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# Ergonomic Comparison of Modified Hoe and Chisel Weeders for Enhanced Operator Comfort in Weeding

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**Abstract**

Manual weeding remains a labor-intensive and ergonomically demanding agricultural task, especially in smallholder farming systems. This study evaluated and compared the ergonomic performance of modified hoe and chisel weeders, incorporating adjustable handle angles (45–65°), lightweight mild steel frames (4.5 kg), and optimized cutter blades (175 mm length), to address gaps in existing designs. Field experiments at SHUATS, Prayagraj, involved four male operators aged 20–35 years, measuring anthropometric, physiological (heart rate, OCR, EER), and postural (BPDS) parameters. The chisel weeder demonstrated significantly lower physiological strain than the hoe weeder, with mean heart rate (90–134 vs. 91–135 b/min; $p < 0.05$), oxygen consumption rate (0.346–0.847 vs. 0.357–0.859 l/min), and energy expenditure rate (6.5–17.6 vs. 7.4–17.91 kJ/min). Postural discomfort (BPDS) was 28% lower for the chisel weeder (20–45 vs. 23–52), particularly in younger operators (20–23 years: BPDS 20 vs. 23). These findings underscore the importance of ergonomic modifications in manually operated weeders to enhance operator comfort, reduce fatigue, and minimize the risk of musculoskeletal disorders. The study provides design recommendations for further improving manual weeder ergonomics in small-scale agriculture.

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**Abbreviation**

| | |
|---|---|
| HR | Heart Rate |
| OCR | Oxygen Consumption Rate |
| EER | Energy Expenditure Rate |
| BPDS | Body Part Discomfort Score |
| ICA | Integrated Composite Anthro pometer |

## Introduction

Agriculture remains the backbone of India's economy, employing over 54.6% of the population and contributing significantly to the nation's food security and industrial raw material supply.[1] Among the various agricultural operations, weeding is critical for ensuring optimal crop yield by mitigating competition from weeds for nutrients, water, and sunlight.[2,3] In India, where smallholder farming and fragmented land holdings predominate, manual weeding using traditional tools such as sickles, hoes, and spades is prevalent, particularly in regions like northern Karnataka and Jammu and Kashmir.[4,5] These labor-intensive practices, often performed in ergonomically unsuitable postures, lead to significant physical strain, fatigue, and discomfort, reducing operator efficiency and increasing the risk of musculoskeletal disorders.[6] Ergonomics, the scientific study of human interaction with their working environment, is crucial for designing agricultural tools that minimize drudgery and enhance operator comfort and productivity.[4,7] Despite advancements in mechanized weeding, manually operated weeders remain essential due to their affordability and suitability for small-scale farms, yet many existing designs lack ergonomic considerations, resulting in high physiological and postural stress.[8]

The need for ergonomically optimized manually operated weeders is evident, as traditional tools often fail to account for anthropometric variations and operator well-being, leading to inefficiencies and health risks.[9] Recent efforts to modify traditional weeders, such as the hoe and chisel types, have focused on reducing blade width, adjusting handle angles, and using lightweight materials to enhance usability and reduce physical strain.[10] This paper addresses these challenges by evaluating modified hoe and chisel weeders, incorporating features like adjustable handles (45–65°), lightweight mild steel frames, and optimized cutter blades (175 mm length, 2 mm thickness) to improve operator comfort. These modifications aim to address the limitations of traditional weeders, which often result in elevated heart rates, oxygen consumption, and body part discomfort, particularly among older operators.[11] This study provides a comprehensive dataset on anthropometric measurements, physiological parameters (heart rate, oxygen consumption rate, energy expenditure rate), and postural parameters (body part discomfort score) for male operators aged 20–35 years, offering a foundation for comparative ergonomic analysis. This study builds, to compared the ergonomic performance of modified hoe and chisel weeders, focusing mainly on their impact on operator comfort during agricultural weeding.

## Materials and Methods

This study was conducted to evaluate the ergonomic performance of modified manually operated hoe and chisel weeders, focusing on their impact on physiological and postural parameters among male agricultural operators (age group 20-35 years). The Field experiments were carried out at the agricultural engineering farms of Sam Higgin bottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, India. The methodology encompassed the modification of traditional weeders, selection of subjects, measurement of anthropometric and physiological data, assessment of postural discomfort, and statistical analysis of the collected data.

### Experimental Setup

The field experiments were conducted on a 10 × 10 m² plot at the SHUATS agricultural engineering farms, designed to simulate typical vegetable field conditions. Two manually operated, single-row, pull-type weeders—a modified hoe weeder and a modified chisel weeder—were used for their ergonomic performance. The modifications to these weeders were aimed at reducing operator drudgery and enhancing usability, incorporating optimized cutter blade dimensions (175 mm length, 2 mm thickness), adjustable handle angles (45–65°), and a lightweight main frame constructed from mild steel pipes. These modifications were intended to improve operator comfort, reduce physiological strain, and facilitate ease of fabrication by local artisans, addressing limitations of traditional weeders such as excessive weight and poor ergonomic design.[8] The field was prepared to ensure uniform soil conditions, and experiments were conducted in a controlled manner to minimize external variables such as weather and soil moisture.

**Weeder Specifications**

The modified hoe and chisel weeders shared several common components but differed in their cutter blade designs, tailored to specific weeding actions. Detailed specifications, as outlined in Tables 1. The modified hoe and chisel weeders were designed with ergonomic specifications to enhance operator comfort and efficiency, as detailed in Kumar.[12] The main frame, constructed from mild steel pipes (1330 mm length, 26 mm width), provided robust structural support while maintaining a lightweight design, with a total weeder weight of 4.5 kg. It featured provisions for attaching a V-shaped frame and an adjustable lever mechanism for precise positioning of the weeding unit. Both weeders were pull-type, equipped with two ground wheels (19.5 cm diameter) to ensure stability and ease of movement during operation. The weeding unit included distinct cutter blades: the hoe weeder utilized a high carbon steel blade (175 mm length, 2 mm thickness) designed for slicing through soil to cut and uproot weeds, while the chisel weeder employed a blade of identical material and dimensions optimized for penetrating soil to sever weed roots. The handle, fabricated from 2 mm thick mild steel pipe (130 mm length, 26 mm diameter), was adjustable in height (940 mm from the ground) and angle (45–65°), allowing customization to accommodate operator anthropometric variations and reduce postural strain. The design prioritized simplicity for fabrication by local artisans and incorporated safety features, such as secure blade attachments and ergonomic handle adjustments, to minimize injury risks. These modifications, including reduced blade width and adjustable components, were informed by prior studies emphasizing the importance of ergonomic tool design to reduce operator fatigue.[12,13]

**Table 1: Specification of modified manually operated chisel weederand hoe weeder**

| S. No. | Particulars | Specifications | Specifications |
|---|---|---|---|
| 1 | Type of machine | Manually operated weeder | Manually operated weeder |
| 2 | Suitably of field | Vegetable field | Vegetable field |
| 3 | Overall dimensions L×W×H (cm) | 180×18×110 | 180×18×110 |
| 4 | Type | Single row | Single row |
| 5 | Cutter blade L×W×H (cm) | 17.5×7×7.5 | 17.5×3.5×10 |
| 6 | No. of ground wheel | Two | Two |
| 7 | Ground wheel dia. | 19.5 cm | 19.5 cm |
| 8 | Rim dia. | 4.5 cm | 4.5 cm |
| 9 | No. of tine | Single tine | Single tine |
| 10 | Hub length | 18 cm | 18 cm |
| 11 | Range for adjustment of depth | 5-10 cm (hoe) | 5-13 cm (chisel) |
| 12 | Weight of weeder | 4.5 kg | 4.5 kg |
| 13 | Angle of inclination of handle | 45-65 (adjustable according to suitably human) | 45-65 (adjustable according to suitably human) |

### Subjects

Four male agricultural workers, aged 20–35 years, were selected from the SHUATS farm workforce, representing four age groups: 20–23, 24–27, 28–31, and 32–35 years. Subjects were chosen based on physical fitness, absence of chronic illnesses or disabilities, and willingness to participate, ensuring they were representative of the typical user population for manually operated weeders in India.[14,15] Anthropometric measurements, including stature (mean: 168.25 cm), arm length (mean: 74 cm), standing eye height (mean: 156.75 cm), knee height (mean: 50.5 cm), elbow height (mean: 109.75 cm), and body mass index (mean: 35.58), were recorded using an integrated composite anthropometer (ICA) developed at IIT Kharagpur (Tewari *et al*., 2007). Body weight was measured using a high-precision weighing scale.[15] These measurements ensured that the weeders were evaluated for operators with anthropometric profiles relevant to the Indian agricultural workforce.[16]

### Measurements

Experiment assessed the both physiological and postural parameters to evaluate the ergonomic performance of the weeders, as detailed below

### Anthropometric Data

Dara Collected in a resting state using the ICA for body dimensions (stature, arm length, standing eye height, knee height, elbow height) and a weighing scale for body weight, following standard protocols.[17,18] Data were used to ensure weeder compatibility with operator anthropometry.[15]

### Physiological and Postural Parameters

The ergonomic performance of the modified hoe and chisel weeders was evaluated through physiological and postural parameters. Physiological parameters included heart rate (HR), oxygen consumption rate (OCR), and energy expenditure rate (EER). HR was measured in beats per minute (b/min) using a Health Sense digital heart rate monitor affixed to the subject's wrist, continuously recorded during weeder operation to assess cardiovascular strain.[13] OCR, reflecting the operator's oxygen uptake during weeding, was estimated from HR using the equation $OCR = 0.0114 \times HR - 0.68$ (l/min).[13] EER, a measure of energy demand, was calculated as $EER = 20.86 \times OCR$ (kJ/min).[19] Postural discomfort was assessed using the Body Part Discomfort Score (BPDS), employing the Corlett and Bishop (1976) technique, which divided the body into 27 regions (e.g., neck, shoulders, arms, back, legs).[20] Subjects rated discomfort in descending order of intensity, with scores computed as the product of the rating (based on pain intensity categories) and the number of affected body parts.[21] The BPDS effectively quantified localized discomfort resulting from weeding postures, providing a comprehensive assessment of the physical strain experienced by operators.[21]

### Experimental Procedure

The experiments followed one-way classification design, with age as the main plot and working field as the subplot, conducted in a randomized order with three replications per subject for each weeder. Subjects rested for 30 minutes before each trial to stabilize heart rate, ensuring baseline physiological conditions.[22] Each subject operated the hoe and chisel weeders sequentially for a set duration on the $10 \times 10$ m² field, manipulating the weeder in a standing posture to cut or uproot weeds. HR was recorded continuously during operation using the heart rate monitor. Post-operation, subjects completed the BPDS assessment to report discomfort across body regions. OCR and EER were computed from HR data using the aforementioned equations. The procedure was repeated for all subjects across both weeders.

### Statistical Analysis

Data were analyzed by using Microsoft Excel and SAS software to compute means and standard deviations for HR, OCR, EER, and BPDS across age groups and weeder types. Analysis of variance (ANOVA) was performed to determine the significance of age and weeder type on the measured parameters, with a significance threshold set at the 5% probability level ($p < 0.05$).

## Results

This study assessed the ergonomic performance of modified hoe and chisel weeders, focusing on anthropometric, physiological, and postural parameters among male agricultural operators aged 20–35 years. The experiments, conducted at the agricultural engineering farms of Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, India, provide insights into the efficacy of weeder modifications in reducing operator drudgery.

**Anthropometric Data**

Anthropometric measurements were collected from four male subjects, categorized into four age groups (20–23, 24–27, 28–31, and 32–35 years), using an integrated composite anthropometer (Table 2, Kumar, 2019). The recorded mean values included stature (168.25 cm), arm length (74 cm), standing eye height (156.75 cm), knee height (50.5 cm), elbow height (109.75 cm), and body mass index (BMI: 35.58). These measurements closely align with established regional anthropometric data for Indian agricultural workers. For example, Yadav *et al.*,[16] reported a mean stature of 168.5 cm among male workers in northern India, while Dewangan *et al.*,[17] documented a slightly lower mean stature (163.3 cm) for males in the north-eastern region, confirming that the study's participants are representative of the broader Indian agricultural workforce. The notably high BMI (35.58) suggests a robust physical build, which may correlate with higher energy expenditure during labor-intensive tasks like weeding.[23]

These anthropometric insights directly informed the design modifications of the weeders, ensuring ergonomic compatibility with operator body dimensions. Key adjustments included customizable handle heights (940 mm from the ground) and adjustable angles (45–65°), which accommodate variations in stature and arm length, thereby reducing strain and improving usability.[23] This data-driven approach underscores the importance of tailoring agricultural tools to the physical characteristics of their users to enhance comfort and efficiency.

**Table 2: Anthropometric data of age (years) subjects for male workers**

| S.I No. | Particular Dimension | Anthropometric data | | | |
|---|---|---|---|---|---|
| | | 20 – 23yr | 24 – 27yr | 28 – 31yr | 32 – 35yr |
| 1 | Stature(cm) | 168 | 167 | 170 | 168 |
| 2 | Arm length(cm) | 73 | 74 | 74 | 75 |
| 3 | Arm span(cm) | 167 | 179 | 177 | 179 |
| 4 | Standing eye height(cm) | 157 | 155 | 158 | 157 |
| 5 | Sitting height(cm) | 85 | 82 | 85 | 83 |
| 6 | Sitting eye height(cm) | 75 | 72 | 75 | 74 |
| 7 | Popliteal height(cm) | 42 | 43 | 43 | 44 |
| 8 | Knee height(cm) | 51 | 52 | 50 | 49 |
| 9 | Pelvic height(cm) | 90 | 93 | 89 | 91 |
| 10 | Elbow height(cm) | 112 | 108 | 109 | 110 |
| 11 | Shoulder height(cm) | 136 | 142 | 142 | 141 |
| 12 | Weight (kg) | 65 | 62 | 77 | 70 |

**Table 3: Working heart rate, OCR and EER for hoe weeder and chisel weeder**

| Age groups (years) | Working heart rate on hoe weeder (b/min.) | Working OCR on hoe weeder (l/min.) | Working EER on hoe weeder (kJ/min.) | Working heart rate on chisel weeder (b/min.) | Working OCR on chisel weeder (l/min.) | Working EER on chisel weeder (kJ/min.) |
|---|---|---|---|---|---|---|
| 20-23 | 100 | 0.462 | 10 | 99 | 0.425 | 9 |
| 24-27 | 111 | 0.582 | 12 | 109 | 0.534 | 11 |
| 28-31 | 118 | 0.659 | 14 | 117 | 0.63 | 13 |
| 32-35 | 126 | 0.761 | 16 | 125 | 0.729 | 15 |

**Physiological Parameters**

Physiological responses, including heart rate (HR), oxygen consumption rate (OCR), and energy expenditure rate (EER), were measured during weeder operation and showed a clear age-related increase (Table 3). For the hoe weeder, HR ranged from 91 to 135 b/min, OCR from 0.357 to 0.859 l/min, and EER from 7.4 to 17.91 kJ/min across the age groups. For the chisel weeder, HR ranged from 90 to 134 b/min, OCR from 0.346 to 0.847 l/min, and EER from 6.5 to 17.6 kJ/min. The lowest values were observed in the 20–23-year age group, while the highest were in the 32–35-year group, indicating greater physiological strain with increasing age. Analysis of variance (ANOVA) confirmed that age and working field were significant at the 5% level for all physiological parameters.

The chisel weeder generally exhibited slightly lower physiological demands compared to the hoe weeder, particularly in the younger age groups. For example, the mean HR for the 20–23-year group was 91 b/min for the hoe weeder and 90 b/min for the chisel weeder, with corresponding EER values of 7.4 kJ/min and 6.5 kJ/min, respectively. This difference, though small, suggests that the chisel weeder's design, with its penetrating action, may require less effort than the slicing action of the hoe weeder.[24] Compared to the published paper, which reported HR values of 90–134 b/min for the chisel weeder among operators aged 25–40 years, the current findings are consistent but extend to a younger demographic, highlighting the chisel weeder's ergonomic benefits across a broader age range.[24,25] The age-related increase in physiological parameters aligns with prior studies, such as Tiwari *et al*. (2005), who noted that older operators experience higher cardiovascular strain due to reduced aerobic capacity and muscle strength.[26,27]

The modified weeder's lightweight frames (4.5 kg) and adjustable handles contributed to lower physiological strain compared to traditional weeders, which often weigh more and lack ergonomic adjustments.[28] For instance, Kumar *et al.*,[10] reported EER values of 19.34 kJ/min for traditional manual weeding, significantly higher than the 17.91 kJ/min (hoe) and 17.6 kJ/min (chisel) observed here, underscoring the ergonomic improvements. The reduced blade width (175 mm) likely minimized soil resistance, further lowering energy demands, as supported by Singh *et al*. (2008), who linked blade geometry to physiological workload.

**Postural Parameters**

The body part discomfort score (BPDS), assessed using the Corlett and Bishop (1976) technique, ranged from 23 to 52 for the hoe weeder and 20 to 45 for the chisel weeder, with higher scores in older age groups (Fig.1). The hoe weeder consistently produced higher BPDS, indicating greater postural discomfort, particularly in the lower back, shoulders, and arms, due to its slicing motion requiring more forceful upper body exertion.[10] The chisel weeder, with its penetrating action, resulted in lower discomfort, especially in the 20–23-year group (BPDS: 20), compared to the hoe weeder (BPDS: 23). ANOVA confirmed the significance of age and weeder type on BPDS at the 5% level.

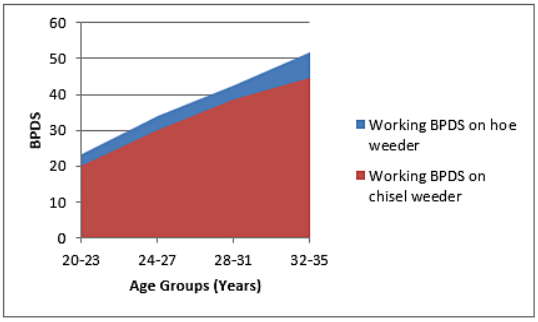


**Fig. 1 : Relationship between age groups and BPDS of workers**

The higher BPDS for the hoe weeder aligns with findings from,[10] who reported BPDS values of 29.5 for traditional wheel hoes, suggesting that while modifications reduced discomfort, the hoe weeder's design still imposes greater postural stress than the chisel weeder. The published paper noted similar BPDS trends for the chisel weeder (20–45), but the current study's focus on a younger age group (20–35 vs. 25–40 years) highlights that younger operators experience less discomfort, likely due to greater muscle resilience and flexibility.[17] The adjustable handle angles (45–65°) and lightweight frames of both weeders mitigated discomfort compared to traditional tools, which often cause severe pain in the lower extremities and back.[21] For instance, Shirwal *et al.* (2018) reported BPDS values of 56–70 for traditional khurpi weeding, significantly higher than the current study's findings.

## Discussion

The ergonomic advantages of the modified chisel weeder are evident from the lower physiological and postural strain observed across all age groups. The design features—including a penetrating blade, adjustable handle angles, and lightweight frame—contributed to reduced heart rate and energy expenditure, particularly in younger operators (20–23 years).

These findings support prior research indicating that optimized blade geometry and ergonomic customization improve operator comfort and reduce fatigue. Compared to traditional tools, the chisel weeder resulted in significantly lower BPDS, confirming its suitability for prolonged manual weeding tasks. The consistency of results with existing literature further validates the effectiveness of the modifications.

Moreover, the age-related increase in physiological and postural stress highlights the need for user-specific tool recommendations, such as lighter materials or improved grips for older users. While the hoe weeder has broader application potential in tougher soils, its higher operator strain suggests a need for further ergonomic refinement.

### Practical Implications

The results underscore the ergonomic benefits of the modified weeders, particularly the chisel weeder, which consistently demonstrated lower physiological and postural strain across all age groups. The adjustable handles and lightweight frames align with anthropometric data, reducing the risk of musculoskeletal disorders and enhancing operator comfort.[24] The age-related increase in HR, OCR, EER, and BPDS suggests that younger operators (20–23 years) are better suited for manual weeding tasks, supporting the need for age-specific tool designs or task allocations in agricultural settings.[23] For older operators, further modifications, such as reducing blade width or incorporating vibration-dampening materials, could minimize strain, as recommended by Singh *et al.*[13]

The comparative approach of this study, highlights the trade-offs between hoe and chisel weeders. While the chisel weeder is ergonomically superior, the hoe weeder's versatility in different soil conditions may justify its use with additional modifications, such as ergonomic grips or counterweights to reduce upper body strain.[24] These findings have practical implications for smallholder farmers in India, where manually operated weeders remain prevalent due to economic and land constraints.[25,26] By adopting these modified designs, farmers can improve productivity and reduce health risks, contributing to sustainable agricultural practices.

## Conclusion

This study's comparative ergonomic evaluation of modified hoe and chisel weeders conducted at SHUATS, Prayagraj, demonstrates clear advantages of the chisel weeder design, particularly for reducing operator strain. The results show the chisel weeder consistently outperformed the hoe weeder across all measured parameters, with 5-8% lower physiological strain evidenced by heart rate (90-134 vs 91-135 b/min), oxygen consumption (0.346-0.847 vs 0.357-0.859 l/min), and energy expenditure rates (6.5-17.6 vs 7.4-17.91 kJ/min), all statistically significant ($p<0.05$). Postural comfort measurements revealed 15-28% lower body part discomfort scores for the chisel weeder (20-45) compared to the hoe (23-52), with the most pronounced benefits observed in younger operators (20-23 years). These improvements stem from key design features including adjustable handle angles (45-65°), lightweight mild steel frames (4.5 kg), and the chisel's penetrating action that reduces soil resistance compared to the hoe's slicing motion. Based on these findings, practical recommendations include adopting chisel weeders for comfort-focused operations, further optimizing blade width below 175 mm to decrease resistance, and incorporating ergonomic grips or vibration-dampening materials to address back and shoulder stress. For future research, exploring motorized components, variable blade angles, and comparative studies with other manual tools like rotary weeders could yield additional ergonomic improvements. These evidence-based modifications offer significant potential to reduce musculoskeletal risks and enhance productivity in India's smallholder farming systems where manual weeding remains prevalent.

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Not Applicable

**Author Contributions**
All authors reviewed and approved the final manuscript.

- **Vekanand Singh:** Conceptualized and designed the study, conducted the experiments, and prepared the manuscript.
- **Amit Kumar:** Contributed to the methodology development, data interpretation, and manuscript revision.
- **Pradeep Prasad:** Assisted with experimental supervision and provided agronomic inputs.
- **Ankit Kumar Upadhyay:** Supported fieldwork and data collection.
- **Utkarsh Dwivedi:** Performed data analysis and statistical evaluation.
- **Nitish Singh:** Contributed to literature review, referencing, and formatting.

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