before and after weeding operation. The blood pressure of all persons engaged for weeding was normal except in treatment M4 i.e., 142/90 mm of Hg.

The ergonomical parameters reported in Table 6 revealed that the pulse rate of operator after use of mechanical weeders as well as manual hand hoe were within the range of 104-120 beats/min and the

Table 5 — Number of bolls per plant & Lint yield (g/ plant) for both varieties

Treatments	Bolls/plant		Lint Yield (g/plant)	
	H1098-i	HD123	H1098-i	HD123
M1	34.00	40.50	40.46	38.47
M2	34.50	41.75	41.05	39.66
M3	33.25	39.25	39.56	37.28
M4	34.00	38.50	40.46	36.57
M5	33.75	38.00	40.16	36.10
Mean	33.90	39.60	40.33	37.61
C.D. factor V	2.32		2.81	
C.D. factor T	NS		NS	

Where V= variety parameter T= treatment parameter

Table 6 — Ergonomically parameters of different weeding method

Sr. No	Parameters	Treatments					
		M1	M2	M3	M4	M5	
1	Pulse rate, beats/min	Before operation	73	72	72	72	72-76
		After operation	107	108	104	122	113-120
2	Blood pressure, mm of Hg	Before operation	120/80	120/80	120/80	120/80	120/80-130/82
		After operation	121/82	119/83	120/81	142/90	135/88



corresponding value of blood pressure was within the prescribed limit with the use of tractor operated rotary weeder i.e., under treatment M1, M2 & M3. The corresponding values of blood pressure were in case of treatment M4 was 140/90 and in manual hoe it was 135-188 mm of Hg. The pulse rate and blood pressure of the operator with the use of walk behind engine operated power weeder was maximum in comparison to other weeders used. It was because of person walking behind the power weeder have to control the direction of power weeder in ploughed land which required more power to control the direction. Secondly the vibration was more which resulted in more fatigue to operator. Study<sup>12</sup> reported that the pulse rate with the use of power tiller as weeder were in the range of 129.8 to 138.8 beats/min.

### Conclusion

The crop and machine performance parameter were recorded at three stages of cotton crop i.e., pre-square, square and flowering. The plant height, canopy of plant & weeding efficiency was recorded at three stages i.e., pre-square, square and flowering. Yield data (g/plant) was recorded under all the treatments taken in both varieties. The plant height was non-significant with the use of different weeders up to stage of pre-square formation whereas there was a significant difference in plant height at square and flowering stage. There was no effect on canopy of plant with the use of different weeder at pre-square and square formation whereas at flowering stage there was a significant difference. The weeding efficiency was found maximum with manual hand hoe (85.5-89.59%). The weeding efficiency with the use of tractor operated weeders was obtained up to the level of 74-76%. It was not possible to operate tractor operated weeders between the plants because of plant spacing was less to operate weeders between plants. The weeding efficiency was more with the use manual hand hoe because of weeds were uprooted between the plants also. There was no significant effect on the number of bolls per plant with the use of mechanical weeders whereas a significant difference was found in both the varieties. The lint yield per plant was more in American cotton (H1098-i) whereas number of bolls per plant was less.

The pulse rate (beats/min) and blood pressure (mm of Hg) were within prescribed limit with the use of tractor operated inter row rotary weeders. The blood pressure of the operator was more 140/90 with the use of walk behind engine operated power weeder

whereas in manual hoe it was 135/88 mm of Hg. However, use of traditional hand hoe equipment requires a lot of muscle power, which results in tiredness, discomfort and pain as well as a reduced field capacity and decreased efficiency. A person's productivity declines as a result of the unergonomic behaviour at workplace. Therefore, using ergonomic solutions at work can improve employee comfort and boost productivity.

Use of tractor operated weeder is therefore necessary nowadays to meet the shortage of agricultural labour, preserve timeliness and lower weeding costs. The performance, weeding efficiency and ergonomics of tractor operated inter row rotary weeder (M2) was found better in comparison to other weeders selected for study. Therefore, the weeder having specification of weeder M2 is recommended and provision for adjustment of row to row spacing should be provided depending upon crop row spacing. Check row planting in cotton may be studied so that the weeders can be operated in both the direction to increase weeding efficiency.

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### Conflict of Interest

The authors declare no conflict of interest.

### Authors' Contributions

AM designed and executed the experiments and wrote the first draft of the manuscript, NKB wrote the protocol and supervised to conduct the experiments, PD, SB and NK general work arrangement. PD assisted in writing this article, supervised the literature searches. All authors read and approved the final manuscript.

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